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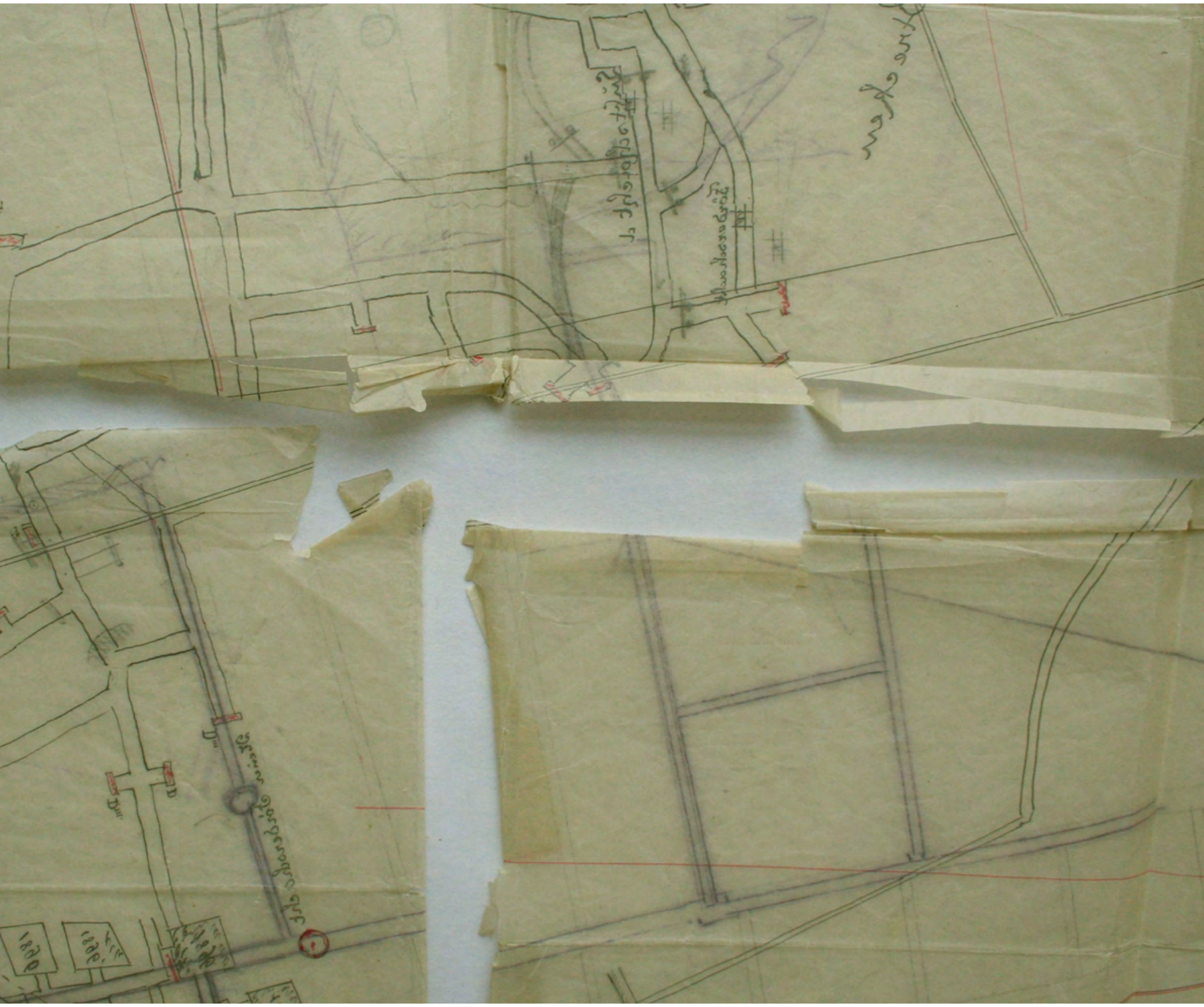

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Content

Foreword

Dear reader,

We have the great pleasure to introduce to you to the second issue of 2023 dedicated to transparent/tracing papers. The use of transparent papers, also referred to as tracing, semi-transparent or translucent papers, is evident in archives, museums, and libraries in many forms. In this issue dear reader, you will have the opportunity and pleasure of being the recipient of 4 fabulous articles.

Their diversity in public collections and their conservation challenges are presented by *Claude Laroque*, in a paper that resumes all the current knowledge about their traits and conservation issues. The technologies used to produce transparent papers, giving their distinctive characteristics are discussed along with their different forms of use and their association with other materials inside the collections.

The paper by *Kateřina Zadinová, Věra Sejkorová Kašparová* and *Luboš Machačko* presents the characteristic damage and restoration of translucent paper, demonstrated on case studies of objects treated at the Faculty of Restoration at the University of Pardubice, Czech Republic. The collected knowledge from their experience, including also tracing cloths, can be of significant value to practitioners in conservation.

Transparent papers are mostly associated with architectural and technical drawings and plans, but they can also be found in letterpress copying books or early office reproductions, that also produce challenges to the conservators' work. Two such cases are also presented in this issue.

The paper by *Agathi Anthoula Kaminari* and *Athina Georgia Alexopoulou* describes the assessment of the condition of Heinrich Schliemann's Copy-Books by means of imaging techniques. A brief overview of the procedure of obtaining copies using a copy press is given, used by pioneer archaeologist and tradesman Heinrich Schliemann to keep records of his correspondence. Assessment of the condition of the bound volumes of semi-transparent copy papers, in association with the used inks was obtained using imaging techniques.

Finally, the paper by *Vassiliki Kokla*, *Myrto Vouleli* and *Anthi Theodoropoulou* examines the evaluation of the state of conservation of 19th century copy letters from the National Bank of Greece. These papers are examined on their semi-transparent supports and used inks, by evaluating ink recipes and reading illegible text, among others. Along with the multispectral imaging, computational techniques such as morphological analysis and image processing that were used, their corresponding conservation treatments are also described.

We would like to give special credits to our peer-reviewers, that offered their specialized knowledge to maintain the high-quality standards of our publication. Also, to the ERC board and national representatives, along with webmaster Emanuel Wenger and social media administrator Penny Banou for their help in the dissemination of our periodical. As always, many thanks to our wonderful proofreaders Katarina Kelsey, Charlotte Wilkinson and Mathilde Renauld and for the final layout Anja Props. And finally, to Patricia Engel, for her devotion and guidance to the process of each publication.

Our final acknowledgement goes to the readers, as well as all the people who offer their services voluntarily, which form the periodical Conservation Update.

Our next issue, will correspond to next year 1/2024, and will be dedicated to **"Collection storage-issues on environmental parameters"**. We welcome papers that provide new research that can challenge traditional views of preventive conservation. Submissions must be sent by the deadline of December 15, 2023.

We wish our readers all the best
Marta **Soliva-Sanchez**
Manto **Sotiropoulou**

We would like to share with you some words about how we chose this topic, “Challenges on transparent/tracing paper”:

I am fascinated by all the different types of paper that have passed through my hands to be preserved and/or restored. One of them that I always find challenging is the intervention of tracing paper. which is one of the reasons why we have chosen this topic. Where we want to open up a space and share with you the knowledge and the experience of this type of work, which doesn't have a lot of literature when it comes to interventions.

Marta **Soliva-Sanchez**

Transparent papers, in the many forms that can be found in libraries and archives, are always challenging to the conservators, as they don’t employ the same qualities and inert degradation factors as traditional paper substrates. I also find that there is more literature provided for transparencies used as tracing paper for architectural and technical drawings and plans. For this issue we wanted to explore the different uses for transparent paper as well, also found as reproduction means of text, such as copy letters, or copy books.

Manto **Sotiropoulou**

Diversity of Transparent Papers in Public Collections: A Conservation Challenge

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Keywords:
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Glassine Paper
Grease-Proof Paper
Oiled Paper
Varnished Paper

ABSTRACT

Documents on transparent paper do not form a homogeneous group that can be isolated from documents on usual paper. Generally they are scattered in various heritage collections, mixed with other kinds of graphic items or with three-dimensional objects, forming heterogeneous sets : drawings of course but also photographs, models, handwritten or printed notes, correspondence, invoices, contracts, newspapers ...

They can be grouped in the following categories: geographical maps, artists' drawings, architectural plans, technical and industrial drawings and decorative drawings.

Documents on transparent paper have other common characteristics such as their dimensions which can vary from some centimeters to a few square meters, the number of items for a single project and the periods covered which start from the 18th century to the present. But above all, their interest, with the exception of artists' drawings, is essentially documentary and historical. They rarely have an autonomous function and are linked to other documents in a chain of production of objects. Being only intermediaries in the manufacturing process, they often disappear, along with their use value. Until very recently, their number and size have led to their disappearance.

From the beginning these common characteristics combined with their spectacular deterioration due to the nature of the constituent materials and their production methods, have given them an ephemeral character. These special features make their management very complex.

The article after a brief historical and technical introduction, will describe the various categories of documents carried out on transparent paper. In conclusion, it will present the challenges that the conservation of these heterogeneous sets of documents represent in an institution.

Introduction

The term "tracing paper", commonly used to designate transparent papers, refers to the function rather than the particular nature of the paper. A drawing can be traced on plain paper or canvas. Transparent paper can also be used for purposes other than drawing, such as electrical insulation or food packaging. The present article will limit its scope of interest to transparent papers used as a drawing carrier and will exclude other categories for domestic or industrial uses.

Transparent papers in heritage collections belong to several categories of documents that generate problems, specific to heterogeneous collections, both in terms of conservation and management. This issue is related to the problem of objects of large numbers and large dimensions with in a collection. Museums, libraries and, above all, public and private archives house these collections.

Documents on transparent paper are ephemeral items, not only because of their initial purpose, but also because of the quality of their constituent materials, which leads to their accelerated ageing. In fact, the various manufacturing techniques used to obtain transparency lead to extreme degradation processes which weaken these documents.

Considered of lesser importance because of their utilitarian vocation, the documents are not carefully cared for and are often poorly preserved. Their initial function as information vectors and their large size lead to repeated and hazardous handling, which is damaging to them and can result in their rapid disappearance.

The survival of these documentary collections is often precarious; finding solutions for their consultation and conservation before they disappear represents a challenge and a matter of urgency for heritage institutions.

The author points out that she has already developed historical aspects and production methods of transparent papers in two previous articles, so these points are only summarized here.[1] For more detailed information, please refer to the thesis mentioned in the bibliography.[2]

Technical and historical overview

Production

The processes used to obtain transparency are not described in detail in this article. We will simply remind that the aim of all treatments is to compact the fibers tightly and fill the voids by expelling air, to allow light rays to pass through the sheet without being scattered. By homogenizing the medium, its refractive index becomes similar to air and the paper becomes transparent.

Paper transparency can be increased either by impregnation with a fatty or resinous substance (*varnished, oiled or waxed papers*), or by intensive refining of the pulp followed by pressing the sheet (*natural tracing paper*), or by pressing the sheet after immersion in a sulfuric acid bath (*sulfurized paper*, also known as *vegetable parchment*), or by calendering a sheet obtained by intensive refining (*glassine paper* and *imitation parchment paper*), or by a mixed technique consisting in impregnating a sheet of natural tracing paper or sulfurized paper with a resinous or grease filler (*artificial tracing paper*).

1 For further information on technical and historical aspects of transparent papers, see : Laroque, C., 2000 and Laroque, C., 2004.
2 Laroque, C., 2003.

These production methods lead to papers with different physical and chemical properties. While a few clues may indicate how transparency is obtained, in general the papers are difficult to identify without analysis. For example, varnish-coated papers, when applied directly to thin opaque paper are generally identifiable. However, this is no longer the case with artificial tracing paper. In this case, chemical analysis of the components and SEM images are required.[3]

The ageing behavior of transparent papers varies from one type to another. Yellowing, loss of transparency and mechanical brittleness are the most frequent results of ageing.

The changes result from the degradation of the composition elements of the paper in combination with factors external to the material, such as its immediate environment.

The loss of initial physical properties results in a reduction in the paper's flexibility and an increase in its mechanical fragility. Paper breaks under even the slightest bending, tensile or pressure stress with consequent loss of material.

The change in optical properties takes the form of two interrelated phenomena: yellowing and increasing of opacity, with the corollary of reduced transparency. These changes can be very rapid.

Historical summary

Technical treatises from the Middle Ages to the end of the 19th century provide various recipes for the manufacture of transparent tracing carriers.

Before the emergence of paper, parchment was used, thinned beforehand and coated with a fatty substance, varnish or glue [4].

3 Laroque, C., 2004.
4 Faidutti, M., Versini C., 1979, p.57-58. Saxl, H., 1954, p.68-87.

The techniques described for making paper transparent are similar: use of drying oils such as linseed or walnut oil[5], or resin-based varnishes such as rosin, sandarac, dammar or mastic, alone or in mixtures[6].

Studies carried out at the beginning of the last century on plant fibers[7] and more specifically on cellulose and starch, led to the discovery in 1846 of the "sulfurization" process, a method that produced a translucent paper known as "vegetable parchment". This discovery is attributed to two Frenchmen, J.A. Poumarède and Louis Figuier[8]. The first patent for this process was registered in 1853 by an English chemist, W.E. Gaine[9].

A few years later, in 1859, the Englishman Taylor published a patent on the use of zinc chloride as a substitute for sulfuric acid, which produced a similar result[10]. The fibers were then said to be "vulcanized"[11].

Industrial production of parchment paper began in Europe around 1860. Germany was the most important manufacturer and later France, Belgium and Austria set up factories. The United States followed suit around 1885[12].

In parallel with the manufacture of parchment paper, research was carried out into the production of transparent paper at a lower cost.

5 Blanchard, Perot, E.M., Thillaye, 1856. Cennini. C., Reprint 1978, p.6-18. Merifield, M.P., 1967.
6 De Fontenelle, J., Poisson, P., 1828. Diderot, D. and D'Alembert, J.L.R., 1772.
7 Berthelot, M., Dreyfus, F.C., Derenbourg, H., 1886. Wurtz, A.D., 1876.
8 Poumarède, J.A., L.G. Figuier, 1847.
9 British Patent Nr 2834.
10 British Patent Nr 787.
11 The term « vulcanization » is used when a reagent (zinc chloride, here) is introduced to create bridges between molecular chains. In the case of paper, this involves gelling the cellulose. Le terme vulcanization est employé lorsqu'on introduit un réactif (le chlorure de zinc dans le cas présent) afin de créer des ponts entre les chaînes moléculaires. Dans le cas du papier, il s'agit de gélifier la cellulose.
12 Kotte, H., 1973, p.90-91.

Around 1878, Robert Emmel, a German citizen[13], carried out studies on the effects of intensive refining of rag pulp, another method for obtaining transparent paper. The process was then adapted to chemical pulps, giving rise to *natural tracing paper*.

The production of glassine paper began late, around 1894. Scandinavians held the monopoly for most of the 20th century. The process consists of cooking a bisulfite pulp at low temperature with lime which then undergoes a lengthy refining process. Finally, the paper is strongly pressed and rubbed on a calender.

Over the 20th century, techniques became more complex by mixing processes: sulphurized or refined papers will be impregnated or coated with resins or oils to improve their characteristics[14].

After the Second World War, synthetic resins were increasingly used, alone or in blends of several polymers, to impregnate paper.

The industry of transparent paper is focusing on three markets: true sulfurized papers, which will become papers for industrial or domestic use; special papers for luxury packaging, which include glassine papers; and lastly, so-called "tracing" papers for graphic use.

Finally, transparent film, essentially made of polyester, will partially replace paper in technical applications[15].

Various document categories

Using the word 'collection' to describe a group of items executed on transparent paper is rarely appropriate because the type of documents executed on transparent supports are not usually themselves a homogeneous group distinct from other works or documents on plain (non-transparent) paper. As said in the introduction, documents or works on transparent supports are found scattered within the various categories of heritage collections, mixed with other kinds of graphic documents and ephemera/supporting work. This often arises when material from specific projects is grouped together and the documents on transparent paper are considered secondary. For example architectural drawings on transparent paper may be kept with three-dimensional scale models of the building to which they relate.

There are however certain collections which usually do contain a large number of documents on transparent paper. These include architectural drawings (permanent or ephemeral architectures such as theater sets); technical drawings, such as those made by engineers; design drawings which mark the steps in the production of objects; scientific drawings, including archaeological drawings; maps; and artists' drawings.

Drawings whether on transparent paper or not, executed during fabrication of a building, a car, or a painting share certain similarities. For example, all include overall drafts (sketches, outlines that convey the author's intention), more finished drawings, and detailed drawings (usually more accurate) which mark other steps in the creative process[16].

Although museums and libraries can hold items from professions that regularly produce works on transparent paper it is primarily public and private archives or other specialized centres which house architectural, geographic and technical collections.

13 Emmel, R., 1914, p.272-73.
14 Rundle, C., 1986. Van der Reyden, D., Hofmann, C. and Baker, M., 1993, p.177-206
15 Adelstein, P.Z., 1988. p.89-101. Anonyme, 1980, p.33-39. Page, S., 1992.

16 Rundle, C., 1986. Van der Reyden, D., Hofmann, C. and Baker, M., 1993, p.177-206

These collections are by their nature heterogeneous, comprising of drawings on a variety of supports, of course, but also photographs, three-dimensional models, manuscript notes, correspondence, invoices, contracts, newspapers, etc. Artists' drawings, on transparent paper on the other hand, belong to more traditional fine art collections and are mainly found in museums.

The development of organizations such as the Committee on the Preservation of Architectural Records (COPAR) in 1970 and the creation of the International Confederation of Architecture Museums (ICAM) in 1979 have elevated the reputation of architectural drawings. Interest in architectural material by the art markets since 1975 coincides with the movement for the preservation of buildings and landscapes[17]. Technical drawings, always considered to be of low artistic value, still generate little enthusiasm. There has however been a growth in interest over recent decades in design drawings in the decorative arts.

Apart from their limited perceived value, transparent paper documents have other common traits. One of these is their non-conformity in size, they can range from the size of a postage stamp to that of a few square metres. Another, and perhaps most important aspect of works on transparent paper is that they are seen as providing documentary or historic supporting evidence rather than as works in their own right.

Thus, from the moment of their creation, these documents are ephemeral in nature, rarely existing on their own, but linked with other documents in a production chain. The drafting process, from conception to completion, of a complex product such as a car, generates dozens of drawings. As these drawings are only steps in the manufacturing process, in many cases, they have not been kept as they take up too much space. At present the use of transparent papers in all areas of traditional use is declining in favour of transparent films, microfilms, or digital images, and thus transparent papers are becoming rare.

Despite the tendency in the past for the disposal of works on transparent paper by their authors, large numbers still survive.

Fig. 1: *French National Archives : Document stacking*

Another common characteristic is the size of collections of utilitarian drawings found among public records. A survey conducted in 1999-2000 by the Institute of Paper Conservation of 221 institutional collections of architectural drawings (including public and private archives, libraries, and museums) showed that collections ranged in size from 500 to more than 50,000 items, with the average being between 2,000 to 50,000 items[18]. In the literature concerning conservation and management of these huge collections, there are many examples in which the quantities of material contained in collections are as-

17 World Heritage Convention, formally Convention concerning the Protection of the World Cultural and Natural Heritage, November 23rd 1972.

18 Collective, 1999. The Institute of Paper Conservation or IPC, (GB), produced in 1999 a collective work called « Care and conservation of architectural plans » which was available online at that time.

sessed[19]. However, the nature of the support, either opaque or transparent paper, is not always mentioned. This lack of detail shows clearly that within many of these collections, documents have not always been classed according to the type of material used as a support. It also shows that these enormous collections form a highly complex whole.

Although the survey of the IPC focused only on the architectural drawings, it can be regarded as a good illustration of the body that represents the collections of utilitarian drawings.

Each group of drawings previously defined, introduced particularities of its own and which are interesting to describe. The collections are described as entities of all types of paper whether they are transparent or not. The four following paragraphs summarize these specificities. The nature of the materials employed (supports and media) will be described in detail only in the section on architectural drawings because their use is redundant in the other categories.

Architectural drawings

Architectural collection materials produced by architects, engineers, and contractors include documents of various kinds that are predominantly two-dimensional. This is also the case for documents produced during the daily management of a company (correspondence, reports, contracts, catalogues, newspapers and records) and the materials the company produces (such as photographs, drawings, prints, books). Three-dimensional works such as models also occur.

Of all the archival material associated with projects it tended to be the drawings that were valued most and indeed retain their value for collections now. The retention of drawings has often led to the disappearance of other documents with the exception of photographs. In fact, before 1870 many architects destroyed even their drawings after the construction of the building because, estimated to be of little interest, the drawings required extensive space for their long-term storage. After 1870 in France, documents acquired a certain legal status and were thus retained[20]. Priority was given to the most highly finished drawings, namely drawings for presentation and execution because of their legal value, while sketches were often discarded. Currently, when an architect's project archive is given to a museum or archive, everything is preserved. This blend of artistic work and archival material however calls for the establishment of a criteria to set out the relative value and importance of individual works in order to solve the management problem of these collections.

Categories of architectural drawings

The material and intellectual management of collections of architectural drawings is a complex activity. Listing and producing documentation relating to a large quantity of work requires a set of clearly defined terms, a common vocabulary, that can be used by the various people involved in managing the collections. Questions of attribution of drawings within any one project may also be problematic as several people may have been involved at different stages of production.

19 See for extensive references : Laroque C., 2003 and in particular Alper, D., 1992, p. 173-178. Bush, A., 1986. Carlson-Schrock, N., 1988, p.3-9. Cook, P., Dennin, J., 1994, p.11-19. Hamill, M.E., 1993, p.24-31. Lavrencic, T.J., 1987, p.139-147. Rowlands, J., 1997, p.7-9. Stone, J., 1987, p.731-738. Yates, S.A., 1984, p.20-39.

20 Daniels, M., Peyceré, D., 2000, p.59-62.

The establishment of computerised catalogues in the form of databases facilitating research in multiple collections has accelerated the formation of an agreed terminology by historians. The nomenclature given below corresponds to the traditional method of the production of drawings by hand[21].

1. Preliminary sketches

These drawings show the initial ideas of the architect and are often executed on any support, even one of poor quality.

Fig. 2: *Administrative Library of Paris: 1937 Exhibition, Project for the Gateway to Overseas France, preliminary sketch*

2. Study or production drawings

These drawings are developed during the project. They are made to scale and are more accurate and precise. They are often made on transparent paper to allow details of previous sketches to be traced.

3. Presentation drawings

These drawings are made at a later stage in the project and are frequently carried out by a specialized draughtsman; indeed, in architectural firms, collaboration between architects and draughtsmen is common and often freelance draughtsmen are involved[22]. These drawings are often made in colour and are executed on good quality opaque paper or transparent paper mounted on card. These are usually drawings of building elevations and may be intended to obtain the approval of a sleeping partner; the execution of the drawing and layout are very highly finished. Presentation drawings are only a small part of the production of an architectural firm.

4. Working drawings

These drawings are carried out once the project has been finalized, after the client's approval and before construction. They are made either by the firm's team or by freelance draughtsmen. They are detailed scale drawings which give final dimensions and symbols. They are used, as in the case of reproductions made from originals, during the construction of a building and are given to the construction company to be used as working drawings. This functional aspect has obviously a direct impact on their conservation. These drawings to scale are very often the only remaining evidence of a building after its construction, as reproductions made from them are legal documents required by French law in order to obtain building permits and to be granted permission by local councils for the newly built building to be signed off on completion of work[23]. Scale

21 Daniels, M., Peyceré, D., 2000, p.23-32.

22 The name of the architect or the name of the firm is inscribed on the bottom right and that of the designer on the left.

23 These documents must be kept for 30 years; in the event of a claim, they can be used to determine re-

drawings are mostly done in graphite on transparent paper while final working drawings are executed in ink on drafting cloth.

***Fig. 3:** French National Archives : Fonds Nenot, La Sorbonne, presentation drawing*

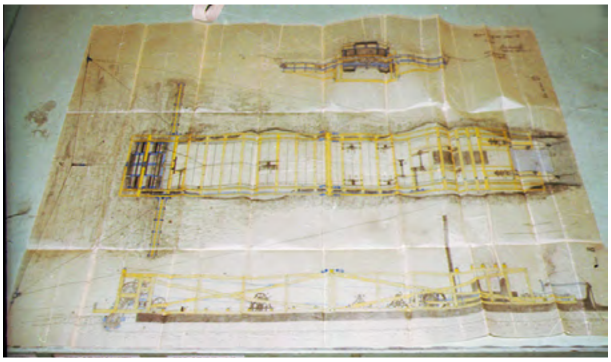

***Fig. 4:** French National Archives : Dredging boat for the Loire, working drawing*

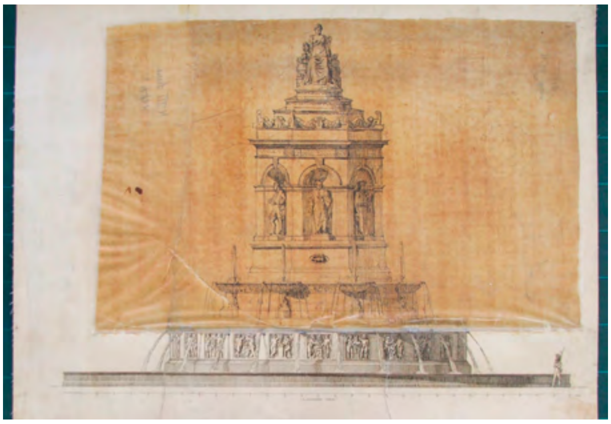

***Fig. 5:** French National Archives : Fountain project in Paris*

5. Archive drawings

These drawings are made once the building has been completed and resemble the presentation drawings closely. Used for publicity or to provide a record, they will be replaced in the 20th century by photography.

sponsibility between the designer - the architect - and the builder - the contractor - for design faults and poor workmanship.

