

ISSN 0034-5806  
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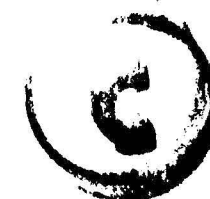
# RESTAURATOR

International Journal for the Preservation  
of Library and Archival Material

Volume 17 · Number 2 · 1996

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Issue dedicated to  
the ICOM Committee for Conservation Meeting,  
Edinburgh, 1-6 September 1996



MUNKSGAARD · COPENHAGEN

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## Obituary

The news that our colleague, Klaus B. Hendriks, passed away on Monday, 27 May 1996, after a continuous and severe illness, reached me immediately. The news affected me very deeply, since we have all lost a friend and a colleague, who, with his many creative ideas and through the profundity of his research work, has played a very important role within the working group. Klaus Hendriks' death is an irreplaceable loss, mostly for the field of photographic conservation but also for the field of the scientific research into paper deterioration, in which he most devotedly kept working.

Klaus Hendriks left Germany in his young years to go to Canada, where he finished his studies in chemistry at the University of Alberta in Edmonton with a PhD and a dissertation on carbon hydrates. For many years Klaus Hendriks worked for the Technical Division of the National Archives of Canada, and in 1991 he became director of the newly founded Conservation Research Division. In 1994 this division became part of the Canadian Conservation Institute.

As long as I have known him, Klaus B. Hendriks has been an active member of the Working Group on Paper of the ICOM Committee for Conservation and for two periods acted as assistant coordinator along with Françoise Flieder. He took part in the foundation of an independant working group for the conservation of photographic materials and was involved as coordinator in its first meeting on occasion of the 10th Triennial Meeting of ICOM-CC. At the end of this period, he went on working for the photographic group together with Bertrand Lavedrine. Along with his main interest in scientific research into methods for the preservation of photographic materials, Klaus Hendriks also took an interest in the problems of paper objects and was therefore an active member of the Working Group on Graphic Documents. He delivered a number of note-worthy lectures on the ageing behaviour of paper, e.g. at the 1994 ARSAG Conference in Paris,

and the last one in Europe on the occasion of the IADA Conference in Tübingen in 1994.

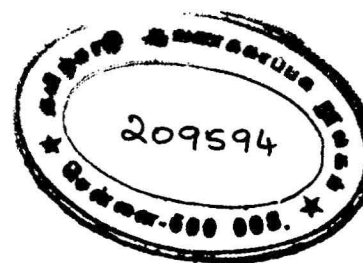
Klaus B. Hendriks contributed a great deal to the work of the conservation community; his most important contribution involves scientific research in the conservation of photographic materials. This is witnessed by his numerous publications. A special mention should be made of his editing a textbook, *Fundamentals of Photographic Conservation*, which, for the first time, gives a complete and structured presentation of this field. One should also mention his works devoted to the field of paper conservation, in which his main interest was the problem of permanence of paper.

Klaus B. Hendriks had an extremely strong personality. He was a brilliant scientist with a perfect sense of responsibility for the problems of the scientific aspects of restoration. He possessed great teaching skills, and he introduced a great number of students into the field of photographic conservation at his laboratories, sharing most willingly and openly his experience with others. He lectured at various institutions in Europe, among them at the University of Göteborg, in Aix-en-Provence, in Paris and at the State Academy of Fine Arts in Stuttgart.

We are going to miss Klaus as a member of our working group, and we will keep thinking of him.

Gerhard Banik

Coordinator of ICOM CC for Conservation Working Group No. 4



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**RESTAURATOR** (ISSN 0034-5806) is published quarterly by Munksgaard International Publishers Ltd., 35 Nørre Søgade, P.O. Box 2148, DK-1016 Copenhagen K, Denmark. USA subscription price is USD 185.00 including airspeed delivery. Periodicals postage paid at Jamaica, NY 11431. **USA POSTMASTER** for North American subscribers: send address changes to Publications Expediting Inc., 200 Meacham Avenue, Elmont, NY 11003. Airspeed and mailing in the USA by Publications Expediting Inc. Printed in Denmark by P.J. Schmidt A/S, Vejens.

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*Restaurator*, 1996, 17, 61

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**RESTAURATOR**

ISSN 0034-5806

## Editorial

On the occasion of the forthcoming 11th Triennial Meeting in Edinburgh, the Working Group on Graphic Documents will present the results of the working program as decided at the end of the last meeting in Washington, DC. For reasons of space limitation, only thirteen group members' contributions and three poster abstracts could be published in the preprints to the meeting.

Thanks to the traditional close cooperation with *Restaurator* - some members of the working group are also members of the Board of Editors of the journal - it was possible to publish another six valuable contributions of working group members in one special issue dedicated to contributions of the Working Group on Graphic Documents of the ICOM Committee for Conservation. Thus, a far broader range of the working group activities can be presented on the occasion of the forthcoming meeting.

As Coordinator of the working group, I would like to thank the authors for their cooperation and their willingness to contribute to the working group activities. On behalf of the working group members, I would like to thank the editor-in-chief of the journal, Helmut Bansa, for his continuous support and for the extensive editorial work involved in the preparation of this issue. I hope that this cooperation will continue in the future.

Gerhard Banik

Coordinator of the Working Group on Graphic Documents

# The Conservation of Hebrew Manuscript No. 8° 2238 in the Jewish National and University Library, Jerusalem: an Evaluation of the Method

by J. STANKIEWICZ

## HISTORY OF THE MANUSCRIPT

This small-sized manuscript (56×61–62 mm) is the oldest known dated Hebrew manuscript.<sup>1,2,3</sup> According to its colophon, at the end of the manuscript (fol. 34 r), it was written in 1106–07: “*I Itzhak Ben Avraham Halevi have written [...] (this manuscript) with Almighty help in the year 1106–1107*”. However, the place of its creation is still a source of dispute among scholars. The form of its decoration shows a resemblance to that of an Egyptian Quran from the 11th century. The character of the manuscript, which presents only the single section of the Pentateuch (Hebrew bible), appears to have been influenced by certain fixed parts of the Quran, in accordance with Islamic tradition. In 1910 the manuscript was sold by Nethanel ben Avraham to Menashe Sabs and later it came into the possession of Mr and Mrs Tulin who, with other items from their collection, donated the manuscript to the Jewish National and University Library (JNUL) in 1965.<sup>4</sup> In June 1985 the manuscript was brought for restoration to the Department of Conservation and Restoration of that library.

## DESCRIPTION OF THE MANUSCRIPT

The manuscript contains 34 parchment leaves gathered in four quires varying in bifolio number and internal construction. The first quire is the most unusual of all. It contains 4 bifolios, two outside as usual and two others side by side and sewn together at the inner fold (Fig. 1). The second and third quires are normal

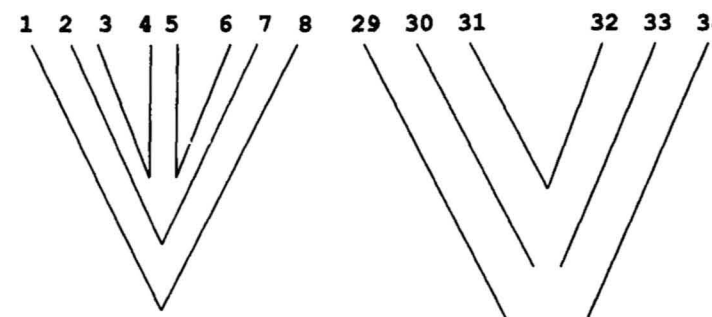


Fig. 1. Construction of the first and the last sections.

quinternios. The fourth and last is a ternio: its two outside double leaves, however, are separated. The yellow shade of the parchment as well as its precise preparation, which blurred the differences between the flesh and the hair sides, suggest that it was prepared by an enzymatic method.<sup>5</sup> This method is described in the literature.<sup>6</sup> It is based on the splitting of hide into three layers after processing it through the fermentation bath. The obtained fractions were scraped and subjected to drying under the tension. This method was very common in ancient times in the Middle East, in both Jewish and Arabic cultures, and it finally disappeared in 15th century<sup>7</sup>. At the time of the creation of the manuscript in question, however, this method was the usual one, whereas the alkaline method of parchment preparation was not as popular. The split parchment distinguished itself by the uniform preparation of both sides of the substrate and by the yellowed shade.

The manuscript is extensively ornamented. At both the beginning and the end (fol. 3r and v) ornamental carpets are displayed in full page, with gold leaf and dark blue ornaments. In the margins small lotus flowers indicate the beginning and end of each part of the text, also in gold leaf with blue painted ornamentation. The gold leaves were placed directly on the parchment without any intermediate layer: no traces of ground or bolus were visible in the damaged illuminations, in particular the fragments with lifted painting or gold leaf layer.<sup>8</sup>

The text is written in a dark brown slightly corrosive ink which has perforated the written part of the parchment in places where an excessive amount of ink was located. As no ink analysis was performed, the exact ink composition is unknown. The perforation along the writing, however, especially in places with extensive deposition of ink (fol. 3, 4, 6, 8, 29, 30, 32), indicates its corrosive character.

There are seven lines in large script with the *masorah* at the bottom and the top of each individual leaf. The *Masorah* is the body of traditional information bearing upon the reading of the Bible and its exact punctuation. Masoretic notes

were usually written in the margins of manuscripts surrounding the biblical text. The number of *masorah* lines in the upper margin is one or two.

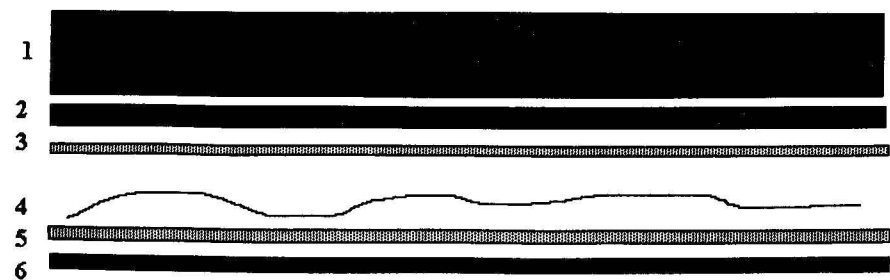
The manuscript is bound in full Moroccan leather on wooden boards and decorated with a geometric blind tooling design, based on three rectangular successive frames of which the internal panel is ornamented with a "*horror vacui*" design. The boards were separated from the text block, and the leather cover was partially detached from the spine. The sewing structure of the manuscript, which had deteriorated in the course of time, had been reinforced with green flax cloth glued to the spine with a thick layer of animal glue.

#### CONSERVATION PROCEDURE

The manuscript had just been subjected to restoration treatment prior to its conservation in 1986. However, there is no record describing the methods and the materials involved. This earlier "conservation" was, possibly, undertaken at the time of the binding, when the missing portion of the front carpet was replaced with new parchment. No pigment consolidation was visible under the microscope and flaking paint was easily detected in the folds of the biofolios. This indicates either the absence of consolidant or its ineffectiveness, if done during that previous treatment.

The remains of the binding were removed from the spine, along with parts of the leather, cloth and glue. The torn sewing was also removed and the manuscript was separated into its individual quires and bifolios. All the leaves were subjected to dry cleaning with a soft Japanese brush and were then humidified between sandwiches of blotters saturated with deionized water.

The softened and humidified biofolios were then cleaned with a water-ethanol-urea solution (50 g of urea in 1 l of 1:1 water/ethanol). The recipe for the cleaning



1 - glass plate, 2 - wet blotter, 3 - dry blotter, 4 - parchment, 5 - dry blotter, 6 - support  
Fig. 2. Arrangement for drying.

solution was modified by the addition of a few drops of glycerol. This created in the parchment a self-adjusting mechanism that controlled its moisture content according to changes in the humidity level of the surrounding atmosphere and thus helped the parchment to remain flexible. For cleaning, the sheets were placed between two supporting sheets and sandwiched between double blotter layers (Fig. 2). The external slice was dampened with the cleaning solution and the whole pack was covered with a light glass plate in order to ensure the delicate and gradual migration of moisture into the parchment. Determination of the required time was difficult, therefore the packing was checked every 15 minutes.

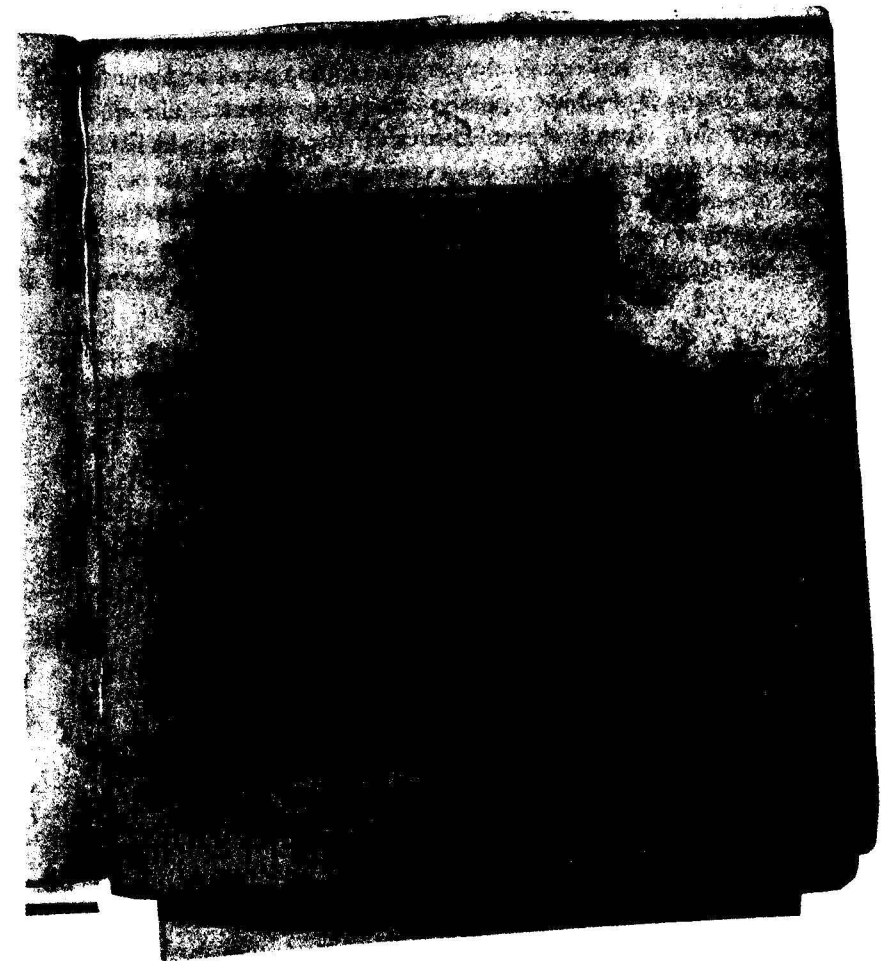


Fig. 3. Front carpet.

While the sheets were still damp, all earlier patches were removed and surplus glue was cleaned away. Finally the separated biofolios were sandwiched between fresh blotters and positioned for final drying. Humidified parchment tends to disfigure whereas wet parchment under pressure increases its transparency. Therefore it is essential to correlate the pressure with the degree of wetness, so that maximum pressure will be applied only to the dry material.

#### CONSOLIDATION

The carpet leaves were consolidated with a weak solution of parchment size, freshly prepared with the 1/3 part of analytical grade iso-propanol and applied with a soft Japanese brush over the paint layer. Then the leaves were sandwiched between two layers of non-woven polyester and blotting paper and placed in the press for final drying. The slow evaporation rate of the solvent, quite apart from its deep penetration, creates an ideal carrier for the adhesive which holds the pigment particles in place. Microscopic examination conducted recently, shows neither color change in the paint layer nor any loose paint particles (Figs. 3, 4).

The most critical points of the conservation procedure were the infills in the text area. All major losses were compensated for with new calf parchment of

medium thickness, chosen because of its resemblance to the original supporting material. The outline of the missing parts was copied onto the new parchment on a light-table. The edge of the borderline path was trimmed and its thickness was gradually reduced to zero level. This treatment provided good adhesion and minimalized overlapping, and the best possible result is attained by also treating the edge of the original in the same manner. In order to prevent uncontrolled changes in the thickness of the parchment, the edge was reduced with the assistance of a small rotating drill with an adjustable speed control unit. Both sides of the new parchment were scratched extensively so that the difference between the hair side and the meat side was barely apparent, as had been done with the original parchment. The contact line between the original and the added material was limited to the thickness of the parchment (Fig. 5). The efficacy of the technique used depended on the strength and flexibility of the glue. The parchment leaves affected by the ink corrosion were placed on the light-table and the internal edge of the perforation was wetted with parchment glue. Then fibers from the goldbeater's skin, carefully retrieved, were put in place to compensate for the losses (Fig. 7).

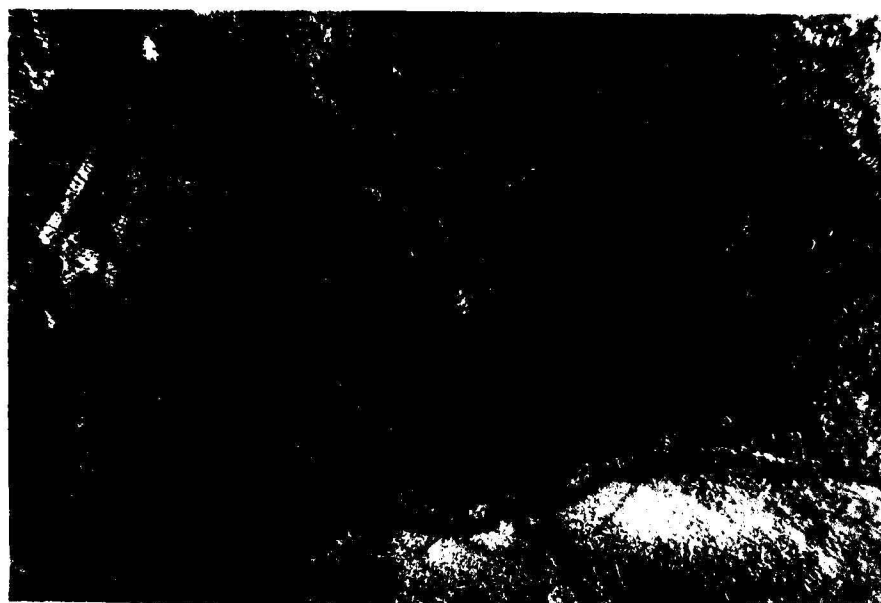


Fig. 4. Detail of the front carpet.

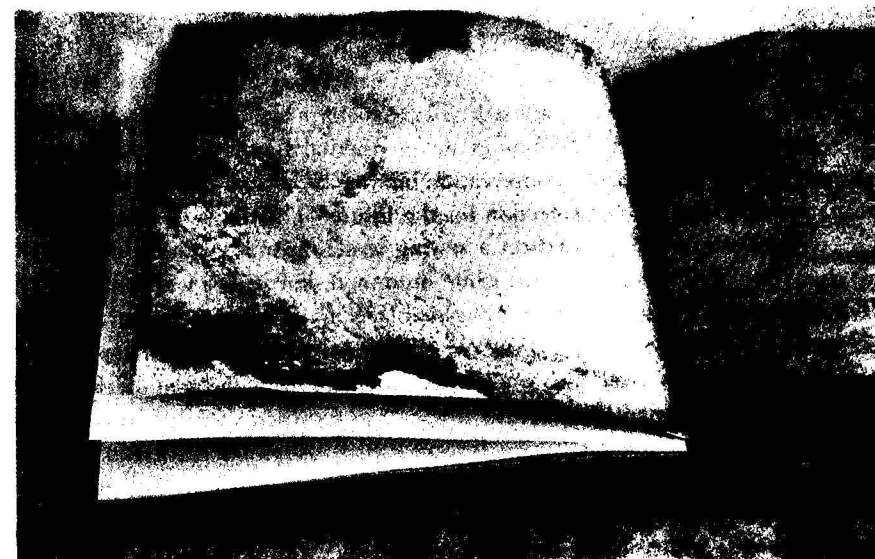


Fig. 5. First page verso after restoration.



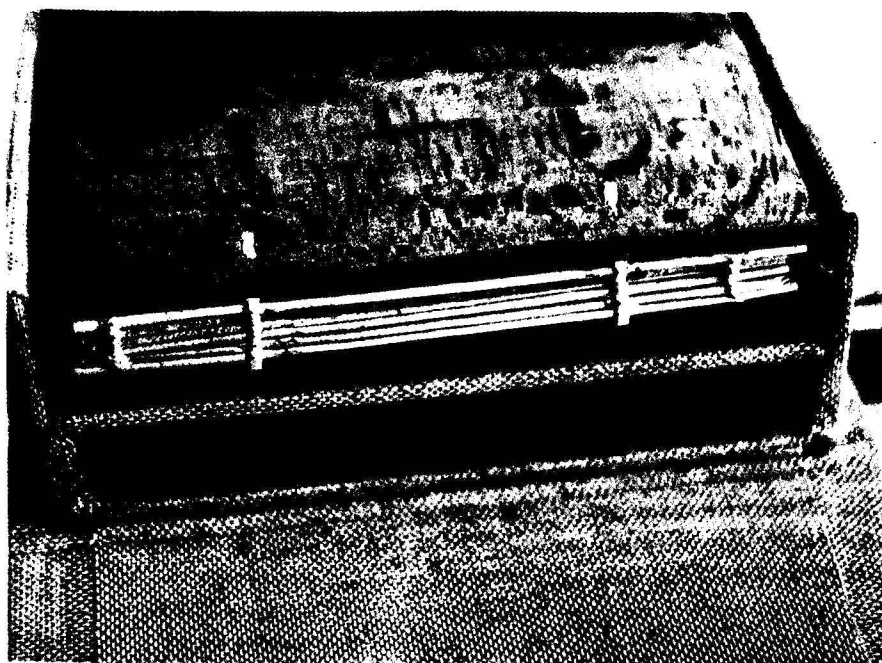


Fig. 6. Sewing structure (after restoration).

