A STILL LIFE WITH METAL SOAPS

A conservation treatment focusing on the prevention of future metal soap formation

Ida Bråthen

A master thesis in paintings conservation
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Institutt for arkeologi, konservering og historie

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A Still-life with Metal Soaps

A conservation treatment focusing on the prevention of future metal soap formation

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Front: Micrograph of the cross-section in 20x magnification.

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Abstract

The project concerned the examination and treatment of a still-life afflicted with metal soaps. Metal soaps are a natural part of the aging process of oil paint, but can cause changes such as increased transparency, protrusions and craters, and complex crusts imbibed in the paint layers. The aim of the treatment was to improve the painting's current condition, as well as consider its long-term preservation by treating it in a way that does not increase the rate of metal soap formation. The main factors affecting this rate are heat, solvents and moisture.

The painting was examined using imaging and analytical techniques to gather information about material composition and condition that would help in determining the direction of the treatment. Based on this examination, both metal soap protrusions and a crust were confirmed. The painting was in overall good condition, but was found to be dirty and with a visually disfiguring varnish. Therefore, cleaning it and removing this varnish were the most critical aspect of the treatment.

To reduce the painting's exposure to moisture, heat and solvents, it was decided to clean it using a gel. Different gelling agents were tested with solvents to both investigate their compatibility with solvents, and to find the one most suited to this project. Four polysaccharide gels, xanthan, Klucel® G, gellan and agar, and one chemical gel, Carbopol® were tested. The results showed that the polysaccharide gels were overall ineffective solvent gels, with the partial exception of Klucel® G. Carbopol® was very effective, and Carbopol® using the solvents acetone and benzyl alcohol was chosen for the cleaning.

The conclusion was that, while it is likely impossible to avoid all use of damaging factors, it is possible to reduce their impact by choosing specific treatments and materials. Binding solvents and moisture in gels is a very helpful tool to aid in this endeavor, and further research into gelling agents is highly encouraged.

Acknowledgements

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Ida Bråthen
Løvenstad, February 2024

Table of Contents

List of tables

List of illustrations

Glossary

AIC – American Institute for Conservation

E.C.C.O – European Confederation of Conservator-Restorers’ Organisations

FCIR – false color infrared

GC/MS – Gas chromatography/ mass spectrometry

HPC – Hydroxypropylcellulose

ICOM – international council of museums

IR –infrared light

IR photography – reflected infrared light photography

IRR – infrared reflectography

LMW – low molecular weight

MW – molecular weight

OM – optical microscopy

PLM – polarized light microscopy

pXRF – portable x-ray fluorescence

RI – refractive index

SEM-EDX – scanning electron microscopy with energy dispersive x-ray spectroscopy

SRAL – Stichting Restauratie Atelier Limburg

TAC – Triammonium citrate

UV – ultraviolet light

UVF – ultraviolet fluorescence

XRF - x-ray fluorescence

1 Introduction

In the late 1990s, a new phenomenon was discovered during the conservation process of *The Anatomy Lesson of Dr. Nicolaes Tulp* by Rembrandt van Rijn at the Mauritshuis museum. The paint surface was covered in small protrusions – some with a white substance inside, and others where the white substance had fallen out, creating dark craters in the surface (Boon et al., 2002, p. 401, 2007, p. 16; Noble et al., 2002, pp. 49–50; Noble, 2019, pp. 1–2, 5–6). The same phenomenon was also identified on several other paintings in the Mauritshuis collection. Eventually, it was observed on paintings in collections all over the world. In the following decades, the phenomenon has been studied comprehensively, and the protrusions were discovered to be metal soaps. Numerous research projects have since been undertaken to understand how metal soaps develop and how to conserve paintings affected by the condition.

This masters' thesis is focused on a still-life that depicts an assortment of dinnerware on a table covered with a red tablecloth (fig. 1). The painting was covered in a discolored and dirty varnish, a layer of surface dirt on the reverse, and the canvas had deformations due to being very loosely tensioned on its strainer. In addition to this, the paint surface had protrusions that appeared to be metal soaps, with some areas being more heavily affected than others.

Fig. 1 The painting, National Museum inventory no. 10219A, before treatment. A larger version of this image can be found in fig. 46.

1.1 Aims and objectives

The overall aim of the project was to complete a conservation treatment that improves the current condition of the painting, as well as taking into consideration its long-term preservation.

As the examination of the painting confirmed the presence of metal soaps, the long-term goal became specified as a research question related to this. Can treatment be performed in a way that does not increase the rate of metal soap formation, and what measures can be taken to achieve this?

In addition to the overall project aim and research question, the following objectives were set:

- Develop a method for cleaning the painting that both enables a total cleaning, and does not increase the rate of metal soap formation.
- Consider if there are areas where other concerns or needs will be more important than the prevention of further metal soap formation, and address these adequately.

1.2 Scope and limitations

"The amount of information that could be gathered on any one object is virtually limitless."(Appelbaum, 2010, p. 17)

This statement by Barbara Appelbaum shows the importance of placing limitations on a project. In a master project limited by time and availability of both materials and analytical methods, it became very important to narrow the scope of the aims and research question to ensure that the project could be completed within the given timeframe.

As part of doing this, it was decided to focus on the use of solvent gels to clean the painting. Gels are a popular topic in modern conservation research, as they have many advantages in comparison to the use of free solvents. Gels are themselves a vast topic, and so it was decided to focus on a limited number of polysaccharide gels. These mainly originate from natural materials such as plants, seaweed and bacteria, and are non-toxic and biodegradable.

Another way to narrow the scope was to limit the number of analytical methods used. Analyses were focused on gathering information relevant to the research question and the treatment of the painting.

1.3 Structure of the thesis

The thesis opens with a discussion on the ethical framework surrounding the conservation profession, as well as on the three important concepts of reversibility, minimal intervention and sustainability, and how these have been utilized in the project. Chapter 2 is the methodology, where all the examination methods and analytical tools used during the project are presented. Chapter 3 concerns the painting itself, describing the condition it was in upon arrival at the student atelier, its provenance and place in art history. Chapter 4 is a literature review that covers the main topics relevant to the research question; metal soaps and gelling agents. In chapter 5, the results of the analyses and examinations are presented and discussed, both individually and in relation to one another. Chapter 6 details the experimental part of the project – the testing of gelling agents and solvents for the cleaning. This chapter is structured like an experimental report and contains methodology, results and discussion related to the gel testing. In chapter 7 the different treatments the painting underwent are described and discussed in relation to the ethics of the conservation profession, the reviewed literature and the results of the analyses and experiments. Lastly, the thesis is concluded in chapter 8 by answering the research question and addressing the aims set forth in the introduction, as well as by providing recommendations for further care and research related to the painting.

1.4 Ethical framework

The conservator is bound by the ethical frameworks set forth by the professional conservator organizations, as well as by local laws regarding copyright protection. In Europe, the E.C.C.O.[1] Code of Ethics serves as a guiding document, outlining the expected conduct and interaction of a conservator with cultural heritage. Articles 5, 9, 10, 11, 12 and 15 are especially relevant to this thesis. They address the conservator's approach to the cultural heritage they work on, the necessity of thorough documentation, and the importance of both learning and knowing one's own limits. Article 9 ties particularly well into the research question, and states:

> *"The conservator-restorer shall strive to use only products, materials and procedures, which, according to the current level of knowledge, will not harm the cultural heritage, the environment or people.*
>
> *The action itself and the materials used should not interfere, if at all possible, with any future examination, treatment or analysis. They should also be compatible with the materials of the cultural heritage and be as easily and completely reversible as possible."* (E.C.C.O., 2003)

The research question focuses on methods for treating paintings affected by metal soaps, aiming to minimize immediate and future damage. This aligns with the article's objective and

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[1] European Confederation of Conservator-Restorers' Organisations

strives to enhance conservators' ability to adhere to the prevailing ethical standards and goals of the profession.

Reversibility, minimal intervention and sustainability

Three of the most important concepts within the ethics of modern conservation treatment are *reversibility*, *minimal intervention* and *sustainability*. “The principle of reversibility” first appeared in conservation in the 1960s, with the first Code of Ethics for conservators written by the IIC American Group in 1967 (IIC-American Group, 1968). It focuses on the idea that all treatments should be reversible, thus minimizing the possibility of long-term effects to an artwork. However, these concepts have been both lauded as unattainable goals and as paradigms of good practice (Udina, 2021, p. 201).

In 1987, Barbara Appelbaum published a critique of the term, and raised awareness of its inaccuracy and misuse. Reversibility became a catch-all term used either to describe various treatment criteria, or used as a synonym for solubility rather than a descriptor for a process (Appelbaum, 1987, p. 65). The problem with this term is that many conservation treatments are inherently non-reversible, such as consolidation, cleaning, or varnishing. For example, with consolidation, a material absorbed into a structure cannot be removed. Appelbaum argued that reversibility should only be used where conservators could “turn back the clock” on a treatment – not to an identical state, but to a state where treatment options are again as broad as they were before the treatment took place (Appelbaum, 1987, p. 66). Instead, she proposed a different term – *re-treatability*. This term can be considered a scaled-down version of reversibility (Muñoz Viñas, 2005, pp. 187–188), and refers to how much a chosen treatment impacts options for the next time. As summarized by Muñoz Viñas, “it only requires that a given treatment not make future treatments impossible”(Muñoz Viñas, 2005, p. 187).

The idea of minimal intervention is another concept that has gained popularity since the 1980s (Ackroyd & Villers, 2003, p. 9). It refers to an ideal of using limited interventions for the treatment of an object. However, as Caple points out, minimal intervention is not a complete statement (Caple, 2000, p. 65). It needs to be used in relation to a goal regarding the object to be conserved, and different objects may have very different goals. This creates a situation where, in comparison to reversibility, minimal intervention cannot be tested. Therefore, Villers suggests that minimal intervention is better considered as an attitude rather than a principle, and defines it as an attitude of rational restraint (Villers, 2004, p. 4). Looking at Muñoz Viñas, he describes this way of thinking of minimal intervention as “it helps keep the work as it is, ruling out unnecessary modifications of the objects" and goes on to point out how this stresses the notion that conservation treatments are not "all-positive" operations (Muñoz Viñas, 2005, p. 190).

The third concept to be discussed is sustainability. Muñoz Viñas associates it with the Brundtland definition; "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." (Muñoz Viñas, 2005, p. 195). This definition encompasses the goals set forth by reversibility and minimal intervention, but frames them in a different way, as it brings up the idea of future users. A future user should gain as much from the artworks that contemporary users and conservators do, which carries with it a responsibility to not perform treatments using materials that are hazardous or which increase the rate of deterioration. This also aligns with goals of decreasing carbon footprint and using materials that pose less of a health risk to both the conservator and the environment.

All these concepts need to be considered in concert. Neither is a complete ideal for conservation, but they all encompass different aspects of what a conservator needs to consider when carrying out conservation treatments. They are the basis for the considerations that have been made in this project, in terms of the choice of both material use and treatments. Another important aspect to consider is the practical reality of the treatment – the allotted time and the availability of analytical tools and materials. Therefore, choosing relevant analyses and treatments that were both applicable to the research question and to the overall treatment, as well as being feasible to complete within the given timeframe became an important part of the decision making. Furthermore, the chosen treatments needed to consider the unique challenges presented by the artwork, and it was important to ensure that, despite the limitations, they did not justify "slipshod work or inadequate research", as phrased by Caple (Caple, 2000, p. 66).

2 Methodology

The decision was made to focus on techniques that relate directly to both the treatment of the painting and to the research question. Analytical methods were prioritized for investigating the ground, paint layers and varnish. These included imaging techniques such as ultraviolet fluorescence (UVF), infrared reflectography (IRR), false color infrared reflectography (FCIR), and x-ray radiography. The painted surface was also examined using stereomicroscopy. Further material examination was undertaking using portable x-ray fluorescence (pXRF), scanning electron microscopy with energy dispersive x-ray spectroscopy (SEM-EDX), thread density measurements, pH and conductivity testing, the Biuret test and chemical spot tests. All the techniques were performed according to the hierarchy of first employing non-invasive techniques to their full extent, before performing microinvasive or destructive techniques.

Archival research

The documentation archive at the National Museum (Nasjonalmuseet) was surveyed to find information regarding the history and provenance of the painting. Art historical literature was consulted to research its art historical context. A literature review was conducted on the topics of metal soaps and gelling agents (chapter 4).

2.1 Imaging techniques

The painting was documented before the treatment began and again at several points throughout the process using a Canon EOS 550D camera with a Canon 50 mm fixed focal length lens. Detail images were taken with an iPhone 12 mini, and all photos were processed in Adobe Lightroom and Adobe Photoshop to enhance details and adjust lighting. In addition to normal illumination, raking light was used to show the topography of the paint layers and deformations in the canvas that may otherwise be difficult to see with the naked eye.

ARTIST multispectral art imaging system (Artist Camera) was used to document the painting using reflected infrared photography (IR), false color infrared accurate color (FCIR), and ultraviolet fluorescence (UVF). These techniques documented the condition of the painting, as well as functioning as an aid in its examination. Reflected infrared photography (spectral range of 700 nm-1100 nm using the ARTIST camera system) can be used to visualize carbon-based underdrawings or other subsurface layers provided the surface layers are transparent to IR radiation (*Infrared Radiation Imaging*, 2022). As carbon absorbs IR, it becomes visible.

FCIR is an image processing technique that combines color and infrared images. By rearranging the color channels of the image processing device, the colors of the created image appear changed ("False-Color Image Processing," 2023). This aided in the identification of different pigments by making similar colors appear more dissimilar (MacBeth & Breare, 2020, p. 312).

UVF excites visible fluorescence in many organic materials, and was therefore a valuable tool in identifying their presence in the *Still-life* (MacBeth & Breare, 2020, p. 306). It was used to identify the varnish layer present, as well as to show previous retouches and stains on the paint surface. In addition to the ARTIST camera system, UVF was performed using a Rofin Flare Plus 2 blue light flashlight for monitoring progress during cleaning, as well as CLE Design Ltd. Vertical UV luminaires (spectral range 355-360 nm) to examine and document the painting.

X-ray radiography was performed using an ICM CP120 by Teledyne ICM. It was done as a part of the examination process and was a useful technique for gathering information regarding the condition and previous history of the painting. Depending on the atomic weight and density of elements present in a material, x-rays may be absorbed or pass through a painting (Stuart, 2007, pp. 78–79). This provides information about the distribution of certain radio-opaque elements such as lead white throughout a painting, and the technique can also uncover changes to compositions (pentimenti), reveal layer structure, damages, as well as providing information on the artist's painting technique (Stuart, 2007, p. 79).

2.2 Analytical techniques

Visual examination and microscopy

Visual examination combined with stereomicroscopy (Leica MZ6 stereomicroscope (6.3× to 40× magnification range)) were used for both documentation and investigative purposes. In addition, examination of the cross-section using both reflected light and UV light was performed on an Olympus BX51 PL microscope (National Museum).