***Fig. 6:** Administrative Library of Paris : Detail of urban planning*

***Fig. 7:** Vivenel Museum, Compiègne : Sarnus Door in Pompei ; final drawing*

6. Other

This category may include conceptual drawings of unrealised projects such as student drawings, drawings for competitions which are unsuccessful, travel sketches, controversial or imaginative drawings, collages or photomontages. There are often several versions of the same drawing, for example presentation drawings on lined paper, copies made on drafting cloth for use as working drawings and reproductions made from drawings on cloth which give specifications for heating, lighting, etc.

Materials for architectural drawings

The nature of materials and tools used in the production of architectural documents has evolved over time. Indeed materials traditionally used by architects such as graphite pencil, black and coloured inks and tracing papers are at present being largely replaced by felt tipped pens and transparent plastic films.

It is not unusual to see certain architects favouring specific materials and techniques. Frank Lloyd Wright, for example, particularly appreciated the hard and smooth surface of tracing paper which permitted incisive pen and ink lines to be drawn. Although he did use other supports, such as white or coloured watercolour papers, Asian papers and drafting cloth.[24]

Nancy Carlson Schrock examined the materials constituting the Peabody collection in Canada, and noted that over a 47-year period the firm used the same materials for the same phases of work: preliminary drawings were made on transparent or opaque papers; presentation drawings with watercolour wash were traced on a drafting cloth which allowed for reproduction due to its transparency; working drawings were first executed in graphite pencil, then in coloured ink and watercolour wash on opaque paper, and later executed on a commercial lined paper[25].

1.Supports for architectural drawings

Architects, in the same way as artists, choose their drawing supports according to two main criteria: the surface qualities required for a given technique and the overall strength to withstand the rigours of working methods where scratches and holes are caused by drawing materials such as the compass, rollers and pens. In addition, cost plays a role in the selection process as the quantity of material used by architects' firms is not negligible. Architects have therefore represented a significant market for paper manufacturers for more than a century, at least from the second half of the nineteenth to the last decades of the twentieth century. Competition between different paper manufacturers can be seen in artists' supply catalogues, which, along with technical manuals for architects and the original documents themselves, represent the main source of information as to the most popular materials and techniques.

The quality of a support varies with the type of drawing. Studies and detailed drawings for construction are executed most often on opaque drawing paper, transparent paper, or plastic film, while presentation drawings are executed on high quality paper, drafting cloth, or transparent paper lined on board.

A list of supports found carrying architectural drawings from the 18th century would include:

- Handmade or commercial watercolour and drawing papers in sheets or mounted on canvas.
- Machine-made papers of various qualities in rolls for large formats.
- Drawing paper in booklets.
- Printed papers of various kinds, such as squared graph paper.
- Trade artist boards for illustration purposes.
- Transparent papers of various kinds, in sheets or laminated on board or on canvas.
- Very thin papers called 'silk paper' stretched around or laminated on watercolour paper, canvas, or paperboard.
- Drafting cloth made from bleached cotton or linen and slightly bluish in colour to increase transparency in the

24 Mac Clintock, T.K., 1986.
25 Carlson-Schrock, N., 1988.

actinic light. Drafting cloth was coated with starch sometimes including wax, resin, or oil, and calendered[26]. Some cloths were coated with cellulose nitrate. Before being used for drawing, the surface was lightly sanded with powdered chalk or coated with a layer of ox-gall to reduce its smoothness. Sometimes the coated face received the drawing and coloured wash was laid on the reverse. This material was seen as being stronger than transparent papers for reproduction. Drafting cloth was used until the twentieth century before being replaced by films[27].

- Plastic films such as cellulose acetate were used around 1950 and polyester were used from 195528.

2. Media and tools for architectural drawings

Media used for architectural drawings vary depending on whether they were to be used as underdrawing (graphite pencil, charcoal, metalpoint, chalk, “transfer medium”[29], “transfer ink”[30]), or as final media (watercolour in pen and wash, inks, coloured pencils, gouache and more recently felt tipped pens and transfer letters).

Pens, ruling-pens, brushes and pricking wheels were the tools most commonly used by draughtsmen.

Materials for erasing included chamois leather, sandpaper or bread, rubber eraser (after 1839) and later after the second world war, synthetic resin erasers and fibreglass pencils. The frequent use of these abrasive substances has often left its mark on the drawings.

At the turn of the twentieth century, the range of practices became restricted as architects turned to dry techniques, especially the graphite pencil, for the execution of working as well as presentation drawings in order to reduce working time. The development of diazotype which allowed the reproduction of graphite pencil lines also encouraged architects to favour the use of graphite.

3. Major photo reproductive processes for architectural drawings

The processes used in the reproduction of drawings are constantly evolving. It seems likely that large-format photocopying will replace the other processes. At present, the processes fall into three chronological groups:

- Pre-19th century, where copies were made by hand by tracing an original.
- Post 1850, when the heliographic wet development processes were developed.
- Early 20th century to 1960, when the diazotype process was used.

The principle of photo-reproductive processes was that a support coated with a photosensitive chemical was placed in contact with a drawing on a transparent material then exposed to light. The sensitive layer was affected by light and the new image appeared after the support was developed either in a bath or through contact with the vapours of a chemical reagent. The drawings appeared in different colours depending on the nature of chemical process used and the method of direct or indirect exposure to light. Initially

26 Patents : Matsuura, 1933 Japan 101.637 and Murck, 1935, US 20018638.
One of the most famous factories is Winterbottom in Manchester, where production began between 1853 and 1872.
27 Lubick, A., 1999, p.40-42. Price, L.O., 1999, p.82-87. Sugarman, J.E., 1986, p.39-60.
28 Adelstein, P.Z.. 1988, p.89-101.
29 Transferring a drawing to another support using rubbed pencil.
30 Inks with added sugar.

all elements of this procedure needed to be made, then after 1876 commercially made pre-sensitised papers were used and exposure was carried out under electric light. From 1920 machines were used to produce reproductions in a continuous fashion.[31]

The ageing properties of these documents are directly related to the method of production which also determines whether they can be stored safely in contact with other materials within the collection. Their preservation requires consideration and care similar to that given to photographic materials.

Technical drawings

Among all examples of objects stagnating in the storage areas of heritage institutions, technical graphic documents are undoubtedly among the most neglected. As utilitarian documents produced in large numbers, they take a large space in terms of volume in the institutions.

As intermediaries between creation and production, intended by their very nature to disappear in favor of the final product, they have embarrassed rather than interested persons in charge of storing them.

But, historians' scientific interest has been growing over the past half-century. As in the case of ethnographic heritage, or more recently industrial heritage, we are witnessing a growing awareness of the importance of preserving these fragile witnesses of our bygone past. Sometimes the sole survivors of a heritage that has totally disappeared - demolished buildings, destroyed objects, totally altered landscapes, intermediate states of paintings that no longer exist - they are the only reference points for studying the structure of a town, an object, an industrial activity, a geographical area, etc.

The term 'technical drawings' covers a very wide field, extending from industrial drawings (i.e. plans of machinery), through design drawings in the decorative arts (such as jewellery, precious objects such as fans, bookbinding decoration, domestic decorative elements such as blinds, lamps, screens, or crockery) and fashion design drawings, to botanical, zoological or archaeological survey drawings[32]. As with architectural drawings, they reflect the stages from design to production of objects.

During the last decades, certain types of technical drawing have gradually changed status. This has been seen for example in the enthusiasm for ships' plans which are increasingly regarded as artistic drawings[33]. As with architectural drawings, ships' plans are rather sophisticated drawings, detailing structural, mechanical and internal designs.

In a similar way, drawings from the decorative arts directly related to popular areas such as fashion, jewellery and furniture are sought after by admirers of beautiful watercolours and can often be seen in exhibitions on these themes[34].

At the end of the 19th century, Berthelot already considered technical drawing to be primarily a vehicle of communication between two steps of production: conception and manufacture[35].

31 Arnow, J., 1982. Bayer, S., M., 1980. Brunner, F., 1984. De Gorter, B., 1949. p.1-11. Griffith, S.R., 1968, p.199. Kissel, E., Vigneau, E., 1999. Proutfoot, W.B., 1972. Wallace, D.K., 1933.

32 Before the invention of photography, explorers were accompanied by draughtsmen.
33 Lyon, D.J., 1983, p.73-77
34 For example in the exhibition «Les bijoux de Cartier » at Petit Palais Museum in Paris, in 1989 or in the exhibition on Registered trademarks in Paris Archives in 2003.
35 Berthelot, M., Dreyfus, F.C., Drenbourg, H., 1886 : « In architects' offices and in machine shops, tracings are made in large numbers to distribute the work to contractors and fitters ».

Technical drawing is seen to participate in the harmonious organization of the work of various players using codes understood by all and which call to mind materials, surfaces, etc. It is essential they provide clear information. Drawings which are simplified to allow a better reading of the structure of objects may be accompanied by explanatory text[36].

The division between inventor and manufacturer goes back to the eighteenth century during which time technical learning began in the arts and craft schools and descriptive geometry appeared[37]. It was at this time that industrial drawing began to develop growing in response to changes in industry[38]. The 19th century saw the development of companies specializing in technical drawing, coinciding with the growth of new activities, such as the construction of railways. Drawing instruments were perfected in response to new requirements for precision, particularly in engineering drawings[39]. In large construction offices, the tracer superseded the draughtsman and often the former was a woman, charged with making a copy in ink on transparent paper of a pencil drawing. Transparent papers offered, in addition to reproduction of drawings, the possibility of easily updating work[40].

Prior to the use of photocopiers, technical drawings on transparent paper, like architectural drawings, were intended to facilitate the quick reproduction of plans for distribution among the various people involved in the production or manufacturing process. Like architectural drawing collections, technical drawing collections include sets of different kinds of drawings which can be divided into originals and duplicates. In many cases the originals have disappeared and originals and duplicates are often seen as having equal documentary value. Copies may take the form of photoreproductions, photocopies, microfilms, prints or photographs.

Depending on the date of production, reproductions are made either on rag papers or machine-made papers. Original drawings were executed on opaque or transparent papers and on coated drafting cloth, or sometimes cardboard. The transparent papers were thin and sometimes impregnated with oils or resins, natural tracing papers, vegetable parchment or imitation parchment paper[41]. The media were similar to those used in architectural drawings: carbon black inks, coloured inks, graphite pencil and watercolour[42].

Dimensions of technical drawings are variable; large-format drawings could sometimes reach several metres, for example the ships' plans drawn to scale directly on the floor before being redrawn on paper

Fig. 8: *Seine Department Archives : Textile designs, factory models*

36 Lambert, S., 1986.
37 See in particular the work of the mathematician Gaspard Monge.
38 Lavoisy, O., Vinck D., 1997, p.1-19.
39 Baynes, K., Hugh, 20th c., without date. F., Hambly, M., 1991. Scott-Scott, M., 1986.
40 Lavoisy, O., 2001, p.7-10.

41 Laroque, C., 2003.
42 Booker, P.J., 1979. Dickenson, H.W., 1949-50, p. 73-84. Page, S., 1997, p. 67-73.
43 Lavoisy, O., 2001, p.15.

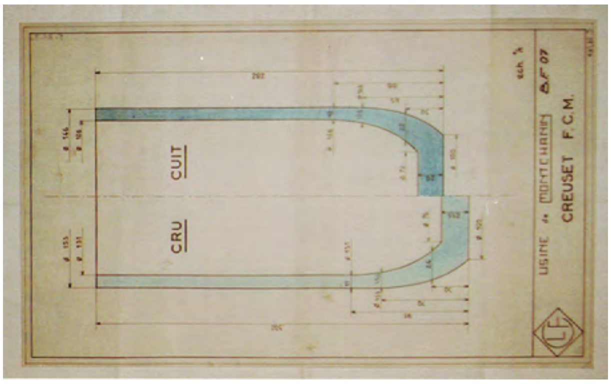

Fig. 9: *Le Creusot Ecomusée : Melting pot, drawing of manufactured part*

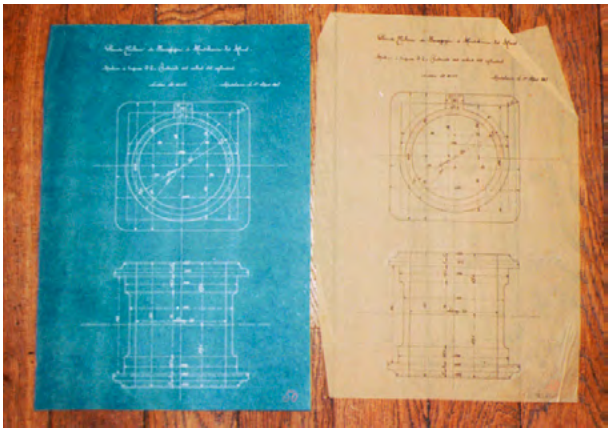

Fig. 10: *Le Creusot Ecomusée : Pipe machine circa 1901, drawing and print of manufactured part*

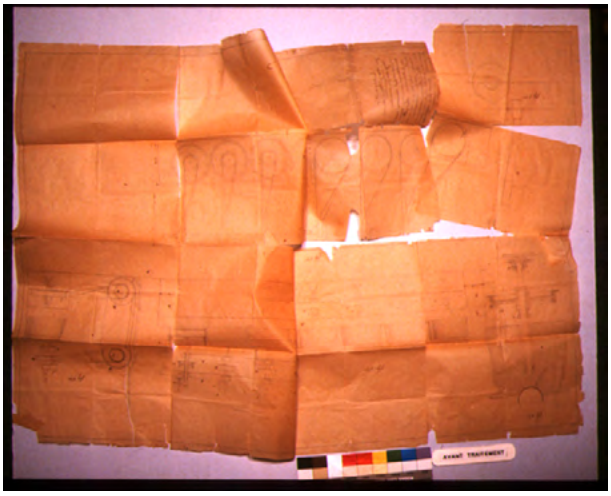

Fig. 11: *Dijon Musem : Grey's mustard machine*

Fig. 12: *City Library, Douai: Robaux Album Nr2, copy of seals*

Fig. 13: *Louviers Museum: Archaeological survey album*

Fig. 14: *Petit Palais Museum, Paris: Hair comb by E. Grasset, Cartier collection.*

Geographical drawings: maps

Archival collections relating to geography, and in particular maps, also include various types of materials. As in the case of architectural records, a nomenclature exists which corresponds to the stages of production of records which facilitates their categorization.[44]

44 Ehrenberg, R.E., 1982, p.12. Friis, H.R., 1950, p.135-155.

1. Field documents

Field documents are supporting material used in the mapmaking process. This category includes sketches done in the field such as perspective drawings of landscapes giving an idea of the general topography, mostly carried out in graphite pencil or ink, sometimes with watercolour highlighting; field notes were usually held within sketchbooks and including measurements, geologic descriptions and quick sketches; and more recently aerial photographs.

2. Processed documents

This includes accurate manuscript maps with precise measurements and executed in graphite pencil and finished in ink, based on field surveys and photographs; graphic documents to various scales; and more recently raw digitized data.

3. Reproductions

Reproductions of maps include copies made by hand, non-printed copies (such as photographs, diazotypes, blueprints, photostatic prints, microfilms), printed copies (such as intaglio etchings, lithographs, or photogravures), globes and models and computer-assisted maps. Only a fraction of this type of document is intended for permanent collections as a large portion of the documents used in the production of the final document itself disappears; this is particularly true for intermediate drawings used in the printing process. The majority of transparent papers occur in this category because the cartographer uses its transparency deliberately in the reproduction of originals on opaque paper, by tracing or producing an intermediate duplication support. The drawings can be very neat, heightened with colour, or on the contrary very stylized. These linear drawings were used in the same way as plans for plant or architectural drawings, as masters for duplication by photomechanical processes.

Articles specifically relating to maps on transparent paper are non-existent although such drawings are found in large numbers in collections[45]. This phenomenon is probably due to a catalogue description of the support and the distinction between drawings on opaque or transparent papers being considered unimportant. Likewise, articles which deal specifically with conservation problems of sets of maps are also rare; thus Ehrenberg chose to deal with the problems of managing collections of both architectural and geographical drawings together in a single manual because, he said, these documents have many similarities, they give particular information in a form more pictorial and symbolic than written and their dimensions affect their storage[46].

Another similarity between maps and architectural drawings whether on transparent paper or opaque supports is the fact that in both additions changes frequently occur. During building work, architects often consider alternatives to architectural elements by overlaying at the appropriate places different elements drawn on flaps of paper. Maps drawn on opaque paper sometimes include pieces of transparent paper upon which changes have been noted and which are adhered over the original.

45 Information on cartography is available through two major professional journals published in England: "Imago mundi, the journal of the international society for the history of cartography" and "The Map Collector".
The Newberry Library research center in Chicago, in existence since 1972, the National Cartographic Information Center (NCIC) in the USA, and the German Coronelli Gesellschaft are all research tools in this field.
46 Ehrenberg, R.E., 1982.

The nature of supports and media in geographical drawings does not vary much from that found in architectural drawings: handmade or commercial drawing papers of variable quality, in sheets, rolls or sketchbooks; transparent papers of various kinds; drafting cloth and plastic films. The media most commonly encountered is the graphite pencil, coloured pencils, black or coloured inks, watercolour, gouache and more recently felt-tipped pens.

Fig. 15: *Douai Library: Cadastral map*

Fig. 16: *Plans-reliefs Museum, Paris: Fort de Joux Work plan*

Fig. 17: *Plans-reliefs Museum, Paris: Map of Verdun*

Artists' drawings

Technical treatises for artists written between the fifteenth and nineteenth centuries offer various recipes for manufacturing transparent paper[47]. However, it is mainly from the end of the eighteenth century that artists made regular use of transparent paper. Collections of the 19th and 20th centuries, therefore, comprise the largest numbers of drawings on transparent paper as older drawings, after their useful lives were over, were destroyed by their makers or others, shortly after an artist's death.

Artists used the transparency of paper for tracing purposes of all sorts, as an intermediate tool in the preparation of a final drawing or painting, or in the creation of a collection of models, or as aids in the printmaking process.

In technical treatises, the materials mentioned for impregnating papers and making them transparent are those used by artists in workshops without care as to their longevity or compatibility with the paper support, such as linseed or nut oils, used alone or mixed with resins and varnishes of various kinds in solvents such as turpentine. Artists also used ready-made transparent papers purchased from colourmen. The nature of documents on transparent paper accordingly varies depending on when it was made[48].

47 Anonymous, 1778. Arsenne, L.C., 1985. Boutard, 1838. Cennini, C., 1978. Cooley, A.J., 1845. Corneille, J.B., 1684. De Fontenelle, J., Poisson, P., 1828. Merrifield, M.P., 1967. As in the case of architectural drawings, there are problems of authorship, as the people involved in the production of cartographic documents are quite numerous. The field survey is carried out by the explorer, the topographer; the preparation of handwritten maps is entrusted to draftsmen, copyists (abbreviated as in the case of art engravings as del. or delin. for delineavit); the transfer of handwritten maps onto copper plates, lithographic stones, photogravure plates is carried out by engravers (abbreviated as sc., sculp., scrip. for sculpsit or scripsit respectively), lithographers or photoengravers; publication is in the hands of a publisher or public

1. Original drawings on transparent paper

Drawing has been seen since the fifteenth century the core subject for artists, craftsmen, and engineers[49]. The apprentice painter was invited to copy the works of the masters, namely paintings, sculptures and drawings. The training taught in art schools which emerged in Europe during the sixteenth century was based on copying[50]; and this would remain the cornerstone of artistic education until the twentieth century. These drawings for the most part, were not 'mechanical replicas' of their models.

Constable identifies four main stages in the execution of a painting[51]. First, the artist carries out a series of preliminary sketches of the future composition which translate his/her idea. Then, there are studies of the various parts with variations which are combined to create a smaller version of the painting. The drawing is then transferred to the painting support. Finally, the artist executes the painting with constant reference to these drawings. Drawings are done at each stage and in this context, transparent papers could become precious tools for rapidly reproducing elements of the composition, or for easily transferring all or part of the composition.

agency; distribution is carried out by the distributor. In general, the person who carried out the field surveys is designated as the map's author, but all other participants may be mentioned on the map. The author, designer and publisher are mentioned in the title block or title. Information concerning engravers and copyists is relegated to the bottom margin, or to one of the edges, in the form of initials.

48 Laroque, C., 2003.

49 Treatises for goldsmiths, cabinetmakers, upholsterers and engineers proliferated in the 16th century. They revealed the work tricks and proposed mechanical solutions to problems. By the end of the 17th century, drawing had become an integral part of a cultured gentleman's education throughout Europe.

50 The Academia del disegno was founded by Cosimo de' Medici in 1563, the Académie royale de Paris in 1648 and the Royal Academy of London in 1728.

51 Constable, W.G., 1979.

This is evidenced by Berthelot in his *Encyclopedia*[52]:

> *It is also sometimes necessary for the artist to trace an initial sketch in which he finds certain qualities and that he could not identically reproduce if he did not have recourse to this artifice. In the oeuvre of the Masters, there are many tracings of first ideas constantly revisited and modified by their authors.*

Many of these drawings on transparent paper have disappeared, and the vast majority of older tracings preserved in collections date from the eighteenth and nineteenth centuries. Yet this practice was widely used long before that time and even the most famous artists will have followed this. Leonardo da Vinci suggested the use of tracing as practical training in perfecting forms[53].

Throughout the neoclassical period[54], and a large part of the nineteenth century, many French artists such as Pierre Narcisse Guerin (1774–1833), Francis Xavier Favre (1766–1837), Anne Girodet de Roucy Trioson (1767–1824), Jean Baptiste Regnault (1754–1829) and especially Jacques Louis David (1748–1825)[55] or Cecil Pierre Puvis de Chavannes (1824–1898) used oiled or varnished papers for their sketches. From 1816, in fact, the sketch was one of the official tests of the Académie des Beaux Arts[56].

These sketches which were therefore preliminary steps in the execution of a painting were considered to be works in their own

52 Berthelot, M., Dreyfus, F.C., Derenbourg, H., 1886.

53 Da Vinci, L., 1987, vol. 2 p.251.

54 Around 1750 – 1830.

55 We know 600 drawings by David on tracing paper, which were copies of refined personal drawings, improved in line with the neoclassical aesthetic of "contour juste". See Wisdom, J.M., « French nineteenth century oil sketches: David to Degas ». Exhibition catalog. 1978, Chapel Hill: The William Hayes Ackland Memorial art center, University of North Carolina.

56 Jan, P., Richir, H., 1989. Paillot de Montabert, 1829.

right, sitting on the border between painting and drawing. They were often executed on oiled paper, the artist considering that the colour of the oiled paper contributing to the effect of the sketch. Intended to seduce, these drawings were very carefully executed. It should be noted that these sketches on paper mounted on canvas around a stretcher have sometimes been mistakenly catalogued as easel paintings.

As a primary support for a sketch but also as a means of recording a composition, transparent paper can be seen to have played a significant role in the execution of paintings. It was also often used to make a finished drawing from a first sketch by tracing and keeping only the essential elements. Evidence of this can be seen by comparison of preparatory drawings with underdrawings in paintings; the former was often done in graphite pencil, as a 'draft composition', while underdrawings were most often executed using pen and are by contrast linear and more exact Thus, in the final sketch before execution of a painting, the artist kept only the relevant parts of the composition. The artist then worked in pen and ink to obtain a clear drawing. This practice was fairly common. The final drawings may have been squared or pricked for transfer of the composition in its entirety or section by section.

The practice of building a collection of drawings (personal drawings, copies or drawings purchased) was adopted by artists from the fifteenth century onward. Many artists drew from life and reused their drawings. The most famous sketchbooks are those of Leonardo da Vinci, but it is known that Rembrandt van Rijn organised his drawings thematically as did Henri de Toulouse-Lautrec later (1864-1901). These drawings represented a source from which the artist could extract material at discretion and that could be traced by the artists to create or improve a composition using their own drawings. These collections of drawings could be transmitted from master to pupil and used by other artists. Tracings also served to lift details from drawings for use in other compositions. It is known that Théodore Géricault (1791–1824), Gustave Moreau (1826–1898), Félicien Rops (1833–1898), Puvis de Chavannes and Edgar Degas (1834–1917) kept details from their works for reuse elsewhere.

Transparent paper had yet another use in perspective drawing; the paper was stretched onto a frame in front of which, a piece of wood was placed through which a hole had been punched through which we can set the desired points for tracing. Another method was to stretch the paper directly on a glass plate, hold the glass plate in front of the image and create the drawing by using the transparency of the glass[57]. These drawings belong both to the categories of original drawing and drawings for the model book.