#### BINDING

After such extensive work, the future preservation of the manuscript will be a major concern, and this consideration affected decisions regarding the binding. Should the former binding be reused, although it was not the original one? If not, should the manuscript be bound in an oriental binding, according to its character? Or should a special conservation binding be chosen in order to provide the manuscript with better protection for the future? The decision went in favor of a conservation binding based on a sewing structure only, without the use of any glue. The quires were sewn on white untanned skin stripes with unbleached linen thread, using the old sewing stations (Fig. 6). The connection between textblock and binding was secured by the endleaves, pasted with parchment glue to the boards. The old binding was placed, together with the manuscript, in a specially designed preservation box.

#### RE-EVALUATION OF THE METHOD

Up to here this article has consisted of an extract of the conservation report produced about ten years ago. Since then the manuscript has been kept in stor-

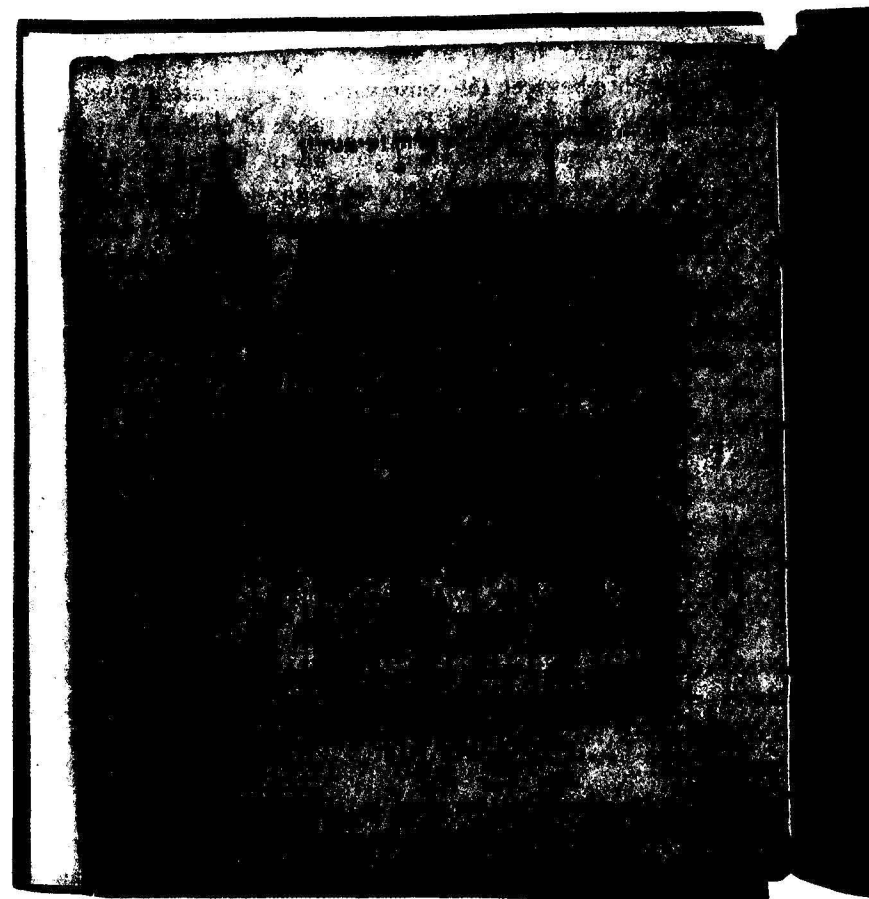


Fig. 7. Compensation of losses with goldbeater skin.

age. During this time, however, it was made accessible to the public on several occasions, and was displayed at a New York public library exhibition at the end of 1989. Therefore it seemed appropriate to re-examine the method of the manuscript's conservation, not only in the light of its rather extensive use but also in order to check the theoretical assumptions that guided the conservation procedure ten years ago.

The process of decision-making in, or choosing the proper strategy for, the conservation of a manuscript is often difficult and complex. The consequences of the decisions taken will not only determine its future appearance, but also the

prospects for its very existence. What kind of guidelines then should be followed, and what information should we have in order to make proper choices? In this sense there is no difference between the conservation of a manuscript and that of other art objects, except for complexity. The vast range of materials involved in the production of one manuscript (including parchment, paper, wood and pigments) creates a very fragile equilibrium that can be distorted very easily by the introduction of new components, no matter how carefully this incorporation of a new element is effected. Testing procedures performed in the course of a restoration can provide data about possible developments but not exact information of what will happen. "Accelerated ageing attempts to artificially simulate in only a few weeks or months an ageing process that occurs over tens or hundreds of years. However, the emphasis should always be on the term 'simulation'. Accelerated ageing can never give an exact picture of what would have happened in reality".<sup>9</sup> In many cases knowledge about the past of the manuscript remains unrevealed, and this increases the possibility of its mistreatment. Therefore, in order to minimize the negative possibilities, it was decided not to use substitutes but instead to ensure the maximum compatibility of the materials used in the conservation with those used in the production of the original object. Thus parchment glue and parchment size, goldbeater's skin or split parchment were used instead of Japanese paper, synthetic glues and artificial tissues. No changes were observed in the course of time: no discoloration appeared along the glue line; no loose ends and no free fibers were visible in the connecting area; and all the compensations and patches remained intact.

The evaluation process would not be complete without some remarks.

- The perspective of ten years is too short for drawing conclusions about the efficacy of the conservation method used and can only offer a description of the state of knowledge at the given time.
- The distance in time allowed us to discuss the principles of this procedure in the light of recent developments in conservation techniques. Should (or could) we have acted differently with regard to what was done in the past concerning manuscript preservation? And if so, in what way? The recently developed technique of reconstituted parchment could be used successfully to compensate for losses. This technique has been presented to the public in a series of articles by Jan Wouters, Lieve Watteeuw and An Pecstadt. Very little can be added to this comprehensive and elegant presentation.<sup>9,10,11</sup> Unfortunately this technique was unknown at the time the manuscript was treated.
- From today's perspective it would appear to be more appropriate to conduct pigment and binding media analysis prior to intervention. However, the use of natural consolidant as a parchment size contributed towards minimizing

potential mistreatment. Natural consolidants (as parchment size) are easy to prepare and their strength is controllable.

## SUMMARIES

### *The Conservation of Hebrew Manuscript 8° 2238 in the Jewish National and University Library, Jerusalem: an Evaluation of the Method.*

The conservation of parchment manuscript 8° 2238 was undertaken in 1985 by the Department of Conservation and Restoration of the Jewish National and University Library, Jerusalem. The procedure included conservation of damaged parchment leaves, consolidation of the fully displayed carpet pages with modified parchment size, reconstruction of the sewing structure, and conservation of the binding. The whole procedure was re-examined after ten years and both the methods used and the condition of the manuscript were found to be satisfactory.

### *La restauration du Manuscrit Hébreu 8° 2238 de la Bibliothèque Nationale et Universitaire Juive de Jérusalem. Evaluation de la méthode.*

La restauration du manuscrit sur parchemin 8° 2238 a été entreprise en 1983 par le département de conservation et de restauration de la Bibliothèque Nationale et Universitaire Juive de Jérusalem. Le traitement a compris la restauration de feuilles de parchemin endommagées, la consolidation des pages entièrement déployées avec une colle de parchemin modifiée, la reconstruction de la couture et la restauration de la reliure. Le traitement complet a été examiné après dix ans et les méthodes utilisées ainsi que l'état de conservation du manuscrit ont été jugés tous deux satisfaisants.

### *Die Konservierung der hebräischen Handschrift 8° 2238 in der Jüdischen National- und Universitätsbibliothek Jerusalem. Eine Bestandsaufnahme.*

Die Handschrift 8° 2238 war 1985 in der Abteilung für Konservierung und Restaurierung der Jüdischen National- und Universitätsbibliothek Jerusalem restauriert worden. Die Arbeit umfaßte neben der Konservierung von beschädigten Pergamentblättern und der Festigung von ganzflächig ornamental bemalten Deckblättern mit modifiziertem Pergamentleim auch die Rekonstruktion der Bindestruktur und die Konservierung des Einbandes. Die Arbeit wurde nach 10 Jahren wieder in Augenschein genommen, und der Zustand der Handschrift kann als befriedigend gelten.

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## A Study on the Biostability of Parylene-Coated Paper

by SVETLANA A. DOBROUSSINA, TATYANA D. VELIKOVA &  
OKSANA V. RYBALCHENKO

### INTRODUCTION

Like every other material of organic origin, paper is subject to aging and destruction. There are various methods of solving the problem of paper durability. Among them is consolidation with polymers. Consolidation has been known to improve the biostability of paper+polymer composites. In restoration practice, intensive use has been made of the protective properties of polyethylene<sup>1</sup>. Polyethylene-coated paper shows no evidence of microorganism growth, while ethylcellulose and acetylcellulose-coated composites can be damaged by microorganisms, although the effects of damage take much longer to occur here than in the controls. In the absence of paper, none of the film types mentioned above showed evidence of fungi growth<sup>2</sup>. It is conceivable that infection of coated paper only occurs when there are microscopic holes due to damage in the coating surface<sup>3</sup>. Polymers are usually applied to the surface of the material in a solution, in melted form or in a deposit of layers of polymer coating. In the last decade, investigations have been pursued into a method of para-xylylene polymerization from the gaseous phase, with para-xylylene in the form of monomeric gas precipitated and polymerized on the surface thus producing a poly-para-xylylene (parylene) film 10-50 µm thick<sup>4</sup>. It has been ascertained that parylene protects paper and extends its durability<sup>5</sup>. This article is a report on our study on the biostability of the new composite paper+parylene compared with the paper+polyethylene composite.

### MATERIALS AND METHODS

The items tested were samples of 100% cotton-pulp paper, 100% sulphate-pulp paper (SaPP), 100% sulphite-pulp paper (SiPP) and newsprint paper.

The paper was contaminated with a suspension of 9 fungi species with spore concentration of 1 mil/ml: *Aspergillus niger* van Tieghem; *Aspergillus terreus* Thom; *Aureobasidium pullulans* de Bary; *Paecilomyces variotii* Bainier; *Penicillium funiculosum* Thom; *Penicillium ochro-chloron* Biourge; *Scopulariopsis brevicaulis* Bainier; *Trichoderma viride* Pers. ex Gray; *Chaetomium globosum* Kunze. The fungi were grown at 28°C for 28 days.

The process of paper sample biodestruction by microorganisms was examined as follows: 1) in submerged condition in a Chapec-Dox medium, with paper samples of 15×100 mm as a single source of carbon; 2) in the exiccator, at room temperature (T) and a relative humidity (RH) of over 90%, to assess resistance to fungi by a 6-point scale according to the Russian Standard GHOST 9.048-89. The ingredient content of the Chapec-Dox medium is: KCl=0.5 g, MgSO<sub>4</sub>=0.5 g, K<sub>2</sub>HPO<sub>4</sub>=1.0 g, FeSO<sub>4</sub>=0.01 g, NaNO<sub>3</sub>=2.0 g, H<sub>2</sub>O distilled=1.0 l, pH=6.0.

When a heavy mould growth was achieved, the following parameters of paper damage were checked: carbohydrate concentration, by the Somogyi-Nelson<sup>6</sup> method; and loss in mass, by weighing. The antifungal effects of the parylene coating were evaluated by the formula:

$$\{(m_1 - m_2) / m_1\} \times 100\%$$

where:  $m_1$  = mass loss in uncoated paper (control);  $m_2$  = mass loss in coated paper.

The degree of fungal damage to the paper was also defined by scanning microscopy. For this purpose the specimens were fixed in 2.5% glutaric-aldehyde vapours for 24 hrs. Then a thin (50-100Å) layer of gold was evaporated onto the tested samples in a sputtering device. The finished samples were examined with a JSM35C scanning electronic microscope with accelerating voltage of 15 kV.

## RESULTS AND DISCUSSION

At standard storage conditions (T=20°C and RH=50%), paper is free of biodegradation effects. However, variation in temperature-humidity conditions or emergencies (RH>70%) may result in the abundant growth of microorganisms on paper.

To reproduce extreme conditions, the experiments were performed in a liquid medium and in the exiccator with a humidity of over 90%. Since the fluid medium is highly beneficial to cellulose consumption by fungi, the most adequate evaluation of biodegradation is loss of paper mass. Identification of the intermediate products of cellulose decay in the cultural media also provides a means of evaluating the intensity of paper biodestruction. The point of experimenting with such different conditions was essentially to identify a method that would provide the most accurate quantitative evaluation of the range of paper damage.

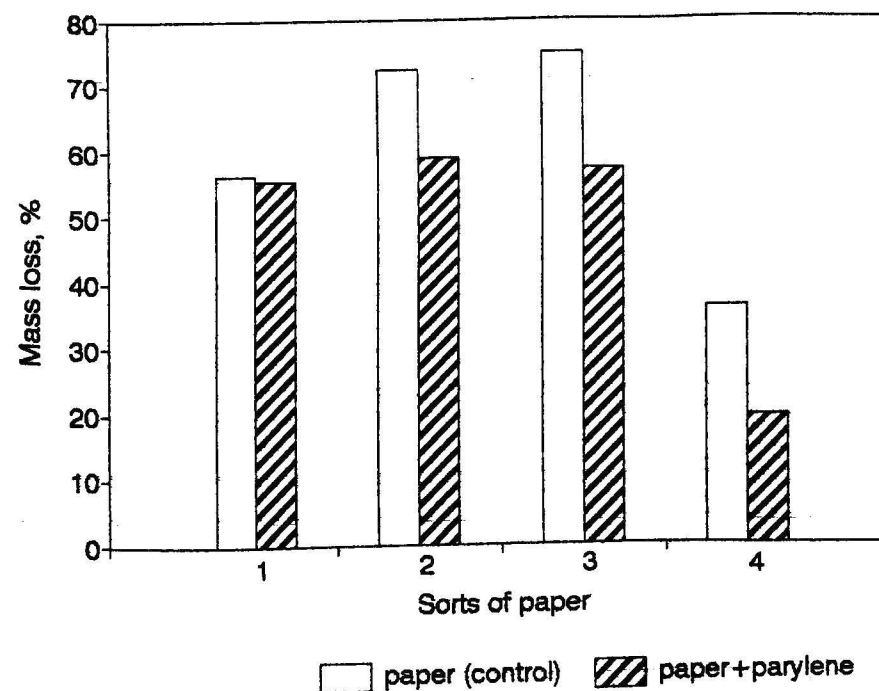


Fig. 1. The mass-loss in different sorts of paper patterns and their composites with parylene under mixed micromycete culture action: 1 – 100% cotton-pulp paper; 2 – 100% sulphate-pulp paper; 3 – 100% sulphite-pulp paper; 4 – newsprint paper.

The degree of destruction in parylene-coated paper that was left in a growing joint fungi culture for a month is represented in Fig. 1. It is evident from the data that parylene contributes to superior bioproofing in the samples tested. This is demonstrated by the vigorous destruction of paper samples with no parylene, which showed a loss in mass ranging in some cases up to 90%. Findings from the visual evaluation of the samples according to the 6-point scale of GHOST 9.048-89 agree with the data of mass loss: the fungi growth on the control paper was evaluated at 3-5 points and on the composites at only 1-2.

A study on the effects of pulp-destroying fungi on polymer coating and other paper types thus indicates that poly-para-xylylene does not serve as a substrate for fungi growth, and that where parylene is used as a coating, it protects paper against biodestruction.

The use of joint cultures of fungi in the experiment does not allow the evaluation of the contribution of each species to the process of paper destruction. Therefore, to examine the growth characteristics of the microorganisms tested,



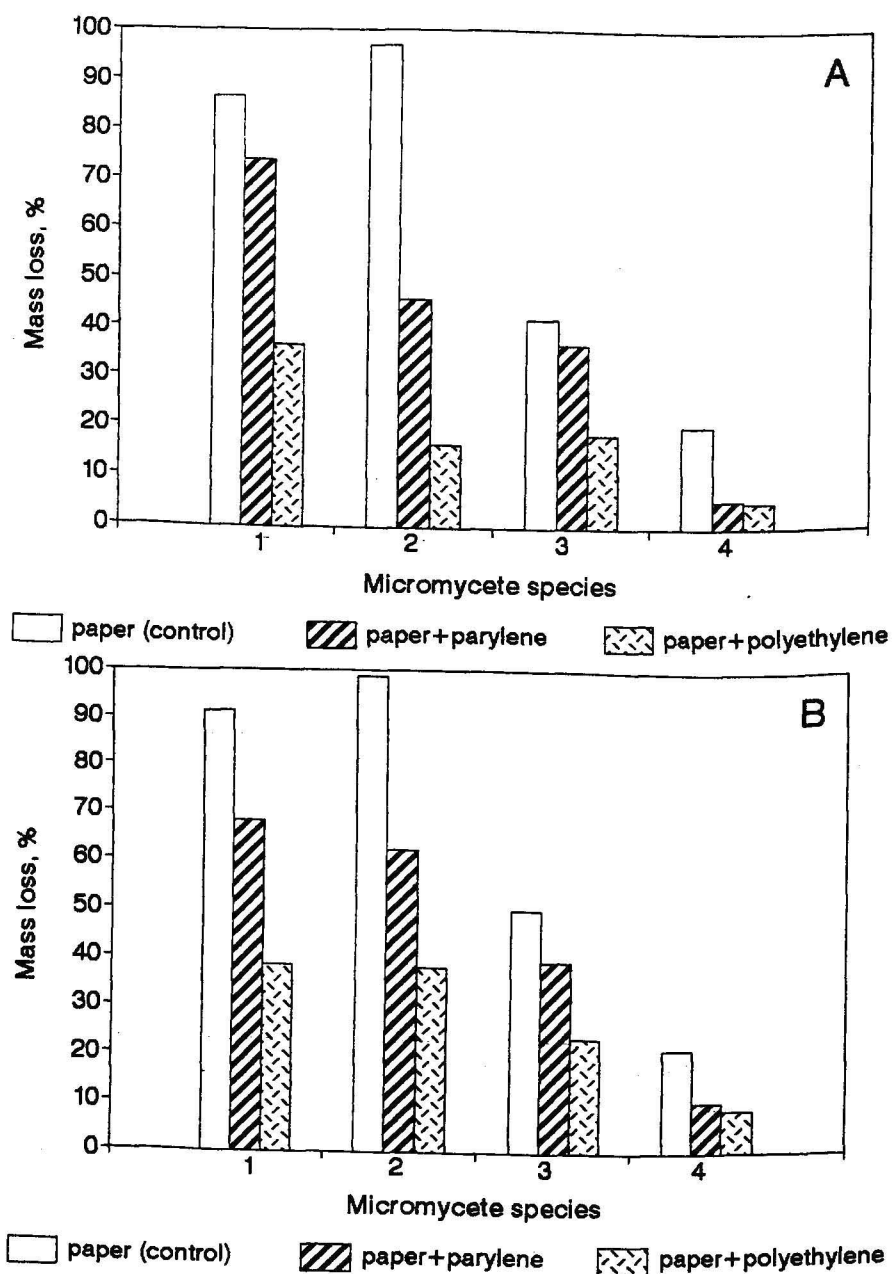


Fig. 2. The mass-loss in different sorts of paper and composites patterns under micromycete action: A – 100% cotton-pulp paper; B – 100% sulphate-pulp paper: 1 – *Chaetomium globosum*, 2 – *Penicillium funiculosum*, 3 – *Penicillium ochro-chloron*, 4 – *Trichoderma viride*.