Thread density measurements

Thread counting was performed in order to understand the thread density of the canvas. This was a part of the art historical examinations of the canvas, and was relevant to the tear mending. Thread counting was performed using a Clas Ohlson thread counter with 10× magnification, through which a 1 × 1 cm square of canvas could be observed. The counter was placed on the canvas and a photo was taken into the device, providing an image that could be used to count threads. The threads were counted in both the horizontal and vertical directions, in 11 spots across the canvas.

Portable x-ray fluorescence spectroscopy (pXRF)

As discussed in the literature review, elements found in relation to metal soaps or metal soap crusts include lead, zinc, potassium, copper and calcium (Cotte et al., 2017, p. 3; Martínez-Casado et al., 2019, p. 228). Identifying whether these elements were present could be of aid in understanding the composition of the soaps, as well as what pigments were present in the painting. To do this, pXRF was utilized. Inorganic pigments are characterized by one or two specific, detectable elements, allowing their identification via pXRF (Stuart, 2007, p. 240). pXRF was performed using a Niton™ XL3T spectrometer with a Geometrically Optimized Large Drift Detector (GOLDD™) + by Thermo Scientific. The instrument was mounted on a tripod during measurements. Four spectra, main (50 kV), low (20 kV), high (50 kV) and light (8 kV) were taken for 30 s each using the "Mining Cu/Zn" mode for a total measuring time of 120 s, using an aperture of 3 mm. NDT Alpha 7.1 software was used to analyze the results.

Sampling

A micro-sample was taken from a single location where suspected metal soap protrusions were present in order to identify their material composition. As the highest concentration was found on the bowl mount on the right-hand side of the painting (fig. 2), this was where the sample was taken (fig. 3). The sample was then embedded in an EasySection using Technovit® 2000 LC resin and Technovit® 2000 varnish. The section was polished using sandpaper and Micro-Mesh® (final polish using 12 000 mesh) to get a good view of the layer structure in the sample, as well as to remove scratches in the surface. The sample provided valuable cross-sectional analysis of the paint layers and was examined with a polarized light microscope, under both regular and UV light.

Fig. 2 The mount on which the bowl was standing had the highest concentration of suspected metal soap protrusions in the painting, marked with an arrow.

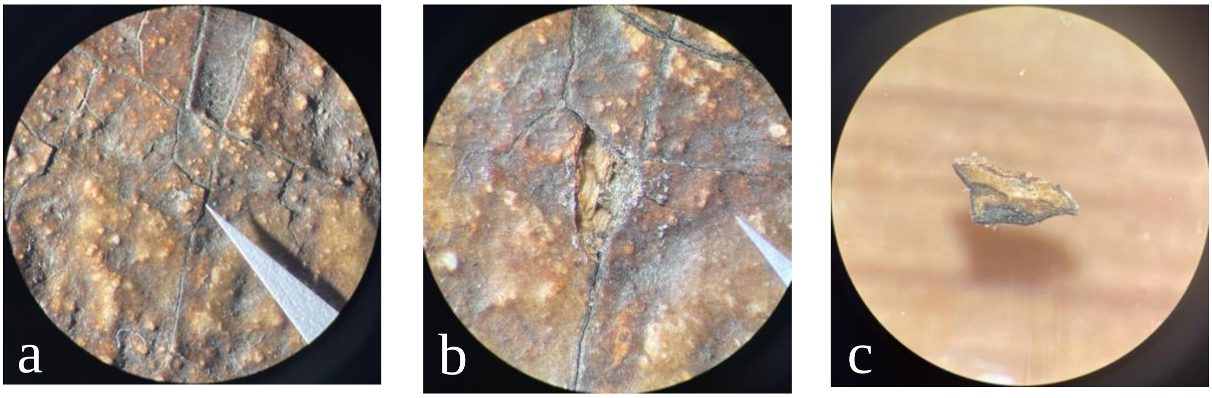

Fig. 3 The sample spot. A: before sampling. B: After the sample was removed. C: The sample after removal.

SEM-EDX

Scanning electron microscopy with energy dispersive x-ray spectroscopy was performed using a FEITM ESEM Quanta™ 450 and used to analyze the cross-section. Backscattered electron images were taken using accelerating voltage of 20 kV in low vacuum mode. EDX analysis was done using an OXFORD instrument X-MAX50 and the resulting spectra and images were analyzed using the AZteclive software. SEM-EDX analysis provided high magnification images of the paint layers as well as elemental analysis (Stuart, 2007, pp. 91–92), allowing for the identification of pigments, and the composition of a suspected metal soap protrusion, as well as what appeared to be a metal soap crust.

The Biuret test

The Biuret test is a tested method for the identification of proteins in a material by help of copper (II) sulphate ($CuSO_4$), which reacts with the protein to form a purple complex when in alkaline conditions (Odegaard, 2005, pp. 144–145; Stuart, 2007, p. 46). A lump of adhesive was removed from the patch on the reverse of the painting and tested in order to assess the type of adhesive used and which solvent would be suitable for its removal. The test was also performed on a piece of the ground layer that had fallen off the very edge of the canvas to identify the binding medium.

Chemical spot tests for binding media analysis

A series of chemical spot tests aided in the identification of the binding medium of the ground layer. The tests were performed according to Unn Plahters methodology, which consisted of dipping a small sample of ground fallen from the very edge of the tacking edge in the selected solvents distilled water, ethanol and sodium hydroxide (NaOH) and observing the sample (Plahter, 2004, p. 165).

Conductivity and pH

Measuring the pH and conductivity of the paint surface and canvas was undertaken to gather information on the condition of the canvas and paint layers. A low pH could be an indication of a high rate or deterioration in the canvas, since acid hydrolysis is one of the main modes of deterioration of canvas (Folch, 2011, pp. 27, 66). Conductivity of the surface was tested as a preparation for the expected aqueous cleaning of surface dirt from the painting. Using cleaning solutions that are hypertonic in relation to the isotonic condition of the paint surface may increase the risk of swelling or softening of the paint layer (Wolbers et al., 2020, p. 528). Hypotonic solutions may cause leaching; a process where molecules are drawn out from the paint surface, causing embrittlement of the films and optical changes such as blanching or desaturation (Burg & Seymour, 2022a, p. 37; Sutherland, 2013, p. 45). The measuring was done by placing 0.45 cm thick plugs made from 3% agarose[2] on the paint surface for 3 minutes and reading the results using first a Horiba LAQUAtwin conductivity meter followed by a Horiba LAQUAtwin pH meter (Rota et al., 2021, pp. 318–319; Stavroudis, 2013). Before measuring on the reverse, the canvas was cleaned with a brush and vacuum to reduce the amount of particulate matter, as their presence may cause inaccuracy in the results (Aguado et al., 2023, pp. 2, 4).

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[2] The recipe for the agarose gel can be found in appendix 4.

3 The painting

The painting is a still-life depicting silver and porcelain dinnerware displayed on a table covered in a red tablecloth. It was painted using a palette primarily consisting of the pigments red, black, yellow, white and brown, as well as some blue used for decorating the porcelain. This chapter will first focus on examining and discussing the painting's condition before treatment. Later, the provenance and art historical context of the painting will be discussed.

3.1 Condition before treatment

Auxiliary support

The auxiliary support was a strainer, which measured 139 cm x 36.8 cm. The strainer consisted of four members and two crossbars, dividing it into three equal sections. The frame itself was constructed using bridle joints. The crossbars had tenons that were set into mortises cut through the horizontal bars. There was no raised lip on the strainer.

The strainer had a slight upward curvature when observed from the front, coupled with pronounced warping in several directions (fig. 6). Notably, there was a distinct discoloration consistent with water damage along the right-hand side, both in the upper, side and lower members.

Primary support

The entire canvas measured 140.7 cm x 41.8 cm, and consisted of two separate pieces measuring approximately 118.8 cm x 41.8 cm (designated as canvas A) and 19.9 cm x 41.8 cm (canvas B).

The tacking margins were quite degraded, mainly due to the presence of a number of holes and missing pieces, especially along the top edge (fig. 4d-e). Additionally, they were very narrow, measuring 1 – 2.5 cm in width. On both the tacking edges and the front of the canvas, a total of 13 holes with oxidation-induced discoloration were found. These were likely tack-holes from a previous support (Hackney, 2020, pp. 128–129). There were also small holes from the tacks used to fasten the frame to the strainer.

Fig. 4 The tacking edges. A: right-hand vertical. B-C: underside D-E: top-side. F: left-hand vertical.

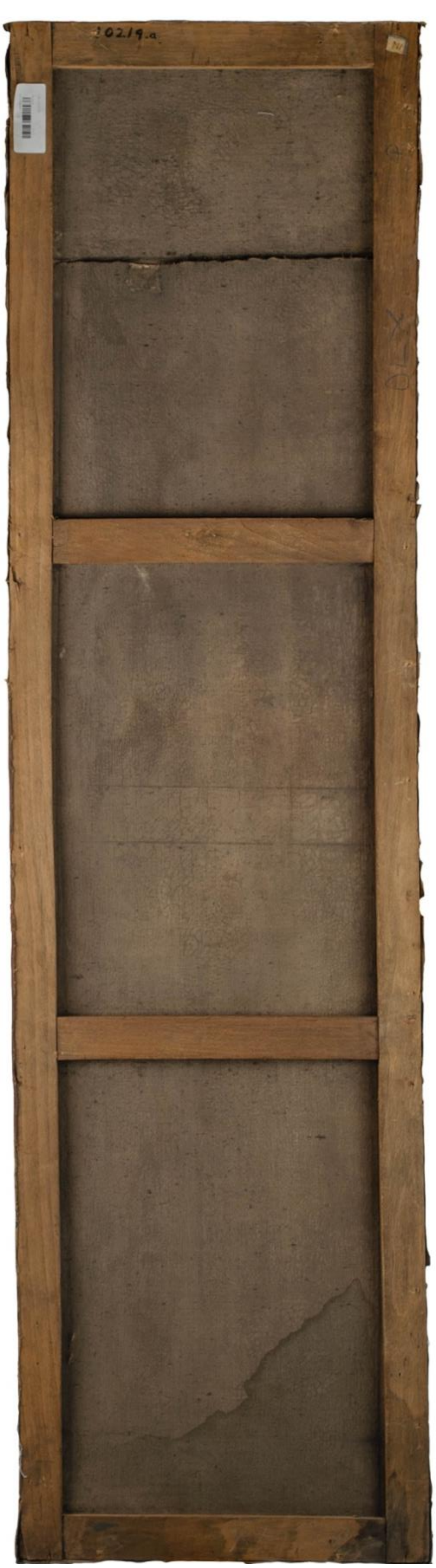

Fig. 5 The reverse of the painting before treatment.

Three areas of tears caused by mechanical damage were found. One consisted of two small tears and was unrepaired (fig. 7a-b), one was a small tear that had been filled and retouched tear but otherwise not mended (fig. 7c), and the last one had been mended with a 2.5 cm x 2,8 cm patch applied to the reverse (fig. 7d-e). It had been filled and retouched, but the fill had partially fallen off.

The reverse was covered in dust and grime, and there were clear imprints in the dirt from the auxiliary supports, showing the outlines of both the current and previous supports (fig. 5). In addition to this, the right-hand side displayed clear signs of water in the form of staining and tidelines. However, despite this there were no indications of mold growth.

Ground layer

The ground layer extended over the tacking edges of the canvas, showing significant loss around tack holes and folds. The ground layer, visible along the canvas edges (fig. 8) appeared to be white or otherwise light in color. Overall, it was in good condition, adhering well to the canvas. Losses in the ground layer corresponded to canvas folds or mechanical damage.

Paint layers

The paint layers followed the ground layer in extending over the tacking edges, and showed a corresponding paint loss around tack holes and folds. The front of the canvas exhibited minimal loss, with the paint well-adhered to the ground layer. Notable losses were seen in impastos (fig. 9) and from mechanical damage. What appeared to be metal soap formation had caused protrusions across the motif (fig. 11). Most notably, the bowl mount on the right-hand side was heavily afflicted (fig. 2), and the paint surface appeared gritty as a result (fig. 10).

In the area where water damage was evident on the reverse, the paint layers seemed to show no corresponding damage.

There were visible retouches over the holes in the canvas (fig. 12a). The holes had been filled and painted over, but several fills had fallen off and the retouches had a slightly different color and gloss than the original paint layers (fig. 12b). Along the edges of the varnish on all sides there were lines and ridges of what appeared to be paint. The ridge along the bottom edge was thicker than the others (fig. 13a-b).

Fig. 6 The strainer after removal of the painting, showing distinct warping.

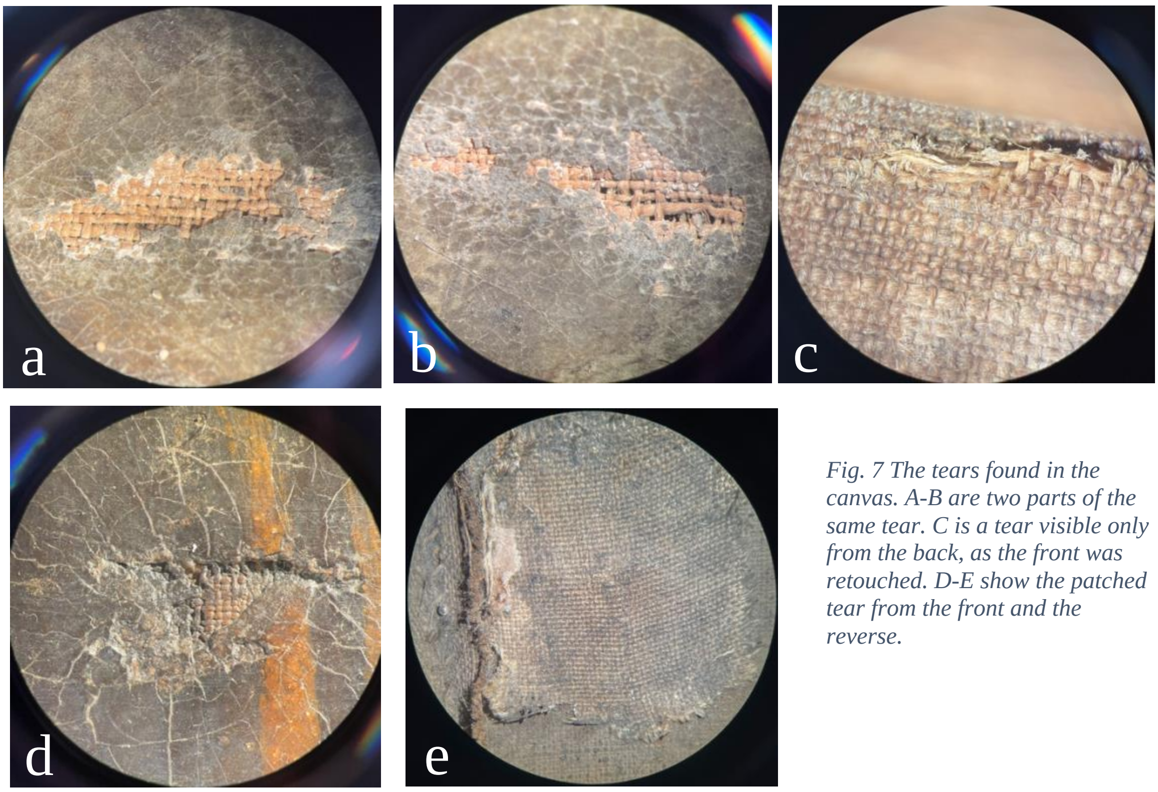

Fig. 7 The tears found in the canvas. A-B are two parts of the same tear. C is a tear visible only from the back, as the front was retouched. D-E show the patched tear from the front and the reverse.