For some artists their choice of transparent paper has been not for its transparency but its texture[58].

2. Tracings using transparent paper for model books

Diderot, in the *Encyclopédie*, tells us:59

> *The manner of tracing using a pen or pencil on oiled Serpente paper is very convenient for artists: it provides them with a quick and easy way to trace the lines of drawings or prints of which they have the enjoyment for*

57 Ayres, J., 1985, p.63-66.
58 For example Sonia Delaunay.
59 Diderot, D., D'Alembert, J.L.R., 1772.

only a short time. I have known artists who had made themselves very good collections of similar tracings and found this a great advantage and a source of much pleasure to be able to look at them on occasion.

Indeed, as mentioned earlier, until the end of the 19th century training in the academies was based on copying particularly the Old Masters. Residents of the French Academy in Rome from the eighteenth to the early nineteenth century therefore copied a great deal from the print collections, both to perfect technique and to build formal and iconographic repertoires[60]. These drawings were generally executed in graphite pencil or more often in ink and/or wash sometimes with white heightening. The method of using a tracing does not damage the original as may happen when tracing from an original with a pointed nib. It should be noted that these drawings could also be a useful aid to a less talented draughtsmen. The technique was also used by engravers or etchers for the same purpose: to create collections of themes from engravings of Old Master paintings or from original drawings[61].

3. Transparent papers as intermediate tools for printmaking

Transparent papers were also used to transfer drawings onto printing plates. These drawings have not survived because they were regarded merely as aids, thus were discarded after use. The original drawing was made with the aid of a camera lucida, then copied onto transparent paper[62]. An intermediary copy was made by transferring the traced drawing to opaque paper: at this point the image was inverted. The intermediary copy was redrawn onto a copper plate covered with varnish and when printed the image appeared in the same orientation as the original.

Diderot gives us an accurate description in the *Encyclopédie*[63]

The etchers who need a very fine line, to make this accurately on their varnish, with the minimum thickness possible, do not make this line with a pen but with a point. They use varnished paper for this . . . Take thin paper varnished with the turpentine spirit . . . apply this paper, which must be dry and which is extraordinarily transparent, to the drawing or the painting: then draw objects you see through it with pencil or India ink. Then removing your paper from the original, turn it; the lines that you have formed and which you will see through will appear arranged contrary to what they are in the original; apply on the plate the side of the paper on which you have drawn; put between this varnished paper and the plate a sheet of white paper having rubbed the side that touches the plate with red chalk or graphite; attach together your two papers with some wax so they do not vary and trace with the point pressing a little more than you would if there was only one paper on the plate; you will have a tracing as it needs to be so that the objects in the print will be as they are on the drawing.

Berthelot who believed that, 'tracings are essential to the etcher when he wants to give an exact reproduction of the work which he intends to interpret', described the same process with some variations a century later[64].

60 Jan, P., Richir, H., 1989.
61 The Louvre Museum owns a collection of 90 pen, red chalk and black stone drawings by Michel II Corneille said the Young (1642 - 1708). He reproduced artists such as the Carracci, Dominiquin and Poussin.
62 Camera lucida : Gettens, R.J., Stout, G.L.,1966, p.289.
63 Diderot, D., D'Alembert, J.L.R., 1772.
64 Berthelot, M., Dreyfus, F.C., Derenbourg, H., 1886.

The use of these papers in the etching process is so common that colourmen from the beginning of the nineteenth century proposed the sale of transparent papers in their catalogues and their use is still recommended today[65].

Transparent paper found yet another use in the lithographic printing of drawings. The colours of the final print are differentiated by tracing from the original on transparent paper. These tracings help the artist and the printer to determine the order in the printing sequences of colours and identify their exact location[66].

Fig. 18: *Vivenel Museum, Compiègne: Copies of Italian paintings 17/18th c.*

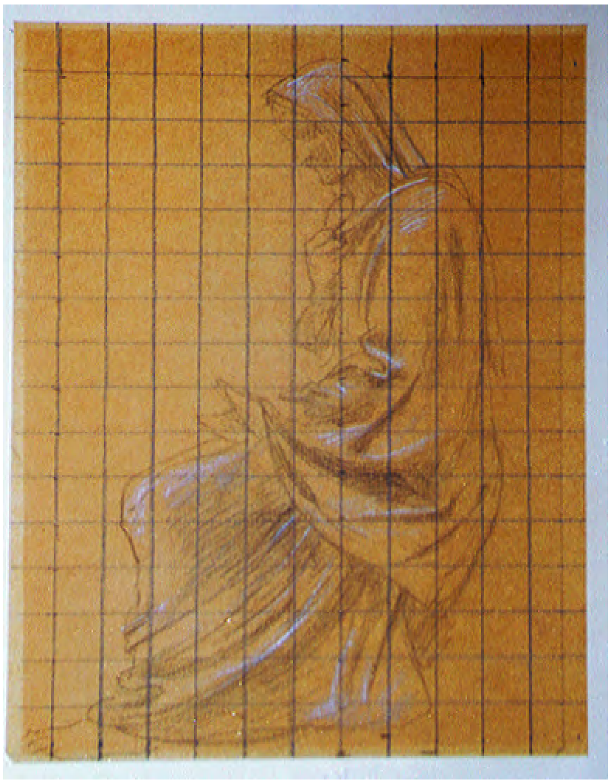

Fig. 19: *Petit Palais Museum, Paris: Study by Puvis de Chavannes*

Fig. 20: *Vivenel Museum, Compiègne: Portrait of Bonaparte by Charles Hoffbauer*

65 Krill, J., 1987, p.126. Béguin, A., 1977, p.81
66 Antreasian, G.Z., 1971.

Fig. 21: *Opéra Library, Paris : Sketch for the vault of the Opera's grand staircase by I. Pils*

Fig. 22: *Private collection, Paris: Greek frieze*

Storage and principles of archival arrangement as conclusion

This final chapter deals only briefly with the thorny problem of storing documents on transparent paper, which is identical to that of storing paper documents of all kinds, in large volumes and of large dimensions, but increased by the greater fragility of transparent papers. This issue has been the subject of numerous publications, only a few of which are cited here.

Understanding the origins of drawings on transparent paper is essential for any head of a collection wishing to establish a procedure for the conservation and classification of the types of documents described above. The challenge is particularly acute for archives and libraries, that house very large, untidy collections of varying value, whereas museums generally house selected collections in smaller quantities.

The difficulty encountered in arranging collections that we will call more generally "technical collections" is linked in particular to the multiplicity of formats, the presence of very large formats, their volume and their relative intellectual value, as we have already mentioned[67].

And as stated in the introduction to this chapter, the fragility of documents that have been severely degraded because of the nature of their components or by the handling to which they have been subjected, adds a further level of complication.

Two simple and essential principles apply to the intellectual classification of architectural and technical archives, and these

67 Ahmon J., 2012, p.15– 21. Carlson-Schrock, N., 1994. Harvey, R., 1992. Langelier, G., Wright S., 1981, p.47-58. Natsikou A., Tsantiri K., Zervos S., 2021. Ritzenthaler, M.L., 1993. Wilson H. 2015, p.54-64 same principles apply to the classification of all archival documents. These practical concepts ensure that each document is firmly linked to the group of documents of which it is a part, and that the meaning of each document enhances the understanding of those to which it is associated. When these principles are respected, the relationship of each document to the whole is always evident, and their meaning and importance can be preserved[68]. This need not to separate documents belonging to the same project, is particularly necessary for technical documents which only have meaning within this group.

However, storing can sometimes be a challenge : how can we find a method that both physically protects the documents and facilitates their consultation and eventual display?

If the classifying system for accessing documents is of first importance, several systems are possible but are often contradictory[69].

One of the systems is to begin by sorting documents according to their value, then grouping them into standard categories, then separating documents which will be consulted from those which will never be used, to arrive at the quality or level of storage needed[70].

In light of this, the importance of understanding the exact nature of the documents and their significance in relation to the whole collection is fundamental. For example, some of these documents retain legal value ; it is therefore necessary to set up a system that takes into account the rules for legal requirements as well as the needs of the various users[71].

Thus, the various partners - archivists, curators, restorers, registers - must agree first on the best compromise to facilitate access to documents at minimum risk[72].

Alper suggests, for example, that criteria of size and chemical stability should precede intellectual classification in the choice of how to group documents[73].

Carlson Schrock, for her part, recommends first, sorting documents by their value, then grouping them into standard categories, with physical separation by format. She also suggests separating documents that will be consulted from those that will never be consulted, in order to choose the level of storage quality[74].

Finally, if we refer to the survey carried out in 1999 by the Institute of Paper Conservation (IPC)[75] on the conservation of architectural drawing collections in various countries, an analysis of the majority responses reveals several important points that have not fundamentally changed until today :

- Overwhelming majority of old buildings, are used to house collections.
- The climatic environment is not controlled.
- Documentation concerning the collections is not computerized.
- Substitute documents, photographs, microfiche and photocopies do exist.
- Restricted access to documents is due to their poor state of preservation.
- The buildings rarely have a separate storage area for documents, which are kept in a large multi-purpose room.

68 Ehrenberg, R.E. 1975, p.55-71. Ehrenberg, R.E., 1982. Daniels, M., Peyceré, D., 2000.
69 Heiser-Sufrin, A., 1992, p. 12-14.
70 Carlson-Schrock, N., Campbell Cooper, M., 1992.
71 Daniels, M., Peyceré, D., 2000, p.65-70.

72 Verheyen P., Davis C., Olson D., 2003, p.131-136.
73 Alper, D. 1992, p.176.
74 Carlson-Schrock, N., Campbell Cooper, M., 1992, p.9-13.
75 Collectif, 1999, IPC.

- Documents are stored flat or rolled on various types of furniture.
- Specific conservation materials are not systematically used.

Although this survey is over twenty years old, the situation is not fundamentally different, and the management of these imposing collections still suffers from the same ills: their sheer volume, their low artistic and intellectual value, and the budgets that should be devoted to them.

Fig. 23: *Disorder in a storage area*

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About the author

Since 2021 **Claude Laroque** is retired from Paris I Panthéon-Sorbonne University as Senior lecturer emeritus where she was in charge of the Book and Paper department.

She holds a Master in conservation and a doctorate in Art history from Paris I University entitled “Les papiers transparents dans les collections patrimoniales, composition, fabrication, degradation, conservation”.

Since 1986 she teaches preventive conservation within the ICCROM program “Prema” (Preventive conservation in sub-Saharian African countries) and in other universities such as Torun University (Poland) or Belgrade University (Serbia), University of Amsterdam (Nederland).

Between 1999 and 2009 she created and directed a course addressed to technicians in preventive conservation (Mention complémentaire Entretien des collections du patrimoine).

From 1998 to 2004 she organized in Paris an international course entitled “From East to West: Japanese conservation techniques – Western prints and drawings”.

Since 2005 she shares her research

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Between 2009 and 2016 she was Head of the Research project “Asian papers: building a database of historical and technical information on papers from Asia” (creation of two data bases on Asian papers : Khartasia (https://khartasia-crcc.mnhn.fr) and Khartasia-Kagi : (https://khartasia-kagi.univ-paris1.fr).

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Characteristic damage and restoration of translucent paper demonstrated on case studies

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ABSTRACT

This article focuses on the long-term experience and restoration of translucent archival supports and tracing cloth. The Studio of Restoration and Conservation of Artworks on Paper, belonging to the Faculty of Restoration, at the University of Pardubice, has cooperated with The State Regional Archives of Litomerice, the State District Archives in the town of Most for many years. Over 15 years ago, we started working on the restoration of translucent supports from the archives collection. In the course of that time, we have developed our restoration methods to treat those unique materials. The information and experience collected throughout the years should help increase the awareness of the issues in the restoration of translucent supports.

Introduction

This article deals with the long-term experience and restoration of translucent archival supports. First, it will introduce the Faculty of Restoration at the University of Pardubice, and its cooperation with the State Regional Archives of Litomerice, Department of the State District Archives, in Most[1]. Then, it will introduce several common types of damage to translucent paper and the methods of restoration. Finally, it shows a study case of frequent damage to this specific type of support.

The Faculty of Restoration at the University of Pardubice was established in 2005 in Litomysl, the Czech Republic. The faculty offers four study programmes, including Restoration and Conservation of Stone and Related Materials, Restoration and Conservation of Wall Painting, Sgraffito and Mosaic, Restoration and Conservation of Paper, Bookbinding and Documents and Restoration and Conservation of Artworks on Paper. *"Special attention is paid to the ethics and aesthetics of restoration, interdisciplinarity, international and national historical monument care principles, technology and relevant legislation."*[2]

The training in the studio of Restoration and Conservation of Artworks on Paper *"focuses on the study of restoration techniques of drawing, graphic art and painting, chiefly on paper support"*[3] including translucent paper and tracing cloth. We have been cooperating with The State Regional Archives of Litomerice, Department of the State District Archives in Most, for more than 15 years; however, we have been working with translucent paper in the studio much longer. Complex restoration[4] of transparent support is part of the studies of one semester in our studio. Besides, at our faculty, there was a workshop focused on the restoration of translucent supports in December 2010[5], where students tried out new procedures. The workshop was taught by a restorer Veronika Kopecká.[6]

Most often, we have encountered technical drawings (mine plans, architectural designs and elements, working drawings and mosaic designs)[7] with extensive mechanical damage, such as cracks, waves, losses of paper support and other typical degradation by mechanical stress. In our opinion, in the course of time, we have developed our restoration methods to treat those unique materials. The information and experience collected throughout the years helps to increase awareness of the issues of translucent supports.

Translucent paper and tracing cloth

Although translucent paper dates back to the 19th century, there was very little information about it. This lack of knowledge could have

1 State Regional Archives, Litomerice, Department of the State District Archives, Most: www.soalitomerice.cz/soka-most/
2 Faculty of Restoration, the University of Pardubice: https://fr.upce.cz/en/fr/faculty/about.html
3 Restoration and Conservation of Artworks on Paper: https://www.fr.upce.cz/en/fr/srcaprm.html

4 Complex restoration: A student restores the whole piece of art from designing the plan, carrying out invasive and non-invasive examination, taking photos to mounting and final restoration documentation.
5 The workshop took place within the framework of European project: Projekt ESF "Restaurátoři pro evropskou unii – inovaci bakalářského studijního programu Fakulty restaurování Univerzity Pardubice". Kopecká/Hurtová et al. (2010).
6 Veronika Kopecká was the head of the studio in 2009–2014.
7 In our studio, we have restored for example: a stucco ceiling design from the State Castle of Bouzov dating back to the 19th century or a large-format pencil drawing by Alfons Mucha dating back to 1935 "Poddaní Nymburští L. P. 1421, Bohu a Pražanům" (1570 mm × 6062 mm) from The Museum of Letohrad. Neslerová (2006); Kopecká (2008), pp. 26, 35.

been caused either by inaccuracies in manufacturing patent records, or the records missing completely. Fortunately, over time, more knowledge has been gained on transparent paper properties, which allows us to approach restoration of this unique material in a more responsible way.[8] The restoration is planned according to the requests of the Archive, because mine plans and designs are usually used by researchers. Due to the cooperation with the Department of Chemical Technology and their analysis capacity, we are able to identify the type of translucent paper[9] and its approximate composition[10]. Thanks to the cooperation with the archives, a different type of translucent support has been recently rediscovered in our country which is called tracing cloth[11].

Fig. 1: *Mine plan "Johann Richard" after restoration – transparent paper and starch cloth. Photo by Anežka Šebestová. (restored in 2023)*

8 Van der Reyden – Hofmann – Baker (1993), pp. 177–206; Page (1997), pp. 67–73; Homburger – Korbel (1999), pp. 25–33; Kissel – Vigneau (1999); Kopecká (2008); pp. 24–26, 35; Price (2010); Glück – Barkhofen – Brücke (2012).
9 There are three production methods of translucent paper: 1 impregnation 2 acid treatment and 3 overbeating paper pulp. Homburger – Korbel (1999), pp. 25–33.
10 We get the composition from the data from the Department of Chemical Technology and their analyses. The FTIR (Fourier Transform Infrared Spectrophotometry) analysis was carried out using a Nicolet 380 Fourier Transform Infrared Spectro-photometer with a diamond ATR crystal, optical microscopy analysis was carried out using an optical microscope Nikon ECLIPSE LV100) and Herzberg colouring test (ČSN ISO 9184-3).
11 Price (2010) p. 49.

Essentially, it is plain woven cotton fabric impregnated with wheat starch, which causes partial transparency of the support.[12] Tracing cloth as well as translucent paper have been used since the mid-19th century mainly for architectural designs. Tracing cloth is a relatively stable support as it is solid and dimensionally stable; on the other hand, its disadvantage is high sensitivity to water and humidity – it loses its shine in contact with water. The State District Archives at Most have an extensive collection[13] of tracing cloths; unfortunately, these are registered as translucent papers. Usually, there are other added pieces of translucent supports because the size of the original plan needed an extension. Currently, we are planning to focus on this unique material.[14]

Causes of damage and its way of restoration

Translucent paper damage is mostly caused by deterioration of mechanical properties, and partly by the production method, such as acid left from production causing degradation, colour changes and support embrittlement. Another problem is mechanical stress.[15] At the State District Archives at Most, they often encounter mine plans and architectural designs; therefore, we can often see folded sheets, cracks, abrasions and smudged media.

Drawings on translucent paper comprise a large scale of media, including ink, pencils, crayons, markers, watercolours,

12 Price (2010), pp. 88–93.
13 The collection contains 28,791 pieces of mine plans, mostly hand-drawn. The collection is not processed so we do not know how many documents made of translucent paper, tracing cloth or other paper supports the collection contains. However, there are probably thousands of them.
14 Stropková (2022).
15 Nesslerová (2008), pp. 16–17.

stamps etc. All those materials have to be included in the restoration treatment because many of them are easily water-soluble – in such cases, we carry out fixing of media with *Cyclododecane*[16].

Paper rupture – tears

In general, it is crucial to repair tears so that they do not enlarge and to be visually acceptable for transparent support. It is essential to mend the tears and then to secure them. Securing tears is performed using adhesives such as *Tylose MH6000, Klucel G* or starch paste, and Japanese paper (depending on the thickness of the support). Adhesives such as *Tylose* and *Klucel* do not affect the transparency of the support.[17] However, we use wheat starch or wheat starch combined with *Tylose MH6000*, as the composition of these adhesives is closer to the support material.

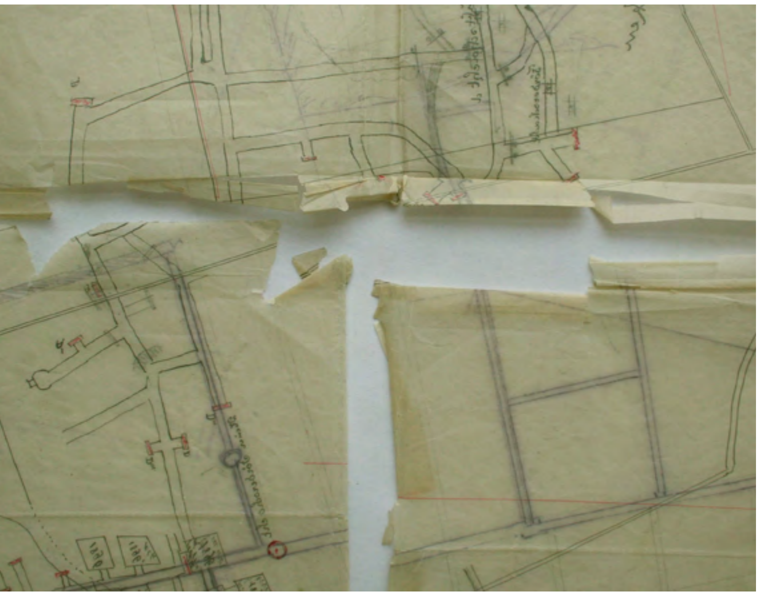

Fig. 2: *Mine plan "Anton Újezdeček, 1894 – 1896" before restoration. Tears. Photo by Danica Čulenová. (restored in 2007)*

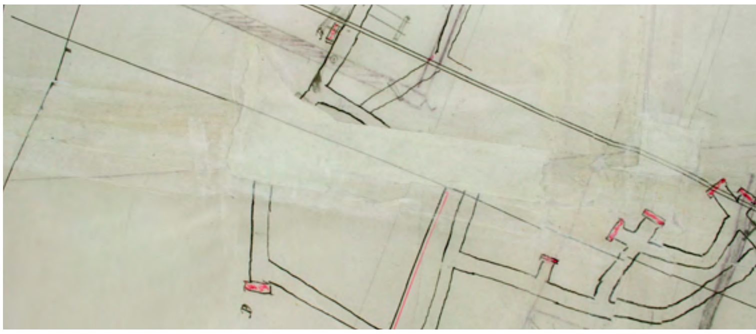

Fig. 3: *Mine plan "Anton Újezdeček, 1894 – 1896" after restoration. Tear repair with Japanese paper and Tylose MH 6000. Photo by Danica Čulenová. (restored in 2007)*

Previous treatments

One of the most frequent non-professional interventions is mending tears with a self-adhesive tape. Those interventions were executed probably during the use of the mine plans in the past. Because the plans had been used daily, folded in piles, or rolled onto tubes in storage, transparent supports were often damaged. Repairs with an adhesive tape secure the position, so the fragments stay together, but using low-quality and partially irreversible materials may cause acidification, wrinkling and colour shifts.[18] Two types of tape are used most often for such mending: brown glue tape and pressure-sensitive tape. To remove the former, we can use a small amount of warm water, while in the latter case, we need to use organic solvents – usually acetone applied with a cotton swab.[19] However, the tapes are often degraded, and can be easily removed dry with a metal spatula.[20] The method of removing the tape is done after prior individual examination.

16 Cyclododecane is a saturated alicyclic hydrocarbon, completely evaporating binder. Possibilities of use: time-limited hardening of the surface to be protected and time-limited hydrophobization. Cyclododecane melt is used for isolation www.eshop.ceiba.cz/cyclododecan

17 Kopecká et al. (2010), pp. 10–11.

18 Vlková (2017), pp. 18–19.

19 Acetone and ethanol cause small changes. However, acetone lowers transparency, while ethanol lowers shine. Toluene is the most sensitive solution to paper support but it is less effective and toxic. Page (1997), p.

20 Page (1997), pp. 69, 71

Fig. 4: *Mine plan "Uiersichtskarte 1: 2880" before restoration. PVC tape. Photo by Markéta Krausová. (restored in 2018).*

Fig. 5: *Mine plan "Uiersichtskarte 1: 2880" after restoration. PVC tape. Photo by Markéta Krausová. (restored in 2018)*

Losses

Mine plans and architectural designs are mechanically damaged; as a result, losses in the paper support occur. In such a case, we perform filling the losses with Japanese paper of suitable weight and adhesive depending on the surface type. We choose the appropriate type of Japanese paper based on the type of paper support. We try to select the one that is the most similar to the appearance of the paper – based on the thickness and paper structure. We tint the colour shade of the supplement by using water-soluble and light-stable Saturn dyes[21]. Another method is filling the losses with paper pulp. In the past, the Faculty of Restoration also carried out research into filling of losses with prepared dyed suspension of hand-cast transparent paper[22]. The best result was achieved when the paper pulp was prepared using multiple grinding without glue.[23] Linseed oil can be used for increasing transparency level; nevertheless, using the oil causes gradual yellowing over time. Unfortunately, we do not have enough space in the studio for the paper mill, thus we do not use transparent pulp anymore.

Cockling, folds and creases

Cockling, caused chiefly by humidity, appears in different sizes and quantities. For overall surface flattening, it is important to humidify the paper support with demineralised or enriched water[24] at first. Every step in which water is involved is extremely risky, so we have to be careful to avoid size and structural changes.[25] Humidification is done through the vapour-permeable membrane *Sympatex* or in a climatic chamber and lasts at least 15 minutes. Then, the archival support is flattened in a hard/soft sandwich[26] under pressure for two weeks.[27] If heat needs to be employed,

21 Direct dyes – Saturn® – Saturn dyes are water-soluble direct light-stable dyes with a strong affinity for cellulosic substrates. They are especially suitable for the extraction procedure of dyeing. They can be combined with each other. They are suitable for dyeing articles that require good light fastness. They are supplied in powder form with a non-dusting finish. Letter of approval No. GOTS-ECOCERT-08-00016. https://dyes.synthesia.eu/cze/organicka-barviva/textilni-barviva#Saturn.

22 Paper – 40:60 linen:cotton. Special paper mill borrowed from the Faculty of Chemical Technology – Institute of Chemistry and Technology of Macromolecular Materials, University of Pardubice. Kopecká – Hurtová (2010), p. 12.

23 Martinková (2008), p. 90; Neslerová (2008), p. 89.

24 Enriched water does not provide alkaline reserve; however, it permits to sufficiently increase pH value of the paper support.