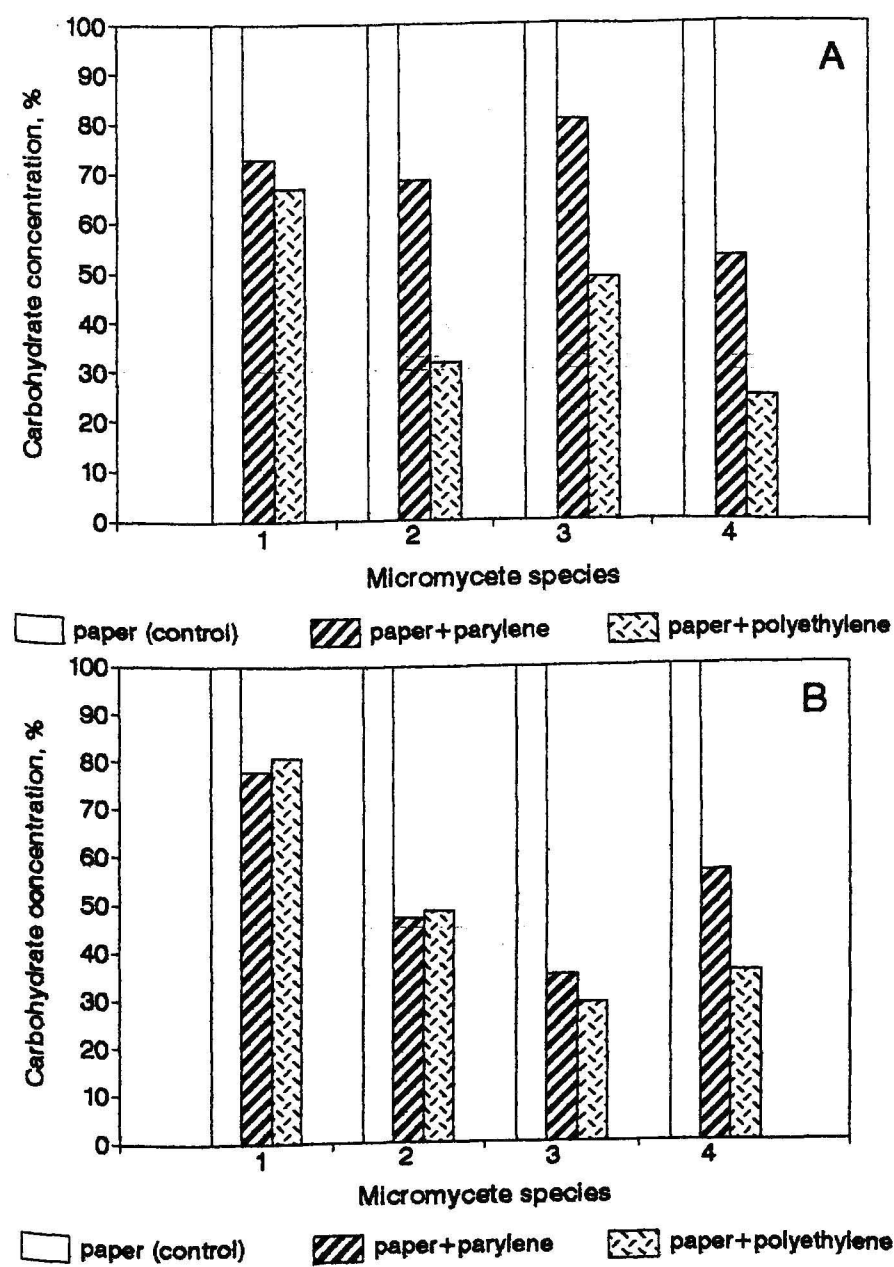


Fig. 3. The carbohydrate concentration in cultural media with paper patterns as a single carbon source for micromycete growth: A – 100% cotton-pulp paper; B – 100% sulphate-pulp paper: 1 – *Chaetomium globosum*, 2 – *Penicillium funiculosum*, 3 – *Penicillium ochro-chloron*, 4 – *Trichoderma viride*.

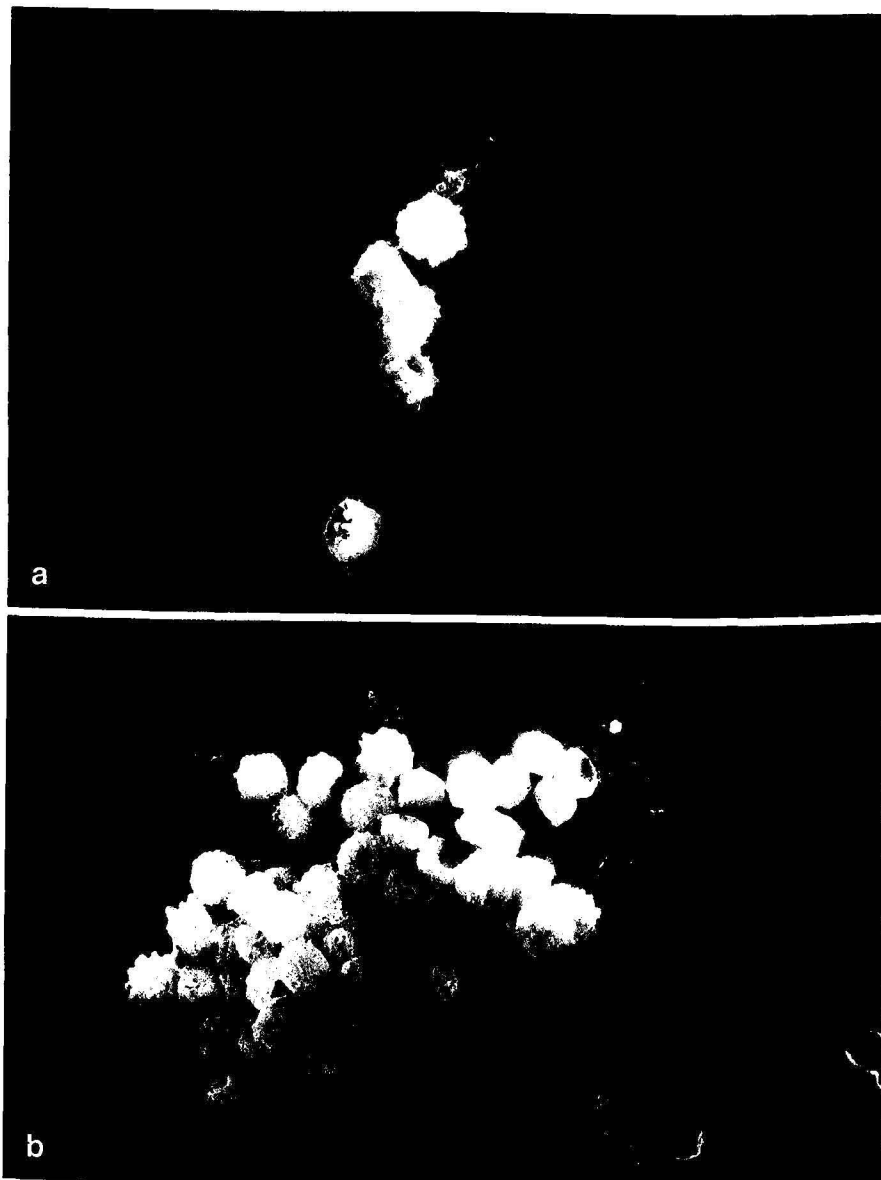


Fig. 4. The electronogrammes of the pattern surface after inoculation with *Aspergillus niger*: a – polyethylene; b – cotton-paper+polyethylene composite. (Magnification  $\times 2000$ ).

the coated paper and composite specimens were infected with each fungus culture individually.

The growth of the different fungi types on the paper+parylene composites demonstrated different protective effects of the coatings (Fig. 2). *C. globosum* and *P. funiculosum* were very vigorous and destroyed both cotton and SaPP up to 90–100%. The protective effects of parylene against destruction by *C. globosum* and *P. ochro-chloron* were approximately the same for both paper types and reached 13–15%. The most effective parylene protection was evident in the case of such an aggressive biodestructor as *P. funiculosum*. Even more effective was the use of parylene against a growing *T. viride*, which grows in paper much more slowly than the other fungi. Nevertheless in the cases of *P. funiculosum* and *T. viride*, the protective antifungal effects of the coating were more pronounced on cotton paper than on SaPP: in the first case we obtained 53% and 74% and in the other 37% and 52% respectively.

Polyethylene-coated paper samples were less affected by fungi than parylene-coated samples, with the exception of *T. viride*. The growing of *A. niger* did not reduce the mass in cotton pulp paper, and the mass loss in SaPP was not significant either. In this case the parylene protective effect was fairly adequate. Effective paper protection by polymers depends on the fact that polymers are not used by fungi as a substrate. The experiment in which five cultures were grown in the



Fig. 5. The electronogramme of cotton-paper+parylene composite surface after inoculation with *Aspergillus niger*. (Magnification  $\times 2000$ ).

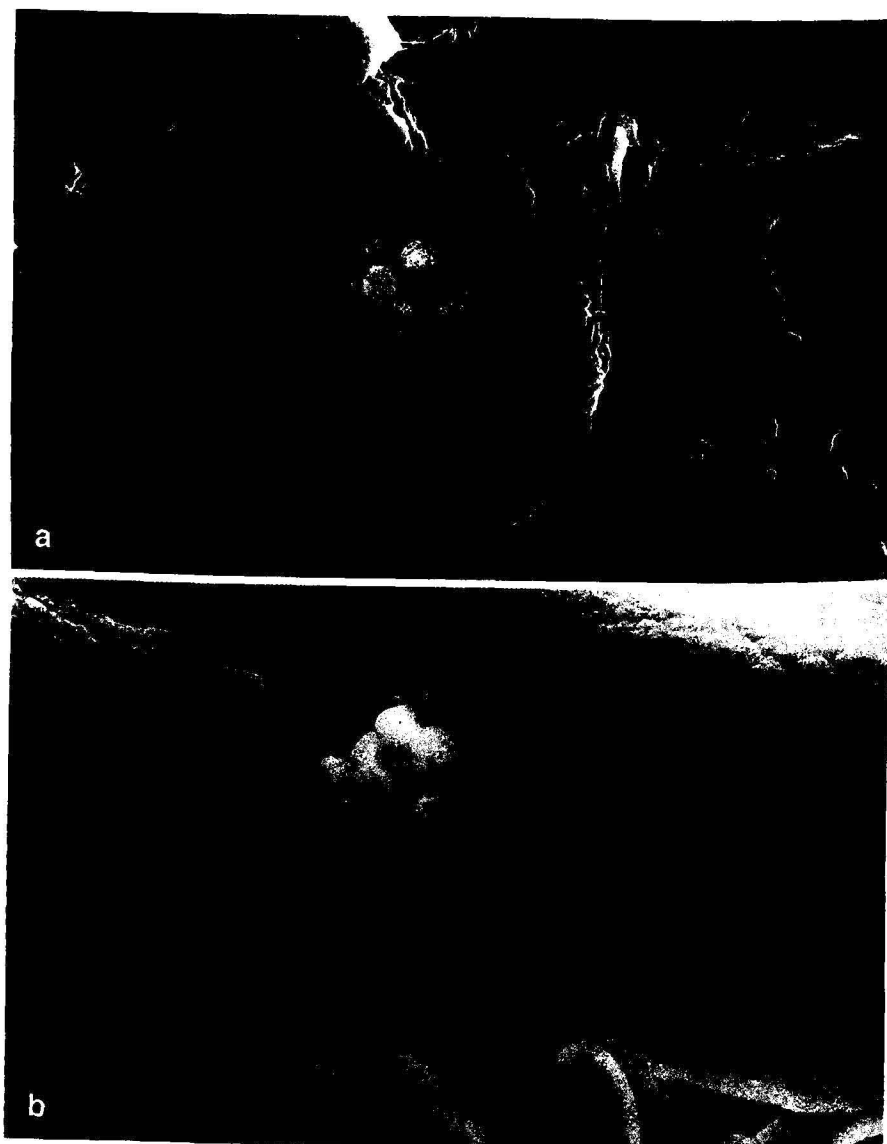


Fig. 6. The electronogrammes of the pattern surface after inoculation with *Aspergillus niger*: a – SPP; b–SPP+parylene. (Magnification  $\times 2000$ ).

same conditions on parylene and polyethylene coatings demonstrated no mass variations.

In the course of paper decomposition, carbohydrates are produced as the inter-

mediate product of cellulose destruction, and therefore serve as indicators of the intensity of paper consumption by fungi in the cultural media. The reduction in mass in the paper samples was assessed at the end of the experiment (28 growth days). We also assessed the amount of the carbohydrate production build-up after only 14 days: later than this a decrease in carbohydrate concentration in cultural media can result from their utilization by fungi. The data shown in Fig. 3 indicate almost the same protective effect by parylene in both paper types examined. Analytical findings concerning the carbohydrate content in the cultural media and the mass-loss parameter in the samples proves the superior efficacy of the polyethylene coating.

It should be borne in mind, however, that the superior protective characteristics of polyethylene appear to depend more on the amount of coating material applied than on its chemical or durability properties. Parylene coatings were 10–50  $\mu\text{m}$  thick and the polyethylene coating 600  $\mu\text{m}$  (0.3 mm on each side of a sheet), i.e. at least 10–12 times that of parylene.

For the purpose of describing the characteristics of mycelium growth and assessing the degree of destruction by fungi of protective coatings, we applied the electronic microscopy scanning technique. The scanning of samples infected with pure fungi cultures – *A. niger*, *P. ochro-chloron* and *T. viride*, was performed in two steps: immediately on infection; and two weeks after the incubation of infected samples in an exiccator with RH of over 90%. The examination of the polyethylene-coated surface showed spore attachment mainly on parts with mechanical defects (Fig. 4a). The scanning of the cotton-pulp polyethylene-coated paper surface demonstrated numerous spore groups in segments with pronounced roughness in the coating surface (Fig. 4b). The microphotographs show spores attached in the hollows formed by paper fibres. In the case of parylene coating, which reproduces the paper surface outlines, the spores were also detected in surface depressions and irregularities between the fibres (Fig. 5).

Comparative electron-microscopic analysis of the different coating and paper sorts thus indicates that significant irregularities on the surface of sulphate-pulp paper are likely to mediate micromycetic spore attachment to a greater degree, as the spore groups are more frequent in this case (Fig. 6a,b).

Evidence from the electron-microscopic analysis of the different coating and paper sorts suggests that mycelial growth on the surfaces examined is accounted for by the consumption of paper in the parts that have mechanical damage in the coating, rather than by the utilization of the parylene or polyethylene proper. Surface electronography of polyethylene, parylene, cotton- and sulphate-pulp paper demonstrates in the series of materials examined that an increased depth in roughness stimulates spore attachment on the surface of the items which facilitates the access of micromycets to paper.

## CONCLUSIONS

1. Gaseous phase deposits of parylene coating on paper improves paper biostability to 13–74%.
2. The initial stage of paper+parylene composite biodeterioration is spore gathering in paper cavities and recesses.
3. Microorganisms injure only paper fibres that do not have parylene protection.

## SUMMARIES

### *A Study on the Biostability of Parylene-Coated Paper*

The article deals with the stability of paper coated with poly-para-xylylene (parylene) as compared with the laminate paper-polyethylene that is widely used in archive paper conservation. The intensity of paper deterioration by fungi was estimated by loss in mass and by the results of electronic microscopy. The investigations showed that mould growth on paper coated with parylene (and polyethylene as well) is the result of fungi consuming the paper in parts with mechanical damage in the coating rather than the result of fungi consuming the synthetics.

### *Etude de la bio-stabilité de papier enduit de Parylène*

Cet article traite de la stabilité de papier enduit de poly-para-xylylène (parylène) par rapport au stratifié papier-polyéthylène qui est largement utilisé en conservation d'archives. L'intensité de la détérioration du papier par des funghi a été estimée par la perte de masse et par les résultats de la microscopie électronique. Les recherches ont montré que le croissances des moisissures sur le papier enduit de parylène (et de polyéthylène également) était le résultat de la dégradation du papier par les funghi ainsi que de dommages mécaniques de l'enduit plutôt qu'une attaque des substances synthétiques par les funghi.

### *Untersuchung der biologischen Stabilität von Parylene-beschichteten Papieren*

Es wird die Widerstandsfähigkeit von Papier untersucht, das mit Poly-p-xylen (Parylen) beschichtet ist, im Vergleich zu dem Laminat Papier-Polyäthylen, das vielfach in der archivalischen Papierrestaurierung eingesetzt wird oder wurde. Die Intensität des Schimmelwachstums wurde im Verlust an Papiermasse und in elektronenmikroskopischer Untersuchung erfaßt. Die Untersuchungen zeigten, daß das Schimmelwachstum auf den untersuchten Laminaten eher im Wachstum auf dem Papier besteht an Stellen, an denen die Kunststoffbeschichtung schadhaft ist, als darin, daß der Kunststoff als Wachstums-substrat für die Schimmelpilze dient.

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## The Examination and Conservation of the Raphael Cartoons

by ALAN DERBYSHIRE

### BRIEF HISTORY<sup>1</sup> AND PREVIOUS TREATMENTS<sup>2</sup>

In 1515 Pope Leo X commissioned Raphael to design a set of ten tapestries, depicting scenes from the lives of Saint Peter and Saint Paul, to hang in the Sistine Chapel. The resulting ten Cartoons were completed by Raphael in Rome during 1515 and 1516. The leading weavers of the day were Flemish and therefore the Cartoons were sent to Brussels to the studio of Pieter Van Aelst where the original set of tapestries was made. This Leonine set is today in the Vatican Museum. Over the next twenty years, four more sets of tapestries were made by other Flemish weavers, most notably by Jan Van Tiegen. Most probably they were made from the original Cartoons except for the *Conversion of Saul* which was sent to Venice in 1521 on its acquisition by Cardinal Grimani; hence a copy must have been made of this Cartoon for the subsequent sets. Two of these sets are extant today, one in Madrid and one in Mantua.

The low warp weaving process used for these tapestries is particularly severe on cartoons. It involves cutting a cartoon up into manageable vertical strips (usually about 90 cm wide) which are then placed under the warp so that the weavers can look through and copy the design. The weavers work on the back of the tapestry, so the finished image is a mirror of the cartoon.

Given the heavy handling of the Raphael Cartoon strips which were used to produce the first five sets of tapestries before 1540, it comes as no surprise that by 1573 they were described in a letter to Cardinal Granvella as being in too damaged a state to be used to make another set for him. He was advised that a further set was therefore being produced from copies.

There is a gap in our knowledge of the Cartoons over the next thirty years or so but it is thought that they were in Genoa at the beginning of the 17th century.

In 1623 the Prince of Wales, later Charles I, arranged to buy the seven Raphael Cartoons that remained by then, and they were brought to England with a view to using them at the newly established Mortlake Tapestry Factory. Francis Cleyn was asked to copy the damaged Cartoons and from these copies further sets of tapestries were made. Daniel Mytens is also thought to have made a set of copies of the Cartoons before his return to the Low Countries in 1634. There are also copies of two of the Cartoons in the National Gallery in Dublin although it is not known when or by whom they were painted.

The Cartoons remained in strips for most of the 17th century although it is recorded that they were hung together for viewing. They were probably also hung together to facilitate the making of the various sets of copies that were made at this time. During this period they were variously stored at Somerset House, Whitehall and the Tower until in 1697 the first major restoration work was carried out by the painter Henry Cooke and the Surveyor of Pictures, Perry Walton. This restoration involved re-integrating the individual strips by lining them onto a canvas support. Some trimming and some retouching took place at this time. This work was carried out in preparation for the rehousing of the Cartoons in the cartoon gallery at Hampton Court, designed by Sir Christopher Wren. It is worth noting that thought was given to the preservation of the Cartoons at this time – the wooden panelling was continued behind the Cartoons “to preserve them from the walls” and also shell gravel was placed in between the ceiling joists as a barrier against accidental fire.

In 1763 the Cartoons were moved to Buckingham House “on their suffering from damp” at Hampton Court. By the end of the 18th century the Cartoons had been moved again, this time to Windsor Castle.

In 1804 the Cartoons, now framed but unglazed in their present Carlo Maratta frames, were sent back to Hampton Court by George III. The opening of the National Gallery in 1824 brought renewed concern about their state of preservation and demands for their removal from Hampton Court to the National Gallery. In fact the Cartoons eventually came to the Victoria and Albert Museum (then known as South Kensington Museum) on loan in 1865.

In 1867, on the advice of Richard Redgrave, the Cartoons were glazed (using three pieces of glass for each frame) and the frames backed with calico. In 1891, in the wake of the Russel and Abney Report, the gallery skylights were filtered with green and orange glass to protect them from fading.

During the first half of the 20th century various suggestions were made to replace the three-sheet glazing but nothing was done at this time. In 1924 the Cartoons were all surface cleaned and re-hung sloping slightly forward in an effort to try and stop dust adhering to the surface. The next major conservation work was carried out in 1934 when six of the seven Cartoons were strip-lined.



### *The Examination and Conservation of the Raphael Cartoons*

The seventh Cartoon, *Sacrifice at Lystra*, will be carefully examined during the current conservation programme to assess if it now needs strip-lining.

The Cartoons were moved to their present location in 1950 and it was the refurbishment of this gallery in the mid-1960's that led to the last major programme of conservation. This programme included re-glazing the Cartoons with a single sheet of plate glass and fitting filters to the backs of the frames. The frames were housed in false walls that could be winched out to provide access to the Cartoons, from the back, in the case of fire. In practice, however, this would have been very difficult to achieve in a short time. The Cartoons themselves were also surface cleaned (using pulverised vinyl eraser), loose areas of paper were consolidated, and finally the Cartoons were retouched using pastel. A number of paint samples were also taken and analyzed by Joyce Plesters<sup>3</sup> of the National Gallery. It was during this analysis that the mystery of the different colouring of Christ's cloaks in the Cartoon *Miraculous Draught of Fishes* – white cloak on Christ in the boat, red cloak on the reflection of Christ in the water – was explained. Plesters found that the white cloak had, in fact, originally been painted red for which a red lake pigment, now faded, had been used. The red reflection had been painted with the relatively stable pigment, vermilion, and has remained unfaded.

#### INITIAL EXAMINATION

The seven remaining Raphael Cartoons and their dimensions are as follows:

1. *The Miraculous Draught of Fishes* (3.19×3.99 m)
2. *Christ's Charge to Peter* (3.43×5.32 m)
3. *The Healing of the Lame Man* (3.42×5.36 m)
4. *The Death of Ananias* (3.42×5.32 m)
5. *The Blinding of Elymas* (3.42×4.46 m)
6. *The Sacrifice at Lystra* (3.47×5.42 m)
7. *Paul Preaching at Athens* (3.43×4.42 m)

The Cartoons are painted in bodycolour<sup>3</sup> on overlapping sheets of paper, each sheet approximately 29×42 cm (11×16 in), stuck down all over onto canvas. In places there are several layers of both paper and canvas visible. Each Cartoon is tacked onto a stretcher and framed.

An initial examination was carried out to assess their suitability for being moved to another part of the Museum for temporary storage.

The major area of concern was the vibration of the canvas against the stretcher. This was noticed during the initial condition check and de-installation. This led us to consider the use of a cami-lining<sup>4,5</sup> or similar solution to dampen these

vibrations. This concern was highlighted by the discovery, at this stage, that on two of the Cartoons the canvas had become stuck to the stretcher bars (this had probably occurred during a previous restoration). These areas were carefully monitored during the move. In practice, however, it was decided that each Cartoon should be placed directly into its travelling frame as it was de-installed. This avoided a potentially risky operation and the travelling frames themselves reduced the vibration to a minimum.