Fig. 8 Visible ground layer, marked with a circle.

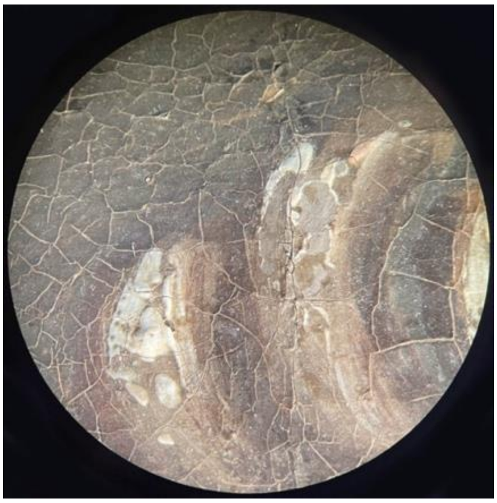

Fig. 9 Paint losses in impasto on the ewer.

Varnish

The varnish layer, measuring approximately 136.2 cm x 34.6 cm, was notably smaller than the current dimensions of the motif. In addition, it was at a diagonal angle across the canvas (fig. 23, p. 30). The varnish itself had become significantly discolored and dirty, as evidenced by the contrast in color between the varnished and unvarnished areas (fig. 14).

3.2 Provenance

The painting, along with two accompanying pieces (fig. 15, 16), was acquired by the Norwegian Museum of Decorative Arts and Design (Kunstindustrimuseet) from H. Bukowskis Konsthandel in Stockholm on the 14th of September 1928 for the sum of 500 kr[3]. (Inventarprotokoll AeL0010, p. 4). A board meeting protocol dated the 12th of October the same year indicates that it was likely the museum director, Thor Kielland who purchased them from an auction on behalf of "the Friends"[4] (styremøte 12.10.28, Protokollbok Aa 0003.).

Museum records indicate that these three artworks all date from the 17th century Netherlands and were "apparently used as overdoors[5] in some private collector's room" (Kielland, 1929, p. 72). In the museum, the paintings mirrored their presumed decorative function, being placed in rooms featuring objects of a similar style or material to their motifs. The painting discussed in this thesis was exhibited in the Silver Room (Katalogperm Heb-L0063), while the other two were hung in the Porcelain Room (Kielland, 1929, p. 72).

Searching databases to find sales catalogues from H. Bukowskis in the relevant timeframe yielded one catalogue from the precise date at which the painting was allegedly bought. On the 13th and 14th of September, there was an auction selling the collection of the deceased wholesaler Hilmer Åberg (H. Bukowskis Konsthandel (Stockholm), 1928). Unfortunately, no painting or trio of paintings matching the descriptions of the *Still-life* and its companions

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[3] Norges Bank estimates that 500 kr i 1928 corresponds to approximately 19 000 kr today.

[4] "Vennene". This likely refers to Kunstindustrimuseets venner – friends of the art industrial museum, a member organization of supporters of the museum.

[5] Other terms for the same include abovedoor, sopraporte, dessus de port, supraport, dørstykke.

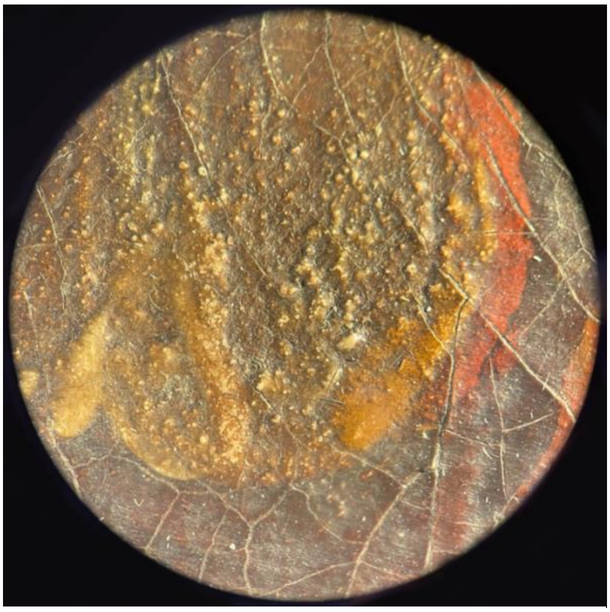

Fig. 10 Gritty surface caused by numerous protrusions. Note how the protrusions can only be found in the yellow area, not the red and brown. This image is a close-up of the bowl mount shown in fig. 2.

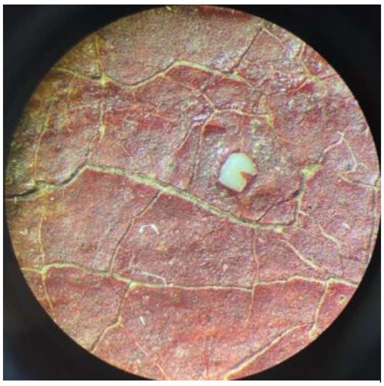

Fig. 11 Example of a single metal soap protrusion in the paint layer. Many such protrusions were found.

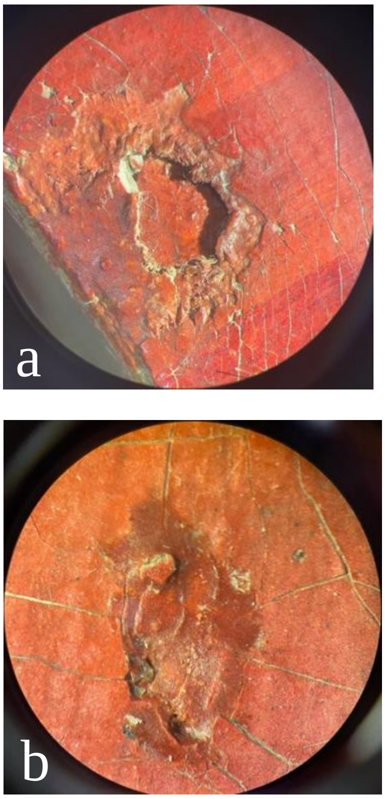

Fig. 12 Right. A: Example of an overpainted hole in the canvas.
B: Example of a mismatching retouch.

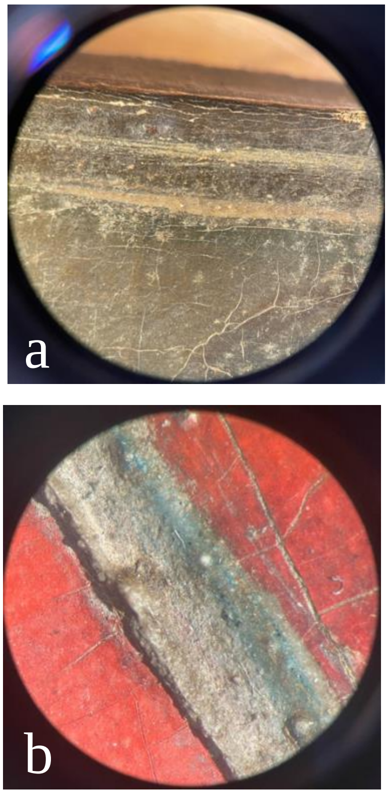

Fig. 13 Lines and ridges on the edges of the paint layer. A: Line along the top edge of the painting. B: The thicker line at the bottom of the painting.

Fig. 14 Color difference between the varnished and unvarnished areas.

could be found in this catalogue. This could mean that the date listed in the inventory protocol was not correct, or there might have been more auctions on the same date. Catalogues from surrounding dates were searched for to see if this could be the case, but none could be found. No further information could be acquired regarding the provenance of the paintings.

3.3 The companion pieces

All three still lives have identical measurements, but the companion pieces were both made of a single canvas piece, rather than two. The first companion painting depicts Greek statuettes on a table in front of three landscapes that appear to be inset in a wall (fig. 15). The second depicts a set of porcelain cups, bowls and vases standing on top of hexagonal objects. There are curtains in the background and the table on which the objects are standing is covered with a yellow tablecloth (fig. 16).

Fig. 15 Painting 10219B Photo: The National Museum

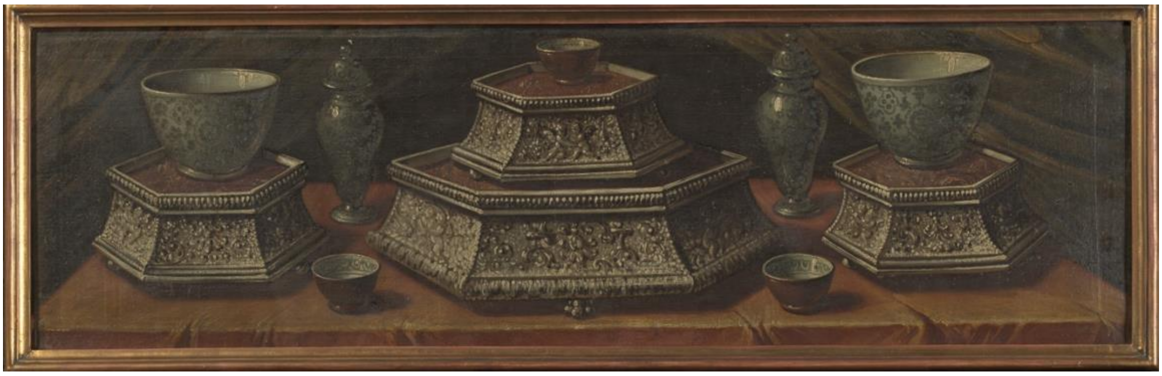

Fig. 16 Painting 10219C. Photo: The National Museum

3.4 Art historical context

In the 17th century, the Netherlands emerged as one of the richest countries in the world, thanks to their enormous success in international trade. As a result, still-lifes commemorating their accomplishments became popular (Kleiner, 2018, p. 739). Still-lifes could be divided into different types based on their contents, such as flower pieces, vanitas paintings, breakfast pieces, or pronkstillevens later in the century (Bergström, 1983, pp. 112-113).

The trio have many traits in common with the early breakfast pieces. Despite not being breakfast-scenes, the trio have many traits in common with the early breakfast pieces. They all depict a large number of objects, each observed and painted in a way where none are subordinate to the others (Bergström, 1956, pp. 98–99). Later on in the century, compositions became more harmonious, with clear groupings of objects, some of which were brought into more focus than others (Bergström, 1983, pp. 112-113).

This indicates that the paintings may date from the early 17th century, rather than the end of the century as suggested by museum records. Their identification as overdoors may well be correct still; their rough paint style, using clear brushstrokes shows that they were likely meant to be viewed from afar, and their unusual format makes it likely that they were made to fit within a specific space.

4 Literature review

The bulk of the research methodology for this thesis focused on a literature review of metal soaps: their origins, effects and how to tailor conservation treatments to mitigate the rate of metal soap formation. Consequently, an extensive review was also conducted on the varying properties of different types of gelling agents. As stated in the introduction, the focus was placed on polysaccharide gels, though, for reasons discussed in Chapter 6, Carbopol gel is also considered.

4.1 Metal soaps

The chemical process of metal soap formation[6]

Metal soaps are organic salts formed by the reaction of heavy metals with fatty acids in the binding medium of oil paints (Centeno & Mahon, 2009, pp. 13–14). This reaction, known as *saponification*, is a natural part of the aging process of oil paint.

Studies on model systems indicate that metal soap formation can start as early as one year after a painting's completion (Noble, 2019, p. 14). Free fatty acids in the binding medium form carboxylate groups, which then react with metal ions from the pigments, creating metal carboxylates (Hermans et al., 2019, pp. 50–51). The most important metals in these compounds are lead and zinc, but cases with copper, potassium, and calcium have also been observed (Cotte et al., 2017, p. 3; Martínez-Casado et al., 2019, p. 228). Lead and zinc are typically found in white pigments like lead white and zinc white. However, lead is also present in other colors, such as lead tin yellow and red lead (Cotte et al., 2017, p. 8; Townsend et al., 2007, p. 27). Another source for lead in paintings is the use of lead driers (Cotte et al., 2017, pp. 10–20; Hermans et al., 2019, p. 48), a practice attested to by recipes from the Middle Ages to the late nineteenth century (Cotte et al., 2017, p. 10).

When metal carboxylates form, they stabilize the polymer network in the oil paint by creating additional crosslinking (Hermans et al., 2019, pp. 52–53), forming what is known as an ionomeric polymer network (Hermans et al., 2019, pp. 52–55). This can remain stable for a long time without progressing to metal soap formation. When metal soap formation is referred to as a positive thing for a painting, it refers to this stabilizing configuration.

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[6] The text in this section is a reworked and translated version of text previously written during an exam (Bråthen, 2023).

For the transition to the aggregate form, a significant fraction of ester bonds in the triacylglycerides in the oil polymer must undergo hydrolysis, releasing saturated fatty acids (Hermans et al., 2019, p. 55; Van Loon et al., 2010, p. 207). These free saturated fatty acids then react with metal carboxylates to form crystalline metal soaps. Once a metal soap nucleus forms, metal ions and free fatty acids are attracted to it, diffusing through the binding media and causing aggregation (Hermans et al., 2019, pp. 56–59). While the aggregate phase is here considered the final form of a metal soap, other phases, including liquid and various glass phases, have been identified (Martínez-Casado et al., 2019, p. 234).

Relevant effects of metal soaps [7]

Transparency

As lead soaps dissolve the layers of lead paint, the affected areas will grow darker (Noble et al., 2005, p. 497). This is because the dissolution of the layer makes it more transparent, and the colors underneath become more visible. If the color layer is a mix of lead and one or more other pigments, the color balance may be lost (Boon et al., 2007, p. 21).

Protrusions and craters

As mentioned in the introduction, small holes, approximately 100-200 µm with a white substance protruding was the first type of metal soap discovered (Boon et al., 2002, p. 401, 2007, p. 16; Noble et al., 2002, pp. 49–50; Noble, 2019, pp. 1–2, 5–6). The holes resembled small craters, with a raised lip indicating that the white material had pushed through the paint layer from below, causing it to crack open (Boon et al., 2002, pp. 402–403). This white substance has been found to be lead soap aggregates. The craters are visible to the naked eye, and where the aggregates have not pushed through, they create a rough surface texture. Accumulation of dirt in affected areas is also common (Boon et al., 2007, p. 21).