25 Vlková (2017), pp. 18–19.

26 Homburger – Korbel (1999), p. 29.

27 It is slightly different from the case study in Paper, a low-pressure suction table is used.[28] The temperature and the pressure depend on the type of transparent paper; however, it mostly worked for us to use about 45°C and 190 Pa.[29] In the case of tracing cloth – if it is unsafe to use water, local flattening is recommended – at first, creases are moistened with *white spirit*[30] and then flattened with a hot spatula.[31] After local flattening, the entire cloth is put under pressure for a few days.

Stains

Unsightly stains can be caused by rising humidity and water action, inappropriate handling of the paper support or *"by absorbing extraneous materials such as adhesives, resulting in embedded stains that are difficult to remove".*[32] It is almost impossible to remove such stains due to the characteristics of the support. Nevertheless, we are able to tone down the stains to a certain extent; therefore, we have to use organic solvents such as *acetone, ethanol, isopropyl alcohol,* or *white spirit*. If we need to increase the cleaning effect, we use *toluene*.[33] Of course, the use of organic solvents requires carrying out tests in every single case.[34] Toning down the stains with solvent can be done in a few ways, e.g. by application of wet blotter poultices, gently patting the stain with a sponge on a suction table, or with a cotton swab.

line, light. Glück – Barkhofen – Brücke (2012), pp. 33–40.
28 Van der Reyden – Hofmann – Baker (1993), pp. 192–193.
29 Janská (2010), 19; Kopecká – Hurtová (2010), p. 12; Kudová (2010), p. 17; Van der Meer (2023).
30 Application of white spirit was chosen based on solubility tests of the media and surface finish. Homolová (2008), p. 9, Čulenová (2007), p. 11; Kopecká (2008), p. 11.
31 Homolová (2008), p. 9.
32 Van der Reyden – Hofmann – Baker (1993), p. 178.
33 Van der Reyden – Hofmann – Baker (1993), pp. 197–200.
34 Kopecká – Hurtová (2010), p. 11.

***Fig. 6:** Mine plan "Friedrich Střimice" before restoration. Stain. Photo by Veronika Kopecká. (restored in 2008)*

***Fig. 7:** Mine plan "Fridrich Střimice" after restoration. Stain bleaching with 5% NaBH4. Photo by Veronika Kopecká. (restored in 2008)*

Embrittled support

If the transparent paper is damaged, embrittled, is fragile, ruptures easily or consists of several pieces, it is dangerous because some fragments might get lost. In this case, backing with Japanese paper can be used, employing *BEVA 371 film®* adhesive at the activation temperature of 65°C. At first, we apply *BEVA* film on Japanese paper; then, we put the pieces of the transparent paper over it. It has several advantages – one of them is a relatively low activation temperature (except for *Filmoplast* R – activation temperature of 110°C) or waterless methods[35] and easy manipulation with fragment assembly.[36]

35Unlike when Thylose MH6000 or Klucel G are used. Page (1997), pp. 71,73.
36 Homburger – Korbel (1999), pp. 26–27; Vlková (2017), pp. 47–54.

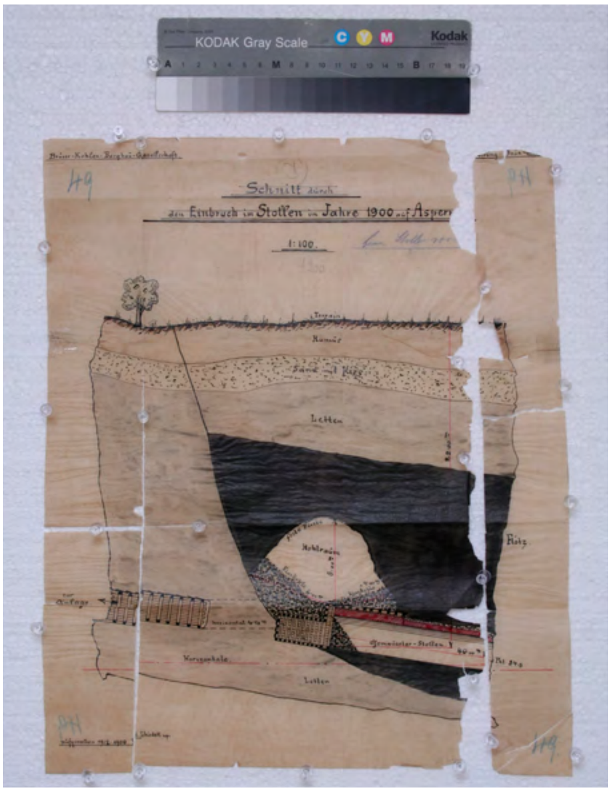

Fig. 8: *Mine plan "Aspern, 1900" before restoration. Fragile support. Photo by Barbora Martinková. (restored in 2007/08)*

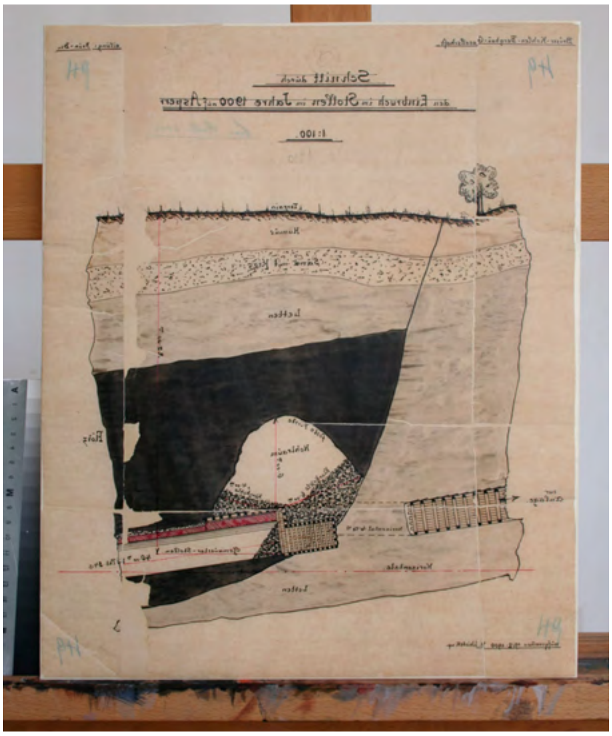

Fig. 9: *Mine plan "Aspern, 1900" after restoration. Application on BEVA 371 film. Photo by Barbora Martinková. (restored in 2007/08)*

Mounting methods

Mounting is an individual solution for the safety of a treated artwork for storage with archival-quality materials. It protects treated artworks from mechanical damage during manipulation and physical or chemical changes during storage. After a discussion with the Archive in Litomerice, we proceeded to two mounting methods. For oversized objects, we prefer rolling them onto an acid-free cardboard tube; on the other hand, smaller transparent papers are mounted to an acid-free Alphacell board with Melinex tapes after the treatment. This allows plans to be accessed more easily for digitisation and research; and with less risk of damage when it is used in the future. In the past, archival support was firmly fixed to cardboard using the strip-lining method. However, this method was rejected because such transparent paper loses its essential character, and it is not possible to employ transmitted light anymore.

The final stage is putting the restored paper that has been rolled up onto a tube or attached to an Alphacell board into an envelope made of *Melinex®*.[37] The recommended values for archiving transparent paper are 18°C (0±2 °C) and 30–50% relative humidity.[38]

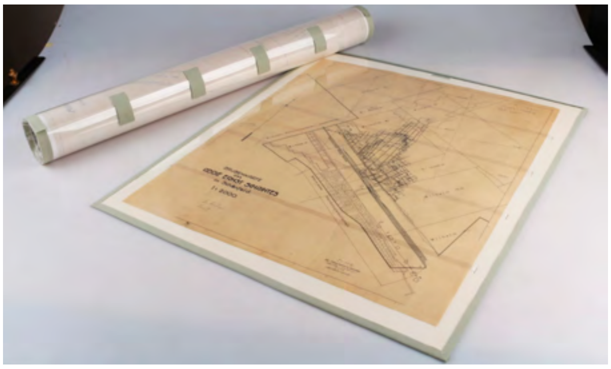

Fig. 10: *Different mounting methods – envelope made of Melinex®*

37 Melinex® 401 – 100% polyester sheet (100 μm). https://www//eshop.ceiba.cz/melinex_401
38 Environmental Conditions for Exhibiting Library and Archival Materials. Version for the Czech Republic – ČSN ISO 11799 (010169) Informace a dokumentace – Požadavky na ukládání archivních a knihovních dokumentů.

Conclusion

There are many questions in the field of translucent paper and tracing cloth restoration. Its great sensitivity to humidity, high fragility and presence of many different media (e.g. pencils, markers, stamps and other media) rank among the biggest problems for conservators, not to mention the lack of written resources dealing with the conservation of these delicate materials. That is why we must pay special attention to all steps of conservation treatment. In our practice, we have developed certain treatment operations that are considered safe for archival materials. In spite of this fact, we feel that we are still at the beginning of the process of understanding these unique materials.

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Assessing the condition of Heinrich Schliemann's Copy-Books by means of imaging techniques

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ABSTRACT

Heinrich Schliemann (1822-1890) is well known for his keen interest in ancient Greece that led him in conducting major excavations such as Troy. Being a well-established tradesman, he was very meticulous in his correspondence and used the copy press procedure to maintain copies of his outbound mail. The majority of Schliemann's copy-books are now kept in the Gennadius Library in Athens, Greece. There are 43 volumes dating between 1845 and 1890 and these cover a wide variety of different copy techniques and materials, as Schliemann showed particular interest in the technological developments.

The application of imaging techniques [visible colour photography (VIS), ultraviolet reflectance photography (UVR), infrared reflectography (IRR), false colour infrared imaging (IRRFC), ultraviolet induced visible luminescence photography (UVL)] helped in recording Schliemann's copy-books archive regarding the condition of the covers, spine, textblock and in some cases loose copy papers, as well as indicating different types of ink and discriminating between diffusion and oxidation halos. Images were acquired from both front (recto) and back (verso) sides of selected representative pages, as well as from single characters using close-up photography.

Introduction

Historic Information about Copy Letters and Copy Books

Copy letters and copy-books[1] were a means of keeping outbound mail in an era when none of the modern technology, such as typewriting, photocopying, or even more advanced technology, such as digital scanning or electronic file keeping, was available. Many alternative handwritten copy methods were invented between the mid-17th and end of the 18th century without any particular public acceptance. The practical way to produce copies was to write them over again by hand, though this was time consuming when it came to multiple copies and the human error was significant, resulting in misspellings that could alter the meaning of the text. In 1780, the developer of the steam engine, James Watt, received a British patent for the copy letter press (British Patent No.1244)[2].

The method is based on the imprinting of the ink of a manuscript in a thin translucent paper. The original should have been written with suitably prepared iron gall ink and the copy should be made within 24 hours, while the ink was still fresh[3]. Even though inks used for writing letters remained wet for such a period that pounce had to be used to absorb excess moisture, drying time was not sufficient to supply adequately legible copies, so special recipes for copying inks were gradually developed[4], which contained sugar or glycerine to prolong their drying time. For the facilitation of the process, the copy paper should be slightly damp. This was achieved with the application of water using a paintbrush or blotting papers or special equipment that was devised for this purpose e.g., a copying paper damper. The wetting was carried out before or after placing the copying paper above in the handwritten page. Then, they were pressed together for 30 seconds between cardboard plates impregnated with oil that limited the movement of water. After the pressing, the copy was removed from the original. During this process the ink passed to the thin copy paper. The imprint of the text on the contact surface of the copy paper constitutes a mirror image of the original. The image passes to its front side, creating the copy[5].

The copy press procedure and its variations have been widely used in the past up to the early 20th century, not only by companies and professionals who needed to keep a record of their orders, expenses and dealings, but also by private individuals who wanted to retain copies of the mail they had sent. Famous people that used the copy press method in the United States of America[6] were Benjamin Franklin, George Washington, James Madison and Thomas Jefferson, and in Europe Johann Wolfgang von Goethe[7], Friedrich Schiller[8], Friedrich Carl von Savigny[9] and Heinrich Schliemann[10].

The copy papers[11] were usually not sized, of small weight, from rags or various plant fibers, without addition of chemicals. Sometimes, copying paper was impregnated with different substances in order to attribute to the paper different characteristics.

1 Rhodes/Streeter (1999), pp.4-6.
2 Mitchell (1937), Rhodes/Streeter (1999), pp.357.
3 Cleveland (2000)
4 Kaminari (2014), pp.31, 110-117.

5 Cleveland (2000)
6 Cleveland (2000)
7 Fischer (2009)
8 Fischer (2009)
9 Titus et al (2006)
10 Kennell (2002)
11 Rhodes/Streeter (1999), p.46-58.

Initially, the binding of the copies was made by hand but later it was carried out in special machines. In the middle of the 19th century, the first copy books of correspondence (copy books or letter books) were circulated from the railway companies that adopted the Watt method of copies in bound form[12]. During the last quarter of the 19th century, the market was crowded with competitive technologies in order to cover the continuously increasing needs for copies. Their durable structure was necessary due to their frequent use and their exposure to handling, humidity and pressure.

Heinrich Schliemann, his Life and Written Legacy

Heinrich Ernst Schliemann[13] (1822-1890) was born in Germany. After years of training and working he became a successful tradesman and accumulated his great personal fortune. In 1863, Schliemann decided to semi-retire and to devote himself to his childhood love of ancient Greece. In 1866-1867 he enrolled in archaeology courses at the Sorbonne, Paris. Schliemann, absorbed by his passion for Homer and archaeology, spent the rest of his life on archaeological excavations, all of which he financed personally. The discovery of the ancient city of Troy (referred to by Homer as Ilion) in Asia Minor in 1870-73 was one of Schliemann's greatest accomplishments and brought him worldwide fame. His other excavations were also significant and include important sites such as Mycenae, Tiryns, and Orchomenos. Most of the archaeological relics found at the excavations' sites are now displayed in the National Archaeological Museum of Athens. The Gennadius Library[14] in Athens, Greece, houses today most of the documentation belonging and related to Heinrich Schliemann. The H. Schliemann archive consists of diaries, original letters, copybooks of letters and other documents.

During his lifetime, Schliemann had visited several different countries and had always kept a diary. From these diaries we learn much about his life. However, his copy books are another important source of information that has not yet been recognised. Apart from writing his diaries, Schliemann, as a tradesman, was used to keeping a record of his outbound mail, so it was only natural for him to also keep a record of his private mail. Within his copybooks the reader realises that Schliemann must have had an inclination for languages because copies of the letters he sent are written in several languages. Indeed, apart from German, he spoke fluent English, French, Greek, Russian, Italian, Spanish, Dutch, Portuguese, Swedish, Latin, Arabic and Turkish. His copies also prove that he also had communication with prominent personalities of his era, such as Otto von Bismarck.

Schliemann's copybooks in the Gennadius Library

The archives of the Gennadius Library house 43 volumes of copy books, under the code Series BBB, belonging to Heinrich Schliemann. They cover a period of time from 1845 until 1890 and they offer a wide variety of different copy techniques and materials, as Schliemann showed particular interest in the technological developments[15] and kept up with state-of-the-art technology of his era.

12 Cleveland (2000); pp.59-80.
13 ASCSA (2023); Voltera oral communication; General Encyclopedia of Secondary Education (1980), pp.3543

14 ASCSA (2023); Voltera oral communication
15 ASCSA (2023)

From 1845 until 1867 Schliemann copied his letters using loose numbered sheets of copy paper and he gathered them until there were enough to be bound as books i.e. volumes BBB1-26. From 1867 until 1890 he used commercial copy letter books of a single brand i.e. volumes BBB28-43. Originally there were more copy books, but some of the volumes were lent to Ernst Meyer before World War II and have never been recovered. They refer to the time between July 1876 - March 1877, March - July 1877, Oct. 1877 - April 1878 and May 1885 - January 1888. These time gaps are not taken into account in the numbering of the volumes, which appears consecutive.

Copybooks BBB1-27 have similar dimensions i.e. 30.8-33.6 cm height, 22.5-23.2 cm width. The thickness of the copybooks varies dramatically from 7.8 cm to 17 cm, depending on the amount of pages bound together into a book. Whole and half bound leather book bindings, with or without corners, and with or without decorative paper or marbled paper of different colour combinations are encountered. Some books contain indices filled in by hand (BBB 7 and 11-24), while others are kept closed with a strap (BBB 14, 16, 17 and 20). Commercially available bound copybooks include BBB11 from Cowan & Co, Edinburgh and BBB15 from Hoffren, St.Petersburg. BBB24 and BBB26 are pink and grey folders respectively, which contain loose copy letters. Volume 27 comprises copy letters bound together by the company Van Anden's portable copying press, London. The different copied inks encountered in these volumes present hues varying from black to brown and reddish ones.

Volumes BBB28-43 comprise Penn Letter Books, which all have the same dimensions 28 x 23.6 x 2.6 cm. They bear greyboard cases, covered by a dark brown-reddish case cloth with PENN LETTER BOOKS written in gold on the front side. The spine cover and the front and back cover corners are covered by beige-light brown leather. The books bear golden decorative lines on the spine cover and at the corners of the front and back cover. They have endpaper and contain an index and a printed alphabetical catalogue as well as printed numbers on the top right of each page. The verso side of the first page contains printed instructions on how to use Penn Letter Books. Copied inks in all Penn Letter Books present a similar brown-reddish hue.

As Schliemann's copy books contain vital information and historic evidence of various aspects, the library needed to assess their condition. Even though visual examination was carried out as it is standard procedure, more in-depth information about the archive's condition was needed regarding especially the paper substrate and the possible damage iron gall copy inks might have induced to it, so that conservators could formulate a well-structured treatment plan. Examination in the non-visible regions of the electromagnetic spectrum could provide this important information, therefore imaging techniques were applied to selected pages of the copybook volumes.

Imaging Techniques

Photography and imaging techniques in general[16] are non-destructive documentation methods as well as diagnostic and recording tools in the hands of those that come in con-

16 Alexopoulou/Chrissoulakis (1993), pp.125-131; Payne (2012); Alexopoulou/Kaminari (2014); Banou et al (2019), pp. 217-225 tact with works of art and relics of historical value. The methods applied in the present study, which are considered to be helpful for the technical examination of paper and inks[17], were Visible colour photography (VIS), Ultraviolet Reflectance photography (UVR), both black and white (B/W) and colour, Ultraviolet induced Visible Luminescence photography (UVL), Infrared Reflectography (IRR) and False Colour Infrared Imaging (IRRFC), in normal and close-up modes, on both sides of the page (recto and verso). The present study was based and applied the protocols that were established through mock-ups and experiments and have already been published elsewhere[18]. In visible photography (VIS), the image of the object is recorded as viewed by the naked eye. It is the most important image, because it presents its true colours, depicts its size and dimensions, records its condition and acts as a reference image for future comparisons.

In UVR[19], while irradiating the surface of an object with ultraviolet radiation, the reflected ultraviolet radiation is recorded. The value of the method relies on the different absorption that various surfaces exhibit in the ultraviolet region. The result is a high contrast image that can help differentiate between areas and leads to their classifications based on their different physicochemical properties. In this case, from all the reflected radiation, only the ultraviolet between 320 nm-380 nm is of importance and must be recorded. For this reason, special barrier filters are used in front of the camera lens, that permit the passing of only this wavelength region, while they cut off all other wavelengths. As ultraviolet radiation is not visible, use of colour films has no meaning, so black and white films that are sensitive in the ultraviolet region have to be employed.

UVL[20] is based on the ability of the ultraviolet to cause luminescence of some substances, mainly organic ones. These substances absorb the photons of the incident radiation, are excited and, since this excited state is unstable, they gradually re-emit the absorbed energy (Stokes law) as a longer wavelength radiation, which in this case is in the visible region. The recorded information comes exclusively from the visible region of the spectrum, so all other radiations, such as ultraviolet and infrared, must be cut off. For this reason, barrier filters in front of the camera lens are used. As some substances absorb the radiation without producing fluorescence, this makes them appear darker in black and white UVL photography, while others appear lighter. In UVL colour photography, the different fluorescence emission wavelengths of the substances result in the recording of different colours on the film. Different colour in the fluorescence of visibly similar substances indicates difference in their chemical composition.

Infrared Reflectography[21] is also a non-destructive diagnostic method for research of works of art, which takes advantage of the penetrating capability of the infrared radiation, between 700 nm-2700 nm, through the upper colour emulsion layers of the object, thus multiplying the in-depth observation of the subsurface, which can reach up to the sketches. Use of longer wavelengths should be avoided, as in those regions the ra-

17 Colbourne (2000); Alexopoulou/Kaminari (2014); Kaminari (2015)
18 Kaminari et al (2021)
19 Alexopoulou/Chrissoulakis (1993), pp.139; Alexopoulou/Kaminari (2014); Cosentino (2015)

20 Alexopoulou/Chrissoulakis (1993), pp.142; Kaminari et al (2013); Alexopoulou/Kaminari (2014); Cosentino (2015); Webb (2020), pp.35-60
21Van Asperen de Boer (1970); Burmester/Bayerer (1993); Alexopoulou/Chrissoulakis (1993), pp.171-185

diation can cause heat side effects that could damage the work of art. The detection of the infrared radiation is made with the help of an electronic system that transforms the non-visible radiation into a black and white optical image, the reflectogram. Infrared reflectography provides useful information about the absorption of materials in the infrared region and consequently reveal information about their chemical constitution. Thus, areas that look similar in the visible, but present different absorption in the infrared, can be differentiated and sometimes classified.

False colour infrared imaging[22] is based on the mutual recording of infrared and a part of the visible radiation that is reflected from the object. The result is a coloured image of the object that contains false colours, indicative of the behaviour of the object in the infrared region. Instead of the visible blue, green and red, the recorded radiations include green, red and infrared (800 nm). The final image is a combined result of these three wavelengths. Apart from multispectral and/or hyperspectral cameras, separate images can also be obtained using specific digital SLR camera models, which can then be combined in an appropriate image processing software to produce the false colour image. False colour infrared imaging is extremely useful in distinguishing different pigments in paintings that visually look the same, but since they have different chemical composition, exhibit different behaviour in the infrared region, thus absorbing and reflecting infrared radiation differently. The final false colours of the pigments will be different, leading to a qualitative discrimination. However, one cannot perform an absolute pigment identification based solely on its false colour, as various pigments might exhibit the same hue of false colour. This remark extends also to other materials such as inks.

The aim of the study was to employ non-destructive imaging techniques in order to document the copy books and loose copy letters and to record the behaviour of inks and papers in both the visible and the non-visible regions of the electromagnetic spectrum as a critical clue towards the documentation of the preservation state and the differentiation of the types of ink.

Experimental

In the beginning, a survey based on visual observations was carried out through the archive of Schliemann's copy books. This step was very important as it presented a glimpse of the overall condition of the archive and thus facilitated the decision-making on the course of action.

Methodology and Instrumentation

Based on the fact that sample acquisition is not always easy to be granted or to perform, especially from inks and manuscripts of historic value, the emphasis of this study was to establish and support that the assessment of the condition of the Schliemann's copy books archive could be carried out successfully through the application of imaging techniques. The methodology employed included the following stages:

- Photographing the outer body and pages of the books in the visible
- Imaging of selected pages in total, detail and close-up mode, recto and verso
- Digitisation of the photographic material

22 Moon et al (1992); Alexopoulou/Chrissoulakis (1993), pp.159; Alexopoulou/Kaminari (2014)

- Process of data
- Results on the state of preservation and eventual categorisation of inks

All non-destructive diagnostic imaging techniques were applied *in situ*, in the Gennadius Library. The instrumentation was transferred from the University of West Attica (former Technological Educational Institute of Athens), to the archives' section in the Gennadius Library. For the different needs of each imaging technique, the archive's room was properly arranged so as to arrange a photographic studio while an adjacent dark room was employed for the specialised imaging procedures that needed complete darkness i.e. UVR and UVL.

For the photographic methods, analogue systems were used. For the visible photography a SLR NIKON F80 camera with NIKON AF MICRO NIKKOR 60mm lens and colour Fuji Film Provia 100F slide films and 2 tungsten OSRAM lamps 500W were used.

In UVL colour photography, a SLR CANON T70 camera with programmable back, a CANON macro lens 50mm and Fuji Film Provia 100F slide films, barrier filters KODAK 2E and two Philips black light lamps MLW 160W were used.

UVL black and white was recorded using the NIKON AF MICRO NIKKOR 60mm lens and KODAK TECHNICAL PAN TP films, barrier filter KODAK 2E and two Philips black light lamps MLW 160W were used.

UVR was shot with a SLR CANON T70 camera with programmable back, a CANON macro lens 50mm and KODAK TECHNICAL PAN TP films, barrier filter KODAK 18A and two Philips black light lamps MLW 160W were employed.

The black and white negative films that were used for UVR and UVL black and white, were developed by the researcher using the appropriate chemicals and controlled conditions. Colour slide films used for visible VIS and UVL were given to a specialized photographer to develop. After the development of the film, digitisation was applied in high resolution mode for obtaining the maximum quality of scanned images, using a Mikrotek ScanMaker 4900 scanner with a special film adaptor in 2400dpi.