Mirror plates were attached to the Cartoon stretcher, which were then used to secure the Cartoon into its travelling frame. The travelling frame was then in turn secured to a rubber-wheeled trolley for movement through the museum. The success of these moves involved slow but steady movement of the Cartoons. Most stress would be put on the Cartoons if the trolley had to stop and then be moved again. The movement of each Cartoon normally required up to six object handlers plus a conservator. The moves had to be carefully planned and usually took place either early in the morning or late in the evening when members of the public and non-essential staff were not present.

An environmentally monitored secure storage area was specially constructed for the seven Cartoons whilst completion of the refurbishment was awaited. A paper gulley was fitted to the bottom of each travelling frame so that it could catch anything that may have become detached during the move or during storage. The enclosed storage area was also fitted with hatches so that regular visual checks could be carried out.

Once the Cartoons were brought back into the Cartoon Gallery and taken out of their travelling frames for examination, access was constantly needed to the back of the Cartoons and this made the use of a false lining impractical. These considerations led to the design and production of the metal easel (Fig. 1) which was used to manoeuvre the Cartoons. This easel can be used to raise and lower the Cartoons and also to hold them at different angles between the horizontal and vertical. These changes of position can be made relatively smoothly thus avoiding the setting up of vibrations in the Cartoon. A wooden A-frame was also used to hold one of the Cartoons – still in its travelling frame – during examination. This meant that at any one time two Cartoons were available for examination.

#### FURTHER EXAMINATION

##### *Camera stand*

A four metre high camera stand was purchased for the programme. This was needed for photography, the infra-red camera and the X-ray source.

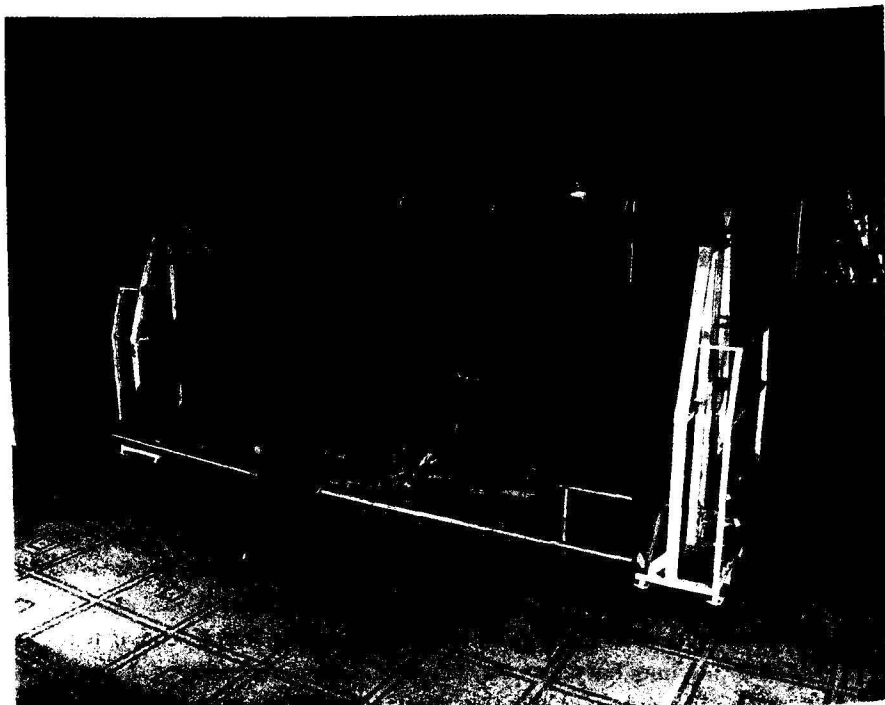


Fig. 1. The Cartoon *Blinding of Elymas* being moved into position on the metal easel.

#### *Raking light photography*

One of the most useful techniques employed is raking light – both for examining the Cartoons and for documenting condition with photography (Fig. 2). To cover such a large area in detail involved taking six overlapping photographs that could then be reassembled. This technique gives a clear indication of creases, tears, cuts and areas of loose paper. Quite significantly, raking light also revealed the presence of a “bulge” some 7–9 cm on either side of each working join, i.e. at the point at which the Cartoon was cut into strips. This initial discovery, backed up later by transmitted light and X-radiography, led to a close examination with the naked eye. The result seems to indicate that each strip of cartoon was strip-lined on all four edges with a fine canvas some 7–9 cm in width. This must, of course, have been attached either at the time of or before the restoration work of 1697. This strip-lining may have been the means by which the Cartoon strips were handled and temporarily butted together for copying and viewing during the 17th century. This seems to be confirmed by the further discovery that at each working



Fig. 2. Detail of a raking light photograph of the Cartoon *Death of Ananias*.

join the left hand vertical strip of canvas usually seems to extend a couple of centimetres beyond the edge of the Cartoon so that it “underlaps” the right hand strip of Cartoon on which the edge of the strip-lining coincides exactly with the edge of the Cartoon. There are also a series of pinholes which, from their consistency of location – at the point of butting together of the cartoon strips, could indicate that the Cartoon strips when displayed were held in place by pinning through the narrow “underlap” of strip lining at each working join. This is an important discovery since previously it had been thought that this fine canvas could have been an overall layer that may have been attached by Raphael. This no longer seems to be the case.

Radio-carbon dating of a sample of this fine canvas was carried out. The results obtained suggested that the canvas was produced in the period AD 1390–1640.

*Transmitted light photography*

This was the first time the Cartoons had been examined by using transmitted light, and this technique proved to be the most effective in helping to reveal the structure of the Cartoon. The image is somewhat complicated by the presence of the stretcher bars and the cross bars of the metal easel. However, quite regular patterns of overlapping sheets of paper are clearly visible. Also evident are the working joins, manifest here as vertical lines of light. The pattern of the canvas is also visible. Numerous patches can also be seen, which must, of course, have been put on before the lining with canvas in 1697. Whether or not these repairs were done in the same restoration campaign is open to conjecture (Fig. 3).

The most important finding from the transmitted light examination was that there is only one layer of paper. The overlaps of these sheets show clearly as a regular mosaic. Examinations in the past have focused on the layer structure partly visible to the naked eye at areas of damage and the working joins. This has obviously misled people into believing that there was a number of original



Fig. 3. Detail of transmitted light photograph of *Death of Ananias*.

layers of paper present, whereas in fact it was just that often these areas had been repaired.

Another interesting discovery from transmitted light was the stamped initials



Fig. 4. Set-up for transmitted light photography.

"CR" on the back of each strip of the *Blinding of Elymas* Cartoon. This is the monogram of King Charles I who owned the paintings from 1625–1649.

Setting up a Cartoon for transmitted light photography was again complicated by the size of the Cartoons and by their multi-layered nature. Transmitted light photography was carried out with a Cartoon on the metal easel with the Cartoon Gallery blacked out. Blacking out paper was attached around the edges of the Cartoon to shield the camera from the flash. The light source, placed behind the Cartoon, consisted of four Bowers soft boxes (flash units), each one with an output of some 3,000 joules (Fig. 4). With the camera shutter open at F11, 20 flashes of the four boxes were needed to produce an effective image. Again this procedure needed to be carried out on six different areas of a Cartoon which were then reassembled to form the overall image. Of course this information formed a useful addition to the condition documentation as it also highlighted areas of weakness such as holes and cuts. Kodak T-Max 400 ASA 5×4 film with extended development time was used.

#### Photogrammetry

This technique is used commercially in ordnance survey work and for taking precise measurements of buildings.

For each Cartoon, 5–6 overlapping pairs of photographs were taken. Each pair of photographs was then put into a stereo plotting machine. In this the operator's left eye views the left hand photograph and the operator's right eye views the right hand photograph. In this way the brain perceives a three-dimensional image of the Cartoon which can be scaled precisely using previously coordinated reference points. A floating mark is used to trace any line work on the image surface and three-dimensional coordinates are recorded using a computer-aided design package.

In the case of the Raphael Cartoons this information was used to plot and measure the overlaps of the sheets of paper, the position of the working joins and any other cuts. In this way we were able to measure the size of every sheet of paper used to make up the Cartoons without having to risk touching the surface in taking measurements by hand. When one considers that each Cartoon consists of up to 200 sheets of paper, the benefits of this particular technique are immediately obvious. The only disadvantage is that the operator cannot always readily distinguish some details from the stereo photograph. For example, the paint layer can confuse the issue as it is not always perfectly clear which way the paper sheets are overlapping. To resolve this the operator needs to verify some details on site with the help of the conservator.

Results so far obtained indicate that the Cartoons were constructed by using

sheets of paper that had had their deckle edges removed and were some 29×42 cm (11×16 in) in size with regular overlaps of some 1–2 cm. The sheets were mainly laid down portrait style but some smaller areas were completed landscape style. Earlier analysis had shown that the paper was linen rag. The relatively thick overall paint layer and the canvas backing makes it impossible to see any water-marks or laid lines. However, the presence of what appear to be rope marks – along the longer edge of many of these sheets of paper – indicate that in fact these sheets are half sheets. This would suggest that the full sheet size would have been approximately 58×42 cm (22×16 in) which corresponds to Reale size. Perhaps half sheets were used to give greater strength to the support. Photogrammetry is also being used to take a measurement of the depth of the bulge that is present in the bottom corner of the Cartoon *The Blinding of Elymas*. Theoretically this measurement could be retaken in the future in order to note any change.

#### X-radiography

During the conservation programme in the mid-60's X-radiographs were taken of selected areas – mainly the heads of the figures – by resting the X-ray film on the surface the Cartoon which was in the horizontal position.

In this current programme it was decided to avoid surface contact. It was also decided that since we wanted to X-ray an entire Cartoon it would be easier to do it in the vertical position. The Cartoon was placed on the metal easel, the bars of which were marked up to ensure that each X-radiograph (35×43 cm) overlapped by a few centimetres. By using the cross bars of the metal easel and the stretcher bars of the Cartoon it was possible to position the X-ray film using pieces of foam (Fig. 5) thus avoiding the need to stick the film to the back of the canvas. Lead letters and numbers (e.g. A1, C3) were attached to each piece of film for ease of reference – it took some 180 X-radiographs to cover one Cartoon. Positioning the X-ray source was fortunately facilitated by the regular pattern of the mosaic floor – also restored as part of the refurbishment programme. For various reasons, such as cost and time, it was decided that complete X-radiography would be taken of only two Cartoons, *Christ's Charge to Peter* and *The Healing of the Lame Man*. For the other Cartoons only selected areas (including all heads) would be taken.

The results so far are extremely useful. The X-radiographs (Fig. 6) show many details, e.g.:

- craquelure and paint loss (often concealed to the naked eye by retouching)
- the pattern of the canvas layers
- the direction and extent of the overlapping of the sheets of paper



Fig. 5. Set-up for placing X-radiograph film in position at the back of the Cartoon.

- the pricking holes (these relate to the copying of the Cartoon and not the making of the tapestries)
- painting technique, e.g. the blocking in of features, which may help reveal the different hands involved in the painting



Fig. 6. X-radiograph detail of St. Paul preaching.

- pentimenti, e.g. Pope Leo originally painted without a cap in the Cartoon *Paul Preaching*
- details covered by repainting, e.g. alteration to some of the buildings in *Christ's Charge to Peter*

After a number of tests it was found that the best results were obtained when the X-radiographs were taken at 22 kV for 30 sec, source-object distance 100 cm, using Agfa film.

#### *Infra-red reflectography*

The Cartoons were examined with an infra-red vidicon. The underdrawing is quite strong in the Cartoons and in many areas is visible to the naked eye. However, some areas of underdrawing showed up much more clearly with the vidicon, e.g. the buildings in the landscape of the Cartoon *Christ's Charge to Peter*. This

method of examination may help to show the initial technique and areas of pentimenti.

#### *Ultra-violet (UV) examination*

This technique proved useful as an initial aid to pigment analysis. Interesting areas of fluorescence could be chosen for further analysis as indicated below. It also revealed the presence of a possible glaze in the shadow areas of different pigments on several of the Cartoons. This "glaze" appeared as a green fluorescence.

UV examination also revealed the location of old retouchings and repaintings.

#### *Pigment analysis*

Some pigment analysis is being done on each Cartoon to add to the information gained by Plesters in the 1960's. The purpose of the analysis is multifold:

- to analyse areas that seem to have discoloured
- to analyse areas that seem to have faded
- to help verify possible areas of retouching
- to analyse the "glaze" apparent under UV examination
- to take cross-sections to try to establish whether there is a layer structure to the paint.
- to analyse the underdrawing: in some areas on the Cartoons the underdrawing seems to have been done with a brush and ink rather than charcoal, and appears to have caused localised flaking of the paint layer

### CURRENT CONSERVATION

#### *Ethical considerations*

At the beginning of this programme consideration was given to the nature of the proposed treatment. Highly interventive treatment was dismissed, after discussion, for the following reasons. The Cartoons are very complicated in structure and this structure itself is not completely understood. One of our aims is to clarify the structure which in places appears to consist of several layers of paper and several layers of canvas. The paint layer itself is also complicated by retouchings and repaintings. Technically therefore any highly interventive treatment would have been very difficult and unacceptably risky to the object. Also, however much the Cartoons are now regarded as great works of art, they were originally conceived

and used as working designs. Most of the damage and their complicated overall structure is a result of this usage and tells us much about their history. This evidence should not be interfered with.

#### *Current condition*

From the above series of examinations plus close visual examination it has been possible to put together quite comprehensive documentation of the present condition of the Cartoons. This has been facilitated by using overlays on the raking light photographs.

There are many areas of old damage on the Cartoons including creases, tears, splitting along pricking holes, craquelure and pigment loss. This is not surprising considering their history. However, despite appearances the Cartoons, though damaged, are quite stable. Only limited treatment as described below was necessary.

#### *Treatment*

For the reasons already outlined interventive treatment has been kept to a minimum and so far has revolved around the consolidating of loose areas of the Cartoons. This work involved the following.

- Surface cleaning of the stretchers and back of the canvas using soft brush, soft cloth and a low-powered vacuum cleaner.
- Re-attaching loose areas of paper using methyl cellulose (low substitution, Merck-BDH, Leicester). This involved two conservators, often working from library steps, one at the front of the Cartoon and one at the back. The conservator at the front would apply the adhesive and press loose areas into place using hand pressure against the resistance provided by the other conservator holding a piece of Plastazote (BXL Plastics, Croydon) at the back of the Cartoon.
- Reinforcing the extreme edges of the Cartoons where they are folded around the stretchers, using a toned Japanese kozo paper and wheat starch paste. These areas had been damaged by stress from the stretchers and by fitting too tightly into the frames.
- Freeing the areas of the support that had become attached to the stretcher bars using a steam generator.

#### *Reframing*

When glazed each of the Carlo Maratta frames weighs approximately three quarters of a ton (700 kg). The handling and manoeuvring of the frames is difficult and



potentially dangerous. In order to reduce the risk to both people and Cartoons a new framing system was designed to enable each Cartoon and its frame to be hung as one entity but on separate supports. It allowed the Cartoon to be positioned on the wall and then the frame to be lifted up to the Cartoon. This involved the precision placing, on the wall of the gallery, of a Plastazote covered metal ledge (for the bottom edge of the Cartoon to rest on). Several metal plates also had to be positioned outside the perimeter of the Cartoon, through which small metal bolts could be screwed into a gap formed by attaching specially shaped blocks to the back of the stretcher. The stretchers are therefore free to move slightly to accommodate structural changes over time rather than being fixed rigidly into the frame. Each Cartoon on its stretcher is not particularly heavy and could have been comfortably lifted by six people. In practice a reach truck was used with a specially adapted support to hold the Cartoon and lift it into position. This proved to be a more secure way of manipulating the Cartoon into position.

The frames were lifted from the A-frame using a system of blocks and pulleys. Discreet fixings have been installed above each frame location for the pulleys. The frames are sealed to the wall (which is covered in polythene behind the Cartoon) using a silicon sealant to try and achieve as good a seal as possible. This should be sufficient to buffer against any rapid environmental changes and to slow down the ingress of particulate matter<sup>6</sup>. The large open nature of the Gallery would make it extremely difficult, if not impossible, to completely control the conditions. The conditions in the Gallery and inside each frame will be environmentally monitored.

In order to minimise the risk of fire the current refurbishment involves ensuring that there are no combustible materials in the gallery apart from the Cartoons. There are also fire curtains at all entrances that can be activated in an emergency.

#### CONCLUSION

The task of dealing with not just one but seven large-format objects created problems throughout the current programme. The main reason for the length of time involved in the Raphael Cartoon project is that the conservation and examination work could not begin until the refurbishment of the Cartoon Gallery was completed. There was simply no other space of sufficient size available in which to carry out the examination and photography. Once the refurbishment was completed, however, it was possible to exploit the large size of the Cartoon Gallery by having two Cartoons back in the gallery at any one time for examination. This allows the curator and conservator involved in the project access to one Cartoon each. This is very useful, of course, for comparing findings between

Cartoons. However, it has been impossible to be able to work on all seven Cartoons at the same time. On completion of examination and treatment it has been necessary to reframe and hang those two Cartoons to make way for the next two. This has proved frustrating because no matter how thorough one is in documenting what one sees, it is always preferable to be able to refer back to the unframed object.

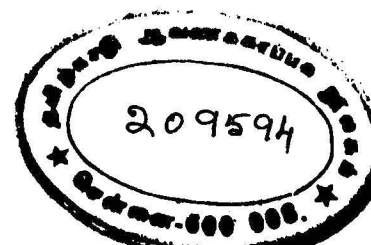
From the work done until now on the Cartoons, it seems that Raphael and his assistants made the support for each Cartoon from a single layer of overlapping sheets of paper. At a later time – probably in the 17th century – the Cartoons, already cut into strips and damaged from usage and travel, were restored by the strip-lining of each strip of Cartoon. At the end of the 17th century these strips of Cartoon were reintegrated by lining them onto a continuous layer of canvas. At the time of the strip-lining, or before, or perhaps at the time of the reintegration of the strips, numerous paper patches were used to reinforce the damaged areas of the Cartoons.

The rigours of time and the constant moving around of the Cartoons over the centuries – usually achieved by their rolling and unrolling – has led to damage and loss to some areas of the paint layer and the support. The stretchers on which the Cartoons are tacked were built to allow the Cartoons to be folded in half for transport, and this method of handling has also contributed to their damage. There has also been some fading, particularly of lake pigments, but generally speaking Raphael used relatively stable inorganic pigments that have resisted change and today look much as they did in his day.

#### ACKNOWLEDGEMENTS

The author is most grateful to the Royal Collection for permission to examine the Raphael Cartoons in detail.

He also would like to thank Dr Sharon Fermor, Head of Paintings, with whom he worked on this project; Susan Lambert, Project Team Leader; Dr Jonathan Ashley-Smith, Keeper of Conservation; and Helen Shenton, Head of Group, Paper and Book Conservation; for their support. Special thanks are also extended to all colleagues in Paper Conservation, in particular: Pauline Webber for her many useful suggestions and practical help; John Wagstaff, now retired; and Mike Wheeler who was often on the “other side of the Cartoon”! Also to Josephine Darrah, Senior Scientific Officer, for taking and analysing the paint samples. This project would not have been possible without the expertise of Peter Riley and his team of Object Handlers; Paul Robins and his colleagues who did the photography; Howard Pearson of Roffey Ltd for the X-radiographs; and John Velnoweth of Plowman and Craven for the photogrammetry.



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*The Examination and Conservation of the Raphael Cartoons*

## SUMMARIES

*The Examination and Conservation of the Raphael Cartoons.*

The Raphael Cartoons form part of the Royal Collection and have been on loan to the Victoria and Albert Museum since 1865. This paper deals with the problems posed in the handling, examination and conservation of the seven large Cartoons (average size 3.5×5.0 metres). Extensive refurbishment of the Raphael Gallery was deemed necessary and this work began in 1992. Part of this brief included the re-designing of the framing system to allow the Cartoons (which are on stretchers) to be hung within their extremely heavy frames but on separate supports.

It was decided that the opportunity should be taken during the refurbishment to examine the Cartoons with a view to assessing their condition and also to try and further our knowledge of their structure. Examination techniques used included infra-red reflectography, X-radiography and photogrammetry. Originally the Cartoons were composed of a single layer of overlapping sheets of paper that were cut into strips as part of the weaving process. Each strip of Cartoon was strip-lined before the end of the 17th century.

*Examen et restauration des Cartons de Raphaël*

Les Cartons de Raphaël font partie des Collections royales et sont en prêt au Victoria and Albert Museum depuis 1865. Cet article traite des problèmes posés par la manipulation, l'examen et la restauration de sept grands Cartons (environ 3.5×5 mètres). Une remise à neuf complète de la Galerie Raphaël a été jugée nécessaire et le travail a commencé en 1992. Celle-ci comprenait une nouvelle conception du système d'encadrement pour permettre de suspendre séparément les Cartons (qui sont montés sur châssis) et leurs très lourds cadres.

Il a été décidé de profiter de cette occasion pour examiner les Cartons afin d'évaluer leur état et aussi pour essayer d'améliorer la connaissance de leur structure. Les techniques d'examen utilisées comprenaient la réflectographie infra-rouge, la radiographie et la photogrammétrie. A l'origine, les Cartons étaient composés d'une seule couche de feuilles de papier se chevauchant, coupés en bandes au moment du tissage. Chaque bande du Carton a été doublée sur les bords (striplined) à la fin du XVIIe siècle.