Crusts

A common effect of metal soap formation is for them to bloom on the painted surface, forming crusts. These are composed of metal soaps that have migrated through the paint layers without forming aggregates. Upon reaching the surface, they react with atmospheric materials and create highly insoluble crusts that are integrated into the original color layers

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[7] The text in this section contains a reworked and translated version of text previously written during an exam (Bråthen, 2023).

(Van Loon et al., 2011, p. 7). This makes them very hard to remove without damaging original material. The composition of the crust is related to the pigments found in the paint as well as to atmospheric pollutants the painting has been exposed to. For example, Rembrandt's *Homer* was found to have a complex composite salt crust, a lead-potassium-sulfate. This is formed from the deterioration of lead paint or drier and smalt[8] interacting with atmospheric sulfur pollution(Van Loon et al., 2011, pp. 5–6), whereas a Hans Memling altarpiece in Antwerp had a surface layer of calcium oxalates, but also containing calcium carbonate and calcium sulfate (Klaassen et al., 2019, pp. 263, 266, 269).

In contrast to transparency and craters, crusts are treatable. Depending on their composition and integration into the original layers, they may be mechanically removed, removed with a chelating agent or thinned using aqueous gels (Noble, 2019, p. 16; Sawicka et al., 2014, pp. 316, 323–329). There is also a case where using erasers was effective; whitish zinc deposits were removed from a Salvador Dalí painting using Stabilo vinyl erasers (Keune & Boevé-Jones, 2014, pp. 286, 290).

Most commonly, crusts are treated by removing or reducing the amount of old varnish imbibed in it, thus reducing the whitening effect, and then saturating it with a low molecular weight synthetic varnish to make it more transparent (Sawicka et al., 2014, p. 315; Van Loon et al., 2011, p. 7).

Factors affecting metal soap formation

There are three main factors affecting the rate of metal soap formation in a painting: temperature, humidity and solvents. These may be introduced to the artwork via conservation treatments, or via the environment (Noble, 2019, pp. 16–17). An increased temperature means that the atoms and molecules a substance is composed of move faster, have a higher collision speed and break apart more easily (Storbritannia Conservation Unit, 1992, p. 39), which increases the speed of all chemical reactions. The effect of humidity has been explained above; in short it is a catalyst for hydrolysis, which is a key step in the saponification process.

Solvents contribute to the formation of metal soaps through plasticizing the binding medium by swelling it, causing diffusion rates for metal ions to increase (Hermans et al., 2019, pp. 51–52). Hermans et al. suggested that the mechanism for metal ion migration within the binding medium was by "hopping" from one carboxylate group to the next (Hermans et

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[8] Smalt is a blue pigment made of cobalt potash (potassium) glass. Other potential sources for potassium include alum and contaminated earth pigments (Mühlethaler & Thissen, 1993, pp. 113–115; Van Loon et al., 2010, p. 207).

al., 2019, pp. 51–52). For this to occur, the different carboxylate groups need to come into close proximity, which means that the polymer segments must be mobile, which they become when plasticized. This can therefore increase the rate at which crystalline metal soap phases grow (Hermans et al., 2019, pp. 57–58).

In addition to these three, atmospheric pollutants play a part in crust formation, as described above. In the past, during the days of coal stove heating, paintings were more exposed to atmospheric pollutants like sulfuric dioxide than they are today (Noble, 2019, p. 14).

4.2 Gelling agents

A gel is a colloid, a substance in which a solid phase is evenly dispersed in a liquid phase. This causes the liquid phase to become viscous, and it may behave more like to a solid than to a liquid ("Gel," n.d.). The solid phase is the cause of this change, and is therefore the *gelling agent*.

Why use a gel?

When cleaning a painting with a free solvent and a cotton swab, the selected solvent is rolled onto the paint surface. The solvent swells or solubilizes the unwanted layers, allowing them to be removed (Chelazzi et al., 2018, p. 292). However, once the solvent is applied to the painted surface, it can penetrate porous substrates and affect not just unwanted materials on the surface, but also original materials within the structure. This can have negative consequences in terms of swelling or leaching of original materials (Chelazzi et al., 2018, p. 292).

When using a gel, the solvent is trapped within the gel matrix. This reduces the solvent diffusion rate into the varnish and paint layers, which limits solvent action on the original structure (Burg & Seymour, 2022b, p. 27). This reduces the risk of swelling of original layers, while also minimizing solvent use. In addition to reducing diffusion rate, gelling also reduces the evaporation rate of a solvent. Because of this, gelling may also allow for the use of less aggressive solvents, compensated for with a longer contact period on the surface (Maranesi, 2017, p. 130).

The greatest concern when using gels is the residue question. All gels will leave some form of residue, whether it be from the gelling component or from non-volatile additives to the gel. These must be cleared from the painted surface (Burg & Seymour, 2022a, pp. 40, 56, 65). The specifics of residue clearing will be discussed in relation to each gel discussed below.

Weak and strong physical gels

Apart from Carbopol®, the chosen gels for this project can be divided in two categories – Weak and strong physical gels. Weak physical gels can only form viscous pastes, due to the formation of molecules within the gel structure – they lack the double helix structure of strong physical gels and only form weak hydrogen bonds (Giraud et al., 2021, p. 74). These gels will always require clearing after use to remove residues from the paint surface. Xanthan, cellulose ethers such as Klucel® G and acrylic gels fall into this category (Giraud et al., 2021, p. 74). An advantage of these gels is that they are easily prepared by mixing the gel powder into the liquid phase. When in use, they may also be agitated with a brush on the paint surface, to promote better contact with the active ingredient (Hinde, 2013, pp. 35–36).

Strong physical gels form semi-rigid peelable films. As they have double-helix coil structures, they will form ordered, rigid 3-dimensional matrices. They are highly water-retentive and offer even greater control over water absorption into the paint surface than weak physical gels, and this is a property that can be modified. If the substrate is highly absorbent, a higher concentration of gel may be used to reduce water absorption into the material (Barbisan, 2018, p. 152). At the same time, a higher concentration leads to less adherence to the surface, but this can be counteracted with weights (Barbisan, 2018, p. 152). The gel can be made into thicker or thinner sheets.

Weak physical gels often leave significant residues, necessitating mechanical removal followed by a rinsing solution. This issue also pertains to strong physical gels, though there are suggestions that clear water gels might suffice for them (Sánchez-Ledesma et al., 2013, p. 189; Volk & van den Berg, 2014, pp. 392–393), and that some strong physical gels may not leave residue (Kanth et al., 2018, p. 455; Maheux, 2015, p. 79).

Both strong physical gels discussed below require heating to prepare, which makes them slightly more complex to make than the weak physical gels. They are mixed with water, heated up, and during the cooldown[9] process active ingredients are mixed in.

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[9] second cooldown in the case of agar.

Hydroxypropylcellulose (HPC)

Hydroxypropylcellulose (HPC) (henceforth be referred to by the common brand name Klucel® G) is a cellulose ether, a polysaccharide derived from cellulose. It is soluble in water below 38°C and many polar solvents, but is insoluble in water above 45°C (Graaff, 1981, p. 81/14/9-1; Kremer Pigmente, n.d.-a). It has found great use in conservation as an adhesive, mixed with non-aqueous solvents for surfaces that are water sensitive (Steger et al., 2022, p. 2). It is a weak physical gel, which means that it cannot form a rigid gel and will remain a viscous paste.

In addition to being used in consolidation, Klucel® G has found some use in cleaning. Since 1997, the Dutch conservation institute Stichting Restauratie Atelier Limburg (SRAL) has been developing a tissue gel cleaning technique which utilizes Evolon® CR non-woven tissue impregnated with Klucel® G (Fife, 2011, p. 2). Their reasoning for choosing Klucel® G is that it is chemically inert with regards to the original paint surface, and most importantly the material retains its solubility behavior over time (Fife, 2011, p. 3). Like other non-rigid gels, Klucel® G does leave residues on the paint surface (Casini et al., 2023, p. 2169), and over time those residues may yellow (Fife, 2011, p. 3).

In 2022, the Oddy test performed on various cellulose ethers including Klucel® G (Steger et al., 2022). The results were that Klucel® G produced in 2017 produced no corrosion on any metal coupons, but Klucel® G from 2021 did produce lead acetate corrosion, which indicates the presence of acetic acid (Steger et al., 2022, p. 2). Upon request the producer did confirm the use of acetic acid in the production process, and that the production capacity for Klucel® had been expanded in 2016, which may explain the difference in results (Steger et al., 2022, p. 9).

Xanthan

Xanthan is a polysaccharide polymer derived from a bacterium, fermented from a sugar source (Giraud et al., 2021, p. 75; Hinde, 2013, p. 35). The principal use of Xanthan is as a thickener and emulsifier in the food and cosmetics industries (Giraud et al., 2021, p. 75), but in recent times it has also found use in conservation as a carrier for water, water-solvent mixtures and emulsions (Hinde, 2013, p. 35). Like Klucel® G, Xanthan is a weak physical gel and so only forms a viscous paste (Giraud et al., 2021, p. 74). On a paint surface, it can be agitated with a brush to promote contact with the active ingredient, and it will still retain its gelled properties (Hinde, 2013, pp. 35–36).

Xanthan is also a very stable gel. It can be used and remains stable at all pH values, and it will not precipitate. At 2% (w/v) concentration it has a pH of around 6, and up to 50% (v/v) alcohols can be dissolved in the solution without the gel collapsing (Hinde, 2013, p. 36). It also tolerates high-salt conditions, which means it can be used on salty surface soils, unlike many cellulose ethers (Hinde, 2013, p. 36).

When working with Xanthan, it is important to note that the molecules are anionic, and therefore the gel is only compatible with anionic or non-ionic materials. This means that it is not compatible with enzymes, which are cationic, and it will be destroyed by oxidizing agents. Similarly to other non-rigid gels, Xanthan will leave residue on a surface and must be cleared after use (Giraud et al., 2021, p. 77). It can be cleared with water, but it has also been found to leave residue even after clearing (Casoli et al., 2014; Giraud et al., 2021, p. 75).

Carbopol®

In contrast to the other gels discussed, Carbopol® is a high molecular weight polyacrylic acid (Stavroudis, 2017, p. 209). It was the first “modern” gelling system introduced by Richard Wolbers in the 1980s, and while it since has become less popular, it remains a staple of solvent gels (Stavroudis, 2017, p. 209). Carbopol® forms non-rigid but highly viscous gels, meaning that they adhere well to the surface they are applied to and may even be used for treatment of vertical surfaces (Stavroudis, 2017, p. 210). It is important however, to never use Carbopol®-gels on porous surfaces, as the gel will penetrate the surface and be impossible to remove.

To enable Carbopol® to form gels with a solvent, it is bound to a base, with which it forms a skeletal structure that allows a solvent to be suspended around it. This is normally done using the cationic surfactant Ethomeen®, which comes in two forms; C-12 which is used for the formation of apolar systems, and C-25, which is used or the formation of polar systems (Burg & Seymour, 2022b, p. 31; Stavroudis, 2017, p. 210).

Carbopol®-Ethomeen®-gels leave significant residues on the surface and thus require a lot of rinsing. In contrast to the other gels discussed, it is paramount to rinse them with a solvent or solvent solution of a similar or slightly lower polarity than the solvent used in the gel. It cannot be overstated that a Carbopol®-Ethomeen®-gel must **never** be rinsed with water, as this will result in strong alkaline activity on the surface (Byrne, 1991, p. 8) due to the intermolecular bond between the polyacrylic acid resin and surfactant unzipping (Burg & Seymour, 2022b, p. 31).

Gellan

Gellan gum is a high molecular weight polysaccharide, produced by the fermentation of the bacterium Sphingomonas elodea (Giraud et al., 2021, p. 75; Kanth et al., 2018, p. 452). It comes in two main forms, high acyl and low acyl. The difference between the two is that in high acyl Gellan gum, there are acyl groups present, which lead to the gum forming soft, elastic, non-brittle gels (*Gellan Gum*, n.d.; Maheux, 2015, p. 70), whereas in low acyl Gellan gum, the acyl groups have been removed, which results in it forming firm, non-elastic brittle gels. The low acyl variant is the one most commonly used in conservation (Kanth et al., 2018, p. 453). To stabilize the structure, it is necessary to add 0.40 g/L calcium acetate (Casini et al., 2023, p. 2169; Kanth et al., 2018, p. 453).

The double helix structure of Gellan molecules means that it can form a strong, rigid gel with enough cohesive power to be a peelable film (Giraud et al., 2021, p. 74; Kanth et al., 2018, p. 455). This gives more control over the absorption of water and solvents into a paint surface than a non-rigid gel, as well as reducing the need for clearance afterward, as Gellan seems to not leave a residue (Kanth et al., 2018, p. 455; Maheux, 2015, p. 79). Gellan has a lower rate of syneresis than agar, and is therefore more effective in terms of water retention (Kanth et al., 2018, p. 453).

The highest workable concentration of Gellan seems to be 4% (w/v), as Kanth found in 2018 that Gellan at 5% (w/v) did not properly dissolve and left residue on the surface (Kanth et al., 2018, p. 456). The same rigidity that makes Gellan desirable may also render it unable to properly clean textured surfaces (Casini et al., 2023, p. 2169), which can pose a problem for paintings conservation.

While Gellan gum has been widely used and written about in regards to paper conservation (Iannuccelli & Sotgiu, 2010; Leroux, 2016; Maheux, 2015; Mazzuca et al., 2014; Russick et al., 2018; Vallieres, 2013), it has not received the same attention within paintings conservation (Kanth et al., 2018; Maranesi, 2017), despite it being a very promising medium.

Agar

Agar is a polysaccharide consisting of a mixture of agarose and agaropectin (Kanth et al., 2018, p. 452). Unlike the other gels discussed, it is extracted from red algae, a living organism in the ocean. Therefore, using agar has a higher environmental cost than the other types of gel. Agarose can also be extracted and used in its pure form, but it is a prohibitively expensive material and thus only used in very limited amounts in art conservation. Regular agar is available at a lower cost, and has a slower rate of syneresis[10] than agarose and is thus preferable to agarose in a lot of artworks (Cremonesi, 2013, p. 180, 2016, p. 363)

Agar has a double helix structure, but upon heating the molecules will adopt a random coil-confirmation. When cooled, it again becomes a double helix, meaning that agar can form a strong rigid gel and a peelable film (Giraud et al., 2021, p. 74). In contrast to Gellan, agar films have the tendency to break apart (Kanth et al., 2018, p. 455), and testing has shown that it does leave some residue (Kanth et al., 2018, pp. 455–456). An interesting aspect of agar is that the coiling of the structure is reversible. Agar may be reheated and re-gelled a theoretically infinite amount of times in the absence of aggressive substances (Cremonesi, 2016, p. 363; Giraud et al., 2021, p. 74).