False colour infrared imaging was carried out with the hyperspectral detector MuSIS HS model 2009 (Forthphotonics Hellas S.A. now Dysis) equipped with a CCD 1/200 Progressive Scan sensor (1600 x1200 pixels, 8 bits, 15 fps) with 34 selectable spectral bands in the range of 400-1000 nm for B&W and colour imaging. The light source was the same as in VIS.

Infrared reflectography was applied with an Arti S.p.A. Vira infrared camera and PENTAX 50mm lens. The appropriate barrier filters were used to exclude the visible region from being recorded. The light source was the same as in VIS.

The chosen documents were photographed in normal, detail and close-up modes, on both sides of the page (recto and verso) and under symmetrical light on copy stands so that their surface would be perpendicular to the camera or the detector. Special archival cushions and plexiglass weights were used to stabilise the pages from movements, ensuring the quality of the recording.

Selection of pages

The initial survey determined the choice of the most characteristic pages on which all the aforementioned non-destructive examinations were applied (Table 1). Special care was taken so that the selection of pages was representative of as many different types of inks and substrate conditions as possible. Another important consideration for this selection was the fact that in volumes bound from loose sheets such as BBB1-17, many and different types of copies were found, because loose documents had been bound together to form volumes, so several pages from each volume were examined. Volumes BBB4, 5 and 18 presented a rather poor state of preservation and were avoided so as to prevent further damage. Volumes BBB14, 16, 19, 20, 21, 22, 23's thickness (15.5 - 17 cm) and lack of spine prevented handling them. However, both categories of poor condition and high thickness volumes were photographed in all six sides in the visible light. Volumes BBB28-43 comprise Penn Letter Books, so four representative examples were chosen.

Table 1 : *Table 1 summarizes all the studied pages and the respective dates*

Volume BBB	Page	Original Date on the Copy
1	23	17 December 1845
1	38a	15 January 1846
1	76	10 or 11 Juny [sic] 1846
2	2	29 January 1847
2	17	1 February 1847
2	76	20 February 1847
3	141b	30 August 1847
3	162a	9 September 1847
3	343	15 October 1847
6	23	13 January 1849
6	140	11 Mai [sic] 1849
8	4	13 January 1850
8	24	17/29 April 1850
8	71	16/28 April 1850
9	5	31 May 1850
9	13	no date
9	288	no date
10	19	13 November 1850
10	26	15 November 1850
10	27	16 November 1850
10	182	30 October 1850
11	2	19 or 20 October 1851
11	48	November 1851
11	89	11 November 1851
11	407	3 February 1852
17	48	no date 1857
17	593a	July 1857
17	939	October 1857
24	20.	arabic writing
24	108	25 Marjo [sic] 1854 or 64
25	33	30 April/12 May 1864
25	112	3 November 1864
26	23	no date
27	181	7 October 1867
27	415	1 June 1868
27	491	no date 1868
28	359	18 January 1870
29	291	Εν Αθήναις 15/25 Μαίου [sic] αωοα [sic]
35	147	Εν Αθήναις 7 Μαρτίου αωοξ [sic]
43	15	Athens, 23 September 1890

Results and Discussion

As aforementioned, a survey was carried out through the entire archive of the copy books. The copy books cover a period of time between 1845 and 1890. Some of the volumes were in very poor condition, preventing any handling, such as volume BBB2. Other volumes were very big in thickness, making them difficult to photograph and dangerous for the objects themselves when attempting to flatten the pages, such as volumes BBB8 and 9. Volumes BBB28-43, the Penn Letter Books, presented similar characteristics regarding their condition and the ink. In total, forty (40) different pages were chosen to be examined by technical photography in this survey.

The Quality of the Copies

Based on previous studies[23] on copy letters and copy books, there are specific categories they can be distinguished based on their overall condition. These categories were detected and identified also in the case of the H. Schliemann archive and have been thoroughly presented elsewhere[24]. Summarising, the copies could be characterised as:

- Excellent copies, referring to the ones that could not be distinguished from original handwritten letters (Fig.1.a),
- Copies of very good quality and satisfactory distinctness (Fig.1.b),
- Poor quality, faint and indiscernible (Fig.2.a), and
- Bad quality copies, comprising blurred and illegible letters with continuous writing without gaps between the characters and/or intense diffusion of ink (Fig.2.b)

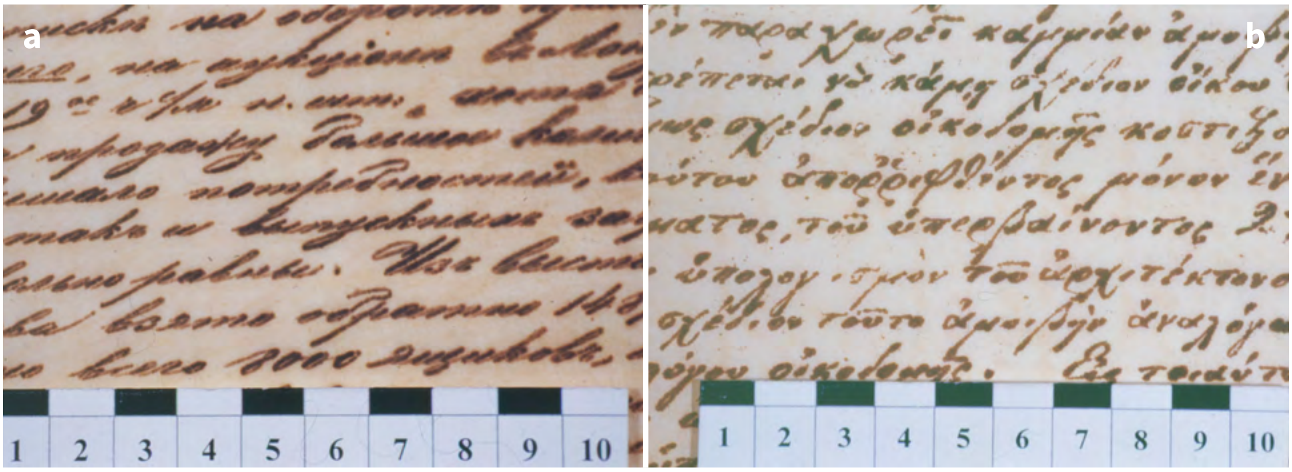


Fig. 1: *Schliemann's archive, the Gennadius Library. (a) Volume BBB2, page 76, visible photography (VIS), detail. Example of a copy that cannot be distinguished from a handwritten letter. (b) Volume BBB29, page 291, visible photography (VIS), detail. Example of a copy of very good quality and satisfactory distinctness.*

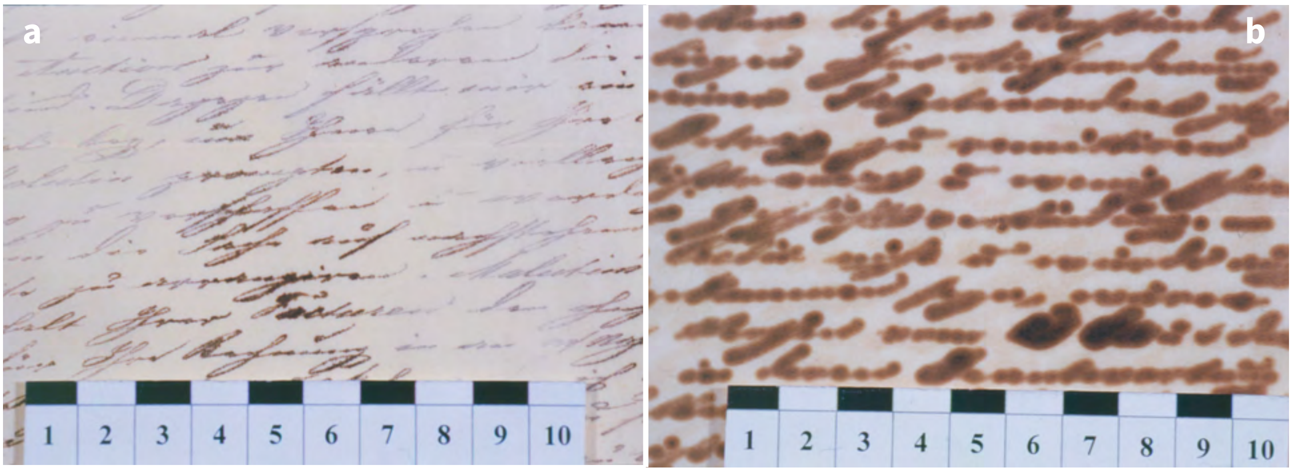


Fig. 2: *Schliemann's archive, the Gennadius Library. (a) Volume BBB3, page 162a, visible photography (VIS), detail. Example of faint and indiscernible copy. (b) Volume BBB9, page 5, visible photography (VIS), detail. Example of a copy with blurred and illegible letters and intense diffusion of ink.*

23 Banou et al (2006); Kaminari et al (2021), pp. 203-217
24 Alexopoulou et al (2012)

In most cases, in the books that were studied, entirely good or bad quality copies were not observed, but rather, they present a combination of copy qualities. Even in one page, differences of the copy quality could be observed (Fig.3.a). In some pages, two different copied letters were observed and in several of those, one text was copied in a vertical direction as to the other one, resulting texts to cross each other (Fig.3.b).

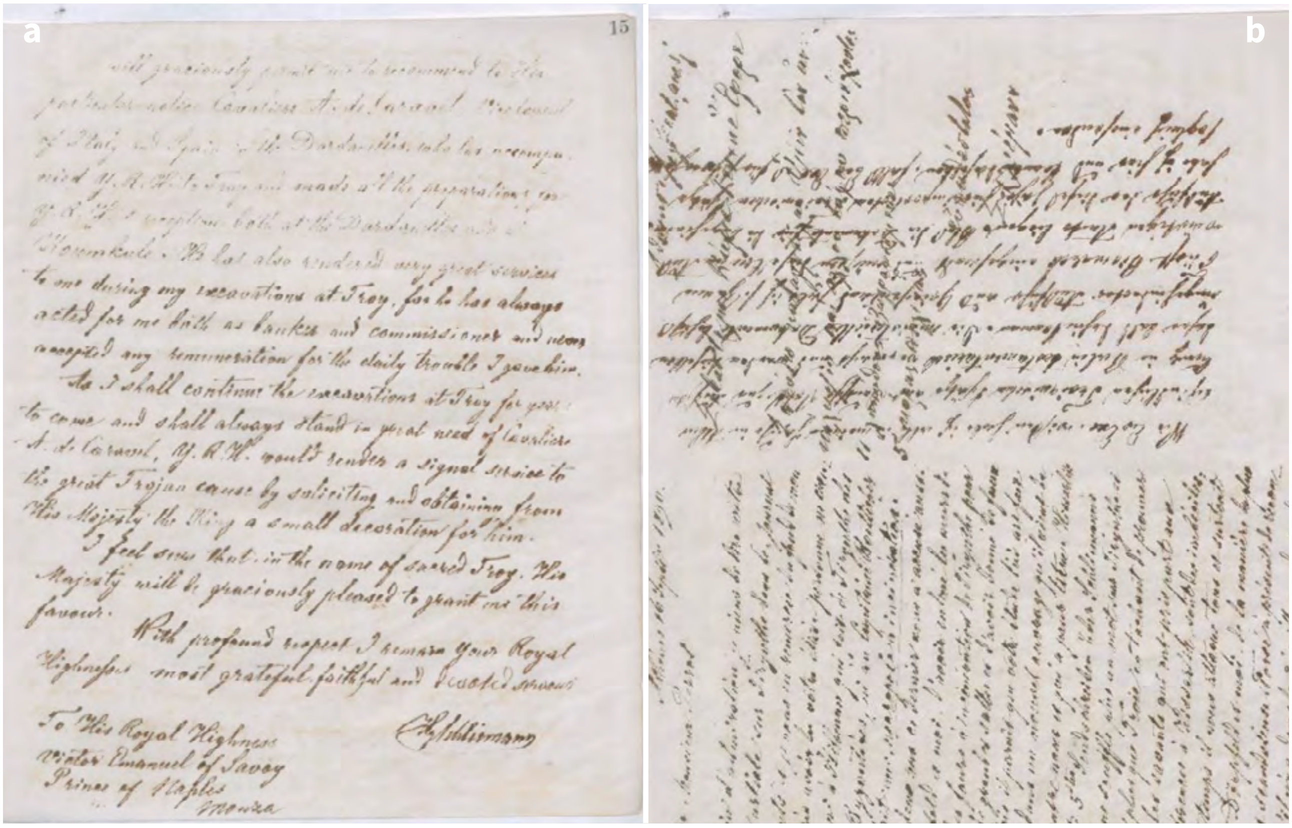


Fig. 3: *Schliemann's archive, the Gennadius Library. Volume BBB43, visible photography, total page. (a) Page 15, an example of combination of different copy qualities on a single page. (b) Page 6, an example of two copies on the same leaf, one crossing the other.*

According to Reissland and Hofenk de Graaf (2000)[25], the thickness of the writing of letters, the distinctiveness and readability of copies depends on: a) the methodology of copy (humid or dry method or other), b) the quality of the writing ink of the original, c) the materials of copy (ink and paper), d) the application of the method, and e) their preservation state. More specifically, in cases that have been copied with the basic methodology of copy (that is to say, with use of iron gall ink and application of humidity and pressure), the method of application is responsible for the result. Based on experimentation on mock-ups[26], pale and hard-to-distinguish copies can result from the application of limited humidity or insufficient pressure. This results in the ink not being properly activated and affects its ineffectiveness in imprinting in the copy paper. Hard-to-read copies arise when excessive or uneven humidity is applied, causing the intense diffusion of the ink, which degrades the shape of letters and unifies letters and words[27]. All of the aforementioned phenomena were observed on Schliemann's copies. Even though Schlie-

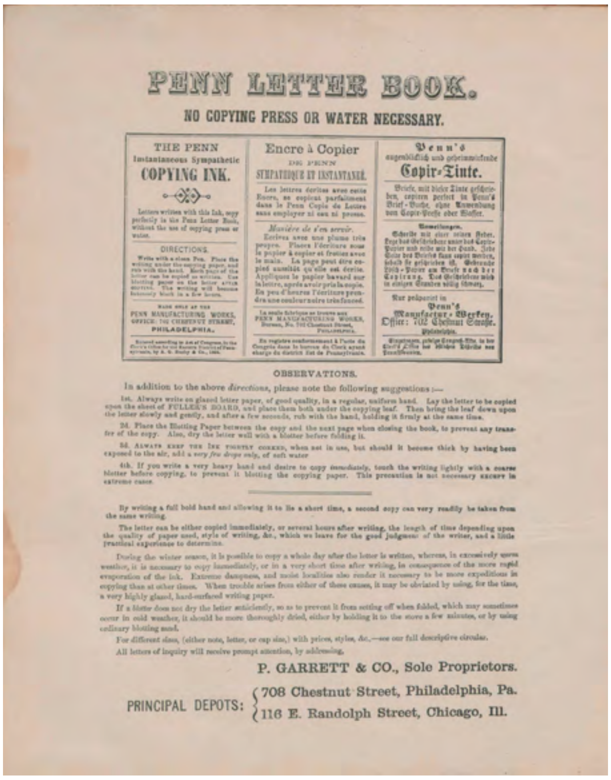
25 Reissland/Hofenk de Graaf (2000), pp.1-4.

26 Kaminari (2014), pp.123-126
27 Kaminari (2014), pp.123-126

mann was a systematic copier[28], the quality of some of his copies can be described as poor, perhaps not because of the materials he used, but rather because of inconsistencies or repeatability in dampening and pressure he applied. However, it must be noted that some of Schliemann's copies are so well produced that they could be mistaken for written documents. Others have formed multiple halos around the letters (Fig.4).

***Fig. 4:** Schliemann's archive, the Gennadius Library. Volume BBB27, page 415, visible photography (VIS), close-up. Each character is surrounded by a diffusion halo and a boundary halo around the diffusion one.*

From 1868 Schliemann started using the Penn Letter Book type of copy books, which is an alternative method of copy, without the use of humidity according to instructions found on the front endleafs. The resulting copies exhibit an adequate quality, the ink presents minimal diffusion, the writing is medium thick and the text is relatively distinct, which allows the presumption that the instructions regarding the method of use have been followed (Fig.5). Discolouration is observed only in copied areas.



PENN LETTER BOOK.

NO COPYING PRESS OR WATER NECESSARY.

THE PENN Instantaneous Sympathetic COPYING INK.

Letters written with this Ink, copy perfectly in the Penn Letter Book, without the use of copying press or water.

DIRECTIONS.

PHILADELPHIA.

Encre à Copier DE PENN SYMPATHIQUE ET INSTANTANÉE.

Les lettres écrites avec cette Encre, se copient parfaitement dans le Penn Copie de Lettre sans employer ni eau ni presse.

Manière de s'en servir.

Ecrivez avec une plume très propre. Placez l'écriture sous le papier à copier et frottez avec la main. La page peut être copiée aussitôt qu'elle est écrite. Appliquez le papier buvard sur la lettre, après avoir pris la copie. En peu d'heures l'écriture prendra une couleur noire très foncée.

Penn's Copir-Tinte.

OBSERVATIONS.

In addition to the above *directions*, please note the following suggestions :—

1st. Always write on glazed letter paper, of good quality, in a regular, uniform hand. Lay the letter to be copied upon the sheet of FULLER'S BOARD, and place them both under the copying leaf. Then bring the leaf down upon the letter slowly and gently, and after a few seconds, rub with the hand, holding it firmly at the same time.

2d. Place the Blotting Paper between the copy and the next page when closing the book, to prevent any transfer of the copy. Also, dry the letter well with a blotter before folding it.

3d. ALWAYS KEEP THE INK TIGHTLY CORKED, when not in use, but should it become thick by having been exposed to the air, add a *very few drops only*, of soft water

4th. If you write a very heavy hand and desire to copy *immediately*, touch the writing lightly with a coarse blotter before copying, to prevent it blotting the copying paper. This precaution is not necessary except in extreme cases.

By writing a full bold hand and allowing it to lie a short time, a second copy can very readily be taken from the same writing.

The letter can be either copied immediately, or several hours after writing, the length of time depending upon the quality of paper used, style of writing, &c., which we leave for the good judgment of the writer, and a little practical experience to determine.

P. GARRETT & CO., Sole Proprietors.

PRINCIPAL DEPOTS: 708 Chestnut Street, Philadelphia, Pa.
116 E. Randolph Street, Chicago, Ill.

***Fig. 5:** Schliemann's archive, the Gennadius Library. Volume BBB43, visible photography (VIS), total page. The instructions page.*

Visual examination of the covers of the copy books confirmed that they are in a good state, with only a few cases presenting damages at the spine and the covers (Fig.6). Huge volumes (Fig.7) may exhibit loss of their covers and/or spine. Tears along the joint of the cover and the spine have been observed, as well as

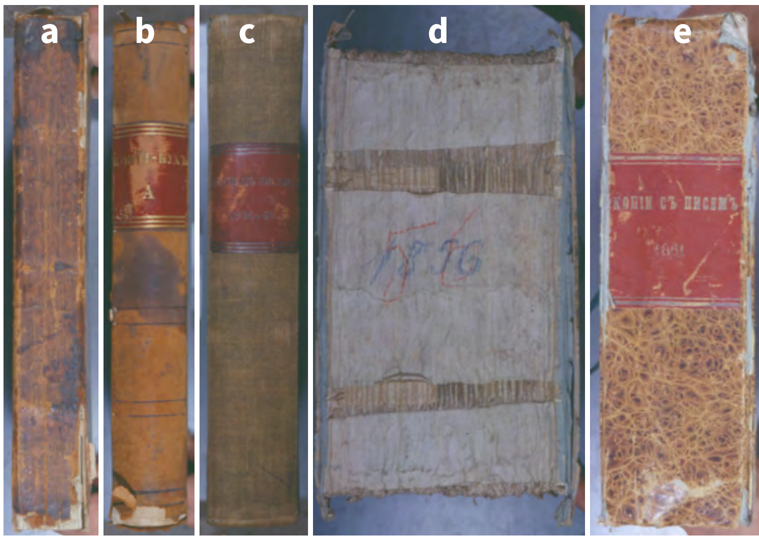


***Fig. 6:** Schliemann's archive, the Gennadius Library. Covers spines: (a) BBB12, (b) BBB13, (c) BBB15, (d) BBB16 and (e) BBB20.*

The Condition of the Covers

All sides of the copybooks were photographed in the visible together with the written documentation of their condition, but imaging techniques in the ultraviolet and infrared region were not applied to them as the study focused on the paper substrate and the inks.

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28 Voltera oral communication; Kennell (2002) detachment of one or both covers. The cover material i.e., leather, paper or textile, is usually damaged at edges and in few cases, it is torn. The majority of the covers of the Penn Letter Books are in a very good condition (Fig.8).

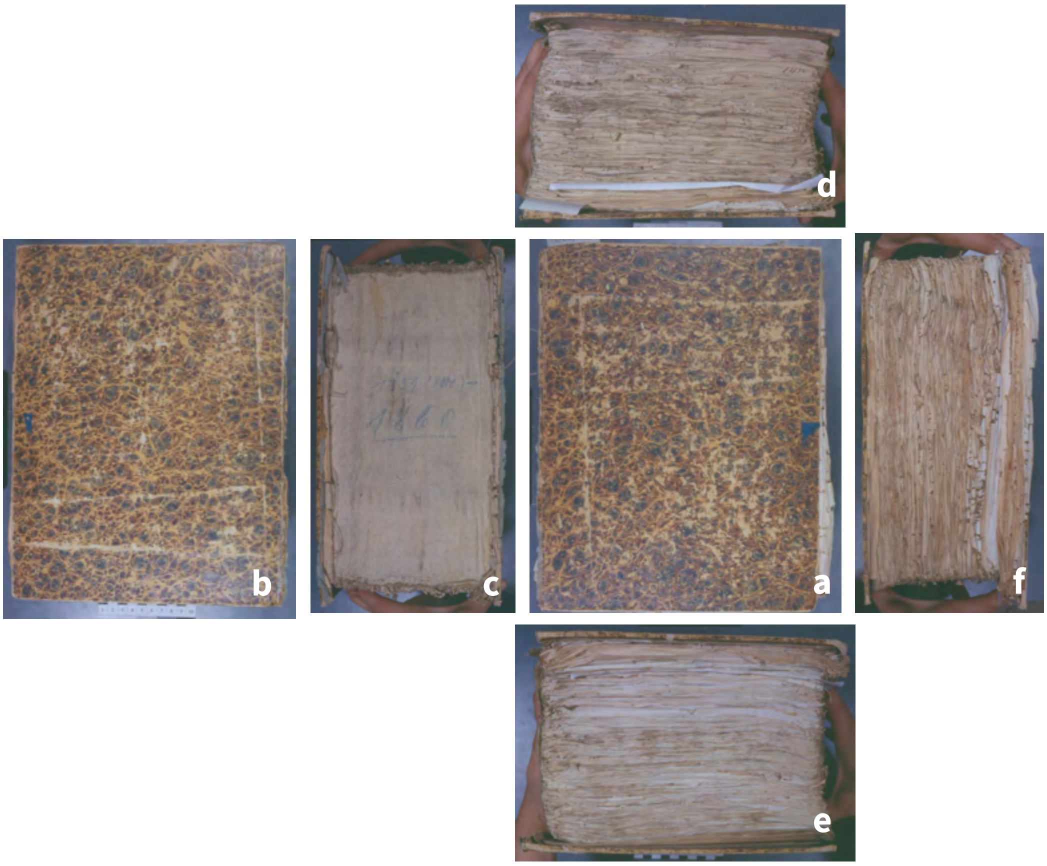

Fig. 7: *Schliemann's archive, the Gennadius Library. Volume BBB19. (a).front cover, (b) back cover, (c) spine, (d) head edge, (e) tail edge, (f) front edge. One of the thickest textblocks encountered in the copybook archive, reaching up to 15.5cm.*

Fig. 8: *Schliemann's archive, the Gennadius Library. Volume BBB43. (a) front cover, (b) back cover, (c) spine, (d) head edge, (e) tail edge, (f) front edge. One of the Penn Letter Books Schliemann used.*

The Condition of the Textblock

The textblock presents limited creases, water stains, paper losses of small extent, and rarely holes and tears. In few cases it was detached from the binding leading to loss of one or both covers and the cover spine and to loose fragments. Mechanical damage through use was evident. Damages through rodents was also observed e.g., BBB5. In the cases of water stains, tidelines were observed on consecutive pages (Fig.9) but the origin of the moist cannot be attributed to incorrect application of the copy method, as the characters of the texts present excellent shape. All in all, given the fact that these books have undergone the pressure applied for obtaining copies, together with the everyday handling, the majority of textblocks presents condition better than expected.