*Die Untersuchung und Konservierung der Raphael Teppichentwürfe.*

Die Teppichentwürfe gehören zu den Königlichen Sammlungen und befinden sich seit 1865 als Leihgabe im Victoria and Albert Museum. Es wird berichtet über die Probleme, die sich aus Handlung, Untersuchung und Konservierung von sieben großen Entwürfen (Durchschnitt 3.5×5 m) ergeben. Eine gründliche Reinigung erschien angebracht. Dies beinhaltete die Neukonstruktion eines Rahmungssystems, welches das getrennte Aufhängen der Blätter (die sich in Spannrahmen befinden) und der extrem schweren äußeren Rahmen ermöglicht. Es wurde entschieden, die Reinigung als Gelegenheit für eine Untersuchung zu nehmen, sowohl ihres Zustandes als auch um ihren Aufbau besser zu verstehen. Die Untersuchungsmethoden umfaßten Infrarot-Reflektographie, Röntgenaufnahmen und Photogrammetrie. Ursprünglich bestanden die Entwürfe aus einzelnen Schichten von überlappendem Papier, die dann, um als Webvorlagen zu dienen, in Streifen geschnitten wurden. Vor dem Ende des 17. Jh. wurden die Streifen auf Leinwand aufgezo-gen.

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## MATERIALS

Methyl cellulose, low substitution: BDH Products, Merck-BDH Ltd, Hunter Boulevard, Magna Park, Lutterworth, Leicester LE17 4XN, United Kingdom.

Plastazote. BXL Plastics Ltd, Mitcham Rd, Croyden, Surrey CR9 3AL, United Kingdom.

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## Publish, Then Perish: The Reclamation of a Collection of Scientific Illustrations

by DIANNE VAN DER REYDEN, HEATHER TENNISON &  
FEI WEN TSAI

### INTRODUCTION: PAST AND PRESENT

The current struggle between access and preservation, which seems to plague some museum and archive collections, has ancient precedence. When reviewed, such historic examples may enlighten individuals as to the possible consequences that may be incurred by this struggle. For example, to scholars of Icelandic history and culture the Sturlunga sagas, written from approximately 1120 to 1260, provide rich insight into the social and economic forces that were present in medieval Iceland. A large compilation of sagas named after an influential Icelandic family in the thirteenth century, the Sturlunga sagas are often called “contemporary sagas”<sup>1</sup> since the events described took place at about the same time as the sagas were written. Although the original thirteenth-century Sturlunga compilation was lost, two vellum copies from the second half of the fourteenth century are known to have survived as late as the seventeenth century. It was at this time that the sagas were again transcribed into books made from inexpensive imported paper. After the contents of the older manuscripts had been transferred to the more accessible and easily read paper substrates, the seemingly outdated vellum codices were considered relatively valueless by the contemporary population and were allowed to go to ruin. One of them was, for instance, cut up into patterns for making clothes!<sup>2</sup> Although it is fortunate that the stories detailed on those vellum folios were preserved for future use, it is highly unfortunate that all of the information inherent to the bound vellum volumes, such as the chemical and physical makeup, can no longer be accessed.

The seventeenth-century Icelanders viewed access as a viable means of preserv-

ing the information that was important to their cultural heritage. Over two hundred years later this view is echoed by some archivists and collection managers who occasionally invoke a “sensible” rule for ranking collections during processing in order to cope with the enormous amount of material in their holdings. The rule holds that original materials that have been published may be considered of less value to a repository than those that have not. Unfortunately, there may have been times when the logic of this guideline has been supported for the sake of storage or perceived cost-benefit to the point that published materials have been allowed to perish.

The preservation of scientific illustrations appears not to have been the subject of great debate. The very nature of their production, for the purpose of publication, makes them an ideal example of this rule: what is published soon will perish. Just as the Icelanders forever lost information that was inherent to the vellum manuscripts, so some scientific illustrations and all of the information that they might carry have been doomed to suffer a similar fate.

But the weary pattern of history continually repeating itself may soon be broken through the efforts of current scientific illustrators and other museum professionals. Our present case involves one of the most famous collections of drawings produced in the late nineteenth century: the dinosaur type specimen illustrations of the O. C. Marsh Collection, portions of which are now at the Smithsonian Institution (SI). The bulk of the collection can be found at Yale University, one of the institutions that funded the expeditions. This paper will: chronicle the collaborative efforts taken to ensure the continued preservation of this historic collection; outline the integrated approach to preservation that was utilized; and discuss how the seemingly contradictory needs of access and preservation may be resolved through interdisciplinary dialogues

### THE COLLECTION

Paleontologist Othniel Charles Marsh, under the auspices of the U.S. Geological Survey and Yale University, was responsible for discovering and naming many of the dinosaurs that are household names today, such as triceratops. The immense collection that he amassed in the late nineteenth century now forms the core of the dinosaur collection in the Division of Vertebrate Paleobiology at the National Museum of Natural History (NMNH), SI. In the 1980s, the original drawings of the specimens, prepared under the direction of Marsh, were moved by a museum specialist who was investigating water-damaged objects that were stored on the tops of cabinets in the department's type specimen room. The illustrations were commissioned for use in a series of important monographs that were to provide



Fig. 1. Side view of Triceratops Skull (Yale University specimen). Original pencil drawing, transferred to a tracing to be published as a lithograph in 1907's *The Ceratopsia*.

the first details as to the orders and families of vertebrates while "illustrating them in the most artistic manner". This desire for artistic excellence can be seen in the monograph *The Ceratopsia*,<sup>3</sup> for which Marsh commissioned over 204 lithographic plates to be made from both drawings (Fig. 1) and wood engravings, as well as pencil and pen-and-ink drawings for the textual portions of the volume. In all, five artists are noted as having contributed to this volume. The lithographic plates were executed by Mr. E. Crisand from drawings by Mr. Frederick Berger. Mr. Berger was also commissioned to produce the pencil drawings that are seen in the plates and text. Important pen-and-ink drawings in the text are by Mr. Sydney Prentice. Drawings representing materials not seen in the American Museum of Natural History are by Mr. Rudolph Weber. Mrs. Lull, the wife of R. Lull upon whose shoulders the completion of the monograph fell, completed the remaining 12 plates that were needed before publication. The Smithsonian's collection holds approximately 1,700 of these drawings, preparatory sketches on kraft paper, and tracings. They were found organized in folders (45×30.5 cm = 17¾"×12") that identified both the specimen and the view that was depicted in the drawing, as well as each drawing as having been either a wood-cut or wood engraving respectively, or a lithograph. There are approximately 160 folders in the collection.

#### THE COLLABORATION

Without the efforts of individual collection managers or other departmental staff motivated to save the collections, the preservation process will never begin, let alone be sustained or completed. Collaboration is the vital first step. When the Marsh illustration collection was located by the museum specialist, its continuing historic and scientific value was assessed as being extremely high despite its published status. The drawings were offered to an archive that, due to its policies, was unable to accept them. Indeed, the archive managers reiterated the early principal of attributing a low value to published materials.

As the years went by, the museum specialist, Dr. Mike Brett-Surman, found individuals who could sympathize with his understanding of the importance of the collection and aid him in his efforts to preserve them. For instance, Dr. Brett-Surman sought out the advice of Ms. Mary Parrish, the departmental scientific illustrator. She had discussions with other Smithsonian illustrators who had begun to take steps to preserve illustration collections in their own departments, and was given information on conservators who could aid in surveying and rehousing the collection.

The collaborating professionals included scientific illustrators, conservators, archivists, collections managers, museum specialists, curators, scientists, and exhibition designers. Each was able to appreciate and enhance the diverse values of the collection, and in the end their insights and enthusiasm made the preservation of this collection possible.

#### THE ANGEL PROJECT

The drawings had been moved from the cabinet tops into drawers by Dr. Brett-Surman in his off-work hours (Fig. 2). In July of 1995, the Conservation Analytical Laboratory's (CAL) Paper Conservation Lab, SI, was notified about the collection, its current housing, and its relative condition. CAL organized an Angel Project in collaboration with the Society of American Archivists (SAA), the Office of the Smithsonian Institution Archives (OSIA) and the Division of Vertebrate Paleobiology (NMNH), and with supporting materials and advice from the Library of Congress (LC) and the National Archives and Records Administration (NARA).

Angel Projects were originally conceived and organized in 1988 by Lisa Mibach (a conservator in private practice). They have been traditionally held in conjunction with the American Institute for Conservation (AIC) annual meetings. They provide local collections in need of conservation assistance with contact to conservators interested in contributing their expertise. The idea of sponsoring an





Fig. 2. Division of Vertebrate Paleobiology Type Specimen Room. Scientific Illustrators look on as a conservator and archivist assess storage conditions.

Angel Project has been used by other individuals. For example, Elizabeth Morse, Paper Conservator at the Harvard University Library, organized one to aid the execution of a large survey. This version of an Angel Project (a modified form of the AIC project organized to coincide with SAA's annual meeting) served as a pilot to work out and demonstrate an ideal procedure for the processing, rehousing, and reformatting of this important illustration collection.

An integrated approach to the preservation of the collection was devised so that there would be minimal physical contact with the illustrations and other supports found in the collection. The process began with the completion of a Preservation Priority Worksheet (Fig. 4) that was originally developed by the SAA in October, 1993.<sup>4</sup> This survey tool utilizes a numerical ranking system and easily-followed matrices to plot the overall risk, exposure, and value of a collection, allowing for unbiased comparison among many different types of collections. The Worksheet is accompanied by a form for entering the information into the Preservation Priority Data Base with reference to the following headings: Collection; Housing Need; Poor Housing; Poor Positioning; Difficult Formats; Damaging Attachments; Holdings Maint. Need (Sum); Use; Exposure; Amount of Damage; Amount of Unstable Material; Overall Condition; Risk; Value; Preservation Priority Score.

Besides the Marsh Collection, there were three additional collections of illus-

trations and other related materials housed in the Division of Vertebrate Paleobiology: the Gilmore Archives (14 envelopes housing approximately 470 drawings and photographs); the Marsh Archives (approximately 300 prints, grouped together with metal fasteners); and the U.S. Geological Survey (approximately 640 prints and drawings). The quick survey on the basis of the Preservation Priority Worksheet allowed the staff an opportunity to compare the problems and overall values of each of the collections. Based on the comparisons, the collections could be ranked in order to determine which project should be targeted first. In this case, the survey was completed by a conservator and the Collections Manager working together. However, in other cases surveyors may be trained to work alone, if necessary. The data generated by the survey is then entered onto a Preservation Priority Data Base so that the collection needs can be easily read and compared. Based on resources available, a priority collection can then be chosen (Fig. 3).

Once a collection is targeted as being a preservation priority, staff time and energy can be allocated to prepare for future preventive conservation initiatives. One such preparatory step is the execution of a Random Sampling Survey.<sup>5</sup> For instance, by surveying ten percent of the collection (noting size, condition, me-



Fig. 3. Fei Wen Tsai leads a discussion on survey techniques for a group of visiting archivists at an Angel Project. (Tennison, Heather, D. van der Reyden, F. Tsai and M. Parrish. "An 'Angel Project' of Dinosaur Proportions," to be published in 1997 by the American Institute for Conservation's Book and Paper Group Annual.)

## PRESERVATION PRIORITY WORKSHEET

INSTITUTION: \_\_\_\_\_ BUREAU: \_\_\_\_\_ DIVISION: \_\_\_\_\_ REPORT #: \_\_\_\_\_

Series/Collection Name: \_\_\_\_\_ Location: \_\_\_\_\_ Bulk Dates: \_\_\_\_\_

Collection Size - number of items: \_\_\_\_\_ number of linear feet: \_\_\_\_\_ number of cubic feet: \_\_\_\_\_

Originals/copies (format): \_\_\_\_\_ Surveyor(s): \_\_\_\_\_ Survey Dates: \_\_\_\_\_

Current Housing: Appropriate materials, techniques and orientation? (circle all that apply and indicate percent of collection):

|                                  |                                          |                              |
|----------------------------------|------------------------------------------|------------------------------|
| <b>Furniture:</b>                | <b>Containers:</b>                       | <b>Container/Item Sizes:</b> |
| shelves (open/closed)            | boxes (record/document/print/phased/box) | letter                       |
| drawers (vertical/flat)          | folders/envelopes (group/individual)     | legal                        |
| racks (vertical/horizontal/roll) | enclosures (plastic/paper/mats)          | oversize                     |

## Part I of Preservation Selection - Value Assessment of the Records

1. Do the records relate to the:
- Mission Statement* of the institution in terms of:
- the topics that are being documented? (i.e. what are the topics?) Yes \_\_\_ No \_\_\_
- the stated purpose? (i.e. what is the purpose?) Yes \_\_\_ No \_\_\_
- the institution's users? (i.e. who are the users?) Yes \_\_\_ No \_\_\_
- Collection Policy* of the institution in terms of:
- the general and specific functions/topics that are of interest? Yes \_\_\_ No \_\_\_
- the relationship of the repository goals to the goals of other repositories? Yes \_\_\_ No \_\_\_
- the relationship of the known world of related documentation of the functions/topics? Yes \_\_\_ No \_\_\_

If the answer to most of the above is Yes, proceed to question #2 below.

If the answer to most of the above is No, then choose one of the following four options.

- Do not accept the records.
  - Refer the records to another institution.
  - Deaccession the records.
  - If the records are retained, do not take preservation action.
2. Does the institution have legal custody of the records or the expectation of obtaining legal custody? Yes \_\_\_ No \_\_\_
- Are the records accessible to users without excessive restrictions or hindrances? Yes \_\_\_ No \_\_\_
- Are there resources to preserve and maintain the records or the expectation of obtaining resources? (resources = policy, environmental control & space, storage furniture & supplies, staff, training, time & funds) Yes \_\_\_ No \_\_\_

If the answers to all of the above are Yes, proceed to question #3 below.

If the answer to any of the above is No, defer preservation action until remedied.

3. Are the records of importance to the institution primarily:
- because of their value to researchers? Yes \_\_\_ No \_\_\_
- If Yes, plot evidential vs. informational value on Matrix 3 below.
- to meet its operational needs or the operational needs of other creating institutions? Yes \_\_\_ No \_\_\_
- If Yes, plot evidential vs. informational value on Matrix 2 below.
- for both operational purposes and for research value to others? Yes \_\_\_ No \_\_\_
- If Yes, plot evidential vs. informational value on Matrix 1 below.

In using the matrices below, keep in mind that:

evidential value pertains to the administrative, fiscal, legal or institutional significance of the records.

informational value pertains to research value for historical, educational, genealogical reasons, or use in public programs.

intrinsic value pertains to the artifactual, monetary, symbolic, or sentimental value.

Determine whether the evidential and informational value as defined above is High, Moderate, or Low.

Plot the evidential vs. informational value on the appropriate matrix to determine the overall value.

Consider deferring analysis of low value materials until after analysing high or moderate value materials.

If the Overall Value is High proceed to Part II; if Low, stop further analysis - take no action.

| Matrix                      | Evidential Value    |   |   | Matrix | Evidential Value            |                             |                             | Matrix | Evidential Value    |                             |        |                             |        |                             |       |   |
|-----------------------------|---------------------|---|---|--------|-----------------------------|-----------------------------|-----------------------------|--------|---------------------|-----------------------------|--------|-----------------------------|--------|-----------------------------|-------|---|
| 1                           | A-High B-Mod. C-Low |   |   | 2      | A-High B-Mod. C-Low         |                             |                             | 3      | A-High B-Mod. C-Low |                             |        |                             |        |                             |       |   |
| Infor-<br>mational<br>Value | A-High              | A | A | B      | Infor-<br>mational<br>Value | A-High                      | A                           | A      | B                   | Infor-<br>mational<br>Value | A-High | A                           | A      | B                           |       |   |
|                             | B-Mod.              | A | B | C      |                             | Infor-<br>mational<br>Value | B-Mod.                      | A      | B                   |                             | C      | Infor-<br>mational<br>Value | B-Mod. | A                           | B     | C |
|                             | C-Low               | A | C | C      |                             |                             | Infor-<br>mational<br>Value | C-Low  | A                   |                             | C      |                             | C      | Infor-<br>mational<br>Value | C-Low | C |

Fig. 4. Preservation Priority Worksheet (Part I).

## PRESERVATION PRIORITY WORKSHEET

Series/Collection Name: \_\_\_\_\_ Location: \_\_\_\_\_ Bulk Dates: \_\_\_\_\_

## Part II of Preservation Selection - Risk Assessment

1. Holdings Maintenance Need

Raw Score: Many = 1, Some = 5, Few = 10, None = 15

| Q1. Housing Needed              | Raw Score | Weighting Factor   | Sum   |
|---------------------------------|-----------|--------------------|-------|
| Q2. Inappropriate Housing       | _____     | 1                  | _____ |
| Q3. Poor Positioning of Records | _____     | 3                  | _____ |
| Q4. Difficult Formats/Sizes     | _____     | 5                  | _____ |
| Q5. Damaging Attachments        | _____     | 7                  | _____ |
|                                 | _____     | 10                 | _____ |
|                                 |           | <b>Total Score</b> | _____ |

2. Level of Use

Q6. Evidence of Past Use \_\_\_\_\_

Q7. Estimate of Future Use \_\_\_\_\_

A=High, B=Moderate, C=Low

**Use Matrix**

| Past/Current Use | Anticipated Use |        |       |
|------------------|-----------------|--------|-------|
|                  | A-High          | B-Mod. | C-Low |
| A-High           | A               | A      | B     |
| B-Mod.           | A               | B      | C     |
| C-Low            | B               | C      | C     |

3. Level of Exposure

A measure of Holding Maintenance and Use

**Exposure Matrix**

| Holdings Maintenance Needs Score | Use Code |        |       |
|----------------------------------|----------|--------|-------|
|                                  | A-High   | B-Mod. | C-Low |
| A-High                           | A        | A      | B     |
| B-Mod.                           | A        | B      | C     |
| C-Low                            | A        | C      | C     |

4. Physical Condition

Structural soundness in terms of the ability to be used.

Q8. Amount of damage or deterioration: \_\_\_\_\_

Q9. Amount of highly unstable materials: \_\_\_\_\_

(A=High, B=Moderate, C=Low)

Emergency: wet, volatile, flaking, mold ... \_\_\_\_\_

High: 2/3rds rotted, etc.

**Condition Matrix**

| Amount of Highly Unstable Materials | Anticipated Use |        |       |
|-------------------------------------|-----------------|--------|-------|
|                                     | A-High          | B-Mod. | C-Low |
| A-High                              | A               | A      | B     |
| B-Mod.                              | A               | B      | B     |
| C-Low                               | A               | B      | C     |

5. Level of Risk

A measure of Exposure and Condition

**Risk Matrix**

| Condition Code | Use Code |        |       |
|----------------|----------|--------|-------|
|                | A-High   | B-Mod. | C-Low |
| A-High         | A        | A      | B     |
| B-Mod.         | A        | B      | C     |
| C-Low          | B        | C      | C     |

6. Final Overall Value Score

A = High (31-55) (house)  
B = Moderate (56-80)  
C = Low (81-101)

7. Exposure Score

A = High (duplicate)  
B = Moderate  
C = Low

8. Condition Score

A = Poor (treat)  
B = Moderate  
C = Good

9. Risk Score

A = High (treat, house, dupl.)  
B = Moderate  
C = Low

## Part III of Preservation Selection - Preservation Priority

1. Overall Value Score as determined from Part I: \_\_\_\_\_

A measure of Evidential Value and Informational Value.

(Intrinsic value to the artifactual, monetary, symbolic, or sentimental value of the record.)

If intrinsic value is also high, decide if the Final Overall Value Score should be adjusted one higher.)

2. Preservation Priority Score

A measure of Value and Risk

**Preservation Matrix**

| Overall Value Code | Risk Code |        |       |
|--------------------|-----------|--------|-------|
|                    | A-High    | B-Mod. | C-Low |
| A-High             | 1         | 2      | 5     |
| B-Mod.             | 3         | 4      | 6     |
| C-Low              | 7         | 8      | 9     |

3. Final Overall Value Score

A = High (1-3)  
B = Moderate (4-6)  
C = Low (7-9)

Note: The following information influences treatment, housing and duplication needs; so please note percentage where applicable.

|            |                       |               |               |            |               |
|------------|-----------------------|---------------|---------------|------------|---------------|
| Formats:   | single/sets of sheets | bound volumes | tapes         | disks      | other         |
| Substrate: | acidic paper/board    | tracing       | coated        | photograph | colored       |
| Media:     | acidic                | fugitive      | flaking       | soluble    | graphic image |
| Condition: | mold                  | riable        | rolled/folded | p.s.tapes  | dirt          |
|            | pests                 |               | torn          |            |               |

Fig. 4. Preservation Priority Worksheet (Parts II and III).



dium, etc.) using a randomly generated numerical system to designate specific objects within the collection, the housing and possible treatment needs of the collection can be quantified and necessary supplies determined and ordered. If done correctly, this technique allows a detailed and statistically accurate assessment of extremely large collections in a very short space of time (i.e. a collection of 5,000 objects in one week by one surveyor).

After the collection has been appropriately surveyed, one can begin to take intellectual control over the collection. For this Angel Project an OSIA archivist outlined the procedures involved in this important step. Using information that was derived from the collection, folder lists were created that would aid in the future retrieval of objects by providing specific information as to the contents of each individual folder. Since the illustrations are used at an item level, a system is necessary by which a drawing can be replaced into its original group in proper sequence.