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[10] Syneresis: The extraction or expulsion of liquid from a gel, in this case the extraction of water from the gel into the painting.

5 Results and discussion of analyses and examination

5.1 Imaging techniques

Raking light

The effectiveness of raking light photography was limited due to the size of the painting. In addition, there was not enough room to have adequate distance between the light source and the painting, which meant that when lit from the left, the entire canvas could not be properly illuminated (Frey et al., 2017, pp. 116–117). Given these practical difficulties, raking light photography was performed from above. The results did not adequately capture the surface topography. It did show the deformations in the canvas resulting from poor tensioning and contact with the strainer (fig. 17). If present, raking light can also sometimes show incisions from transfers, but nothing like this was visible in the raking light image.

Fig. 17 Raking light image. Canvas deformations can be seen, especially strainer marks. A larger version can be found in fig. X, p. X.

Reflected IR photography

Reflected infrared photography showed no carbon-based underdrawings (fig. 18). There may not have been an underdrawing or it could have been drawn in a different medium. The color of the ground layer may also have played a role, as infrared light reflects better from white grounds (Bailey et al., 2022). The ground layer in this painting will be

Fig. 18 Reflected infrared photograph. A larger version can be found in fig. X, p. X.

discussed further in *5.2, Optical microscopy* and *SEM-EDX*, but it was likely white or light brown. Another possibility is that in the near infrared spectrum in which the photos were taken (700-1100 nm) the pigments did not become transparent enough to reflect through the paint layers.

FCIR

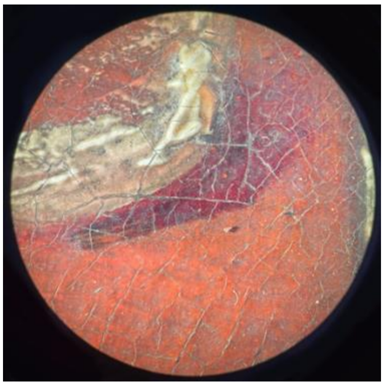


Fig. 19 The red in normal light. No FCIR close-up images were available.

False color infrared color correction was a very useful tool for examining the painting (fig. 20). It identified the use of two different types of red – a red that turned orange (fig. 19), used for a deep red color in shadows and folds, in addition to the main red which then appeared yellow.

In addition, FCIR showed the presence of a blue pigment, identified from it turning red in the image. Prior to doing FCIR, the presence of blue had gone undetected as the color itself was severely discolored and looked gray when viewed normally (Hayem-Ghez et al., 2015, p. 941). These discoveries provided areas of interest for further pigment analysis using pXRF (Casanova-González et al., 2020, p. 3). It also highlighted the artist’s painting technique. Several white highlights, especially on the ewer, had a red tint to them, illustrating that the artist very likely mixed blue with the white to create the stark white of the highlights.

Fig. 20 False color infrared image. A larger version of this image can be found in fig. X, p. X.

UVF

Before cleaning, UVF photography showed a varnish that fluoresced with a clear green tint, which is an indication of a natural resin varnish such as mastic or dammar (Measday et al., 2017). As fluorescence intensifies with the age of the film, it is likely that it is an older varnish (MacBeth & Breare, 2020, p. 307). Another noteworthy factor is the uneven distribution of the varnish, particularly visible in the upper half of the painting (fig. 23).

Fig. 21 Close-up of white fluorescence around retouches.

The difference in fluorescence could be an indication of an unevenly applied varnish, with the stronger fluorescence being a thicker layer. UVF also made overpaints appear dark, and around many of them, the varnish fluoresced white (fig. 21). This may be an indication of hide glue (Measday et al., 2017), and its presence around the damages made it likely that this showed old consolidation measures.

Fig. 22 Close-up of the UVF photograph, showing evidence of water damage.

In chapter 3, water damage on the reverse was observed, but no water damage was visible on the front. However, when viewed under UV light, stains were found in the corresponding corner, showing evidence of water damage in the upper left-hand side (fig. 22). This indicated that the water damage had indeed seeped through to the front of the painting.

Fig. 23. Photograph showing ultraviolet fluorescence. Notice the uneven varnish layers in the upper half of the painting. A larger version of this photo can be found in fig. 48 (p. 84).

X-ray

X-ray imaging offered a very clear view of the craquelure patterns in the paint layers. Most of the surface was covered in textural age cracks. Using Spike Bucklow’s system for craquelure description, the craquelure found on the *Still-life* can be described as giving a general impression of being random and square, with small islands of paint. The lines were jagged and the direction was straight with an overall horizontal direction, and there was mainly a connected network with a uniform crack width (Bucklow, 1997, p. 131; Bucklow et al., 2020, p. 298). This type of craquelure formation is typical for Dutch 17th century paintings on canvas (Bucklow, 1997, p. 136).

In addition to the age cracks, there were cracks following physical phenomena, which is a phenomenon Bucklow refers to as Euclidian cracks (Bucklow et al., 2020, pp. 296–297). These could be divided into “integral cracks” associated with the auxiliary support, and “extraneous cracks” related to accidents that have happened to the painting. The most noticeable integral cracks were those following the edge of the strainer. This is a very common feature of canvas paintings, and is caused by a combination of fluctuations in relative humidity (RH) and temperature, and the canvas simply bending against the strainer edge (Michalski, 1991, p. 235). As the strainer had no raised lip, there would have been nothing to prevent this action. As for extraneous cracks, a circular “whorl” type pattern was found in the center of the ewer, indicating an incident of mechanical damage to that location.

The x-ray also highlighted multiple areas of paint loss. The losses were generally found close to the edges of the canvas, and were mainly related to mechanical damage, such as canvas tears or folds, as discussed in chapter 2. There was minor paint loss connected to the strainer-related cracks.

A diagonal line that appeared to be a pentimento was visible behind the candlestick. This was likely intended to be a curtain or similar falling across the background on the left side of the painting. (fig. 24). No other compositional changes could be found.

Fig. 24 X-ray radiograph of the painting. The diagonal line is noted with an arrow. A larger version of this image can be found in fig. 53 (p. 86).

5.2 Examination methods and analytical techniques

Optical Microscopy

When the paint surface was examined with a stereomicroscope, a variety of deposits could be observed on the paint surface. The presence of droplets of an unknown resin and general surface dirt was noted all over, with higher concentrations in more textured areas. Along the edges of the varnish layer, strips and ridges of what appeared to be deposited material were observed. In the microscope, this material appeared to be thin ridges of paint (fig. 13). Additionally, in the bottom right-hand corner, a deposit was found outside of the varnished area (fig. 26c). The paint surface also appeared to have a layer of crust. Initially it was believed that this crust was part of the paint layer, for example as a metal soap crust or a crust of dirt, but its clean removal by help of acetone indicated that it instead was part of the degraded state of the varnish layer (fig. 26a-b).

The patch on the reverse was found to be very dirty, stiff and somewhat loose. When the edges were lifted, a lot of dirt was observed underneath, adhering to the adhesive on the patch (fig. 23). This was of particular concern as glues adhere poorly to dirty surfaces, meaning that the patch was likely to be unstable (Burg & Seymour, 2022a, p. 14). Corresponding to the patch, from the front, the tear was dirty and not esthetically pleasing, as the fill had partly fallen off and the retouch was not level with the surrounding paint (fig. 7d).


Fig. 25 The patch on the reverse, showing the presence of dirt on the patch adhesive.

During examination of the cross-section (fig. 27), the layers of ground and paint could be observed. Five different layers were identified, as well as what appeared to be an isolation layer, which is an unpigmented layer of binder separating the preparation layers from the paint layers (Stols-Witlox, 2014, pp. 73-74). Layers 1-3 appeared to be below the isolation layer, and layers 4 and 5 were above it. The center of the cross-section was a white protrusion, where specks of yellow could be observed, indicating that it had pushed through the yellow layer to the surface of the painting. The bottom three layers were the ground; an unpigmented layer of filler material (1), a pigmented layer of white with what appeared to be blue specks (2), and a semi-translucent light brown layer (3), likely an imprimatura (Stols-Witlox, 2014, pp. 74–75). The paint layers were a dark yellow layer (4), followed by a bright yellow layer (5).

When viewed under UV light (fig. 28), the ground layers appeared white, whereas the paint layers appeared orange. These results are difficult to interpret. According to Measday et. al., orpiment fluoresces light yellow in UV light, whereas lead white may fluoresce a dull orange (Measday et al., 2017). On the other hand, Carden suggests that lead white fluoresces “rose-white or bluish white to white”(Carden, 1991, p. 27).This shows the unreliability of UV to conclusively identify pigments and highlights the importance of doing further testing to ascertain their elemental composition.

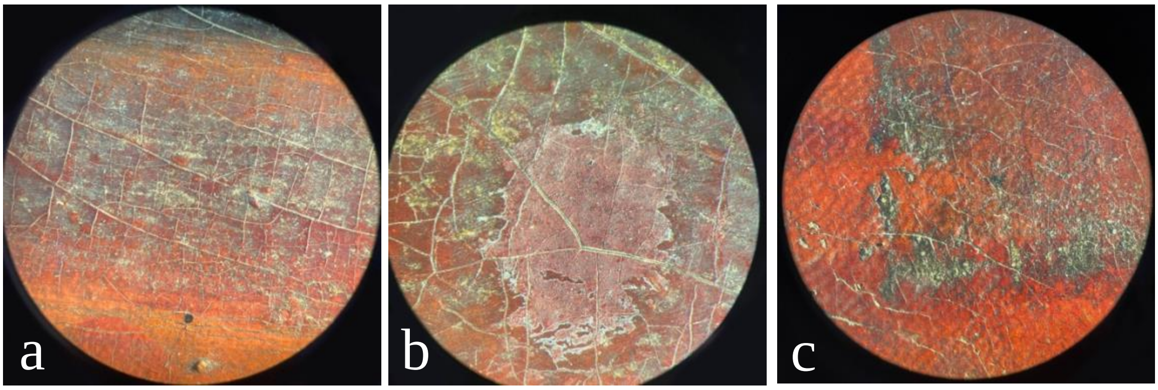


Fig. 26 Surface deposits found in the painting. Image A shows a layer of crust. B shows a similar crust removed with acetone and C shows surface deposits in the lower right corner of the painting.

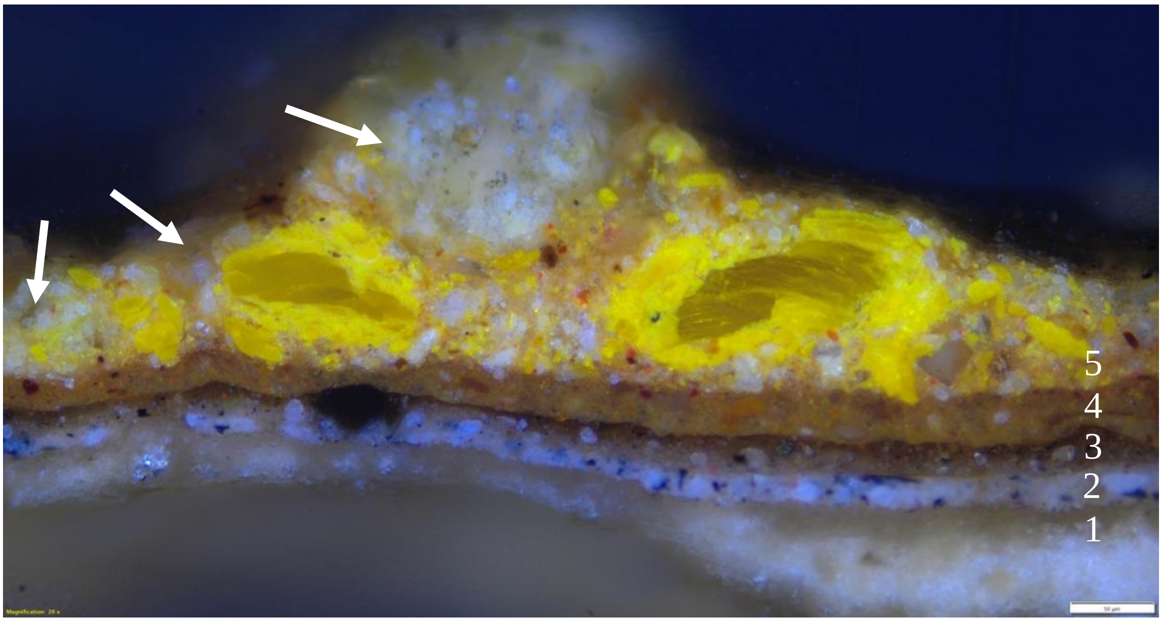
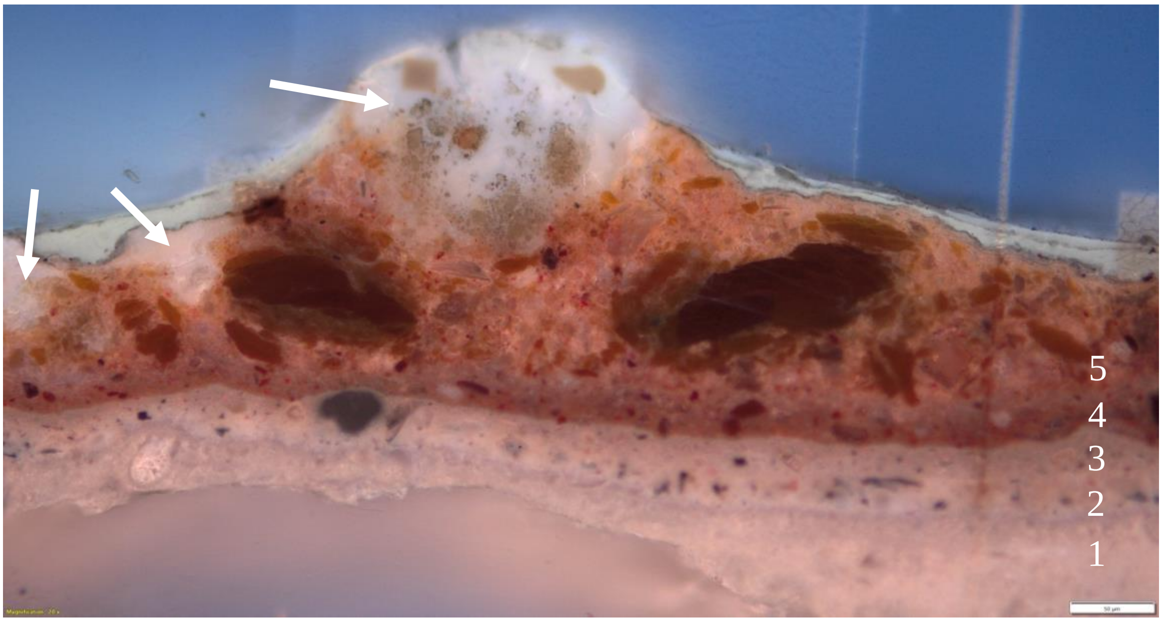


Fig. 27 Micrograph of the cross section. The numbers show the different paint layers, and the arrows point to the three noted protrusions.