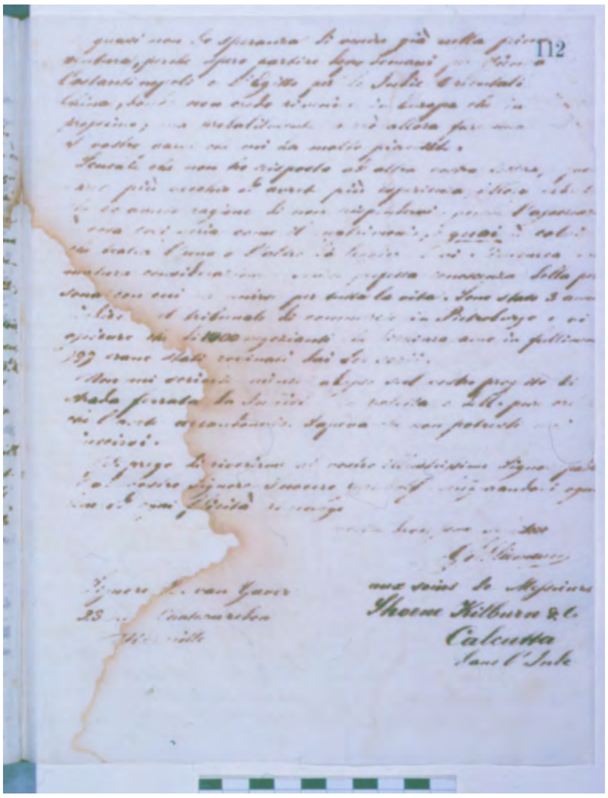

Fig. 9: *Schliemann's archive, the Gennadius Library. Volume BBB25, page 112, recto, visible image (VIS). One of the tidelines observed in the copybooks. It is irrelevant from the copying process, as the same marks were observed in previous and following pages. It is important to notice that even though the textblock was wetted after the copying procedure, the text has remained relatively intact.*

The Condition of the Paper Substrate

This part refers to the deteriorations of the paper substrate that are caused by the copy ink, a fact that constitutes the most corrosive factor of deterioration. The corrosion[29] that iron gall inks cause to the paper is the result of hydrolysis, which is caused by excess sulphuric acid. Sulphuric acid is produced as a by-product during ink manufacture, and of oxidation catalyzed by the presence of the divalent iron Fe(II) ions. The acidic hydrolysis results in the depolymerisation of cellulose, and as a consequence, the progressive decrease of the mechanic durability of the paper. The oxidation of cellulose creates cross-linking, as well as chromophores and acidic groups, which consequently result in the decrease of the ability to absorb water, fluorescence, and the change of colour of paper.

During the ageing of iron gall ink, sulphuric acid diffuses into the surrounding paper, while iron ions remain in the direct perimeter of ink regions. Thus, acidic hydrolysis is mainly responsible for the degradation of the paper that surrounds the ink, while the oxidation that is catalysed by the iron ions takes place in the inked regions[30] and in their direct perimeter. The deteriorations that the copy letter books present are similar to those caused by iron gall inks; hence they present the corresponding stages of corrosion. Lacing, discolouration, embrittlement and fragility were observed, resulting in breaking of the

29 Stroud (1985); Cleveland (2000)
30 Reissland/Hofenk de Graaf (2000), pp.1-4.

paper support and losses. In the copy books, the brown discolouration around the letters could be because of the diffusion of the ink due to bad application or due to the degradation of cellulose.

Offsetting of the previous page in the book has been observed in several cases. One must bear in mind that the ink that comes in contact with the copy paper belongs to the verso side of the page on the left. Offset was detected as shadowy letters between the lines of the text. In volume BBB2, UVR imaging (Fig.10b) enabled the detection of offset even though the phenomenon is barely noticeable compared to the visible image (Fig.10.a). In this case UVL did not show any results. However, there were multiple cases where during the UVL colour imaging, offset was detected as luminescent characters, which appeared brighter than the paper substrate and copied letters. It must be noticed that in the corresponding visible image, no trace of offset was observed. This means that, in accordance with Reissland/de Graaf (2000), if the offset ink is classified in the first stages of ink corrosion, it can be detected through ultraviolet induced visible luminescence, even if it still is not visible to the naked eye.

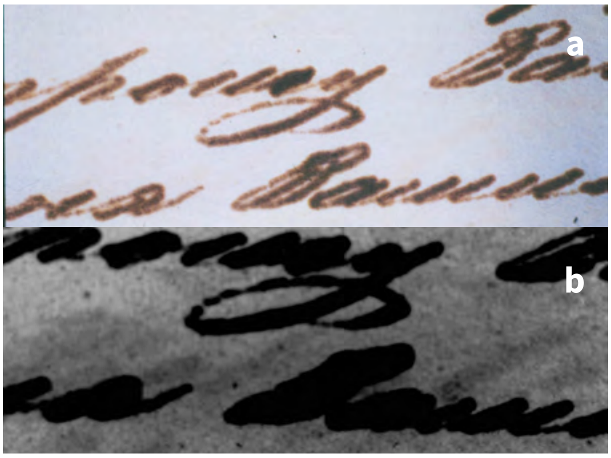

Fig. 10: *Schliemann's archive, the Gennadius Library. Volume BBB2, page 17, recto, close-up. (a) Visible colour photography, no offset can be detected. (b) Ultraviolet reflectance photography, offset can be observed.*

Ink differentiation

Inks cannot be safely categorised unless full chemical analysis is carried out, so the term differentiation is used instead. Imaging techniques cannot connect an ink to a specific category; rather the comparison of images of a large number of inks can help separate them into smaller groups, based on their behaviour and response in the ultraviolet, visible and infrared. Even though the inks contained in Schliemann's copy books were thought to be iron gall and/or copying inks, so major categories such as carbon ink, sepia, bistre etc were excluded, similarities and differences could be observed thus enabling their grouping. Penn Letter Books exhibited use of the same ink, as all techniques produced images of identical properties, hinting that Schliemann did not deviate from materials of the given instructions.

Close-up photography

The use of close-up photography proved to be invaluable for the study of the copies. This mode was applied in all photographing and imaging techniques, thus providing macro information of all regions of the spectrum in both reflectance and luminescence phenomena. The most important features that can be recorded are the ink patterns at the verso side that are indicative of copying inks (Fig.11.a), magnification of characters so that halos around them were distinguishable (Fig.11.b), as well as cases of micro fluorescence around characters that was not detectable by photographing the entire or even a detail of the page.

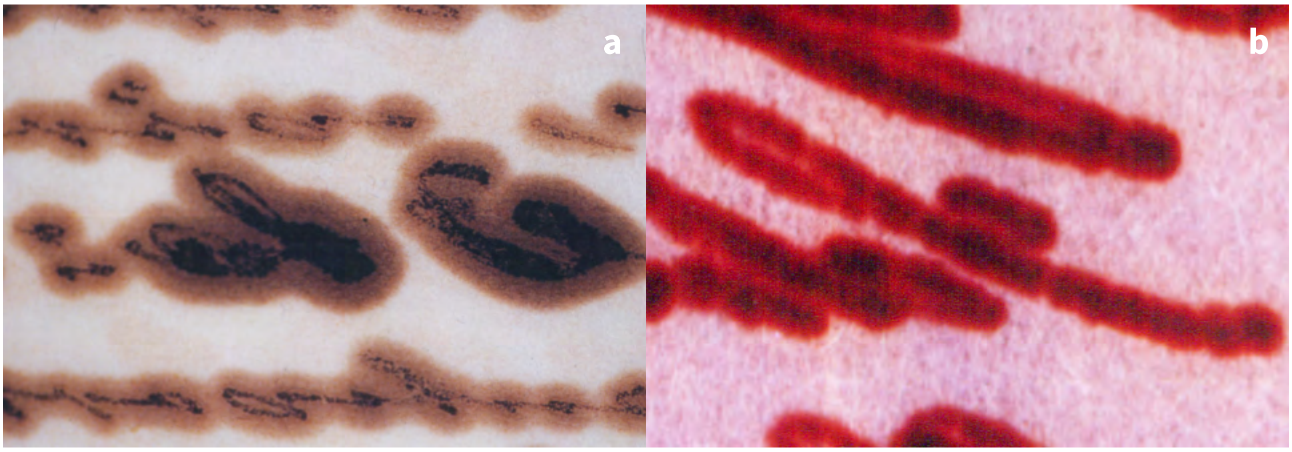

Fig. 11: *Schliemann's archive, the Gennadius Library. (a) Volume BBB9, page 5, verso side, visible colour photography, close-up. The dotted pattern of the ink is indicative of the copying procedure. (b) Volume BBB10, page 182, verso, ultraviolet induced visible luminescence photography (UVL), close-up. The halo around the characters is strongly fluorescing in bright reddish colour.*

Ultraviolet techniques

In accordance with the previous studies on mock-ups[31], both UVR and UVL imaging produced interesting facts about the inks. The most important is that the comparison of visible, UVR and UVL images can help differentiate whether a halo observed around letters is due to diffusion or oxidation phenomena. A general observation concerning all Ultraviolet Reflectance images is that they are very dark grey and the inks are all black (Fig.12.b and 13.b). UVR images of inks, due to their high contrast, enable the definition of the boundary of the ink, rather than that of the letter. This means that if a letter has diffused, presenting a diffusion halo around it, the UVR image will show the character and the diffusion together as a black image. In the visible the character is clearly differentiated from the diffusion (Fig.12.a). On the contrary, oxidation halo retains a pale grey tone, clearly differentiating it from the core of the characters, similar to the image in the visible(Fig.13.a and 13.b).

In Ultraviolet Luminescence black and white photography, copy inks exhibit different tones of grey, from pale to dark grey (Fig.12.c and 13.c). The main advantage of this technique is that the diffusion halos can be differentiated from the main body of the letters, as they appear in a lighter tone of grey than the character (Fig.12.c). The oxidation halo is barely visible with this method. (Fig.13.c)

Fig. 12: *Schliemann's archive, the Gennadius Library. Volume BBB25, page 112, recto, close-up photography. (a) Visible photography, (b) Ultraviolet reflectance photography (UVR), (c) Ultraviolet induced visible luminescence photography (UVL). The letters are surrounded by a diffusion halo.*

31 Kaminari (2014), pp.129-132; Kaminari et al (2021)

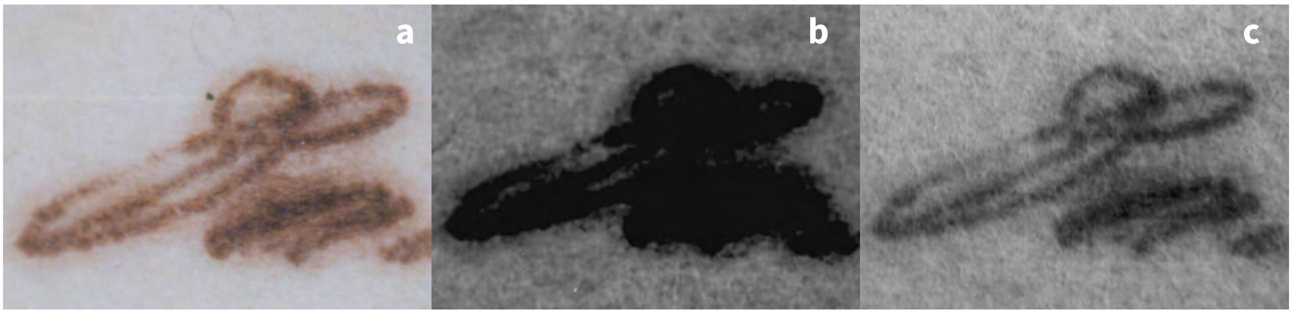

Fig. 13: *Schliemann's archive, the Gennadius Library. Volume BBB3, page 343, recto, close-up photography. (a) Visible photography, (b) Ultraviolet reflectance photography (UVR), (c) Ultraviolet induced visible luminescence photography (UVL). The letters are surrounded by an oxidation halo.*

Ultraviolet Luminescence colour photography can be very useful in another way, as it can help in differentiating inks from one another (Fig.14). Differentiation is possible because, when stimulated by ultraviolet light, the core of the letter fluoresces with a different colour, especially in cases where additives exist within the inks. The diffusion of a letter can be distinguished from the core of the letter as it usually exhibits either a different colour from the core or a lighter version of the same colour of the core. Furthermore, luminescence can reveal whether the iron gall ink corrosion has begun and/or is on its early stages[32] and in Schliemann's archive this was detected in some cases of offset (Fig.15.b). Another important information recorded with this method was the fluorescence on the outer side of the tideline. It is well known[33] that the wet and dry interface of the tideline promotes cellulose degradation and hence exhibits fluorescence. In the case of the copies, through accidental wetting of the paper, some of the constituents of the ink might be drifted by water and end up piling at the tideline (Fig.15.a), enhancing the fluorescence phenomenon during the first stages of ink corrosion (Fig.15.b)

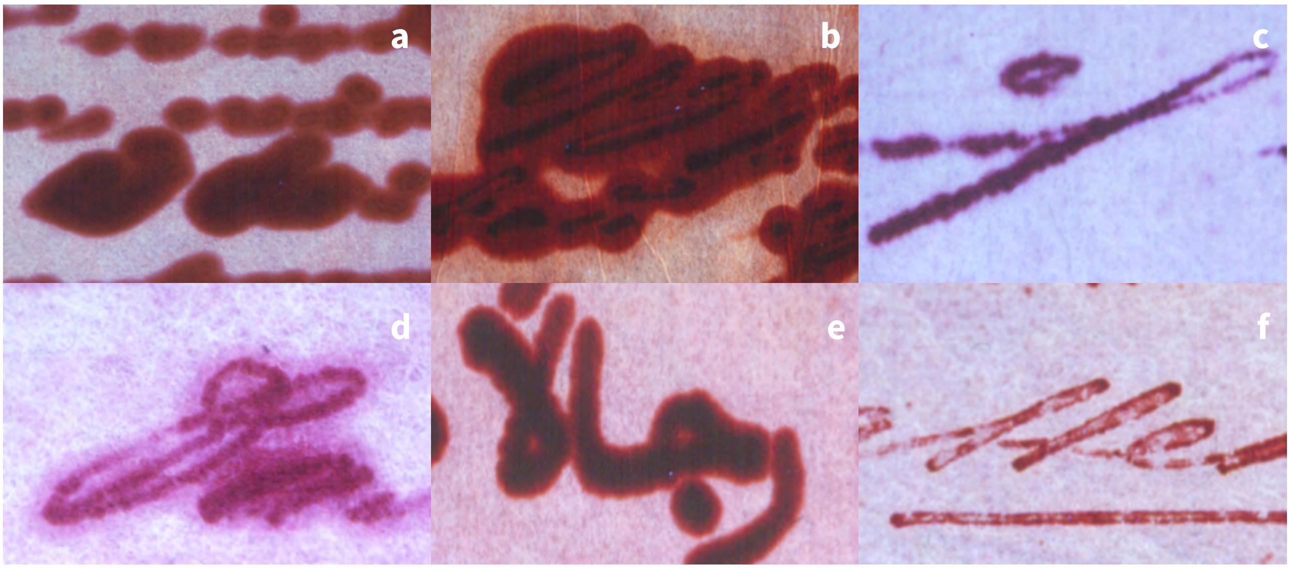

Fig. 14: *Schliemann's archive, the Gennadius Library. Ultraviolet induced visible luminescence photography (UVL), close-up, recto sides. (a) Volume BBB9, page 5, (b) Volume BBB10, page 19, (c) Volume BBB3, page 162a, (d) Volume BBB3, page 343, (e) Volume BBB24, page 20, (f) Volume BBB11, page 2. The different hues in the luminescence of the inks and the paper substrate can differentiate them from one another.*

32 Reissland/Hofenk de Graaf (2000), pp.1-4.
33 Pedersoli/Ligterink (2001); Jeong et al (2014)

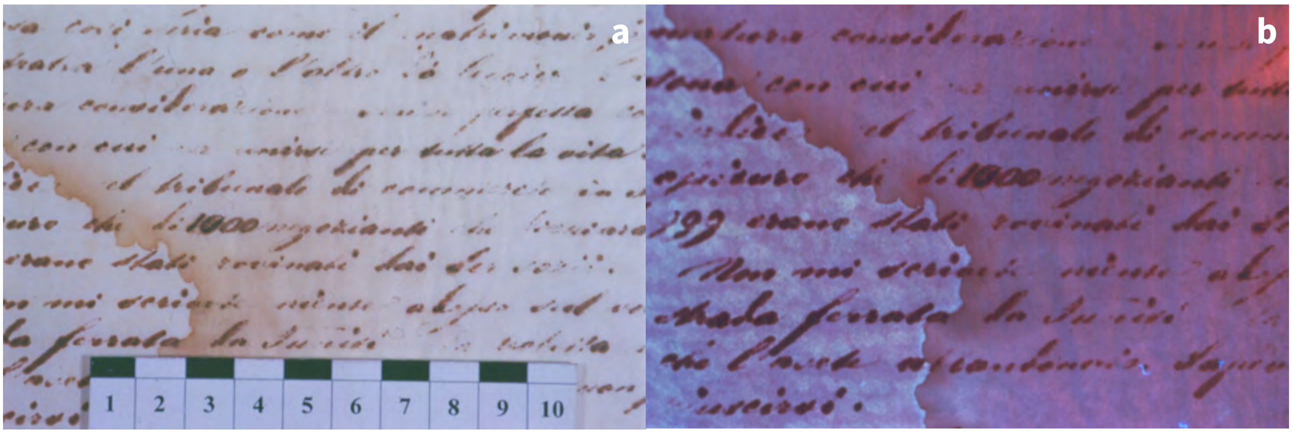

***Fig. 15:** Schliemann's archive, the Gennadius Library. Volume BBB25, page 112, detail, recto. (a) visible image (VIS) and (b) ultraviolet induced visible luminescence colour image (UVL). Not only the outer boundaries of the tideline are fluorescing, luminescence can also be observed from offset phenomena between the lines.*

Infrared Techniques

The behaviour of the copy inks in the infrared differs little. The inks' black and white images vary from almost transparent, light grey to medium grey tones. A fascinating aspect of infrared reflectography images (IRR) is that they can show clearly the circumference of the core of the letter (Fig.16). Diffusion halos can generally be visible, but only as a blur, without concrete boundaries. It must be noted that the area of paper with water stains appears darker than the rest of the area.

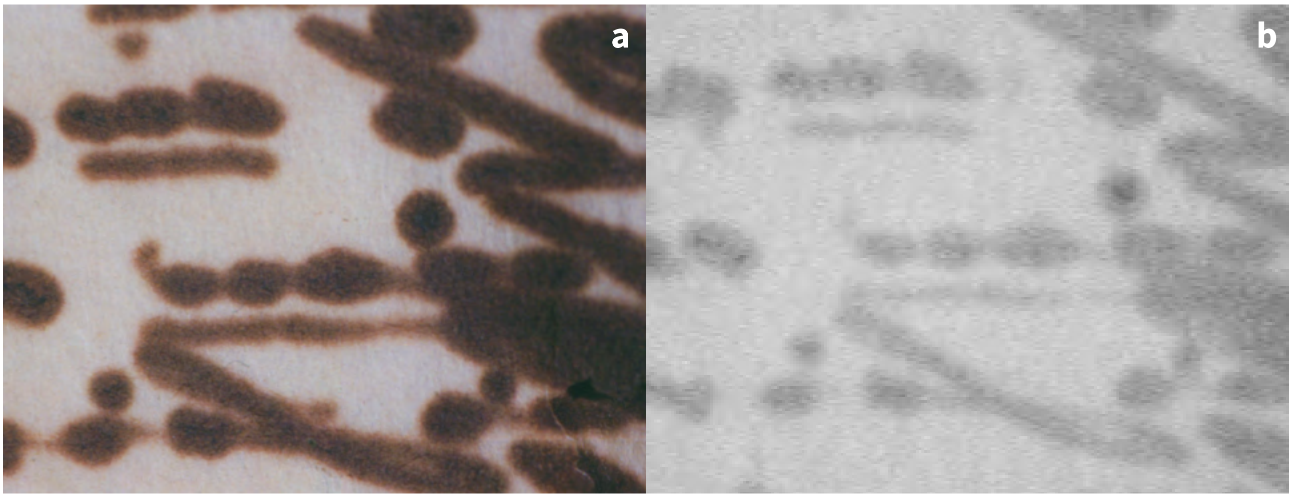

***Fig. 16:** Schliemann's archive, the Gennadius Library. Volume BBB3, page 141b, close-up, verso. (a) visible image (VIS) and (b) infrared reflectography image (IRR). The core of the letter, free from any halos, can be detected.*

As false colour infrared combines wavelengths from both the visible and the infrared, the information obtained with this method refers to both visible and IR regions. In some cases of illegible letters due to diffusion, the core of the letter can be distinguished more easily. The false colour of iron gall inks varies slightly between reddish or brown-red, thus different recipes of iron gall inks cannot be discriminated using solely this method without chemical analysis.

Conclusions

By using non-destructive imaging techniques, this research recorded the condition of Heinrich Schliemann's copy-books archive. Based on the study, it is evident that Schliemann did not produce similar quality copies due to irregular damp and/or pressure applied during the copy procedure.

The application of the non-destructive techniques helped in the closer examination of the inks used and can be of assistance in recording and distinguishing single characters thus rendering the words of texts more legible, as well as to better understand the phenomenon, oxidation or diffusion, responsible for the halos.

The application of the imaging methods is limited to objects that can be handled without risk of damaging them, excluding the thick volumes encountered in the Schliemann copy book archive.

The deteriorations are more intense in the cases where a larger quantity of ink was used, such as when the writing appears intense and thick, but also when excess humidity was applied. The external factors of deterioration, and mainly humidity, constitute decisive parameters for the state of preservation of the papers and books and the extent of deterioration of inked regions. Finally, the current state of preservation of the text and the books is generally shaped by the extent of deteriorations that occurred with the passing of time as well as the conditions of storage.

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Evaluating the state of conservation of copy letters on transparent support and their corresponding conservation treatments

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ABSTRACT

This study investigates the changes observed in manuscript inks in copy letters written on semi-transparent paper supports. In this paper, we explore the causes of degradation: the recipes of the inks, historic copying techniques and their current preservation condition. Their state of preservation was documented using non-invasive methods, such as multispectral imaging, macroscopically and microscopically, in different wavelengths of the electromagnetic spectrum. In many cases, the preservation state of the transparent paper was deterioration caused by copying inks, rendering the texts illegible. The visible changes to the texts were usually due either to the inks extending beyond their writing limits or to their incomplete copying onto the paper support. Historical documents of the 19th century are a significant source of information about the materials used to create documents and books of the period, such as copy letters and copy books. Using macroscopic and microscopic multispectral imaging, three types of alterations were identified that were related to ink composition and copying technique. Based on their state of preservation and multispectral imaging, computational techniques such as morphological analysis and image processing were applied to the selected images to read the illegible texts. Conservation treatments were also applied where the copy inks eroded the paper support and caused extensive damage to it. They can strengthen worn semi-transparent paper and reduce the brittleness of paper supports. The proposed methodology yielded particularly satisfactory results in determining which inks and semi-transparent papers were used, of the deterioration factors of the texts and of the legibility of the correspondence in the copy book “Outgoing Letters of the National Bank of Greece 1853-1858”

Introduction

Copying inks were used from the late 18th century (Titus, Sonja, 2006). These are usually speciality inks used for copying correspondence texts and which in most cases are iron gall inks. Copy texts were often used as protocol so that public or private institutions knew their outgoing correspondence. Initially the texts were copied on individual sheets which were then bound together as the copy books. At the end of copy books an alphabetical index was included, in which the details of the recipient were noted. Most of these books contain between 500-1000 sheets. These types of books can be found from the 19th century to the early 20th century. The copy books were written in black ink on transparent paper.

In many historical sources of the 19th century recipes of inks and papers can be found that describe the copying, the inks and the paper used. Various references record the ingredients of inks, paper and their manufacture (Lehner, 1892; Ainsworth & Helpworth, 1904; De Champour & Malepeyre, 1855; De Champour & Malepeyre, 1875 (Update version)). The inks referred to in these historical sources were used for different purposes, such as for handwriting or for printing on paper or other supports, as well as for copy books.

Copy books usually display deterioration often found in writing inks. These inks have been determined to be iron gall inks (Beth, 2011; Titus et al. 2006) and their oxidation and the extensive damage to the paper supports are caused by the inks' composition. Today, copy letters and copy books are a field of study both for the texts they contain and for the burdensome preservation condition they present. Their state of preservation creates multiple problems in reading the texts, with many of them being illegible due to the diffusion of the inks and their oxidation. But in some cases, the diffusion of the inks may have come from the careless copying of text, creating expansion of the letters or discontinuities in the copied texts. For these reasons, scientists interested in copy letters have carried out research and studies on the materials and manufacturing techniques, as well as the preservation problems they present. However, these studies are isolated and fragmentary. Beth et al. (2011) investigated the nature of manufacturing materials used in copy letters written by Spencer Fullerton Baird, in the Baird Collection of Smithsonian Institute using analytical methods. They also studied what preservation interventions could be carried out on these copy books, as well as what practices could be applied when digitising them. In 2009 Beth studied two copy books belonging to the collection of the Center for American History, at the University of Texas at Austin. In this study a questionnaire was created and submitted to professionals who manage and maintain copy books. Thus, a survey of the University of Texas Center for American History's copy books was conducted, exploring preservation interventions that could be applied to them. Titus et al. (2006) investigated the process and materials used in the manufacture of copy books, giving important information about their manufacture, while also creating a method that stabilises the iron gall inks. Ubbink & Partridge (2003) suggested a conservation treatment to stabilise copy inks that should be followed by appropriate storage.