Devising a system for designating series within the collection was the next task to be undertaken. Knowledge pertaining to the history of the collection, and the technology that was used in the production of the published images, was useful for this step. Curators from the Division of Graphic Arts, National Museum of American History (NMAH) were asked to assess the collection and give advice as to the order in which the illustrations could have been produced. It was verified at this time that the collection held a relatively complete series detailing the lithographic transfer process, beginning with preparatory sketches of the fossils and finishing with the tracings that were utilized in the transfer of the drawing to the lithographic stone. The tracing paper exhibits a whitish outline that follows the contours of the corresponding drawing, characteristic of the scoring that would be seen in the engraving process of the lithographic transfer.<sup>6</sup>

Proper housing and reformatting, two integral components in the preservation of a collection, are the next steps in this systematic approach. Two actions that aid in the continued care of the collection are: providing a protective barrier between the illustrations and the environment (or researchers who may be studying the collection); and providing access to the images without involving the original object (which could remain in storage).

In devising the prototype housing for the collection, decisions were based on the sensitivity of the media and the fragility of the substrate. For example, custom-sized polyester L-welds (for thin tracings) and flush folders (for the friable graphite illustrations) were used for this project.<sup>7</sup> The Table, which illustrates housing options for various paper-based items, can be utilized in this step. It was recommended that the collection be relocated from its current housing in wooden drawers to museum quality storage, like map cases of fused powder-coated chromium-plated steel or anodized aluminum, to further protect the illustrations from fluctuating environmental levels and other unplanned disasters.

Table. Housing options for various types of paper-based items, compiled by D. van der Reyden.<sup>7</sup>

| SUPPLIES                                                                            |                     | Type of Item |                            |                      |                      |               |              |                                 |              |               |                   |                 |          |
|-------------------------------------------------------------------------------------|---------------------|--------------|----------------------------|----------------------|----------------------|---------------|--------------|---------------------------------|--------------|---------------|-------------------|-----------------|----------|
| (NOTE: Only preferred materials and techniques are checked; others may be approved) | 1 INK (ink (f. m.)) | 2 PENCIL     | 3 RELIEF OR INTAGLIO PRINT | 4 PLANOGRAPHIC PRINT | 5 HAND-COLORED PRINT | 6 WATER-COLOR | 7 PHOTOGRAPH | 8 DOCUMENT OR MANUSCRIPT SHEETS | 9 NEWS PRINT | 10 PHOTO COPY | 11 NEGATIVE SLIDS | 12 BOUND VOLUME | 13 OTHER |
| POLY-ESTER                                                                          |                     |              |                            |                      |                      |               |              |                                 |              |               |                   |                 |          |
| L-WELD                                                                              | X                   |              |                            | X                    |                      |               | X            |                                 | X            |               | X                 |                 |          |
| POCKETS                                                                             | X                   |              |                            | X                    |                      |               | X            |                                 | X            |               | X                 |                 |          |
| MATCH-BOOK WRAP                                                                     | X                   |              |                            | X                    |                      |               | X            |                                 |              |               |                   |                 |          |
| BOOK BAND                                                                           |                     |              |                            |                      |                      |               |              |                                 |              |               |                   | X               |          |
| BOOK JACKET                                                                         |                     |              |                            |                      |                      |               |              |                                 | X            |               |                   | X               |          |
| POLY-ESTER BOOK                                                                     |                     |              |                            |                      |                      |               |              |                                 |              |               |                   | X               |          |
| POLY-ESTER LENS STRIPS                                                              |                     |              |                            |                      |                      |               |              |                                 |              |               |                   | X               |          |
| ACID-FREE FOLDER PAPER                                                              |                     |              |                            |                      |                      |               |              |                                 |              |               |                   |                 |          |
| FOLDER                                                                              | X                   | X            | X                          |                      | X                    | X             | X            | X                               | X            | X             |                   |                 |          |
| FLUSH FOLDER                                                                        | X                   | X            | X                          |                      | X                    | X             | X            | X                               | X            |               |                   |                 |          |
| FOUR FLAP FOLDER                                                                    | X                   | X            | X                          |                      | X                    | X             | X            | X                               |              |               | X                 |                 |          |
| ACID-FREE MAT. BOARD                                                                |                     |              |                            |                      |                      |               |              |                                 |              |               |                   |                 |          |
| WINDOW MAT                                                                          | X                   | X            | X                          | X                    | X                    | X             | X            |                                 |              |               |                   |                 |          |
| WINDOW MAT WITH WRAPPER                                                             | X                   | X            | X                          | X                    | X                    | X             | X            |                                 |              |               |                   |                 |          |
| SLING MAT                                                                           | X                   | X            | X                          | X                    | X                    | X             | X            |                                 |              |               |                   |                 |          |
| SINK MAT                                                                            | X                   | X            | X                          | X                    | X                    | X             | X            |                                 |              |               |                   |                 |          |
| INSERT MAT                                                                          | X                   | X            | X                          | X                    | X                    | X             | X            |                                 |              |               |                   |                 |          |
| JAPANESE TISSUE HINGE (V OR T)                                                      | X                   | X            | X                          | X                    | X                    | X             | X            |                                 |              |               |                   |                 |          |
| PHOTO-CORNERS                                                                       | X                   | X            | X                          | X                    | X                    | X             | X            |                                 |              |               |                   |                 |          |
| HORIZONTAL BOX                                                                      |                     |              |                            |                      |                      |               |              |                                 |              |               |                   |                 |          |
| PRINT BOX                                                                           | X                   | X            | X                          | X                    | X                    | X             | X            |                                 |              |               |                   |                 |          |
| VERTICAL BOX                                                                        |                     |              |                            |                      |                      |               |              |                                 |              |               |                   |                 |          |
| PHASE BOX (4 f. box)                                                                |                     |              |                            |                      |                      |               |              | X                               | X            | X             |                   | X               |          |
| DOCU-MENT BOX                                                                       |                     |              |                            |                      |                      |               |              | X                               |              | X             |                   |                 |          |
| RECORD BOX                                                                          |                     |              |                            |                      |                      |               |              | X                               |              |               |                   |                 |          |

NOTE: ALL MATERIALS ARE ACID-FREE OR BUFFERED UNLESS NEUTRAL IS REQUIRED FOR SENSITIVE MEDIA; ALL TECHNIQUES ARE NON-ADHESIVE UNLESS HINGING

The reformatting of the collection takes place after the illustrations have been stabilized through the rehousing efforts. Considerations as to reformatting options (digital, microfilm, transparencies or preservation photocopies) should be made in advance, based on the needs of the collection, any financial limitations, the technology and time available, as well as staff training.<sup>8</sup> Two different options were recommended for the reformatting of this collection. To ascertain permanent copies of the oversized illustrations and sketches, large format color transparencies were recommended. Digital imaging, while not a medium of preservation, was also suggested to allow for fast and easy access to researchers.

# ACCESS VERSUS PRESERVATION

Once the collection has been processed, rehoused and reformatted, the accessibility (and consequently the value) of the collection will logically increase. This fact, in light of the previous status of the collection, seems to be a great irony. The notion that easier access to a collection leads to its increased value as a holding should have dictated in the beginning that the preservation of this collection, and others like it, should never have been considered inconsequential. Access to the information found on original documents or illustrations is, in actuality, only a small part of the greater ideal of preservation of the original. Increased efforts must be made to ensure that original materials are stabilized by proper care and storage, rather than allowed to languish into oblivion. This is especially critical since the original materials contain chemical and physical information that can in no way be fully reproduced, and that can be diminished or lost if allowed to deteriorate. Through collaborative efforts like this Angel Project, solutions can be advocated and implemented to save the original materials and the artifactual evidence that can only be preserved in those originals. Although society has been grappling with the seemingly contradictory needs of preservation and access for hundreds of years, it is surprising that we, as modern-day scholars and caretakers, have only recently begun to implement plans to facilitate both.

# ACKNOWLEDGEMENTS

The authors would like to give their thanks to all of the collaborators mentioned in this paper, as well as: Paul Theerman; Elaine Hodges; the staff of the Department of Paleobiology, NMNH, SI; the staff of OSIA, SI; Andrew Robb; Holly Anderson; the SAA "Angels"; and Alice Tangerini. The project would not have begun without all of their efforts. Also, we would like to thank Lisa Mibach for inspiring the Angels Project, and the staff and supervisors at the Conservation Analytical Laboratory, SI.

# SUMMARIES

## *Publish, Then Perish: The Reclamation of a Collection of Scientific Illustrations*

The need to cope with enormous amounts of material has occasionally resulted in the sacrifice of original materials that have been published, based on the "rule of thumb" that once published, these materials are of less value to a repository than those materials that are not published. One of the most famous collections of drawings produced in the late 1800s, the dinosaur type specimen illustrations of the O. C. Marsh Collection, almost fell victim to this practice. This paper chronicles the collaborative

efforts taken to preserve this historic collection; outlines the integrated approach to preservation that was used (including a discussion of the various types of surveys, folder lists, prototypical housing materials and storage, and duplication procedures); and discusses how the seemingly contradictory needs of access and preservation may be resolved through interdisciplinary dialogue.

## *"Publié ensuite détruit", la récupération d'une collection d'illustrations scientifiques*

Le besoin de venir à bout d'énormes quantités de documents a parfois eu pour résultat le sacrifice de documents originaux qui avaient été publiés, se fiant, à vue de nez, qu'une fois publiés ces documents ont moins de valeur pour un dépôt que ceux qui ne sont pas publiés. Une des plus célèbres collections de dessins réalisés à la fin du XIXe siècle, les illustrations de spécimens de dinosaures de la collection O.C. Marsh a failli être victime de cette pratique. Cet article relate les efforts communs réalisés afin de sauver cette collection historique, expose l'approche intégrée qui a été suivie pour la conservation (comprenant une discussion des différents types d'inventaires, listes de fardes, prototypes de matériaux d'archivage et de rangement et systèmes de duplication) et montre comment des nécessités d'accès et de conservation apparemment contradictoires peuvent être résolues par un dialogue interdisciplinaire.

## *Veröffentlicht zum Untergang: die Erschließung einer Sammlung von wissenschaftlichen Illustrationen*

Die Konfrontation mit sehr großen Mengen von Sammelgut hat gelegentlich dazu geführt, daß ein bestimmter Typ desselben, nämlich Vorstufen und Vorlagen für die Veröffentlichung eines Werkes, dem Verfall preisgegeben wurden, in der Annahme, daß solche Stücke weniger wertvoll seien als unveröffentlichtes Material. Eine der berühmtesten Bestände von Zeichnungen aus dem späten 19.Jh., die Dinosaurier-Druckvorlagen in der O. C. Marsh-Sammlung, wäre beinahe dem zum Opfer gefallen. Der Aufsatz beschreibt die Bemühungen zum Erhalt dieses historischen Bestands, die in Zusammenarbeit verschiedener Institutionen abliefen. Es wird über die vorbereitende Planung, die infrage kommenden Schutzkartonagen, Aufbewahrungsbedingungen, Schutzkopien u.s.w. berichtet. Weiter wird diskutiert, wie der scheinbare Widerspruch zwischen Erschließung und Konservierung durch interdisziplinären Dialog gelöst werden kann.

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## Structure of Paper Fibres in Ancient Manuscripts: Acidic Decomposition and Deacidification

by M. CARME SISTACH ANGUERA

### INTRODUCTION

The restoration of manuscripts involves somewhat different work from the restoration of printed papers. The earliest extant papers in Catalonia are the Chancery documents dating from the reign of James I, in the early 13th century. We carried out tests on these documents to establish their fibre structure and their sizing. We also used them to compare the results of two deacidification processes that can be used on manuscripts: one using an aqueous solution of calcium hydroxide, and the other an aqueous solution of calcium and magnesium bicarbonates. These two solutions were each applied to three different manuscript samples: the first written with light iron-gall ink on good paper dating from 1350; the second written with non-acidic black ink on thinner paper from 1712; and the third a document from 1576 written with a very acidic ink that has corroded the document.

### FIBRES AND SIZING

Most of the documents from the period from the beginning of the 14th century to the end of the 15th century show characteristics of manufacturing processes specific to the Valencia region.<sup>1</sup> They have long fibres without shredded edges. The manufacturing process seems to have been rudimentary. Rag fibres that had served as textile before being employed in the manufacture of paper can be seen clearly on the surface of the paper. Most of the documents exhibit a shine indicating that they were burnished after sizing.<sup>2</sup> The earliest paper made in Valencia was sized with vegetable glue made from rice or wheat; small pieces of vegetable matter can be seen clearly on the surface of the documents. The starch glue on



Fig. 1. Optical image of linen fibre from a document dated at 1315. Magnification 400.

the edge of the fibres can be identified by using Herzberg reagent or a specific reagent containing iodine and iodide.<sup>3</sup> Later on, papers were sized with animal glue, but the date when this change in technique took place has not been established. Investigation shows that the fibre in this early 14th century paper is linen, and we can also see the barely worked fibre margins. The simple machines used to rinse the fibres at this time were probably not abrasive. The paper edges show textile characteristics, and its structure shows the lines perpendicular to the axis which identify the fibre as linen and hemp (Fig. 1).

Testing various samples from the 14th–18th centuries and comparing their degree of paper fibre conservation show clear differences between those that come from well conserved documents and those from documents degraded by acidity, humidity and micro-organisms. Samples affected by acidity have fibres that have been cut by the hydrolysis of the cellulose chain that affects the microfibrils within the fibre. The weakness of the paper in acid-degraded samples is due to the destruction of the macroscopic fibre structure (Fig. 2 and 3) as a result of its altered molecular stability. The fibres broken by acidity appear frayed, with microfibrils protruding from the ends of the cross-sections. Further differences in the fibres can be noted and measured at their edges. In the later documents the fibres have been worked to a higher degree, and show fine fibres going through



Fig. 2. SEM image of fibres from a 14th century document degraded by acidity. Magnification 330.



Fig. 3. Optical image of acid-degraded fibres.



Fig. 4. SEM image of fibres from a non-acidic document from 1712. Magnification 250.

the edges (Fig. 4). This information is useful for studying the degree of fibre degradation.

#### IRON-GALL INK

The composition of iron-gall inks causes them to behave in a particular way. A high iron content deepens the blackness of the ink and maintains this colouration over long periods of time. Acidic ink reacts with the paper, both hydrolyzing and oxidizing the cellulose, thereby destroying the inner crystalline structure of the fibres.<sup>4</sup> Oxidized cellulose cannot bind one chain to another, and cannot bind fibres together as well as normal cellulose.

The amount of iron is in proportion to the amount of ink, and in turn proportional to the quantities of tannin and iron sulphate used in the preparation of the ink. Ink made with a high iron sulphate content will be blacker and more corrosive when the concentration of the tannin extract increases, and as a result the amount of sulphuric acid produced in the reaction also increases. Some iron-gall ink is absorbed by the fibres by capillary action, and some remains on the surface of the paper in small deposits. These small quantities of sediment can be observed between the fibres of the paper and can be crystalline. Large quantities

of black ink can produce sediments on the paper and this brings about the corrosion process.<sup>5</sup> There are other factors in the degradation of manuscripts, apart from the acidity of the ink, as paper-making techniques change over time. The quality of the fibre, the thickness of the paper and the substances added during the manufacturing process, these all have important consequences for the stability of the paper. The treatment of the rags in the initial manufacturing process also affects the degradation of the fibres.<sup>6,7</sup> If the rags were beaten aggressively, the degree of degradation can be high even if there is low acidity.

#### TESTING PH

Each of the samples noted above were tested. A pH reading was taken on the surface of the ink and on the margin of the written surface. The results show that the corrosive samples are one unit more acidic on the ink than on the margin (Table 1).

The deacidification treatment was tested by measuring the surface pH, and by comparing the analyses obtained before and after deacidification treatment by scanning electron microscopy (SEM) and X-ray microanalysis.

#### TREATMENT PROCESS

Prior to deacidification, the samples were soaked in 25 ml of a 10% aqueous solution of alcohol for a period of one minute. The sample was removed from the alcohol solution and left to drain in the open for a further minute.

The same quantity of deacidification solution, 25 ml per 3 cm<sup>2</sup> of paper surface, was used on each of the samples.

The samples were bathed in a 10% alcohol solution in order to increase the papers' alkaline retention: alcohol reduces the water's surface tension and permits the deacidificant solution to enter the paper more easily. At the same time, any soluble acidic substances in the paper are eliminated by the bath.

Two solutions were used for deacidification. One was semi-saturated aqueous calcium hydroxide and the other calcium and magnesium bicarbonate. This en-

Table 1. pH of several dated documents.

| Sample                      | On the ink | In the margin |
|-----------------------------|------------|---------------|
| Light ink (1350)            | 7.1        | 7.4           |
| Black non-acidic ink (1712) | 6.0        | 6.5           |
| Acidic ink (1576)           | 3.6        | 4.5           |



Table 2. Solubility of several compounds involved in deacidification.

|                                    | K <sub>s</sub>      | Solubility (g/l) |
|------------------------------------|---------------------|------------------|
| MgCO <sub>3</sub>                  | $1 \cdot 10^{-5}$   | 0.212            |
| Mg(CO <sub>3</sub> H) <sub>2</sub> | $4.5 \cdot 10^{-1}$ | 70.04            |
| CaCO <sub>3</sub>                  | $4.8 \cdot 10^{-9}$ | 0.0049           |
| Ca(CO <sub>3</sub> H) <sub>2</sub> | $5.2 \cdot 10^{-5}$ | 3.807            |
| Ca(OH) <sub>2</sub>                | $5.5 \cdot 10^{-6}$ | 0.823            |

Table 3. SEM and X-ray microanalysis. Results before and after deacidification: Ca<sup>^</sup> and Mg<sup>^</sup> mean that the amounts of these elements on the samples have increased.

|                        | Light ink                                                 | Black non-acidic ink                                                                                                  | Acidic ink                                                                                              |
|------------------------|-----------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------|
| Before deacidification | S<Ca<br>Fe                                                | S<Ca<br>Fe <sup>^</sup>                                                                                               | S>Ca<br>Fe<br>S in uninked areas                                                                        |
| After deacidification  | Ca <sup>^</sup> Mg <sup>^</sup><br>Fe<Ca<br>Fe<Mg<br>no S | Ca <sup>^</sup> Mg <sup>^</sup><br>CaCO <sub>3</sub> MgCO <sub>3</sub> on the paper surface and on the fibres<br>no S | Ca <sup>^</sup> Mg <sup>^</sup><br>at lot of CaCO <sub>3</sub> and MgCO <sub>3</sub> on the ink<br>no S |

abled us to work with different pH values: 10.5–12.34 in the case of the calcium hydroxide, and between 8 and 8.5 in the case of the bicarbonate solution. The alkaline reserve in the paper varies according to the solubility of the substance employed (Table 2). The bicarbonates have higher solubility than calcium hydroxide. As they become carbonates their solubility decreases, and the alkaline buffer formed in the paper increases. The alkaline buffer will be sufficient if the calcium to magnesium ratio is 5:1.

#### SEM AND X-RAY MICROANALYSIS RESULTS

The results of the SEM images and the X-ray microanalysis of the calcium hydroxide and the magnesium-calcium bicarbonate tests are given in Table 3. The conditions in the microanalysis were the following: accelerating voltage 10 kV, 20 kV; 100 000 magnification; working distance 37 mm; model JSM 840 (Jeol Ltd.) electron microscope with scanner AN 10000 (LINK Systems) and BE window.

The SEM images showed that there was more CaCO<sub>3</sub> sediment on the ink than on the surface of the paper (Fig. 5).



Fig. 5. SEM image of Mg and Ca placed on and between the paper fibres in a very acidic sample from 1576. pH=3.5.

After deacidification there was hardly any sulphur left in the ink. In the acidic samples the sulphur disappeared from uninked areas, even when there had been relatively high levels of sulphur before deacidification (Fig. 6–8).

#### DEACIDIFICATION

The calcium-magnesium bicarbonate (5:1 calcium to magnesium) was expected to give better results than the calcium hydroxide. The first results indicated that the best process for manuscript deacidification was that with the bicarbonate solution. By comparing these two deacidification processes we were able to note some differences, in particular the following points.

- The lower pH of the deacidificant bicarbonate solutions (8–8.5) compared to the calcium hydroxide ones (10–12.34).
- The higher solubility of the calcium and magnesium bicarbonates.
- The good alkaline buffering placed on the paper both by the calcium hydroxide and by the calcium-magnesium bicarbonates.