Fig. 28 Micrograph of the cross section in UV light. The numbers show the different paint layers, and the arrows point to the three noted protrusions.



The two were clearly separated by a hard line that corresponded to the presumed isolation layer. The protrusion was white, and two smaller potential protrusions could be seen on the left-hand side of the major one (fig. 25, 26, arrows). UV also provided a clear view of the varnish (fig. 29). A minimum of two layers, separated by a layer of dirt could be clearly distinguished. The crust noted in fig. 26a was likely a part of the soil layer between the two varnish layers, as seen in the cross-section. A layer of what appeared to be dirt could also be observed beneath the varnish.

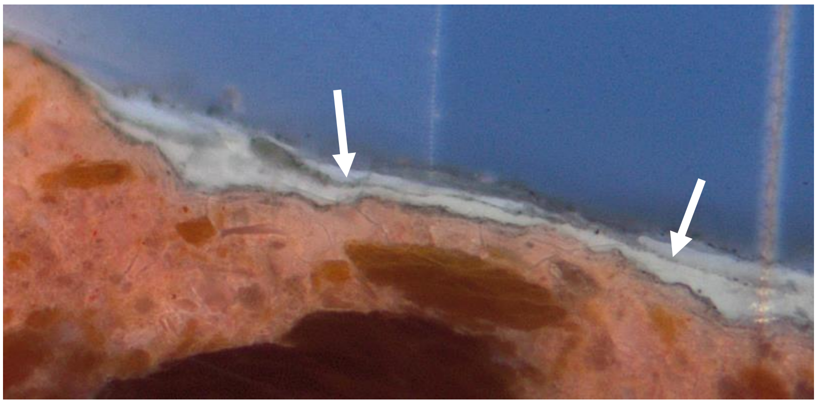


Fig. 29 Macro of the varnish layers, showing the two different varnish layers with a dirt layer between, marked with arrows. What appears to be dirt can also be observed underneath the varnish layers.

Thread density measurements

The thread count was measured in 11 spots across the canvas, 8 in canvas A and 3 in canvas B. The complete measurements and measurement spots can be found in table 7, but the average results are summarized in table 1. Measuring thread density also showed that the canvas was woven using a plain weave (fig. 30).

Table 1 Average thread densities (See table 7 for complete measurements)

	Canvas A	**Canvas B**
Vertical	24.38 threads/ cm	26.67 threads/ cm
Horizontal	24.50 threads/ cm	24.00 threads/ cm

Given the alleged time period of 1670-1699, this thread density was found to be unusually high. It was compared to other 17th century paintings from the collection of the Centraal Museum in Utrecht (Franken, 2017), Rembrandt and Vermeer’s canvases which have been extensively documented (Johnson, 2017; Wetering, 1997, pp. 98–99), French 17th century canvases (de Carbonnel, 1980, pp. 13–15) and a few from Caravaggio (Vodret, 2016, p. 23). All of these show a significantly lower thread count, but the Centraal Museum collection shows a trend of the thread-count going down throughout the century. This could support the suggestion that the painting may be older than first believed, possibly from the first half of the 17th century.

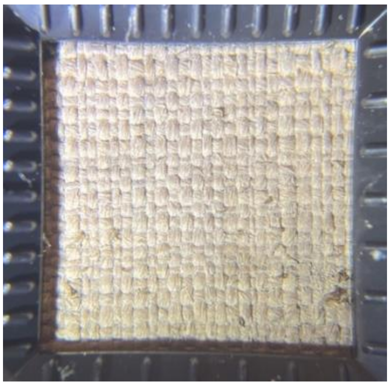


Fig. 30 An example of a thread measurement. The square measured 1 x 1 cm. The canvas weave is clearly visible, showing a plain weave.

pXRF

pXRF analysis was instrumental in determining the pigment composition of the painting. It helped identify many of the pigments present. All the spectra are located in appendix 1 (p. 107). The lowest atomic number elements cannot be detected by XRF, and it is dependent on the detector used and instrument setup how low an instrument can go. Elements in organic compounds – carbon (C), nitrogen (N) and oxygen (O) cannot be detected (Bezur et al., 2020, p. 155), and other low number elements common in pigments, such as sulfur (S), phosphorus (P), aluminum (Al) and magnesium (Ma) may or may not be detectable (Bezur et al., 2020, p. 58). In relation to this, it was found that all white, grey or black areas mainly showed lead (1, 2, 4, 6, 7, 11). This suggests that the black likely has an organic origin, such as a charcoal black.

All four red spectra (5, 8, 9, 10) contained mercury (Hg), indicating that the main red pigment used was vermillion (mercury sulfide, HgS). Sulfur only registered in three of the spectra (5, 9, 10), but the last one showed the same or a similar peak, though unidentified. In the dark red spectra, there was noticeably less mercury, and more calcium and iron. This is likely a different red pigment, perhaps an iron oxide or similar.

The two spectra taken from blue décor (3, 12) showed arsenic (As), potassium (K), cobalt (Co), nickel (Ni) and silicon (Si). These are all elements found in the pigment smalt, and especially arsenic and nickel can be used to confirm the pigment as smalt over other cobalt-containing compounds, as they are common impurities in the pigment (Mühlethaler & Thissen, 1993, p. 122).

The spectra taken from the mounted bowl on the far right (13) showed arsenic. As the arsenic peaks largely overlapped with lead peaks (Bezur et al., 2020, p. 153), this information was initially discarded. However, when viewed in conjunction with the SEM-EDX results below, arsenic is shown to be a part of the pigment orpiment, the main pigment used on the mount.

In all spectra taken, a background of lead (Pb), calcium (Ca), iron (Fe) and nickel was identified. This could be an indication of their presence in the lower layers of the painting, in the ground layer, an imprimatura or an underpainting. Based on the observations from the micrograph (fig. 27), calcium was likely part of the ground layer (1), the lead was the white preparatory layer (2), and the iron could be from the light brown preparatory level. If the blue specks in layer 2 were smalt, the nickel could be a pigment impurity. However, no other elements related to smalt were registered in any spectra outside of ones featuring blue décor. This made it unlikely, but there was a possibility of there simply not being enough to pass the detection limit (Bezur et al., 2020, p. 147).

All spectra also show traces of copper (Cu), but the reference spectrum taken using ethafoam (14) [11] as the target also showed copper, meaning that the copper likely originated in the spectrometer itself.

SEM-EDX

The main purpose of performing SEM-EDX was to identify the protrusions in the painting. It was also helpful in analyzing the elemental composition of the paint layers in the sample, as well as discovering and analyzing a crust on the surface. Five electron images were taken. All SEM-EDX images can be found in appendix 2 (p. 115). Images 1 and 3 show all layers of the cross-section and was used to analyze the elemental composition of each layer, and image 3 is also used to identify the protrusion. Image 2 is a closeup of what was found to be a crust and was used to identify the components of said crust.

In the elemental maps created from images 1 and 3, the ground layer (1) contained calcium, oxygen and carbon, which shows that it was made from chalk ($CaCO_3$), rather than gypsum ($CaSO_4$). This supports the origin of the painting as being northern European, as chalk was commonly used in the north, whereas gypsum was more common in the Mediterranean countries (Gettens & Mrose, 1954, p. 174). The first preparatory layer (2) mainly contained lead, but particles of a blue color were observed. One such particle was observed to contain oxygen, potassium, silicon and a slight amount of arsenic. This suggests that the blue used in the preparatory layer was also smalt, although

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[11] Ethafoam is a polyethylene foam with the chemical formula $(C_2H_4)_n$, meaning that it is composed only of elements that cannot be detected by XRF.

no cobalt was registered. It is also relevant to note that no nickel was registered, despite being a constant presence in the XRF spectra and a common impurity in smalt. This could indicate that the presence of nickel in those spectra was contamination or a misidentification. That neither nickel nor cobalt was registered could also simply mean that any amounts present were below the detection threshold of the EDX spectrometer.

The second preparatory layer, the imprimatura (3) contained carbon and lead. This composition did not allow for an explanation of the dark color in the micrograph. The lower paint layer (4) had less lead content than the layers above and below, but oxygen and iron were present in the larger particles, as well as calcium. This suggests a yellow earth pigment. The top layer (5) contained large particles of arsenic and sulfur, which indicated orpiment. There was also an even spread of lead particles in the layer, as well as a few seemingly aggregated spots (A, B, C, D).

Image 3 showed the suspected metal soap. The EDX maps showed that it primarily contained lead, oxygen and carbon. This was in line with metal soap composition as discussed in chapter 3, containing primarily lead carboxylates, and it confirmed the protrusion as a lead soap. The presence of chloride in the soap could also be noted, which implied that the lead soap aggregate likely also contained lead chlorocarbonate (phosgenite) (Boon et al., 2007, p. 20).

Lastly, image 2 shows what likely was a metal soap crust. Looking at the elemental maps, there was a clear layer of lead on top of the orpiment, in addition to what might be lead aggregates on the left-hand side. In addition to lead, the crust contained oxygen and appeared to contain calcium. Like the aggregate soap, the crust contained chlorine, indicating that being a component.

As mentioned in chapter 3, the area with the highest concentration of metal soap protrusions was the location of the sample. This enabled the study of the elemental composition of this area with the aim to uncover why this particular location was so heavily afflicted. As is clear from the distribution of gritty surface texture on the mount (fig. 10), the soaps follow the orpiment and there is a marked absence of soaps in areas where darker pigments are more prominent. This may indicate that something within the orpiment is the cause of the abundance of soaps in this area. Sulfur has been found as a component of surface crusts (Van Loon et al., 2019, p. 286), but no presence of sulfur was found in either the crust or the aggregate. No literature was found discussing the role of arsenic in metal soap formation. This is an area where comparison to the companion pieces would be encouraged, and further study is a possibility.

The Biuret test

The ground showed no color change when examined, which indicated that it did not contain proteins (table 8). The patch adhesive yielded an immediate reaction and turned purple, indicating the presence of protein. This made it highly likely that the adhesive was an animal glue, and therefore that it would be soluble in water.

Chemical spot tests

The samples showed no reaction to the distilled water or to the ethanol, but immediately saponified in contact with NaOH (table 9). This is indicative of an oil-based ground layer (Plahter, 2004, p. 165), and it is in line with the results of the Biuret test.

Conductivity and pH

Measuring the conductivity before cleaning will highlight the isotonic condition of the painting surface. This means that it shows the speed at which ions are transported through the paint. (Wolbers et al., 2020, p. 528). It is desirable to produce a cleaning solution that is relatively isotonic in relation to the painted surface (Burg & Seymour, 2022a, p. 37). This means that it is desirable for the concentration of the aqueous solution to be similar to the concentration of molecules in the paint surface. Hypertonic solutions (conductivities higher than 10× – 20× the isotonic condition of the surface) should be avoided because of substantial risk of swelling and softening of the paint (Soldano & van den Berg, 2014, p. 409; Wolbers et al., 2020, p. 528), and hypotonic solutions will draw out molecules from the surface in a process called leaching (Burg & Seymour, 2022a, p. 37).

Table 2 Average conductivity measurements (see Table 10 for complete measurements)

	Before	**After cleaning**
Front	7.16 µS/ cm	5 µS/ cm
Reverse	40.1 µS/ cm	10 µS/ cm

Overall, the measurements taken show a decrease in conductivity after cleaning, which when compared to measurements found in literature (Osmond & Carter, 2013, pp. 116–117), seems to be reasonable. However, it is likely that the results for conductivity both before and after testing are invalid. Wolbers alleged that that isotonicity for normal oil bound artist’s paint is usually in the range of 50-300 µS/ cm (Wolbers et al., 2020, p. 528). In comparison, the student’s results showed very low conductivity (1-36 µS/ cm), except one measurement of 144 µS/ cm (Table 10). This indicated either a fault in the methodology for testing or in the instrument itself. A possible source of error was that adding drops of water was needed to connect the two sensors on the Horiba LAQUAtwin meter, and adding too much water would risk diluting the measurements and thus introduce inaccuracy (Hughes, 2017, p. 65). Hughes recommended keeping it to a single drop. In a video explaining the process, Chris Stavroudis was able to use no water in his conductivity measurement (Stavroudis, 2013, time 4:45-5:00), but the student was unable to do the same and needed at least one drop to connect the sensors. Another source of error related to this could be the plugs themselves, as ideally they should be perfectly homogenous in terms of both height and diameter, and made with a biopsy punch to ensure this (Aguado et al., 2023, p. 4).

pH is the measurement of the concentration of hydrogen ions (H^+) present in water. When the amount of H^+ and OH^- are equal, the solution is considered neutral, and has a pH of 7. If there are more H^+ ions, the pH is lower than 7 and the solution is acidic. If there are more OH^- ions, the pH is higher than 7 and the solution is basic. The pH scale is logarithmic, which means for each number up or down, the increase in acidity or basicity is tenfold (Folch, 2011, p. 65).

Table 3 Average pH measurements (see Table 10 for complete measurements)

	Before	**After cleaning**
Front	6.05	6.29
Reverse	5.48	5.75

Canvas is a cellulosic material as it is made from plant material, and understanding the level of its acidity is important to assess the level of degradation within the canvas. As mentioned in the methodology, acid hydrolysis is one of the main methods by which cellulosic materials break down (Folch, 2011, p. 28). Cellulose consists of long polymer chains made up of glucose monomers, and when deteriorating, these chains are broken down into monomers. This process is called depolymerization (Folch, 2011, p. 85), and it results in increased brittleness in the canvas (Rizzo & Burnstock, 2003, p. 49).

Acidity can be introduced to the canvas both via endogenous means, such as its fiber or manufacture, or exogenous means, such as materials introduced during conservation treatments or the environment (Rizzo & Burnstock, 2003, p. 49). By measuring its pH, the level of acidity within the canvas can be monitored, and measures such as deacidification can be undertaken if the level is deemed too low (Folch, 2011, p. 66; Rizzo & Burnstock, 2003).

The results from measuring the pH in the painting showed that the canvas was in overall good condition, and the increase in pH after cleaning showed that the levels of acidity were reduced after cleaning. These results could potentially provide a good starting point for a regular monitoring of the canvas, allowing for the assessment of the canvas degradation over time.

In literature, discussions on measuring pH and conductivity are mostly related to modern, water sensitive oil paintings and acrylic paintings, and the tailoring of aqueous treatments to suit these paintings. In this regard, more importance is placed on conductivity. (Dillon et al., 2014, p. 52).

6 Testing of gelling agents

Cleaning is the part of a conservation treatment where exposure to solvents and humidity is at its highest. The condition report and results from the analyses showed that the painting was structurally in good condition. However, it was very dirty and had an aged and degraded varnish layer. Therefore, it was determined that cleaning was likely the most critical aspect of the treatment, and thus the one that needed the most focus. The gelling agents that were tested were the ones discussed in the literature review; Klucel® G, Xanthan, Gellan, Agar and Carbopol®. Initially, only the polysaccharide gels were to be used but due to the low effectiveness, the acrylic polymer Carbopol® was added to the test.