In addition, there are some sparse studies on the copying process and the materials used in copy books and copy letters.

Reissland et al. (2017) studied 90 historical ink bottles that contained some amount of ink. Among other inks, they reported that iron gall inks, wood-wood inks and aniline were used as copying inks, adding materials such as sugar or glycerine, etc., so that these inks could be used in copying texts. Muhlen (2016) presented an overview of the process of making transparent papers, describing their characteristics, as well as materials used to achieve the transparency of these papers. Nadeau (2002) in the book Encyclopedia of Printing, Photographic and Photomechanical Processes described the copying process used between the period 1850-1950.

Copy letters and copy books were often used in the outgoing correspondence of banks. As such, they contain information about their operations and transactions and important information about the history of both the banks and the countries in which they operate. The National Bank of Greece, as one of the oldest banks in Greece, used copy letters and copy books in its outgoing correspondence and thus today over two thousand and thirty-five copies of books belong to the Bank's historical archive. Of these 1,721 are on transparent copy paper (dating from 1841-1941) and 314 on opaque paper. The oldest is the book we will study and consists of 1,016 pages. Two texts have been copied on each page. Similar to most copy books, the copy texts have been written in black ink on transparent paper. Extensive alteration of the texts and several paper losses caused by oxidised inks can be seen. Figure 1 shows the percentages of texts showing no damage and texts showing various deteriorations. Deteriorations can be divided into four categories: ink diffusion beyond the writing limits, visible inks from the back text, paper losses caused by ink oxidation, and copy defects.

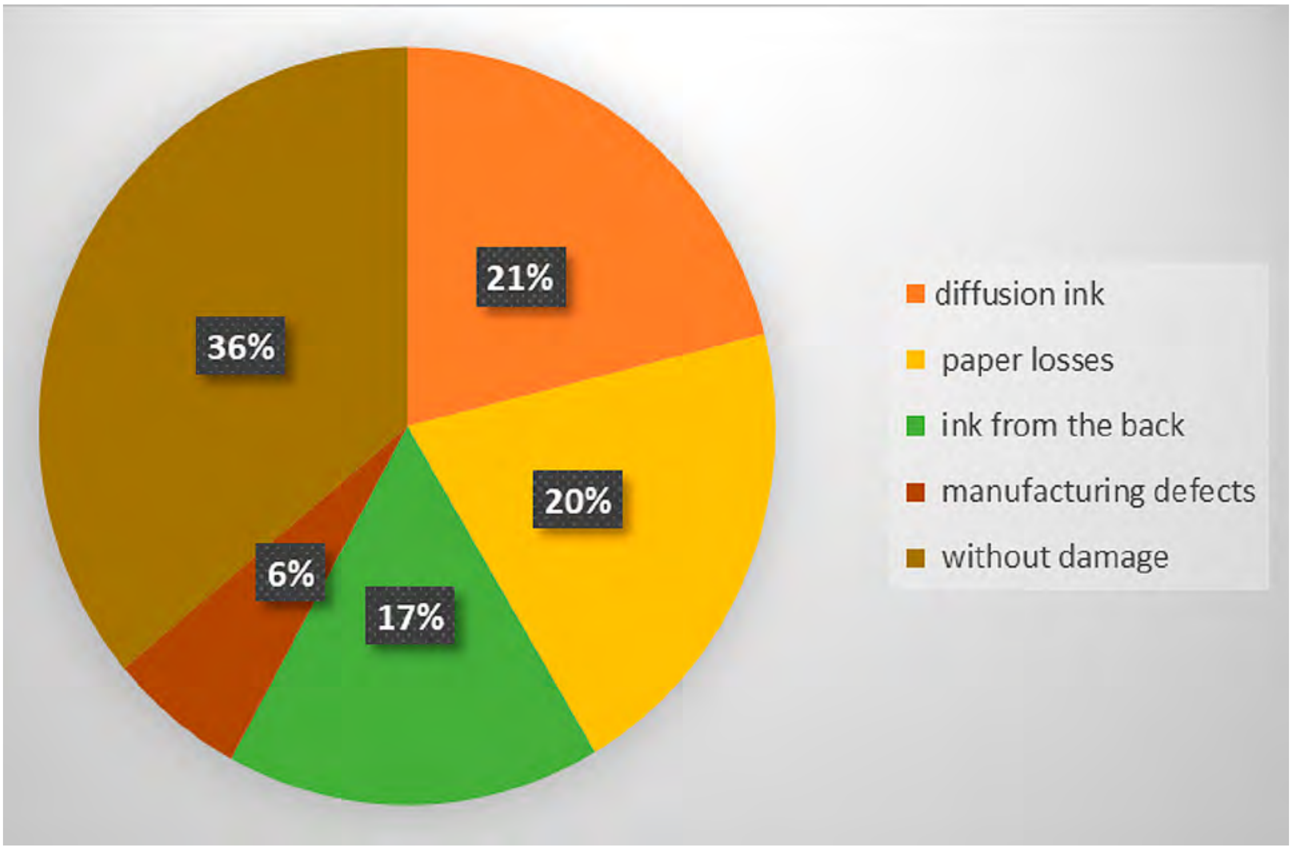


Fig. 1: *The percentage of the most important deteriorations that are presented in the pages of the copy book studied.*

The copy book "Outgoing Letters of the National Bank of Greece 1853-1858" is the oldest copy book of the National Bank and displays some of these conservation challenges. The copy book contains copy letters over a five-year period in the 19th century. During the 19th century, and especially after the middle of the century, there were many changes in both the manufacture of transparent papers (Mühlen, 2016; Valente, 2010) and the manufacture of copy inks (Wild, 2014; Bicchiere et al., 1993). Thus, the applied methodology was chosen with the following objectives:

- To determine the condition of the copy inks and their paper supports.
- The identification of the materials used to copy texts.
- Depending on the inks' condition, interventions should be decided on to allow the illegible texts to be read.
- To select conservation treatments for the paper supports damaged by the inks' oxidation to preserve them for the future.

Methodology

The following methodology was implemented:

- Collection of information on the paper and ink used in the copy book "Outgoing Letters of the National Bank of Greece 1853-1858", from the archive of the bank and from the copy book itself that was studied.
- The application of multispectral imaging that allowed the determination of the condition of the copy book and the inks and papers used in it.
- The use of SEM/EDS analysis which can provide information on the paper fibers and chemical components of the paper and ink compositions.
- The reading of illegible texts.
- Conservation of the copy book.

Collection of historical information on inks and paper used in copy books

The information collected about the making of the copy books was carried out through information retrieved from:

- The original copy books and documents of the historical archive of the National Bank.
- Secondary literature of the period of the copy book to be studied.
- Primary source material on copy letters and copy books.

Information on the materials used to make the copy letters and copy books was retrieved from the following primary source material:

- Lehner Sigmund, The Manufacture of ink, Henry Carey Baird & CO, translated from German by Brannt T. William Philadelphia, 1892
- Ainsworth Mitchell and T.C. Helpworth, Inks. Their composition and manufacture, Charles Griffin & Company, LTD., London, 1904
- MM. De Champour, F. Malepeyre, Nouveau manuel complet de la Fabrication des encres, MANUELS-RORET, Paris, 1855, 1856
- MM. De Champour, F. Malepeyre, Nouveau manuel complet de la Fabrication des encres de toute sorte, MANUELS-RORET, Paris, 1875 (Revised edition)

Multispectral imaging

Copy inks are mainly iron gall inks and present two main problems. One is their preservation condition and the other their legibility. The basic components of copy inks deteriorate over time due to the oxidation of their ingredients. Thus, an extension of the ink trace is observed beyond the extent of the writing, with the result that the texts are illegible. As well as deterioration of the writing inks due to their oxidation, another issue affecting legibility arises from the process of copying the texts from the original source to the copy book. Often, either the copy inks were unsuitable[1] for the purpose or the process followed to create the copy text was not done properly, resulting in the letters of the texts not being copied in their entirety or line gaps in the copy letters.

For these reasons, many texts are illegible either in part or in whole. Such cases are also present in the copy book "Outgoing Letters of the National Bank of Greece 1853-1858". Images of the text in the copy books were taken in different electromagnetic spectrum bands to document their state of preservation and investigate the potential legibility of illegible texts.

Macroscopic imaging

Two DSLR cameras were used for image capturing, the Nikon D 5200[2] in the visible and the Fujifilm XT-10 Mirrorless Full Spectrum[3] (Figure 2) in the infrared and ultraviolet bands of the electromagnetic spectrum.

In addition to the cameras, there were two lights, a color scale, a gray scale, and different optical filters on the camera lens, as described below, each capturing the different bands of the spectrum:

1. Images in the visible band: The optical filter of 486[4] B&W was placed to the front of camera lens and the couple of lamps[5].
2. Images in the ultraviolet band: The lighting derived from a couple of UV black lights[6], while in front of the camera lens the optical filter of 403[7] B&W was used.
3. Images in the infrared band: The couple of lights emitted in the visible and the infrared, as above, and in front of the camera lens the optical filter 093[8] B&W was placed.
4. Images in the visible-infrared band: The lights emitted in the visible and the infrared as above, and in front of the

1 Inks made for writing, not copying. Therefore, in their composition they did not have the necessary ingredients for copying. The addition of ingredients that could help copy the letters also lacked cohesion with the inks composition.

2 Nikon D 5200 24-megapixel camera with Spectral sensitivity of Nikon DSLR approximately 400-780 nm and Nikon Nikkor Af-S 18-55 mm zoom lens, https://www.dpreview.com/forums/post/61721967.

3 Fujifilm XT-1016-megapixel full-spectrum camera with Nikon Nikkon 50 f/1.8 lens. The sensor in the Fuji camerais sensitive approximately between 360 nm and 1100 nm (G. Meynants, A. Bart Dierickx, D. Uwaerts Alaerts, S. Cos, S. Noble, A 35mm 13.89 Million Pixel CMOSActive Pixel Image Sensor. IS&T's PICS Conference: Image: Processing. Quality, Capture, Systems Conference 2003, pp 58–61).

4 This filter allows imaging in the visible and blocks ultraviolet and infrared radiation (Handbook, B+W FILTERS, Optical Perfection World-Wide, p.21).

5 Philips lamps MASTER TL-D Super 80 15W, https://www.researchgate.net/deref/https%3A%2F%2Fwww.assets.lighting.philips.com%2Fis%2Fcontent%2FPhilipsLighting%2Ffp927922284014-pss-en_ae.

6 Philips blacklight TL 8W lamps, https://www.vedgroup.net/products/philips-tl-8w-blb-1fm-10x25cc-tl-mini-blacklight-blue.

7 This filter allows images to be captured in the ultraviolet, reflectance and fluorescence images (Handbook, B+W FILTERS, Optical Perfection World-Wide, p.21).

8 This filter allows images to be captured in the infrared, up to 800 nm (Handbook, B+W FILTERS, Optical Perfection World-Wide, p.19).

camera lens the optical filter 099[9] B&W was placed.

In combination, the images taken in different bands of the electromagnetic spectrum (visible, ultraviolet, infrared) yielded satisfactory results regarding the documentation of the conservation condition of the copy letters, recording various damages whose boundaries and extent are clearly distinguishable (Kaminari et al. 2021). Based on these images we get information about the surface and texture of papers and inks. For every visible text image, there are images in the ultraviolet, infrared, and visible-infrared bands. Finally, digital microscopic images are taken from selected bands of the electromagnetic spectrum, such as visible, ultraviolet, infrared.

Microscopic imaging

Microscopic multispectral imaging was used because certain features can be clearly distinguished that are not legible or distinct in macroscopic images, allowing for more accurate and precise results concerning the macroscopic images.

The microscopic images were obtained using two microscopes which take images in the visible, ultraviolet, infrared and bands where fluorescence occurs. Both of the microscopes which have magnification of X10 up to X200 are:

- The first[10] can capture images from the bands between 400-780 nm in the visible. Additionally, it combines 400 nm LED excitation lights and an emission filter that cuts at 430 nm.
- The second[11] can take images in the ultraviolet and infrared radiation range. The radiation bands are 395 nm in the ultraviolet band and 940 nm in the infrared band.

Using the above methodology, images were taken from various texts of the copy book "Outgoing Letters of the National Bank of Greece 1853-1858".

Figure 2 shows some typical examples of copy letters on page 68. In the visible band, the actual colours of the text ink and the paper support can be seen, as well as their preservation condition. In this band, the text inks found on both sides of the paper support are also evident, a result of which is that one text is often confused with the other. In addition, the text ink on the recto side shows an extensive spread, causing the ink of the letters to extend beyond their boundaries. In the ultraviolet band, the inks on both sides significantly absorb this radiation, creating further confusion between the two texts. This effect is made even more confusing by recording the entire extension of the ink appearing in this spectral band. In the visible-infrared band, the text inks of both sides are evident, but they are not evident in the same way. Because the ink of the verso is less evident than the ink of the recto side: they can be distinguished from each other. In the infrared band, ink absorbs this radiation moderately to minimally, while expansion of the letters beyond their writing boundaries is not particularly apparent, showing mostly the writing itself. Also, the ink on one side is not evident on the other side.

9 This filter allows images to be captured in the infrared, up to 520 nm (Handbook, B+W FILTERS, Optical Perfection World-Wide, p.19).
10 http://www.schut.com/PDFs

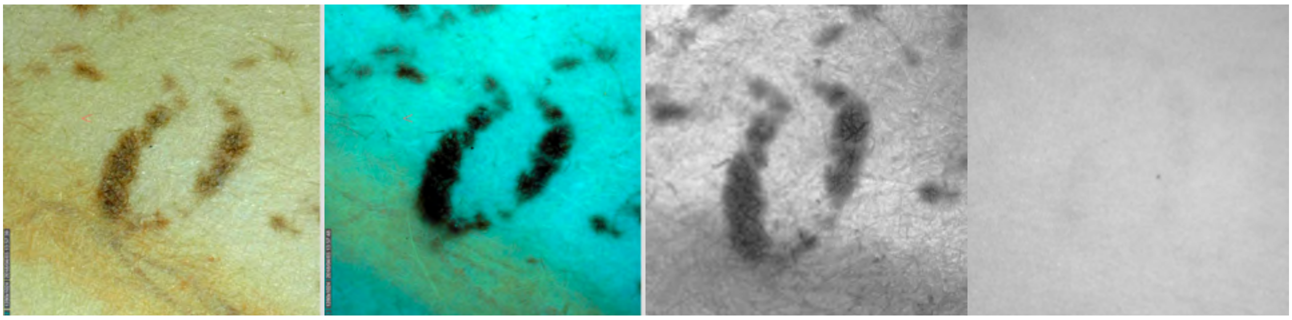
11 https://docs.rs-online.com/a1f4/0900766b814406e5.pdf

Visible band | Ultraviolet band (approximately 360-400nm)

Band between approximately 550-1100nm | Infrared band (approximately 800-1100nm)

Fig. 2: *Macroscopic imaging. Text on page 68 in different bands of electromagnetic spectrum.*

Figure 3 shows the microscopic images of a letter on page 994 in different bands of electromagnetic radiation, such as visible, infrared, ultraviolet, and area where fluorescence occurs. In the visible images, the color and texture of the ink and paper support are apparent. In ultraviolet induced visible fluorescence, the ink significantly absorbs the radiation. Images in the ultraviolet band present similar results, regarding the ink absorption, but in the images in the infrared band, the ink does not absorb or only slightly absorbs infrared radiation.



Visible band | Fluorescence band (400-430nm) | Ultraviolet band (395nm) | Infrared band (940nm)

Fig. 3: *Microscopic imaging of the letter O in the text of page 994. Magnification x 50*

SEM/EDS analysis

Energy dispersive X-ray scanning electron microscopy (SEM/EDX) gives important information on the ink's composition, images of fibers and of the paper support at high magnification, allowing further information to be received on the materials that constitute the copy letters and their support. Electronic scanning electron microscope (SEM) was JEOL JSM-6510LV connected to the energy-dispersive X-ray spectrometer of Oxford X-act. The analysis was accomplished using micro-sampling (Klockenkamper et al., 1993) after taking some particles of the material on small cotton swabs. The micro-samples were placed in a BDL-TEC CED 030 carbon evaporator for 10 minutes. The micro-samples were then examined in vacuum conditions using an accelerating voltage of 20 kV and a working distance of 10 mm. All micro-samples were investigated using BSED (Backscattered Electron Detector), which contributed to their examination. The SEM images were in magnification X200-X500.

Results

The study of historical resources is combined with the application of multispectral imaging and SEM/EDS analysis in order to obtain results on:

- The state of preservation of the copy letters in the book "Outgoing Letters of the National Bank of Greece 1853-1858".
- The paper that was used in the book belonging to the Historical Archive of the National Bank of Greece
- The inks used in copying texts
- The reading of illegible texts
- Conservation treatment decisions.

Historical studies

The collection of historical information allowed us to have first the information about the materials used in the copy letters, their original markets and various other manufacturing information about the copying process.

On the front endpaper of the copy book there is text followed by a drawing that describes the copying process, as well as giving information about the company that created the particular copy book (Figure 4). This provided the following information:

- The copy book studied for this paper and others belonging to the Historical Archive of National Bank of Greece were produced by Waterlow & Sons in London. The specific company address is also referred to.
- Detailed description of the copying method.
- The price of copy books according to the pages they contain.
- The price of different amounts of ink used in copying.

Fig. 4: *Information on the copy process in the inner side of the cover page.*

Information from the beginning of the 20th century on the purchase of copying paper, as well as the bank's distribution policy in its branches throughout Greece, was found in documents in file A1S3Y3B18 of the Historical Archive of the National Bank. This information describes that the bank bought the paper used in the copy books from Berlin, specifically from the Rotaprint market "Rotacopie" factory and then distributed it to its various branches, which are mentioned, as it is also mentioned the quantity with which it supplied each branch.

The information obtained from the historical references describes the types of inks used to create the copies, as well as the basic components of the inks and paper supports.

The following information was received about the inks:

- Copying inks contained Logwood, tannins, iron or copper sulfate, binder (sugar, honey, glycerin, gum arabic, etc.) and additives (potassium chromate or dichromate, phenol, etc.)
- Other types of inks are also described
    - The composition of which is based on various anilines.
    - Special pencils used to copy letters.
- Regarding the papers, they are thin papers which were impregnated or coated with aqueous solutions of gallic acid and/or iron sulphonate and/or binding material (sugar, glycerin, gelatin, etc.). The papers could be divided into the following categories:
    - Papers that must be soaked with moisture during the copying process.
    - Papers that should not be soaked with moisture during the copying process.
- Finally, information is retrieved on the manufacture of the copy books.

From contemporary literature, information on the copying process (Nadeau, 2002), ingredients of inks and paper supports that they come usually from the analysis of materials of copy letters. Furthermore, information on problems created in materials of these books are reported. Antoine Beth (2011 and 2009) and Titus et al. (2009 and 2006) have thoroughly investigated the manufacture materials of the copy letters and they have identified in depth the damage they cause.

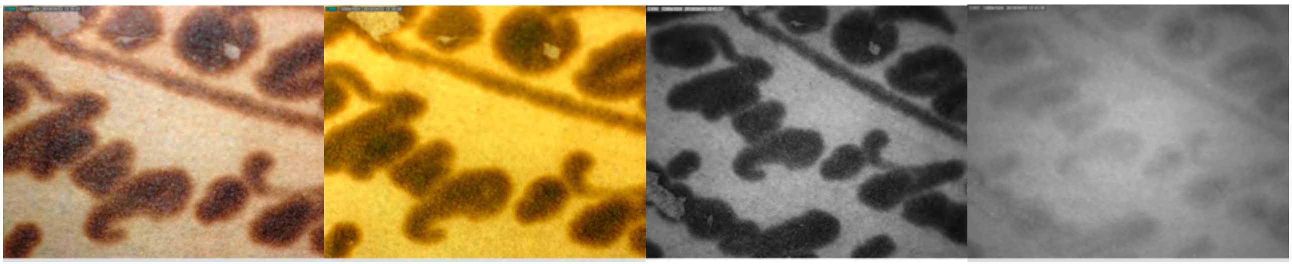
Multispectral imaging

The determination of the preservation condition served a two-fold purpose in this research since it allowed us to document the relationship between the preservation condition of the inks and the illegible texts, as well as the categorization of their condition in relation to deterioration inherent in the materials and the imperfections of the copying process.

The paper losses and the ink diffusion caused mainly by oxidation of the inks were identified, as well defects which occurred during the copying process. In this process, defects can be caused by inks that have either not been fully copied, leaving only traces of the writing, or have extended beyond the boundaries of the letters due to poor copying.

By taking images of the pages of the book's copy letters, the preservation condition of the materials used in the writing of the texts is established. The main damages shown are from the ink’s diffusion, the ink’s oxidation and subsequent disintegration of the paper suppors, followed in several cases by loss of text and tearing of the paper support.

Figure 5 shows the extension of the text ink beyond the limits of the writing due to the ink’s oxidation, as well as the deterioration of the paper support resulting in the loss of the paper and part of the text.



Visible band | Fluorescence band | Ultraviolet band | Infrared band

***Fig. 5:** Microscopic imaging on page 85, in magnification X20.*

Such damage, in addition to threatening the preservation of the book, also rendered the text illegible. The most significant problems are listed as follows

- •Diffusion of ink in an area much larger than the limits of the writing resulting in the alteration of the text. This diffusion is caused by ink oxidation (Figure 6)
- Many times, the text inks of both sides of paper support appear strongly on both pages, resulting in both texts being confused with each other (Figure 7).
- Oxidation of the paper support, resulting in some cases in its complete decomposition and destruction of the text (Figure 8).

It should be noted that the expansion of the text or the incomplete text can also occur due to factors other than oxidation of the inks. Such factors may be carelessness in the copying process, unsuitable copying inks, the duration of copying, or the time between original writing and copying of the text. Such cases were also found in the texts of the copy book "Outgoing Letters of the National Bank of Greece 1853-1858", such as the discontinuities in the text due to the poor adhesion of the ink to the paper support, shown in Figure 9, and diffusion caused by poor copying process, as we see in Figure 10.