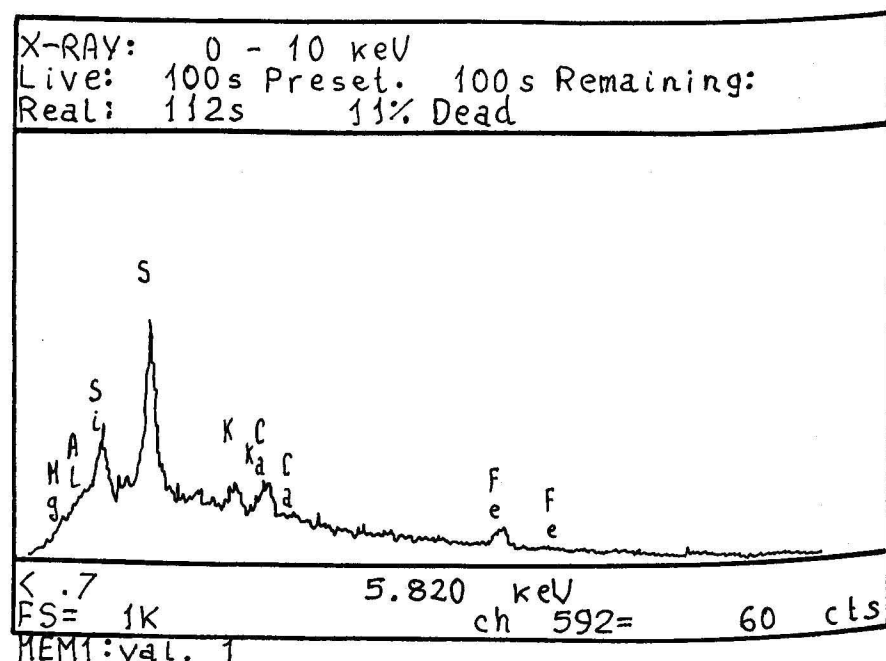
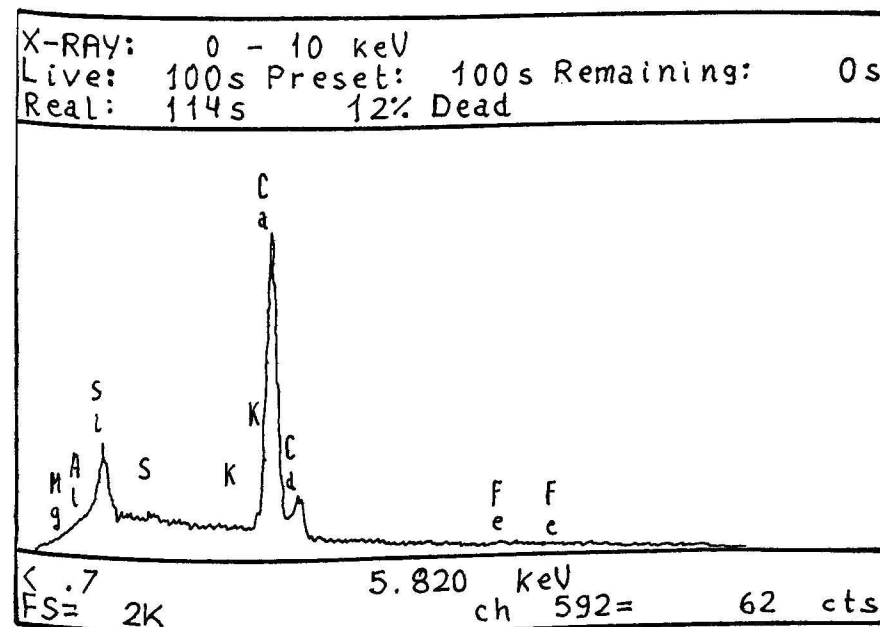


Fig. 6. Count-rate diagram of the very acidic sample from 1576 in an uninked area. Sulphur.

Fig. 7. Count-rate diagram of the very acidic sample from 1576 in an uninked area after deacidification with  $\text{Ca}(\text{OH})_2$ .

In effervescing  $\text{CO}_2$ , the magnesium bicarbonate solubilizes before the calcium bicarbonate due to its solubility, so if we control the ratio between the calcium and the magnesium carbonate we can control its solubilization. The effervescing  $\text{CO}_2$  converts all magnesium carbonate to magnesium bicarbonate, before acting on the calcium carbonate. After testing several ratios we thought that the solid ratio should be 5:1 calcium carbonate to magnesium carbonate. We thus had 300 ppm of magnesium for every 200 ppm of calcium in the bicarbonate solutions.

#### PHYSICAL AND MECHANICAL TEST

We carried out several tests in order to obtain data on the changes in paper strength. After comparing results we found that the samples that had been washed and then soaked in the deacidificant calcium hydroxide solution suffered a 30% loss in tensile strength. Tests of the tensile strength of sized samples, however, showed increased strength.

We believe that this loss of strength in samples that had not been sized was probably due to:

- the loss of sizing when the samples were soaked in the bath;
  - the action of the alkaline solution on the oxidized cellulose, when the pH > 10.5.
- When we used calcium and magnesium bicarbonates, the tests on unsized samples showed that tensile strength decreased less than with the calcium hydroxide. It is reasonable to think that this can be explained by three factors.
- The reduced action of the less alkaline bicarbonate solutions on the oxidized cellulose.
  - The fact that the magnesium is placed on and between the fibres coupling the cellulose chains (Fig. 9).
  - Magnesium ion retains some covalence. It can participate in coupling cellulose chains, binding not only the acidic groups but also hydroxyls.

#### CONCLUSIONS

The first results of comparing several samples with fibres degraded by acidic inks led us to the following conclusions.

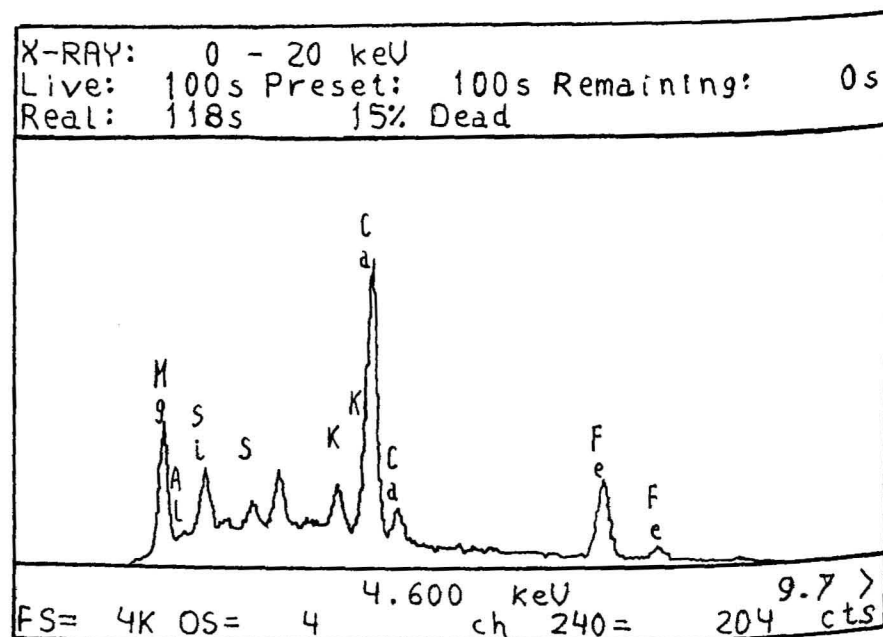


Fig. 8. Count-rate diagram of the very acidic sample after deacidification with calcium-magnesium bicarbonate in an inked area.

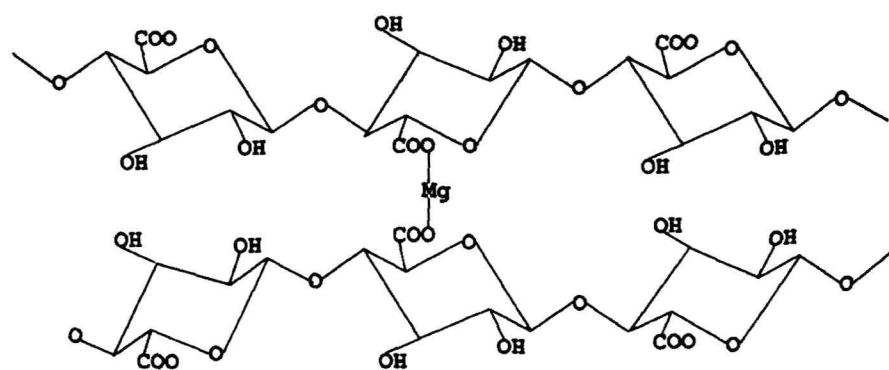


Fig. 9. Cellulose chains oxidized and coupled with  $Mg^{2+}$  ions.

- Catalan papers from the 14th century have long fibres without shredded edges. The fibres of documents from the 16th century are more shredded.
- The sizing for documents before 1350 in the Chancery Section was made with starch glue. In later papers we found both animal and starch glue up to the end of the 15th century when only animal glue was found.

- Fibres are broken when the paper is very acidic, although the craftsmen were very good at manufacturing the ancient paper. We tested this by optical and SEM images.
- Tensile strength and other physical and mechanical properties can change when paper is soaked in a water bath and then in deacidificant solutions. We obtained better results with calcium-magnesium bicarbonate solutions than with calcium hydroxide. It is established that magnesium bicarbonate destroys the sizing of old papers, but the effects of the high pH of calcium hydroxide on the cellulose chains are worse.
- The improvements in the physical and mechanical properties were probably due to the fact that as the oxidized acidic products in very acidic paper are solubilized, sulphur disappears. The acidic groups in the cellulose chains were coupled with the alkaline metals such as Ca and Mg. We found the magnesium-calcium bicarbonates gave better results.
- This work is still in progress. We hope to do further tests to identify the optimum calcium-magnesium bicarbonate ratio. We used 0.05M  $Mg(HCO_3)_2$ . We found that the amount of calcium in the bicarbonate solution is also important.

#### ACKNOWLEDGEMENTS

This work was carried out at the Arxiu de la Corona d'Aragó, at the Paper Department of the Polytechnic University of Catalonia and at the Scanning Electron Microscopy Service of Barcelona University. This work has been financially supported by the Spanish government's Comisión Interministerial de Ciencia y Tecnología (CICYT). It is a partial result of the research project SEC 95-0125, which is part of the National Research I+D (Investigation and Technological Development).

#### SUMMARIES

##### *Structure of Paper Fibres in Ancient Manuscripts: Acidic Decomposition and Deacidification*

Fibres in paper documents from the 14–18th centuries are mostly of linen or hemp. Two deacidification processes on several manuscript samples were tested. One used a semi-saturated aqueous calcium hydroxide solution and the other calcium and magnesium bicarbonates. The aim of this work was to compare these two solutions in rag paper documents deteriorated by iron-gall ink.

The results showed that the calcium and magnesium bicarbonates produced better improvements in the paper and in the iron-gall ink than the calcium hydroxide solution. The best results were obtained with a calcium:magnesium ratio in the bicarbonate solution of 5:1. Among other results, we noted the

following. The blend of bicarbonate resulted in a lower pH than the calcium hydroxide. The high solubility of the calcium and magnesium bicarbonates helped to give the paper a good alkaline buffering. The magnesium improved the paper permanence.

*Structure de fibres de papier dans les manuscrits anciens: décomposition acide et désacidification*

Les fibres de documents sur papier des 14-18e siècles sont principalement du lin ou du chanvre. Deux procédés de désacidification ont été testés sur plusieurs échantillons de manuscrits: une solution semisaturée d'hydroxyde de calcium et une solution de bicarbonates de calcium et de magnésium. Le but de cette recherche était de comparer les deux solutions sur des documents en papier chiffon détériorés par l'encre ferro-gallique.

Les résultats montrent que la solution de bicarbonates de calcium et de magnésium améliore davantage le papier et l'encre ferro-gallique que la solution d'hydroxyde de calcium. Les meilleurs résultats sont obtenus avec une proportion de bicarbonates de calcium et de magnésium dans la solution de 3 pour 1. Parmi les résultats, nous avons également observé ce qui suit: le mélange de bicarbonates donne un pH plus bas que l'hydroxyde de calcium, la grande solubilité des bicarbonates de calcium et de magnésium permet de donner au papier une bonne réserve alcaline, le magnésium a amélioré la permanence du papier.

*Zur Struktur der Fasern in altem Papier: säurekatalysierter Abbau und Entsäuerung*

Die Fasern in Papierdokumenten des 14. bis 18. Jh. bestehen überwiegend aus Leinen oder Hanf. Es wurden zwei Methoden der Entsäuerung an mehreren Handschriften beispielhaft erprobt. Die eine arbeitet mit halbgesättigter wässriger Lösung von Calciumhydroxid und die andere mit Calcium- und Magnesiumbicarbonat. Zweck der Untersuchung war es, die Wirkung der beiden Methoden auf tintenfraßgeschädigtes Hadernpapier vergleichend zu untersuchen. Es ergab sich, daß Calcium- und Magnesiumbicarbonat eine stärker verbessernde Wirkung auf Papier und Tintenfraßschaden hat als Calciumhydroxid. Die beste Wirkung ergab sich bei einem Verhältnis Calcium:Magnesium=5:1. Weitere Ergebnisse: Die Bicarbonatmischung bewirkt ein niedrigeres pH als Calciumhydroxid. Die gute Löslichkeit der Bicarbonate trägt zum Schaffen einer nennenswerten alkalischen Pufferung des Papiers bei. Das Magnesium führt zu einer Verbesserung der Papierfestigkeit.

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## Degradation Caused by Cellulose Diacetate: Analysis and Proposals for Conservation Treatment

by D. AUBIER, J. M. BLENGINO, A. C. BRANDT & N. SILVIE

### INTRODUCTION

Before the Second World War a number of documents kept in the Oriental Division of the Bibliothèque Nationale de France in Paris were put between panes of glass. Over the years, however, many panes were broken and they were therefore replaced with cellulose acetate sheets. The trade name of the material was Rhodoïd, a product of the French firm Rhône Poulenc. This material was used from the 1950s to the mid-1970s.

The documents mounted in this way belong mainly to the Pelliot Collection and comprise the following groups: 94 manuscripts with paintings from the 9th and 10th centuries; 65 xylographs from the 19th century printed on paper; and 2000 text fragments written in Sanskrit, Kuchean, Chinese or Uigur from the 6th to 10th centuries.

Unfortunately the Rhodoïd sheets degraded over time and now show the following changes in various degrees: warping, decomposition (Fig. 1), smell of acetic acid. For these reasons it was decided to remove the most precious documents from the Rhodoïd sheets and to mount them in a passe-partout, like drawings or prints. However, the text fragments are still waiting for adequate treatment and rehousing. Because of their fragility and their fragmentary condition, they require high quality protection. It is therefore not possible to mount them permanently in the passe-partout. Furthermore, as these documents have text on both sides it would be more practical for handling to enclose them between transparent sheets.

Before choosing a new mounting, we studied the changes suffered by the documents.



Fig. 1. The degradation of a Rhodoïd sheet. (Photo by Service de la reproduction, BnF)

### MANUFACTURE OF CELLULOSE ACETATE

Cellulose acetate was discovered by Schutzenberger in 1869 and further described by Franchimont. In 1890 Cross and Bevan thought of using cellulose acetate in the manufacture of artificial textile fibers. During the First World War Clément and Rivière used it as a varnish for aeroplane tarpaulins.

Champetier & Monnerie<sup>1</sup> give the following description of the manufacturing process of cellulose acetate. In general the raw material used is a wood pulp of high alpha-cellulose content (94–99%) because the acetylation induces severe degradation of cellulose. Acetic acid – containing water and, if necessary, a small amount of sulphuric acid – is added to induce a slight hydrolysis of the chains for increasing the reactivity of the cellulose. The reaction of acetylation is achieved with acetic anhydride and a catalyst ( $\text{ZnCl}_2$ ,  $\text{H}_2\text{SO}_4$ ,  $\text{HClO}_4$ , etc.) Acetic acid is added to facilitate the penetration of the solution into the fibres (acetylation in a homogeneous medium). The product of this reaction is a primary acetate combined with 62.5% acetic acid which contains a small amount of sulphuric acid or perchloric acid in an esterified form. The transformation into a secondary acetate reduces the amount of acetic acid from 62.5% to 54–56%.

The secondary cellulose acetate precipitates when water or diluted acetic acid



is added. After drying, pulping and washing with hot water, the cellulose acetate is dried with hot air. The acetic acid is recovered. If all these operations are performed correctly, the sulphuric or perchloric esters are destroyed and the secondary acetate will be stable.

In the manufacture of sheets for protection or packing, the cellulose acetate combined with 54–56% acetic acid is used. It is dissolved in acetone in the presence of a plasticizer (triphenylic phosphate). After filtration and out-gazing the collodion is transformed into a film.

#### DEGRADATION OF CELLULOSE ACETATE

For many years cellulose acetate was considered to be a stable long-term polymer. It has been used widely as archival material to encapsulate fragile paper. The scientists who were consulted in the 1950s by the curators of the National Library only warned of the possible deformation of the cellulose acetate sheets under the influence of heat or humidity. For mounting they recommended the sheets be cleaned with a rag soaked in alcohol. As a preventive measure they advised the disinfection of the sheets and the documents with trioxymethylene (paraformaldehyde). Finally the documents were put between two sheets of Rhodoïd and linen strips were pasted around the perimeters to prevent the penetration of the air. Formol was added to the glue.

According to Edge<sup>2,3</sup> the degradation of cellulose acetate is the cause of deacetylation and hydrolysis, speeded up in the presence of strong acids ( $H_2SO_4$ ). This could be the result of an inefficient washing of the initial product or of the absorption of sulphur dioxide ( $SO_2$ ) at the surface of the sheets. The oxidised form of sulphur dioxide is sulphur trioxide which combines with the humidity in the air and is transformed into sulphuric acid ( $H_2SO_4$ ), a mineral acid. The degradation was characterized by the strong smell of acetic acid and the presence of a crystalline deposit on the surface of both the sheets of Rhodoïd and the document. The film felt greasy to the touch which could have been due to the release of the plasticizer.

Hon<sup>4</sup> emphasizes that different mechanisms are involved in the degradation of cellulose acetate: decrease of chain length by hydrolysis; reticulation related to elimination of substitutes; the presence of free radicals as a result of photo-oxidation. If humidity is present, cellulose acetate is degraded mainly by hydrolysis. The degradation is less serious, if the degree of substitution is high, which is why cellulose triacetate is more stable than cellulose diacetate.

Murphy<sup>5</sup> has proved that degradation is accelerated by the presence of several

salts of transition metals (chromium, cobalt, palladium, silver) and the presence of chlorine.

#### ANALYSIS OF THE DEGRADATION PRODUCTS

##### *Preliminary study*

An analysis of the degradation products was performed on two documents of the Pelliot Collection: a xylography from the 10th century, which is a representation of the *Très Saint Roi Céleste Vaisranava*; and a manuscript, probably from the 6th century, written in brown ink, the *Udanavarga* 2, 4 (Figs 2, 3). The Conservation Department of the Bibliothèque Nationale de France took pH measurements on the surface of these two documents. The pH values were within the range of 4.1 and 4.7. The pH of the Rhodoïd was about 3.

The first document showed a more or less uniform white deposit on its surface. The second document was covered with white concretions. Microbiological analysis also performed by the Conservation Department laboratory showed that these alterations were not related to mould contamination.

##### *High Performance Liquid Chromatography (HPLC)*

In order to identify the nature of these deposits, the Bibliothèque Nationale de France asked the VALECTRA Laboratory owned by *Electricité de France* (EDF) to perform several analyses by High Performance Liquid Chromatography (HPLC). This method allows the separation of the different specimens of anions in relation to their different speeds of migration. The principle of the method is given in Fig. 4. The chromatogram of a sample taken from the xylography of the *Très Saint Roi Céleste Vaisranava* is given in Fig. 5.

The sampling was made with a cotton stick that had been impregnated with deionized water for 10 minutes to eliminate the bleaching by-products of the cotton. The stick itself was made of inert plastic to avoid any contamination of the sample. The cotton stick was applied to the surfaces of the documents and the Rhodoïd. Only the cotton was conserved in 5 cm<sup>3</sup> of deionized water in a hermetically sealed tube. The liquid was injected directly in the chromatograph for analysis.