6.1 Aim

In line with the research question, the aim of testing the four different types of gels was to determine which gel was the most suitable for cleaning the painting without increasing the risk of further metal soap formation. As discussed in the literature review, the three main risk factors for metal soap formation are humidity, solvent exposure and a high temperature. Ideally, the chosen gel should have the following properties:

- Effective varnish removal
- High water retention, resulting in no moisture to the reverse – showing that the gel did not penetrate through the paint layers.
- Minimal clearing

6.2 Testing procedure

Prior to the testing of gels, a selection of free solvents was tested separately using cotton swabs in order to ascertain which solvents were suitable for varnish removal (table 11). The examinations of the varnish layer gave strong indications of a natural varnish resin, and due to this, polar solvents were tested. The common polar solvents isopropanol, ethanol and acetone were tested in the order they are listed; from the least polar to the most polar. They were all successful in dissolving and removing the varnish. However, isopropanol required significantly more mechanical action and thus was comparatively less effective than ethanol and acetone (table 11 for visual results, numerical evaluation in table 14).

Although acetone was more effective, ethanol was chosen to be the solvent for the gel testing, as all the gelling agents were compatible with it. This would allow for comparison between the different gelling agents. In addition, a less polar solvent could theoretically be compensated for with a longer exposure time, as explained in the literature review (Maranesi, 2017, p. 130).

The gels were prepared according to recipes and methods found in the literature[12]; Each gel was applied to the surface left for a specific amount of time. The gel was then removed, and the reverse of the canvas was checked to determine whether moisture had penetrated through or not. Afterwards, the gel was cleared with an appropriate solvent and the reverse was checked once more (table 12 for visual results, numerical evaluation in table 14).

Klucel® G

According to SRAL, the ideal concentration for this gel is 2%-4% (w/v) (Fife, 2011, p. 2). As it is compatible with alcohols, it was mixed directly into ethanol. Two concentrations of Klucel® G were tested, 3% (w/v) and 4% (w/v).

Xanthan

In order to gel, Xanthan needs to be mixed with water, but it can tolerate having up to 50% alcohol added to it. Therefore, the mixture tested was 50% ethanol in a 2% (w/v) solution with xanthan and distilled water. It was tested at 2% (w/v) and 3% (w/v) concentrations (Hinde, 2013, p. 36).

Agar

Agar was tested at 3% concentration. Like with Xanthan, the gel needs water to gel and can only tolerate a certain amount of solvent in the matrix. It was prepared according to the recipe found in the book *Varnish Removal* (Burg & Seymour, 2022b, p. 34) and contained 20% ethanol. The same recipe was also used to test agar gel with acetone.

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[12] For the specific recipes, see appendix 4.

Gellan

Gellan was tested using the same recipe and concentration as agar, with the addition of calcium acetate to stabilize the gel (Casini et al., 2023, p. 2169; Kanth et al., 2018, p. 453).

Carbopol® EZ2 Ethomeen® C25

Two different Carbopol® EZ2 -Ethomeen® C25-gels were tested. One mixed solely with acetone, and one mixed with 80% acetone and 20% benzyl alcohol. These gels were mixed according to a recipe provided during the cleaning course[13], but other mixing options may also be found in literature (Stavroudis, 2017, p. 212).

6.3 Results and discussion

Tests using Klucel® G at 3% (w/v) proved to create a very runny gel with a loose texture, and so it was not tested on the painting. At 4% (w/v) the gel had a much better, thicker working consistency. At the 1-minute mark it was ineffective, and after 3 minutes it had a medium effect. It did dissolve some varnish, but it left a lot of residues. Klucel® G was not tested for 5 minutes because the red and yellow pigments were shown to be sensitive to all aqueous media tested (table 12, table 14). Therefore, clearing the gel using distilled water could have caused major pigment loss. No loss was noted at 3 minutes because the Klucel® G did not penetrate all the way through the varnish layers.

The Xanthan gel was hardly able to dissolve the varnish, even after 5 minutes on the surface (Table 12). The working consistency of the 2% solution was very good, and the gelling agent is very compatible with many of the cleaning agents used in art conservation. It is certainly one to keep testing in the future, but in this case it did not work. The 3% solution did not gel properly in the allotted time, and thus was not tested on the painting.

Agar and Gellan both left wet spots before clearing, and neither had an appreciable effect on the varnish. This showed that neither had the desired water retention qualities. The reason for their poor performance may have been that the concentration of gelling agent was too low, making the gel wetter. When compared to the 4% agarose gel made for pH and conductivity testing, that gel seemed a lot firmer and drier than these two. Another possibility that concerns both Xanthan, Agar and Gellan was that the

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[13] For precise recipe, see appendix 4.

concentration of solvent in the mixture may have been too low to be effective. Gellan and Agar only contained 20% ethanol, and Xanthan 50%.

Agar was also tested with acetone, after all ethanol gels had been shown to be ineffective. This gel did not have any effect on the varnish layers either. Xanthan and Klucel® G were both incompatible with acetone, and therefore could not be tested.

Overall, the tested polysaccharide gels gave poor results. This indicated that the varnish layer was more cross-linked and thus more challenging to remove than initially assumed, but it could also be an indication of poor usage of the gels. Klucel® G has a history of being used with solvents for varnish removal at SRAL, as part of their tissue-gel cleaning strategy (Fife, 2011, 2017), and it had noticeably better results than the others. The others are more commonly used for aqueous cleaning. Cindy Scott investigated the possibility of using agar as a solvent gel, and found that on at least one surface tested, an acrylic emulsion on a plaster tile, acetone on cotton swab was effective, but an acetone-agar gel proved ineffective (Scott, 2012, p. 77). Overall, she found agar to be a very promising medium for solvent cleaning, but did acknowledge difficulties when using solvents like acetone; it had a low miscibility with agar unless mixed with ethanol before gelling, and the volatility of the solvent could cause rapid cooling of the gel during mixing, causing it to solidify before the solvent was fully mixed in (Scott, 2012, p. 80). Cremonesi and Casoli disagree with this, arguing that agar should only be used as a gelling agent for aqueous media. Polar solvents possess their own spectrum of actions, and if the ionization ability of water is added, while effectiveness may increase, the selectivity of the treatment will decrease (Cremonesi & Casoli, 2017, p. 27).

Gellan has found great use in paper conservation, and it has been used with some success in art conservation (Maranesi, 2017). A master thesis written by Jayme Vallieres investigated the possibility of using gellan-ethanol gel to remove adhesives from paper, and found success, which was the reason for making the attempt (Vallieres, 2013), in the hope that it might have an effect on varnish as well.

Richard Wolbers introduced chemical gels such as Carbopol® and Pemulen to the field of conservation, and in recent years has advocated for the use of xanthan, alongside Chris Stavroudis (Hinde, 2013, p. 35; Stavroudis, 2017, pp. 214–215; Wolbers, 2017, pp. 5–6). Despite their considerable academic authority on the topic, literature remains sparse on the topic of xanthan gum in paintings conservation, especially for use as a solvent gel.

Since the polysaccharide gels were ineffective on the varnish layer, other gel formulations were considered. Pemulen is an acrylic emulsion gel oft mentioned in literature (de Visser & Odlin, 2017; Hinde, 2013; Stavroudis, 2017), but it was not available to the student in the time available for the cleaning, and so was discarded. Instead, two Carbopol® EZ2-Ethomeen® C25-gels were tested. Carbopol® was chosen because of several factors; its presence in literature, the student had previous experience using it on complex varnishes and both Carbopol® EZ2 and Ethomeen® C25 were available for use in the student atelier.

The first Carbopol® EZ2 -Ethomeen® C25-gel was mixed with acetone as the solvent, and the second with 80% acetone and 20% benzyl alcohol. They were both cleared using cotton swabs with acetone. Both the tested gels were effective at dissolving the varnish. Neither gel left moisture marks on the reverse, but the clearing did. This meant that the clearing with acetone did penetrate through all the paint layers and exposed the original materials to solvents.

The acetone-gel was noted to leave some varnish residues even after 3 minutes, especially when used on larger areas (~10-25 cm^2). It was not desirable to increase surface time, as the gel was quite potent and could have a negative effect on the surface or cause pigment loss. Benzyl alcohol is a solvent (phenylmethanol) often added in small amounts to aid in the removal of aged or insoluble varnishes (Burg & Seymour, 2022b, p. 22-23). Therefore, a gel was made including this solvent to see to see if it could lower exposure time and possibly reduce the amount of varnish residues – and thereby reduce the amount of clearing needed to remove both the gel and the residues.

When testing the acetone benzyl alcohol gel, it was noted that after 2 minutes on the surface, it had similar results to what acetone had at 3 minutes, but if left for 2:30 or 3 minutes, there were hardly any varnish residues left. No pigment loss was noted during testing. Stavroudis’ comment on Carbopol® gels is that “perhaps the most significant feature of Carbopol-based solvent gels is that the utility of the final product is greater than the sum of the parts” (Stavroudis, 2017, p. 210). The carboxylate groups that form part of the gel polymer give the Carbopol gels a “mild, chelation-like ability”, and this, he asserts, is what added that “special magic” of these gels (Stavroudis, 2017, p. 213).

Disadvantages experienced when using these gels were that when left on the surface, they became stiffer and somewhat rubbery, which made them harder to remove and harder to clear. Their high polarity required the use of acetone for clearing, which increased the solvent exposure of original materials. In the end, it was decided to clean the painting using the acetone benzyl alcohol gel, as it had the greatest potential to remove the varnish effectively and to reduce clearing.

7 Treatment of the painting

The following chapter discusses the conservation treatment of the painting, and the concepts discussed previously in the thesis were put into practical use. So far, the main discussion has focused on metal soap formation during cleaning, but in this chapter, metal soap formation is further discussed in relation to the other treatments that were performed; consolidation, structural treatments including tear mending, replacing the strainer, flattening and strip lining, varnishing, infilling and visual reintegration. The following treatments are listed and discussed in the order they were performed.

7.1 Surface dirt removal tests

Prior to removing a varnish, it is imperative to remove any surface dirt on top of it, as the dirt will interfere with the solubility parameters of the underlying varnish and might make it more difficult to remove (Burg & Seymour, 2022a, p. 14). The strong and even fluorescence of the varnish layers in UV light gave an indication that there was little surface dirt present. It was suspected that the varnish may have been surface cleaned in the past. Small spot tests were attempted using deionized water and triammonium citrate 1% (TAC) on cotton swabs. These tests showed that the varnish surface had likely been cleaned in the past, as no or very little dirt pickup was noted. Therefore, the student proceeded with varnish removal.

7.2 Cleaning the reverse

The reverse of the canvas underwent preliminary cleaning using a fine brush and vacuum cleaner in order to remove dust and loose particles (Burg & Seymour, 2022a, p. 19). Fine cleaning using polyurethane sponges was not undertaken until after the consolidation and cleaning of the motif, to prevent any loose paint from falling off as a result of mechanical action on the reverse.

7.3 Varnish removal

As noted in the condition report, the paint surface was very discolored, due to both the discolored varnish, the general dirt accumulated on the surface and the visually disturbing lines of deposited material. As the selection of solvent and gelling agent has been thoroughly discussed in prior chapters, this section will instead concern the practical aspect of treatment, challenges encountered during this process, and an ethical discussion about the chosen method in regard to the research question.

When performing the varnish removal, the Carbopol® EZ2 -Ethomeen® C25-gel with acetone and benzyl alcohol was applied to the surface in squares of ca. 16 cm^2 (4x4 cm). The gel was left on the surface for 2:30 minutes and then removed with dry cotton swabs. A stereomicroscope was used for the remaining process of clearing the painting. The microscope was used to monitor surface changes, pigment loss or any paint flakes that could come loose during cleaning. When looking at the paint layers, a lot of varnish residues could be found, especially in more textured areas. These were loosened with a scalpel before being removed with a cotton swab and acetone. Using the microscope helped ensure that any paint flakes that came loose could be immediately consolidated and that all residues of both gel and varnish were removed.

Fig. 31 The painting halfway through varnish removal,

One of the advantages of using a gel was to reduce both the painting's and the conservator's exposure to solvents during the process. This goal was achieved, but as the varnish was very complex it did require both a stronger gel and more mechanical clearing afterwards than desired. However, leaving the gel on the surface for 2:30 minutes allowed it to dissolve the varnish to a great extent, and examination of the reverse showed that no solvent bound in gel form penetrated through the paint layers. This confirmed that the gel was effective. The solvent exposure required to dissolve the varnish without the gel would likely have been higher, in addition to the amount of mechanical action that would have been required on the surface to remove it.

7.4 Surface cleaning

After the successful removal of the varnish, what appeared to be a layer of surface dirt on the paint layers was found. Based on SEM-EDX analysis (image 2, discussed in chapter 5), it may also have been a metal soap crust or efflorescence. As discussed in the literature review, these crusts can often be very hard to remove, as the lead moving through the paint layers will have reacted with atmospheric pollutants and formed insoluble crusts (Klaassen et al., 2019, p. 266; Van Loon et al., 2011, p. 7).

To investigate the possibility of this being a crust, a variety of aqueous cleaning agents were tested on this layer. These are listed in the table below, along with some of their relevant properties (table 4). The tested cleaning agents were mainly chelators, as they are capable of sequestering certain metal ions from the film (Burg & Seymour, 2022a, p. 42). Providing that the metals in the crust are ones the chelator has an affinity for, a chelator could be used to dissolve a complex crust or efflorescence. An example of this use can be found in the article “An Investigation into the Viability of Removal of Lead Soap Efflorescence from Contemporary Oil Paintings” by Alysia Sawicka et al., where two oil paintings containing lead soap crusts were cleaned using the chelator ethylenediaminetetraacetic acid (EDTA), which sequesters lead ions (Sawicka et al., 2014, pp. 320–329). As EDTA was not available in the atelier in the given timeframe, it was not tested. However, it is important to note that the results from this were not wholly positive; in one of the case studies, the efflorescence came back, and it is suggested that such treatment may exacerbate the formation of efflorescence (Sawicka et al., 2014, pp. 329).

Before testing the cleaning agents on the surface, their pH and conductivity were tested. This was important due to the issue of isotonicity discussed in chapter 5. If a cleaning solution is relatively isotonic in relation to the paint surface, both in regards to its conductivity and its pH, it lessens the risk of undesirable consequences such as swelling or leaching (Burg & Seymour, 2022a, p. 37; Soldano & van den Berg, 2014, p. 409; Wolbers et al., 2020, p. 528). In this case, it was found that the conductivity measurements of the cleaning solutions were quite similar to the ones of the painted surface. This seemed to be quite positive, but it could also be a symptom of a faulty conductivity meter. Therefore, the results were treated with great skepticism.