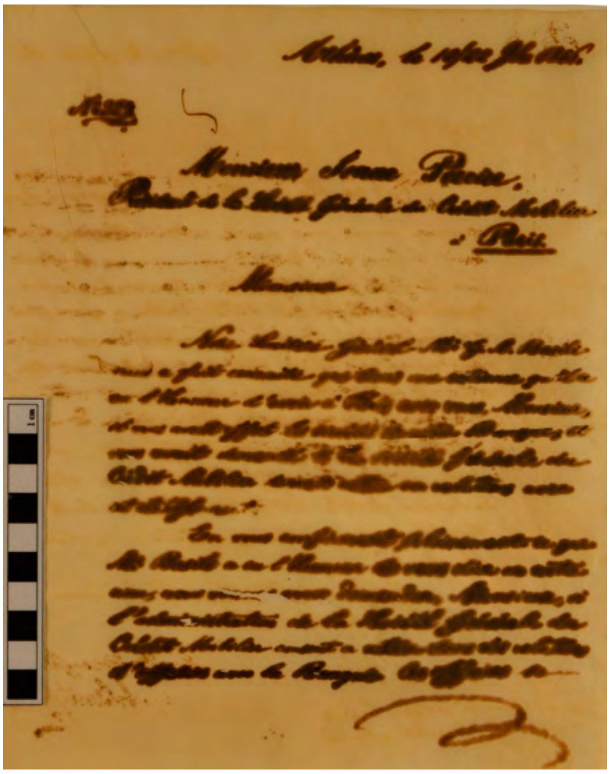


***Fig. 6:** Macroscopic imaging of page 646 Example of text diffusion caused by ink oxidation.*

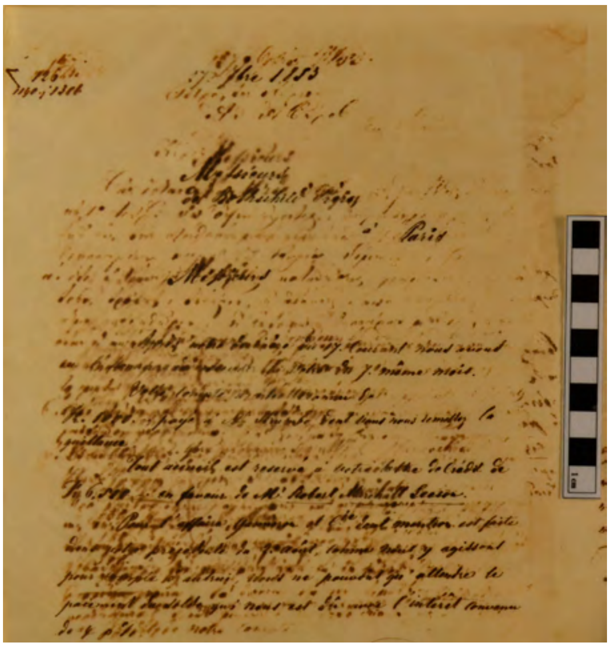


***Fig. 7:** Macroscopic imaging of page 74. Example of text appearance on both sides of paper support.*

Visible band

Fluores-cence band

Fig. 8: *Macroscopic and microscopic imaging of page 989. Example of paper damage caused by ink oxidation.*

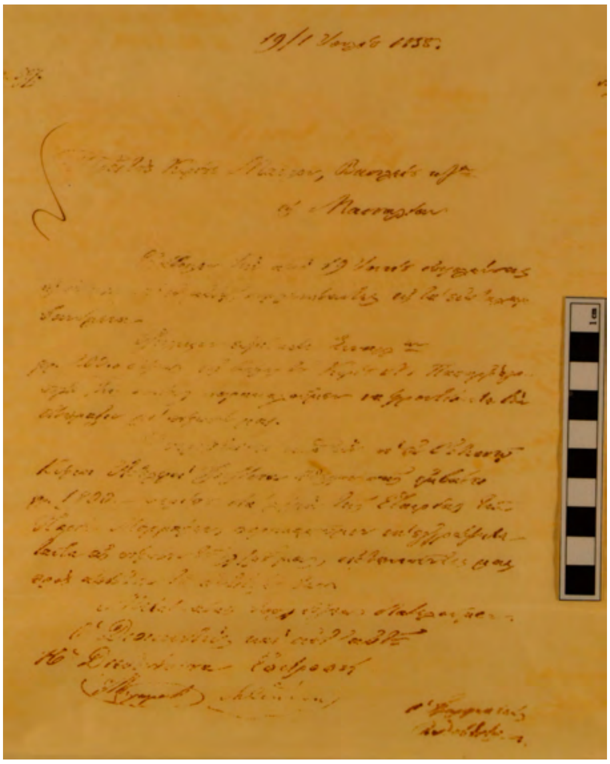


Fig. 9: *Macroscopic imaging of page 994. Example of poor ink adhesion to the paper support.*

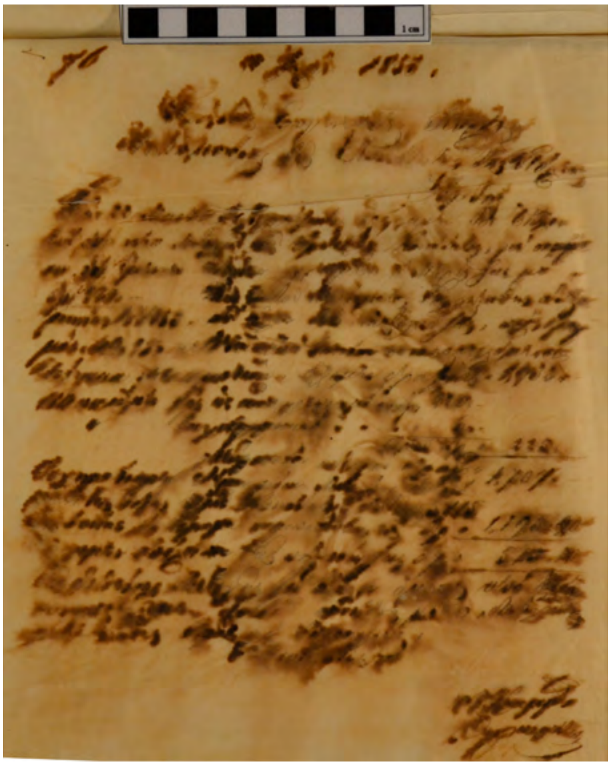


Fig. 10: *Macroscopic imaging of page 41. Example of diffusion caused by poor copying process.*

By categorizing the condition, both the appropriate digital tools for reading many illegible texts could be selected and the points where conservation treatments needed to be made to prevent any further degradation of the media.

The condition of text inks can be divided into two categories based on the multispectral imaging. Those text inks that extend beyond the boundaries of the writing and those text inks that show discontinuities. The inks that present an extension beyond the boundaries of the writing, their condition may be due to either their oxidation or manufacturing defects during copying. The ink that has spread and/or oxidized extends beyond the boundaries of the writing renders the texts illegible. Text ink that shows discontinuities is usually caused by improper copying, also making the text hard to read. Texts that don't present ink diffusion caused by oxidation have a better state of preservation.

1 Reading texts using the combination of multispectral imaging and computational processing. Text images of various wavelengths provide us with an important ability to read illegible writings and texts. Depending on the levels of legibility of the texts and their condition, one or two images are selected from different bands where the text is less illegible. Considering that a digital image is essentially a mathematical matrix, algorithms used in the field of morphological analysis and image processing can be applied. Thus, such techniques were applied to the selected images so that the texts were easy to read.

The techniques we applied to reading of the texts were as follows:

- Image enhancement techniques or intensity transformations, such as local contrast enhancement (image enhanced by contrast transformations) and reallocation of luminance values (threshold transformation) (N. Mohanapriya, Dr. B. Kalavathi, 2014, Maini R., 2010)[12].
- Morphological image processing using operators such as dilation and erosion (dilation and erosion combining gray-scale morphology) or (morphological reconstruction) as well as opening and closing techniques (Sonka 1998:559-574, Davies, 2005:233-249)[13].
- Spatial image processing filters were applied such as sharpening filter etc. (Gonzalez, 2004:89-98, Davies, 2005:47-93).

The selection of text images at different wavelengths of the electromagnetic spectrum and the subsequent application of morphological image processing techniques enabled the reading of illegible texts caused either by oxidation of inks or manufacturing defects during copying.

The following images show typical examples applying the proposed methodology. Figure 10 shows a text example in which the ink had spread beyond the writing limits, making it particularly difficult to read text, while Figure 11 shows a text example in which the writing ink presents discontinuities resulting in faded inks.

Figure 11 shows in the first column, on the left, ink in the visible band and in the second column, ink in the infrared band. In the third column, the first line shows the image of the text word "temps" in the visible band, in the second line, the image of the same word in the infrared band, in the third line, the infrared image after applying contrast-stretching transformations, and in the fourth line the same image after applying spatial filters.

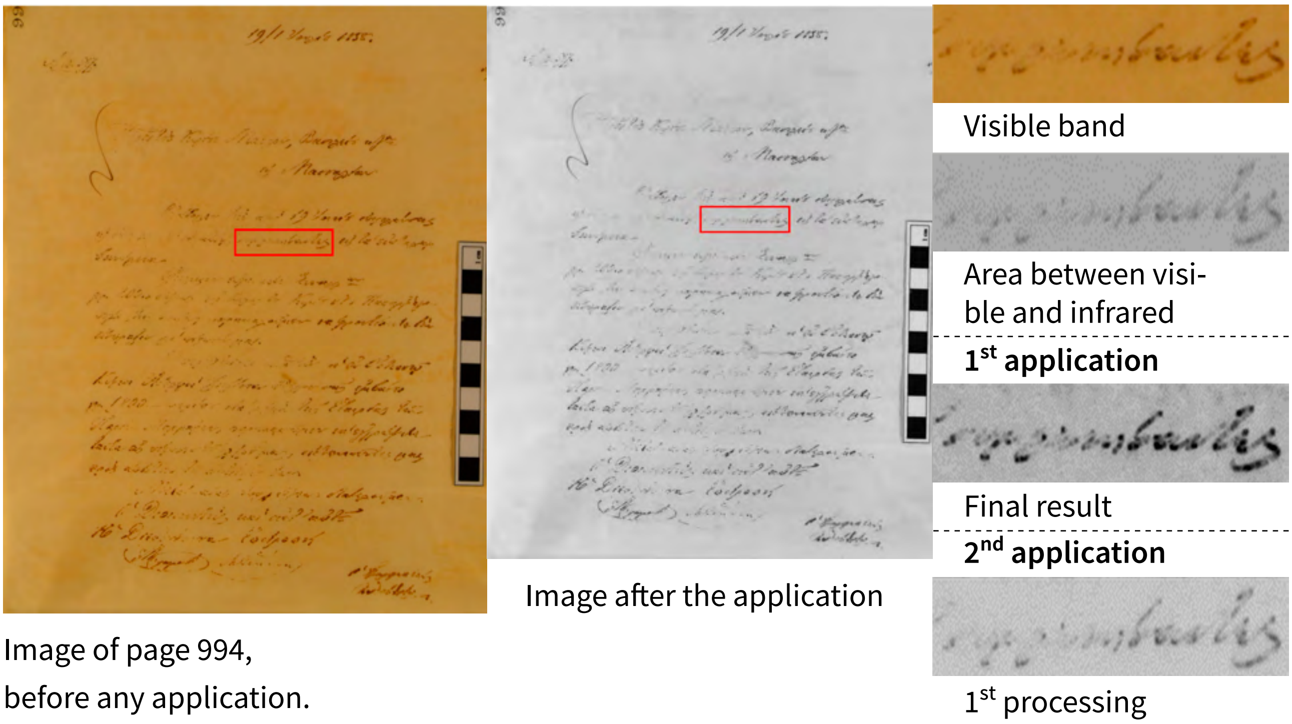
Figure 12, in the first column, shows

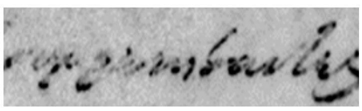
12 Most spatial domain (manipulating individual pixels of image) enhancement operations are given by the form g (x, y) = T [f (x, y)], where f (x, y) is the input image, g (x, y) is the processing image and T is the operator applied in the neighbourhood of (x, y) (Gonzalez, 2004:66-84 Maini et al., 2010:8-13).

13 The dilation of B by A, denotes $B \oplus A$, is defined as $B \oplus A = \{z|(\ )z \cap B \neq \emptyset\}$ (eq. 1), where $\emptyset$ is the empty set and A structuring element.
The erosion of B by A, denotes $B \ominus A$, is defined as $B \ominus A= \{z|(A)z \cap Bc \neq \emptyset\}$ (eq. 2).
$B \circ A = (B \ominus A) \oplus B$ (eq. 3)
$B \circ A = \bigcup \{(A)z \,|(A)z \subseteq B\}$ (eq. 4), where $\bigcup \{\bullet\}$ denotes the union of all sets inside the braces, and $B \circ A$ is the union of all translations of A that fit entirely within B (Gonzalez, 2004:338-350).

the text in the visible band, in the second column, the text after applying the image processing. In the third column, two ways of retrieving the text are presented. In both cases, the image used was in the area between visible and infrared. In the first attempt (third line of third column), grey scale morphology using a combination of the dilation and erosion was applied, while in the second attempt (fourth and fifth line of the third column) morphological reconstruction using opening and closing and then applying spatial filters

Fig. 11: *Example of the application of the proposed methodology, before and after the application.*





Final result

Fig. 12: *Example of the application of the proposed methodology, before and after the application.*

Depending on the reason the texts became illegible, different techniques are used to read them. When texts are illegible due to ink oxidation, in most cases, infrared images are more suitable for the application of computational erosion techniques, and therefore better results in reading illegible texts. When texts are illegible due to discontinuities caused by improper copying, in most cases, ultraviolet images are more suitable for applying morphological computational image processing. Texts with ink diffusion due to copying defects have less successful results for reading illegible texts.

Results of SEM/EDS analysis

The analysis of the inks and the paper support allowed us to learn the elements that make up these two materials to create copy books. Based on this information, the preservation state was further understood, as well as the risk of extending the damage to the paper support caused by the ink of the copy letters. The analysis of the two materials was done using Scanning Electron Microscopy (SEM) on 10 ink samples and 5 paper samples from various pages of the copy book "Outgoing Letters of the National Bank of Greece 1853-1858".

Microscopic observations through the electron microscope determine that the paper support is made of plant fibres, which likely came from cloth rags, common at the time in papermaking (Mühlen Axelsson, 2016; Page, 1997). From fibre images taken via SEM, flax fibres are identified (Figure 13).

The Figure 14 obtained through SEM shows the fibre breakage, which was detected in several areas where oxidised inks were.

SEM/EDS analyses were performed both to find the elements found in the compo-

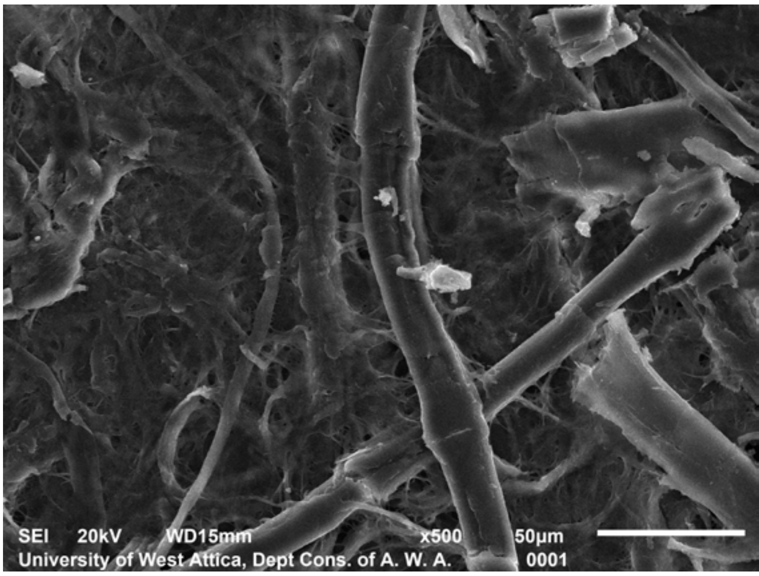


Fig. 13: *Microscopy image of paper on page 1011*

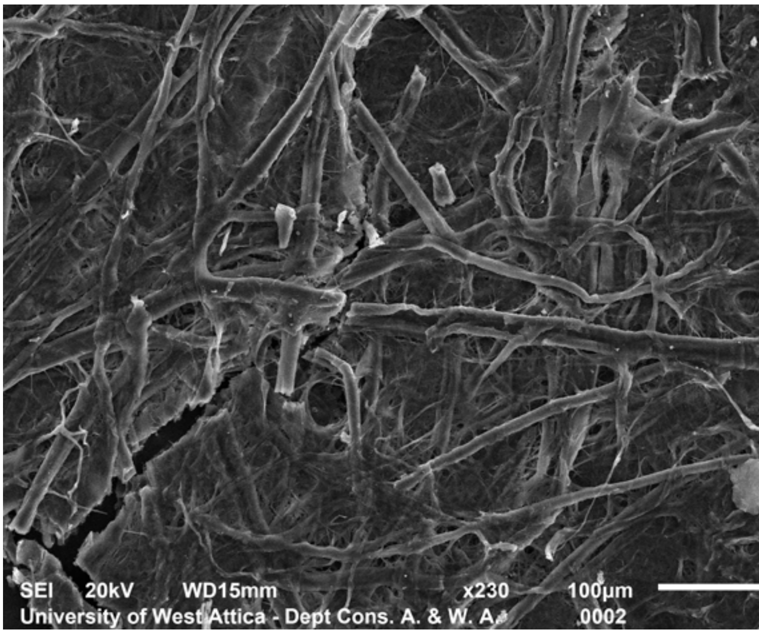


Fig. 14: *Microscopical image using SEM that presents the fibre breakage on page 318.*

sition of the paper support and the inks used. It is clarified that most ink samples consist of ink on a paper support. Carbon (C) and oxygen (O) values are assumed to be mainly derived from organic materials such as the paper support, hence they don't show in the Table 1. Table 1 shows the pages from which ink samples were taken, the elements detected in the ink samples, and the date written in the text from which the sample was taken. Based on the ink samples analysed, it is confirmed that the inks contain elements of iron (Fe) and sulfur (S) which indicates that these copy inks are iron gall inks as reported in the international literature (Beth, 2009; Tintus et al., 2006). In addition, the element copper (Cu) was detected in low concentration and has been found in the composition of irongall copy inks, while it is also mentioned in the above literature. Finally, other elements were also detected in smaller amounts, such as silicon (Si). Sample 9 consists exclusively of very small pieces of copy ink.

Table 1: *Elements detected in copy inks using SEM/EDS analysis*

	Page	Chemical elements (Concentration %)	Date
1	41	Na (0,07), Si(0,08), S(0,20), K(0,08), Ca(0,15), Fe(0,22), Cu(0,11)	1853
2	77	Na (0,43), Mg(0,06), Si(0,07), S(0,38), K(0,46), Ca(0,32), Fe(0,56), Cu(0,10)	1853
3	85	Na (0,20), Mg(0,16), Al(0,05), Si(0,18), S(0,17), Cl(0,06), K(0,11), Ca(0,10), Fe(0,18), Cu(0,11)	1853
4	318	Na (0,19), Al(0,05), Si(0,05), S(0,42), K(0,15), Ca(0,07), Fe(0,39), Cu(0,09)	1855
5	472	Na (0,32), Mg(0,09), Al(0,10), Si(0,10), S(0,95), K(0,45), Fe(1,72), Cu(0,14)	1856
6	665	Na (0,06), S(0,24), K(0,05), Ca(0,08), Fe(0,24), Cu(0,07)	1856
7	680	Na (0,16), Al(0,05), Si(0,06), S(0,30), K(0,13), Ca(0,12), Fe(0,38), Cu(0,08)	1857
8	989	Na (0,56), Al(0,07), Si(0,06), S(0,88), K(0,37), Ca(0,10), Fe(1,35), Cu(0,07)	1858
9	1011 (small pieces)	S(0,11), Fe(0,13), Cu(0,11)	1858
10	1011	Na (0,27), S(0,44), K(0,16), Ca(0,06), Fe(0,64), Cu(0,09)	1858

Also, in the case of the paper analysis, the carbon (C) and oxygen (O) values are not presented in Table 2 for the same reasons that they didn't show in Table 1. Table 2 shows the pages from which paper samples were taken, the elements detected in the paper samples and the date written in the text from which the sample was taken. Some elements of the paper samples detected are commonly detected in aqueous environments such as sodium (Na) and chlorine (Cl). Also, the presence of calcium (Ca) is related to the paper manufacture. Sulfur is detected only in the case of the paper support on page 38, whilst iron (Fe) and copper (Cu) detected, in most cases, may come from the copy inks. Because the sulfur (S) was not detected in most studied papers, these papers are considered to be chemically untreated, and this is also confirmed by the date of use, since chemically treated transparent papers were introduced to the market after 1857 (Bachmann, 1983) or 1860 (Wilson 2015).

Table 2: *Elements detected in transparent paper support using SEM/EDS analysis*

	Page	Chemical elements (Concentration %)	Date
1	38	Na (1,43), Mg(2,35), Al(0,71), Si(1,50), S(2,98), Cl(1,67), K(0,81), Ca(8,44), Fe(0,47), Cu(0,66)	1853
2	260	Na (0,09), Cl(0,08), Fe(0,07), Cu(0,13)	1854
3	306	Na (0,05), Mg(0,03), Si(0.10), Cl(0,10), K(0,06), Ca(0,20), Fe(0,07), Cu(0,09)	1855
4	555	Ca(0,11)	1853
5	1011	Al(0,07), Si(0,13), S(0,06), Cl(0,09), K(0,08), Ca(0,38), Fe(0,08), Cu(0,10)	1858

SEM images allow recognition of the fibres in the paper samples, while elemental analysis yielded significant results on the elements found in the paper structure and the ink composition used in the copybook texts. Plant fibres are recognized in the paper samples. Such fibres have been used in paper production (as textile rags) before industrial paper production (wood pulp). Elemental analysis of the paper documented the use of calcium (Ca) in all samples. The detection of sulfur (S) in such quantity in the first sample could suggest that it may relate to the manufacturing of the transparent paper. In addition, elemental analysis of copy inks detected that are iron gall inks in which has been used iron sulfate and some amount of copper sulfate.

Conservation treatments

The conservation treatments were carried out in the conservation laboratory of the Historical Archive of the National Bank of Greece and aimed to:

- Conserve the damage found on the pages of the book
- Reduce the risk of further damage
- Select materials to be used in the conservation based on their elasticity, transparency and effect in relation to the inks and paper supports of the texts
- Ensure elasticity at the points of intervention, so that the book page can be opened without the risk of breakage and
- Ensure the transparency of conservation treatments and the materials used in them so that the reading of the texts is not hindered

Oxidation of inks created two types of damage:

- Inks that have oxidised the paper to such an extent that fibre breakdown has been caused by cracks at the writing points and/or loss of text and paper supports and
- Inks that have oxidised the paper, but fibre breakdown and paper tearing were not observed.

Conservation treatments focused on the local repair of oxidised inks and their transparent paper support. Deciding on conservation treatments was based on literature (Pataki-Hundt et al. 2021; Jacobi et al. 2011; Titus et al. 2009; Ubbink & Patrridge 2003; Page 1997; Rodgers 1988) reporting on similar damage and the condition of copy letters based on the multispectral imaging. Conservation treatments were chosen to be carried out on the damaged points with both breakage of paper fibres and extensive oxidation of the paper support without fibre breakage. Treatments in this second category were performed on the basis of the risk they present for the future damage extension. If the risk was small for the damage extension, the treatments were aimed at strengthening the fibres and paper supports. Klucel G in 1% ethanol was chosen, which has similar working properties to methylcellulose (Titus et al. 2009), giving sufficient strength, elasticity and transparency in the application points, while not affecting the inks and supports in which it was applied to. In case of damage with breakage of fibres and risk of extension of it, treatments were performed with Klucel G in 5% ethanol and using Japanese tengujo paper 9 g. Application of the fibre fixing and paper support using Klucel G in ethanol or Klucel G in ethanol and Japanese paper did not affect the inks and the paper supports, giving the appropriate flexibility and strength. Moreover, both applied materials did not obstruct, allowing the texts to be read. The final result had little effect on the final paper thickness of the pages. Figure 15 presents an example of conservation treatments using Klucel G 5% and tengujo 9g.

Figure 16 presents the conservation treatments using only Klucel G, whose film can only be seen using raking light, while in any other direction of lighting no alteration of the surface and colour of the inks and paper support is observed.

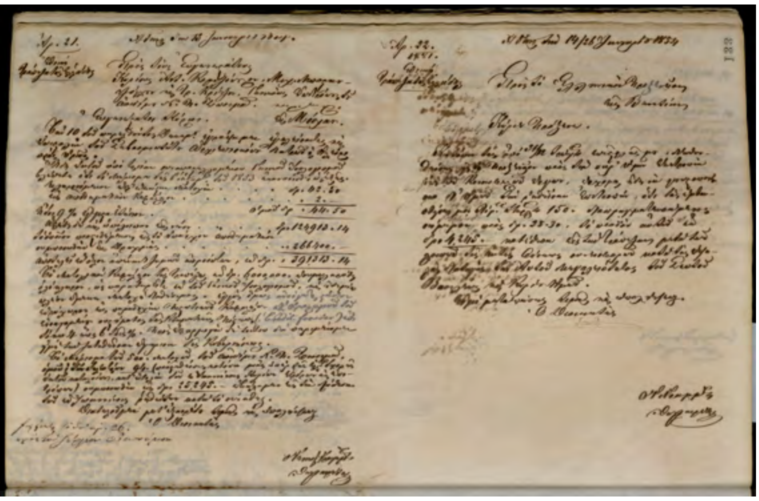


Fig. 15: *Conservation treatments on copy letters using Klucel G and tengujo.*

Fig. 16: *Conservation treatments on copy letters using only Klucel G.*

Both categories of conservation treatments yield remarkable results in the stabilisation of copy letters, providing the appropriate elasticity, transparency, and protection of copy inks and their transparent supports.

Conclusions - Future work

The methodology achieves successful results in enriching information about copy letters, their use in financial institutions, the copying process used, inks and paper supports used and especially those found in Greece and the financial institutions working there since at least the 19th century. Furthermore, the condition of the inks was determined and most of the texts that were illegible were made legible. Further deterioration was also hindered.

The historical information recovered is considered important both for the production of copy letters and books, as well as for the use of copy books in Greece and its branches, thus providing the first information on the use of these books in Greece. In addition, information is retrieved on the papers used for copying letters by the National Bank, as well as the copying process recommended by the partner company for the bank's copy books.

Multispectral imaging and the combination of images from different bands of electromagnetic spectrum allowed to document the preservation state of texts (inks and transparent supports), giving significant results that the decision of conservation treatments was based on. Multispectral imaging constituted also the basis for the application of computational processing of those images so that the illegible texts of the studied copy book could be read. The most satisfactory results for reading of the illegible texts were obtained in those texts which presented a similar degree of diffusion, oxidation and discontinuity. In this way, illegible texts were read and valuable information about the correspondence of the National Bank during the years 1853-1858 was recovered. However, the application of the computational process showed that its further development on the copy letters can provide more results in the analysis or recognition of texts.

The SEM/EDS analysis yielded significant results on the recognition of fibres of transparent paper used in the copy book belonging to National Bank and the chemical elements of inks and transparent paper support. The detected chemical elements of inks are corresponding to the composition of iron-gall inks used in copy letters (Beth, 2011). Furthermore, fibres of paper samples can be recognized as vegetable fibres and the elemental analysis yielded information on the paper manufacture. Further elemental analyses may yield more results on the compositions of inks and transparent supports, thus giving a better insight into their manufacture during the 19th century.

The application of conservation treatments gives the necessary protection and elasticity to the copy inks and transparent paper supports for the future. The conservation interventions did not affect the inks and supports to which they were applied, while they did not significantly alter the thicknesses of the book pages.

Although conservation treatments have succeeded in stabilising the condition, further studies should be carried to protect and conserve copy letters and copy books.

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