The results of the analyses are given in Tables 1 and 2. There was a fairly high amount of acetate ions: 0.2 to 2  $\gamma$  (microgrammes) per cm<sup>2</sup>. On the manuscript *Udanavarga* a significant concentration of chloride, bromide and sulphate was present. These components could be residues from the catalyst (sulphuric acid and perchloric acid), present at the moment of manufacture, that had not been

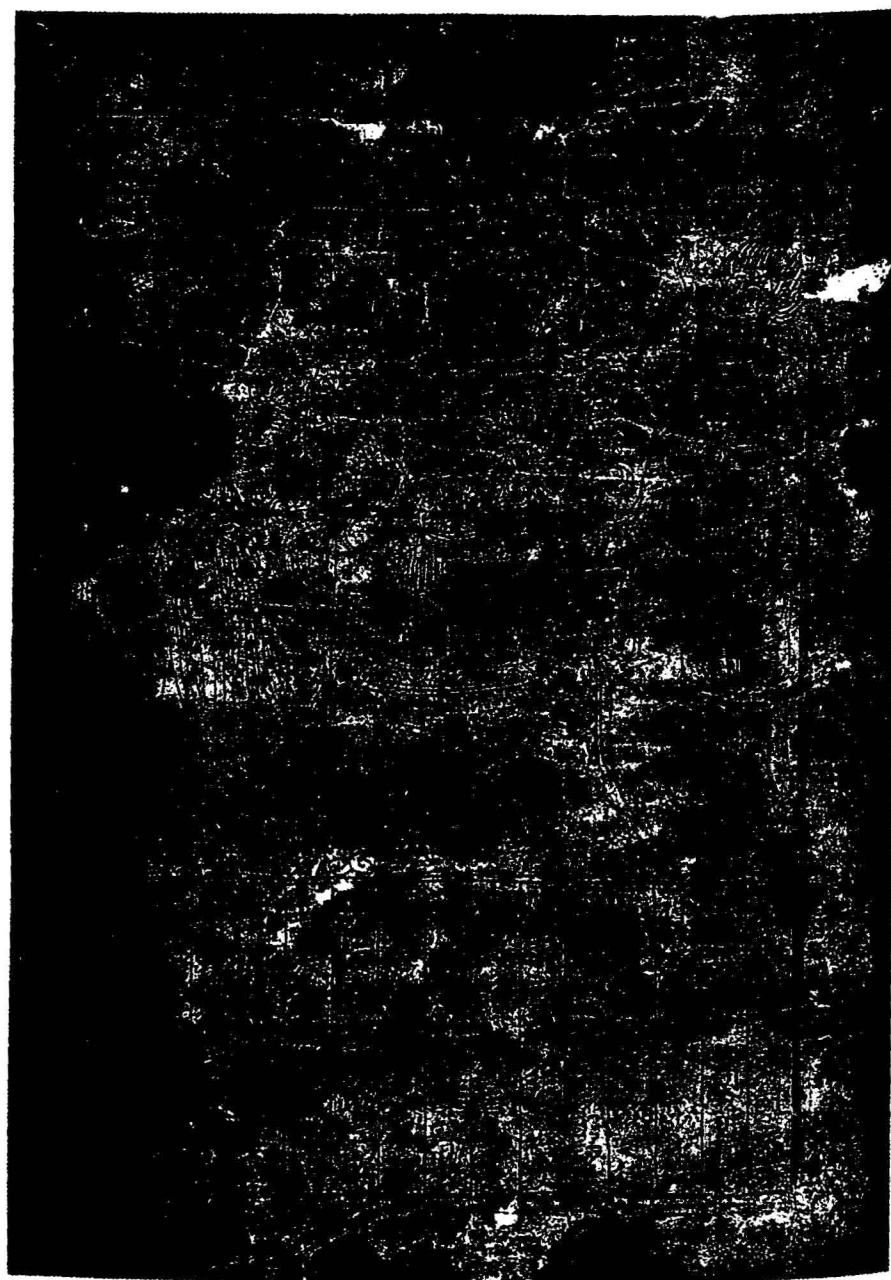


Fig. 2. The xylography *Très Saint Roi Céleste Vaisranava*. (Photo by Service de la reproduction, BnF)

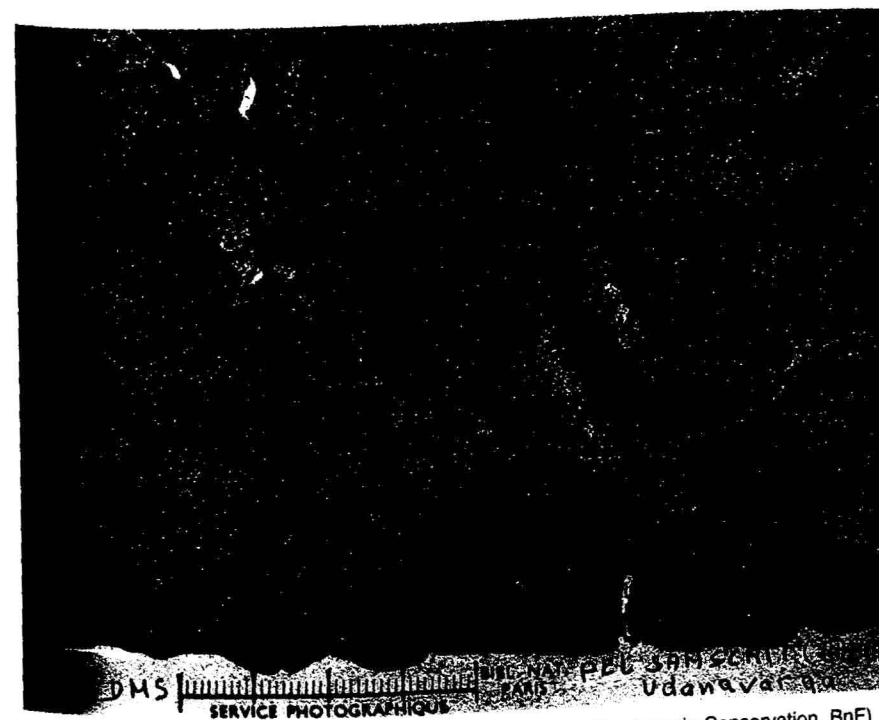


Fig. 3. The manuscript *Udanavarga 2,4*. (Photo by Direction des Services de Conservation, BnF)

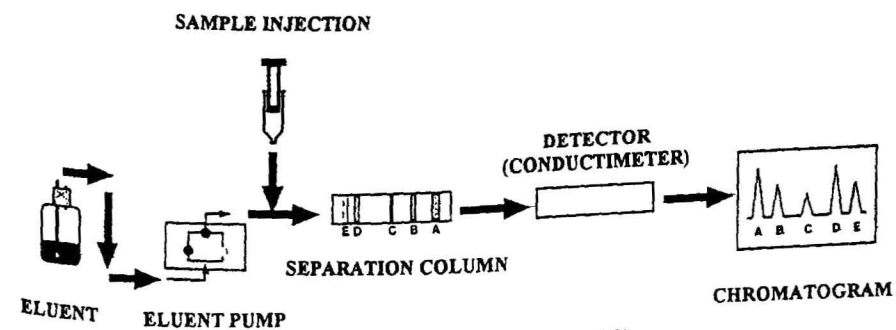


Fig. 4. Principle of High Performance Liquid Chromatography (HPLC).

washed out. The pH values were consistent with this hypothesis and also confirmed the work of Edge.<sup>2,3</sup> The high concentration of nitrates has not found any explanation for the moment.

Table 1. Anions detected in the sample from the document *Très Saint Roi Céleste Vaisranava*

| Anion     | Time of retention<br>(min) | Pic altitude | Concentration<br>(ppb) |
|-----------|----------------------------|--------------|------------------------|
| Fluoride  | 4.64                       | 466          | 1                      |
| Acetate   | 5.15                       | 9107         | 254                    |
| Glycolate | 5.60                       | 396          | 3                      |
| Formiate  | 6.44                       | 5055         | 16                     |
| Chloride  | 8.38                       | 21125        | 63                     |
| Nitrite   | 9.15                       | 331          | n.s.                   |
| Bromide   | 11.36                      | 986          | 6                      |
| Nitrate   | 12.28                      | 6242         | 42                     |
| Phosphate | 13.96                      | 1757         | 19                     |
| Sulphate  | 16.66                      | 7281         | 38                     |
| Oxalate   | 20.15                      | 1406         | 34                     |

Table 2. Concentration of the specimen

| Specimen   | F <sup>-</sup> | Br <sup>-</sup> | Cl <sup>-</sup> | NO <sub>2</sub> <sup>-</sup> | NO <sub>3</sub> <sup>-</sup> | PO <sub>4</sub> <sup>3-</sup> | SO <sub>4</sub> <sup>3-</sup> | CH <sub>3</sub> -<br>COO <sup>-</sup> | H-<br>COO <sup>-</sup> | HOCH <sub>2</sub> -<br>COO <sup>-</sup> |
|------------|----------------|-----------------|-----------------|------------------------------|------------------------------|-------------------------------|-------------------------------|---------------------------------------|------------------------|-----------------------------------------|
| Xylogr. 1  | n.s.           | n.s.            | 2               | n.s.                         | n.s.                         | 2                             | 6                             | 48                                    | 3                      | 1                                       |
| Xylogr. 2  | 1              | 6               | 63              | n.s.                         | 42                           | 19                            | 38                            | 254                                   | 16                     | 3                                       |
| Sanscrit 1 | n.s.           | n.s.            | n.s.            | n.s.                         | n.s.                         | n.s.                          | n.s.                          | 246                                   | 37                     | 31                                      |
| Sanscrit 2 | n.s.           | n.s.            | 946             | n.s.                         | n.s.                         | 52                            | >500                          | 195                                   | 29                     | 43                                      |
| Rhodoid 1  | n.s.           | n.s.            | 90              | 1                            | n.s.                         | 18                            | 518                           | 78                                    | n.s.                   | n.s.                                    |
| Rhodoid 2  | n.s.           | n.s.            | 90              | 13                           | n.s.                         | n.s.                          | 10400                         | 121                                   | n.s.                   | n.s.                                    |

The present manufacturer of Rhodoïd, Sic Plastic Company, has proved by infra-red spectroscopy the presence of triphenylic phosphate, the plasticizer of the cellulose diacetate. The greasiness of the Rhodoïd sheets could be directly related to the release of this plasticizer.

The degradation of the Rhodoid sheets was without doubt due to the presence of residual sulphuric acid. According to Sic Plastic, the degradation could have been accelerated by the preliminary cleaning and disinfection of the Rhodoid sheets.

The white concretions on the surface of the documents were due to the salts formed by the reaction between sulphuric acid and acetic acid with the fillers present in the paper.

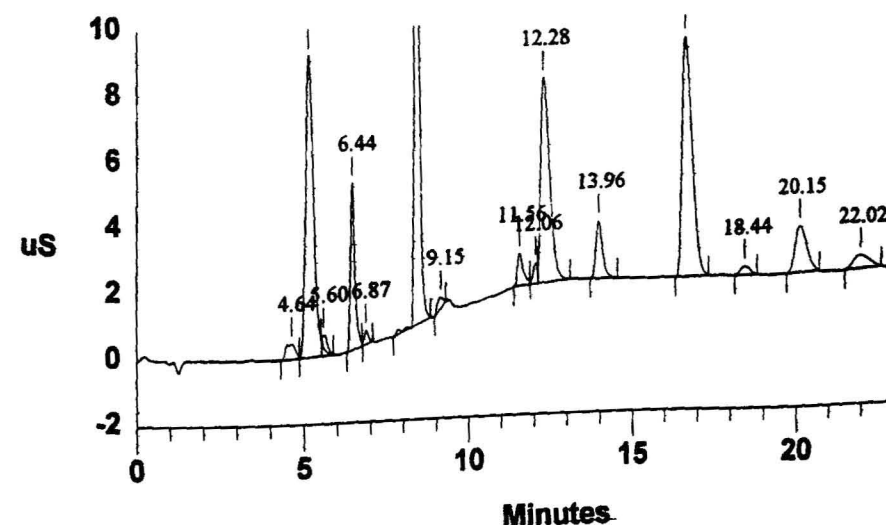


Fig. 5. Chromatogram of the analysed sample from the document *Très Saint Roi Céleste Vaisranava*.

## FIRST INTERVENTIONS

Considering the results of the analyses, a solution had to be found as soon as possible in order to remove and stabilize the products of degradation present in the documents, before rehousing them. The first step was to remove the Rhodoïd from the most valuable documents, a total of 200 paintings, woodblock prints and stencils. The pH was tested in the Conservation Department laboratory of the Bibliothèque Nationale de France. The pH was mostly between 5.2 to 5.5, the lowest value being 3.55 and the highest 6.8. The documents were then matted in acid-free and buffered paper (calcium carbonate) wrappers (Fig. 6). We expected a progressive neutralization of the acidity through contact with the calcium carbonate. In fact, pH measurements taken a year later from selected samples gave significantly higher results.

Due to the fragility of the documents and the presence of dyes and pigments that might bleed, any deacidification treatment directly affecting them was avoided, even spray methods.

The state of these objects was a warning. The problems caused by the presence of degradation products in the documents are complex and the curator confronted with them must be careful and conscientious. Before a new rehousing material and method can be chosen, it is necessary to solve three problems.

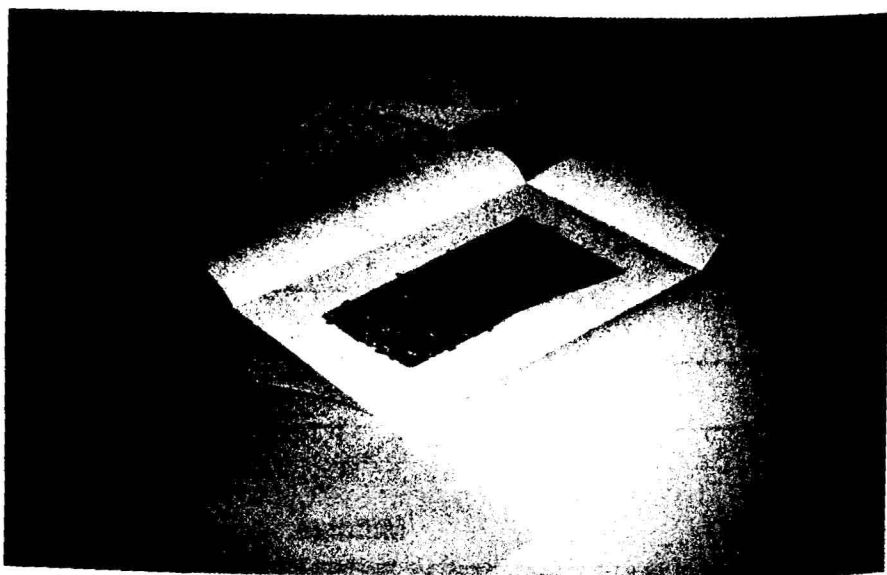


Fig. 6. The temporary rehousing of the documents that were removed from the Rhodoid. (Photo by Direction des Services de Conservation, BnF)

- Is it necessary to extract or neutralize the degradation products in the original documents?
- If yes: what is the best method?
- What method and material should be chosen for rehousing the collection?

#### REHOUSING

The choice of rehousing is influenced by several parameters:

- the "anonymity" of the collection
- the nature of the documents
- the coatings, dyes and inks present in the documents
- and whether writing is present on both sides of the document pages

The nature of the documents and the fact that most of them have not yet been identified by specialists require that the handling of the documents should be kept to a minimum. Due to their extreme fragility, great care must be taken in the selection of the proper way and materials to preserve them. These documents are

part of the most ancient evidence of the use of paper in the world. Many were kept in damp environments for centuries. They have lost their sizing and they are so brittle and fragile that it is not possible to handle them or to treat them by immersion. Prior to any treatment the coatings, inks and dyes have to be tested. Precise identification of the nature of these substances may be undertaken in the future to help conservators choose appropriate treatment. The red and the black inks are not water soluble but they are sensitive to rubbing.

As many of the documents have writing on both sides of the page, a transparent material would seem to be suitable for rehousing, but care must be taken not to reproduce the mistakes made in the past. At present, many different transparent plastics are available such as Cellophane, polystyrene, cellulose triacetate, polyethylene, polypropylene, polyvinyl chloride, polycarbonate, polyester, but one can only guess which is best suited to the preservation of documents.

Taylor<sup>6</sup> offers information and recommendations on protective films used for the preservation of philatelic material. He does not recommend Cellophane (a cellulose ester) because residual amounts of acid from the manufacturing process (carbon disulphide CS<sub>2</sub> and sulphuric acid) may remain in the final product and set off mechanisms of degradation. According to Taylor polyvinyl chloride films should not be used either because under unfavourable conditions (heat, pressure, moisture) the film can release hydrochloric acid.

In general films that contain additives (such as plasticizer, coatings, slip agents, antioxidants or solvents) should not be used. Plasticizer can migrate and react with papers, inks, etc. Polyvinylidene and polyacrylate (which contain such additives) should be avoided. Slip agents, used to modify the optical properties of many films, are abrasive. Some solvents are used in the manufacture of a polyethylene resin or to introduce ingredients into the product. Residual amounts of solvents can cause trouble. Antioxidants can induce discolouration. Taylor gives the results of tests carried out in 1985 with 5 films used for the preservation of photographs: cellulose triacetate, polystyrene, polypropylene, polyvinyl chloride and polyester. The best result was obtained with an uncoated film of polyester – Mylar D from Dupont de Nemours. According to Taylor, cellulose triacetate films (more stable than cellulose diacetate), polypropylene and polyethylene films can also be used. Cellophane, polyvinyl chloride and polyvinylidene chloride (Saran) films should not be used.

Most curators and conservators recommend using uncoated polyester films for preservation. Unfortunately polyester films, as all plastics, are electrostatic and must not be used for the preservation of fragile media such as pastel, charcoal, etc., as indicated by Laroque.<sup>7</sup> For specific cases, Verdu<sup>8</sup> recommends the use of polycarbonate films because they show strong resistance on aging.

The most common techniques for the preservation of fragile documents with



writing on both sides are: encapsulation between two sheets of polyester (Mylar D or Melinex 516); or encapsulation between two sheets of glass. Each technique has its advantages and disadvantages. Glass is heavy and breaks easily. In addition, its use requires specific storage equipment. Although it is chemically inert, it may be degraded by the products of degradation present in the documents. According to Banik,<sup>9</sup> salt migration on the inner sides of the glass plates may occur. This mechanism was observed on glass used to preserve papyri in the Austrian National Library. Padfield<sup>10</sup> points out that changes in climatic conditions may accelerate this mechanism, resulting in a loss of transparency in the glass and the alteration of the document inside the encapsulation. In addition, glass requires neutral materials for sealing the edges, which may pose a problem.

The use of polyester (Mylar D or Melinex 516) for encapsulation offers many advantages. Techniques for sealing such as ultrasonic welding or sewing are interesting. Encapsulation by sewing has been used with great success at the British Library.<sup>11</sup> Both techniques allow the preservation of several fragments in the same encapsulation. But because of the electrostatic charge, the use of polyester should be avoided for papers with several layers or papers that tend to disintegrate, because the fibres may be attracted to the surface of the plastic. In spite of the many advantages that polyester offers, care must be taken because we do not know how polyester may react in contact with chemically degraded documents. In addition, Williams<sup>12</sup> warns against the phenomenon of microclimate and condensation that may occur and develop inside the encapsulation.

#### CONCLUSION

The choice of rehousing the Pelliot Collection should be governed by consideration of whether it is possible or not to extract the acids and salts from the documents. It must be kept in mind that there will still be a risk that these products will continue to be active and harmful.

Among the various treatments possible, ethanol might be tried in order to eliminate the plasticizer residues and increase the penetration of the water which could then be used afterwards to remove the salts. Blotters, cotton or poultices soaked with ethanol or water and applied to the surface of the papers might be an efficient method if we first checked that the pressure would not damage the inks. The suction table might be also useful but care should be taken because the pressure could cause a bleeding of the inks from the surface of the document that was applied against the blotter or filter paper. All these methods will be tested in the conservation laboratory and checked by analysis.

At present, the two thousand fragments to be rehoused are being gradually

removed from the Rhodoïd, placed in acid-free buffered paper folders and stored in temporary preservation boxes. A research programme is in progress and each document is submitted to an examination. The results are put into a data base that has been built up (the software used is ACCESS). These data will facilitate the construction of a conservation programme for the entire collection.

#### ACKNOWLEDGEMENTS

We express our thanks to the VALECTRA laboratory of EDF for carrying out the HPLC. We especially thank Noel Lacoudre and Regis Bertholon for their advice. We also thank Sic Plastic for the infra-red spectroscopy analysis.

Moreover we thank Claude Laroque, Assistant Lecturer at the *Maîtrise de Sciences et Techniques conservation-restauration des œuvres d'art* at the University of Paris-I Panthéon Sorbonne, who worked on this project with a group of four students in October 1993 and who directed the Master's degree project of Nathalie Silvie during her internship at the Bibliothèque Nationale de France from October 1993 to March 1994.<sup>13</sup>

Finally we thank Brigitte Leclerc, Head of the Laboratory of the Conservation Department of the Bibliothèque Nationale de France, and Nathalie Pingaud, Research Assistant, for the analyses they performed, and Monique Cohen, Director of the Oriental Division of the Department of Manuscripts at the Bibliothèque Nationale de France, for her advice and authorization to publish the results of our research.

#### SUMMARIES

##### *Degradation Caused by Cellulose Diacetate: Analysis and Proposals for Conservation Treatment*

For many years cellulose acetate has been considered to be a stable long-term polymer. It has been used widely as a base for cinema film and also as archival material for encapsulating fragile paper. This material has now been proved to be highly unstable, breaking down and releasing acetic acid and plasticizer. From 1950 to 1975 at the Bibliothèque Nationale de France, cellulose acetate was used to encapsulate thousands of documents and fragments in the oriental manuscript collection. Now all these documents have to be removed from this material.

This article gives a short description of the production of cellulose acetate and its properties and then presents the results of analyses performed on materials previously used at the Bibliothèque Nationale. Consideration is then given to the most appropriate measures for saving the documents, most of which are badly damaged. Finally there is a discussion on the encapsulation of fragile and valuable documents.



*Dégradações causées à une collection de manuscrits par leur conditionnement: analyses et propositions d'intervention*

Pendant longtemps le diacétate de cellulose a été considéré comme un matériau stable. Il a été utilisé pour fabriquer des films et également pour encapsuler des documents fragiles.

Aujourd'hui on sait qu'il s'agit d'un matériau très instable qui se dégrade en exsudant de l'acide acétique et des plastifiants.

A la Bibliothèque Nationale du diacétate de cellulose, sous l'appellation *Rhodoid*, a été utilisé entre 1950 et 1975 pour protéger des documents du Département des Manuscrits orientaux. Tous ces documents doivent être à présent reconditionnés.

Cet article présente les principaux résultats d'analyse des documents dégradés et les premières mesures de sauvetage. Des propositions sont faites pour arrêter la dégradation des documents et pour choisir un matériau plus adéquat pour leur reconditionnement.

*Chemischer Abbau verursacht von Cellulosediacetat: Analyse und Vorschläge für eine konservatorische Behandlung*

Viele Jahre lang galt Celluloseacetat als ein stabiles Polymer. Es wurde weithin als Trägermaterial für Kinofilme und auch als archivalisches Montagematerial gebraucht. Jetzt hat es sich als sehr instabil erwiesen, es baut ab und setzt dabei Essigsäure und Weichmacher frei. An der Bibliothèque Nationale war Cellulosediacetat in den Jahren 1950–75 zur transparenten Montage von Tausenden von Dokumenten und Fragmenten aus der Sammlung orientalischer Handschriften verwendet worden.

Nach einem kurzen Überblick über die Herstellung von Celluloseacetat und seine Eigenschaften werden die Ergebnisse einer Analyse des früher an der Bibliothèque Nationale verwendeten Materials mitgeteilt. Weiterhin werden Überlegungen angestellt über geeignete Maßnahmen zur Rettung der von ihm schwer geschädigten Objekte. Schließlich wird der Einsatz von modernen transparenten Kunststoffen diskutiert, die für die Montage brüchiger wertvoller Dokumente besser geeignet sind.

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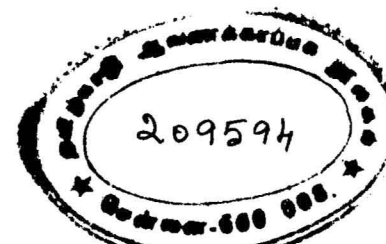
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