The testing showed that the only effective cleaning agent was the TAC (Table 13, table 14). However, as is clearly shown in table 14, the effect extended to the red and yellow paint layers. A reason for this could be that the same affinity that makes chelators a possible solution for metal soap crusts also make them a risk to paint layers composed of metals, such as vermillion, orpiment, iron oxide and lead. However, *all* the tested cleaning agents caused pigment loss in the red vermillion and yellow orpiment paint layers, meaning that the sensitivity was not exclusive to chelators.

When the sensitivity was discovered, red paint outside of the varnished areas was also tested. The purpose was to determine whether the sensitivity was due to the varnish removal or a property of the paint layer. When it was found that the latter was the case, the question arose as to why the paint was sensitive. Water sensitivity has been found in paintings from the early 1900s to the present (Cooper et al., 2014, p. 296), but finding information on older oil paintings showing water sensitivity in the paint layers was challenging, and nothing similar to the sensitivity found in this painting was found.

Table 4 Tested cleaning solutions and their properties

Distilled water	**Ammonium hydroxide (NH_4OH)**	**Triton X-100 1%**	**Triammonium citrate (TAC) 1%**	**Citric acid, buffered with NaOH**
	Chelator p. 44	Non-ionic surfactant. p. 54	Chelator	Chelator
pH 7.02 Cond: 9 µS/ cm	pH 7.7 Cond: 34 µS/ cm	pH 3.78 Cond: 73 µS/ cm	pH 7.24 Cond: 13.90 µS/cm	pH 6.5 Cond: 3.16 µS/cm
Water soluble salts present. Not deionized. p. 34	May cause saponification in the oil layer. p. 44	Reduces the surface tension of water. p. 51	Affinity for iron (III) and copper (III). p. 42	Affinity for calcium, copper (II) and iron (III). p. 42
High surface tension, ineffective as a cleaning agent. p. 34	May cause color change in pigments sensitive to alkali solutions.	Aids in solubilizing dirt components p. 51	Can be hazardous to metal-containing pigments. p. 42	Can be hazardous to metal-containing pigments. p. 42

All information has been taken from Burg & Seymour, 2022a. Page numbers are listed in the table.

However, two possibilities stood out; The first was that the sensitivity of the paint layer was caused by the crust. Since metal soap related surface crusts are often integrated into the original paint layers, it may have caused chemical changes that have made the pigment sensitive. Another option was that the binding media used for the vermillion could have had an additive that caused the sensitivity, but this would have required further testing such as GC-MS[14], which was not available for this project. Since TAC was the only cleaning agent that had any effect on the potential crust layer, the other cleaning agents were discarded. TAC was tested both as a free agent and bound in Klucel® G. Binding it in Klucel® G helped concentrate the effect on the crust layer, but clearing the gel with distilled water still caused pigment loss.

It was decided that within the constraints of the project, the red and yellow paint layers could not be cleaned in an ethical and satisfactory manner, and the decision was made to leave these areas uncleaned.

The black and white parts of the painting were cleaned using TAC 1% bound in Klucel® G, taking care to avoid all red, and no pigment loss was noted in either of these areas. After the cleaning of this area, the line noted in x-ray (fig. 24) presumed during the investigation to be a pentimento became visible as a previously unnoticed color difference between the area to the left and right of this line became apparent (fig. 32). This meant that the painting had not undergone any compositional changes as it was made.

Removing the lines of deposited material was desirable as they were not original to the painting, did not reflect the original size of the painting and were visually disturbing. They were insoluble in all tested solvents as well as aqueous cleaning solutions and were instead either mechanically removed completely or reduced in visibility using a Tiranti 47 modelling tool. This tool was found to be blunt enough not to damage the paint layers, but still effective at removing the lines.

Fig. 32 Close-up of the newly uncovered color change in the background.

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[14] Gas chromatography/Mass spectrometry

7.5 Consolidation of paint layers

When choosing an adhesive for the consolidation of the paint layers, several factors had to be considered; the original materials that make up the painting, the compatibility of the adhesive to these materials, the optical and aging properties of the adhesive in relation to the environment in which the painting will be stored and/or displayed, re-treatability and the type of media failure present (Burg & Seymour, 2023, p. 51; Romano, 2022).

The three adhesives that were considered were Klucel® G, sturgeon glue and Lascaux 4176 Medium for Consolidation (MfC). Some of their properties are summarized in the below table for comparison (table 5). When comparing these, Klucel® G was discarded quickly, as the properties were not what was needed for local consolidation of oil paint. The desired qualities were low viscosity, as the paint layers were not very porous and even the cracks did not allow adhesives to penetrate. In relation to the research question, avoiding the use of unnecessary heat was desirable, so the choice was made to cover and weigh down the consolidated spot and leave it for the next day instead of using a heated spatula to dry it (Marriott et al., 2010, p. 35).

Using an adhesive of a higher pH value than what was measured on the paint surface and the canvas could help increasing the pH value around damages, lessening acid-induced degradation in these already exposed areas. A neutral or slightly above it pH would be ideal (Flock et al., 2023, p. 235).

As the consolidation took place concurrently to the cleaning, it was desired to use an adhesive that required little in the way of preparation and application. Ideally, only the adhesive itself, needles/tweezers and a brush. Using a heater, required for keeping sturgeon glue liquid would take up space, and having to either reheat or make a new batch daily or weekly would be both time consuming and wasteful when it had already been established that very little was going to be needed, since as noted in chapter 3, the paint layers for the most part adhered well. For these reasons, Lascaux 4176 MfC was chosen.

The one exception where a lot of paint loss was found was the tacking edges. Where the canvas had curled or folded, the paint had become powdery as a result. Due to the inaccessibility of these folds, it was not possible to consolidate the paint at this stage. Doing so would risk the canvas stiffening into a folded position. The consolidation of this area will be discussed again in *7.8 Strip lining*.

Table 5 Comparison of adhesive properties

Klucel® G	**Sturgeon glue**	**Lascaux 4176 MfC**
Soluble in water and alcohols (Soppa, 2022, pp. 1574–1575).	Soluble in water. Solvents can be added to the mix. Once dried, difficult to re-solubilize.	Can be thinned with water. Soluble in aromatic hydrocarbons, xylene, toluene, acetone and MEK.
pH ~ 7	pH 6.0 - 7.5	pH 8.5
Low tensile strength. More suitable for consolidating powdery paint than adhesion (Soppa, 2022, pp. 1574–1575).	Low surface tension, flows well beneath paint flakes.	Low viscosity, good penetration.
Prone to photochemical degradation.	If necessary, a 1:1 (v/v) ethanol/ distilled water mixture can be used to lower the surface tension. (Petukhova & Bonadies, 1993, pp. 23–26)	Good long-term stability.
Excess can be removed with water or alcohols.	Compatible with the materials of older oil painting.	Excess can be removed with saliva up to 24 hours after application (Marriott et al., 2010, p. 34).
All information gathered from Burg & Seymour, 2023 (p. 56-62) unless otherwise noted.		

7.6 Tear mending

Prior to tear mending, the patch from the reverse of the canvas was removed. As discussed in chapter 5, when studied in the microscope the patch was found to be stiff, restricting the movement of the surrounding canvas, there was a lot of dirt underneath it and the repair was not esthetically pleasing. Therefore, it was decided to remove the patch and repair the tear anew.

Fig. 33 The four tears in the painting are marked with the letters A-D, and the holes are marked with dots.

The Biuret test (discussed in chapter 5) had shown the adhesive to be protein-based, leading to a hypothesis of animal glue, which is soluble in water. Cotton swabs with distilled water[15] were carefully rolled over the patch surface, and a scalpel was used to loosen the now softened glue and patch from the canvas surface (fig. 37). The patch was easily removed, and moist cotton swabs were rolled across the surface to remove glue residues. Once dry, the surface was cleaned with a polyurethane sponge to remove any excess dirt.

The decision was made to perform *single-thread bonding repairs* to all the rifts, as this is the least invasive alternative (Flock et al., 2023, p. 235). The method has commonly been called the thread-by-thread tear mending method, or Heiber method, as it was pioneered by Winfried Heiber in the 1980s (Heiber, 2003, p. 35). He recommended using a mixture of 20% sturgeon glue in water and 10% wheat starch paste in water, mixed 1:1 (Heiber, 2003, p. 44; Heiber et al., 2020, p. 407), which has become a staple for tear mending. This adhesive was chosen for the repairs.

Table 6 Tear dimensions

	A – line	**B – line**	**C – T shape[16]**	**D – T shape**
Vertical	-	-	0,85 cm	0,65 cm
Horizontal	0,53 cm and 0,7 cm	1 cm	2,01 cm	1,22 cm

For tears A, B and D, many threads were able to meet, but very few overlapping threads were found. This meant that butt joints and butt joints with bridging threads were

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[15] Excess water had been blotted away with paper to reduce the amount of moisture.

[16] During the cleaning, a minor studio accident occurred, resulting in a small tear (tear C). Both the incident and the damage were immediately documented and reported to the project supervisor, Noëlle Streeton and National Museum conservator Thierry Ford.

the most common joints (fig. 34, 35). In the few cases where it was possible, overlapping joints with fiber intermingling were performed. In tear C, there were more overlapping threads, allowing for more mends with intermingling threads (fig. 36a-d).

A major challenge was the thread density of the canvas. As discussed in chapter 5, average thread density was 24.3 cm in the vertical direction and 24.5 cm in the horizontal direction in canvas A, which was where all tears were found. In the close-up images of each tear (fig. 33 – 38), it can be noticed how tightly woven the canvas fabric was. This allowed for very little space to move thread fibers around, and in cases where bridging threads were necessary, the bridging threads had to be split into fibers as they were thicker than the canvas threads.

The most complicated tear was D, where the patch had been (fig. 38a-b). The fibers were very degraded and tore easily, and there were many missing threads that could not be connected. This led to the decision to use modern linen threads as to bridge the gaps, by connecting these to existing threads and creating a weave to connect the two sides (Young, 2003, pp. 55–56). Several threads had to be fastened by lap bond to the canvas on one side, where the corresponding thread end was too degraded to use. The tight weave of the original canvas could not be replicated, so a slightly looser weave was made. (fig. 39a). Because of the patch, the area surrounding the tear was also degraded, which decreased he overall strength of the area (Young, 2003, pp. 55–56). This led to the decision to attach a patch in addition to the repair (fig. 39c). The patch was made from Hollytex, a nonwoven polyester textile (Heiber et al., 2020, p. 433). This textile was chosen because it is very thin, reducing patch bulk. Choosing a single layer of 25.4 µm thick BEVA® 371 film as the adhesive was done for the same reason, with the aim of lessening the chance of the patch telegraphing[17] on the motif. For the same reason, the edges of the Hollytex were feathered to create a smoother transition point between the patch and the canvas (Heiber et al., 2020, p. 439).

The 13 holes on the front and tacking edges were also patched using the same method as for tear D. Most of these holes were round, with no connecting threads or edges that could otherwise be mended.

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[17] Telegraphing: when the outline of the patch becomes visible on the front (Heiber et al., 2020, p. 439).

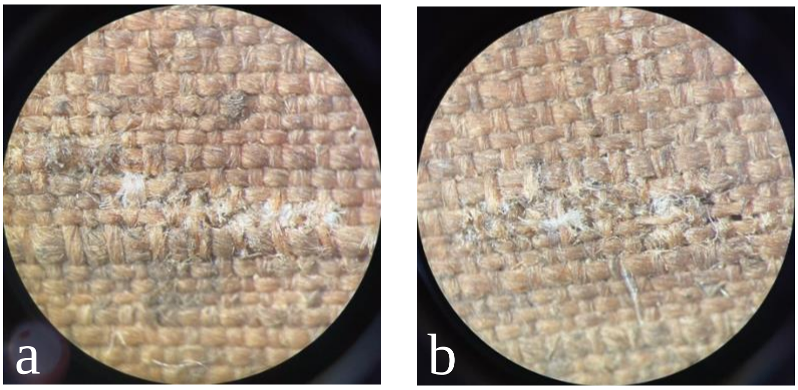

Fig. 34 Tear A after repair. A: the left side repaired. B: the right side repaired.

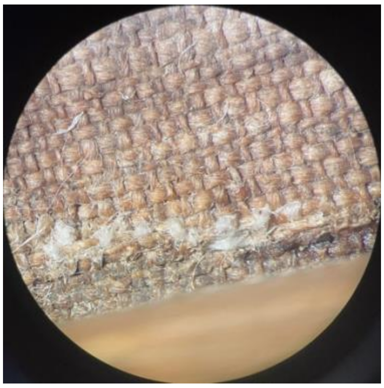

Fig. 35 Tear B after repair

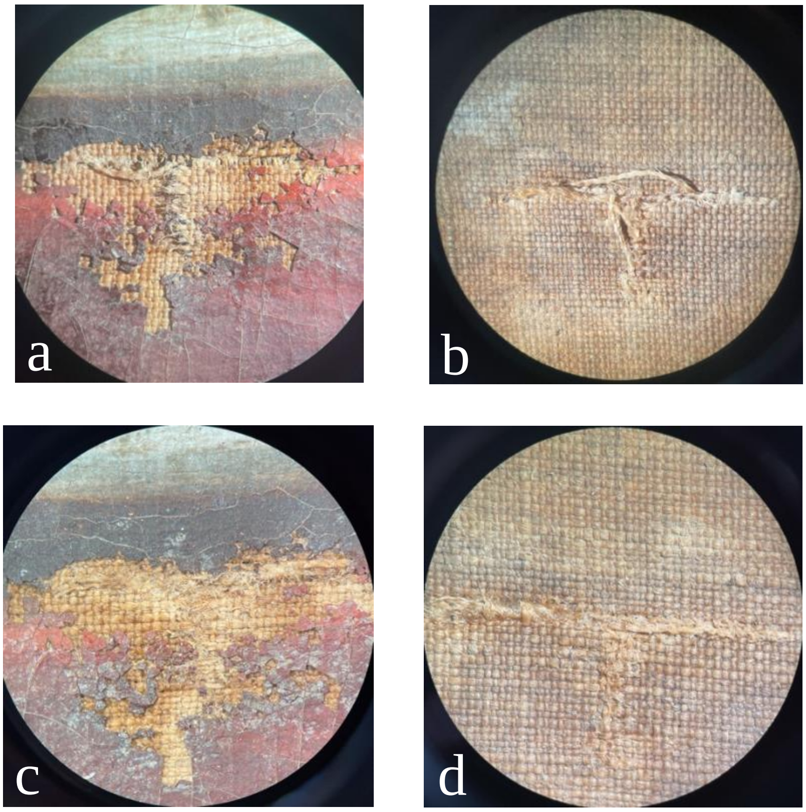

Fig. 36 Tear C before and after treatment. A-B: Before treatment. C-D: After repair.

Fig. 37 The patch during removal. Note the black glue and dirt.

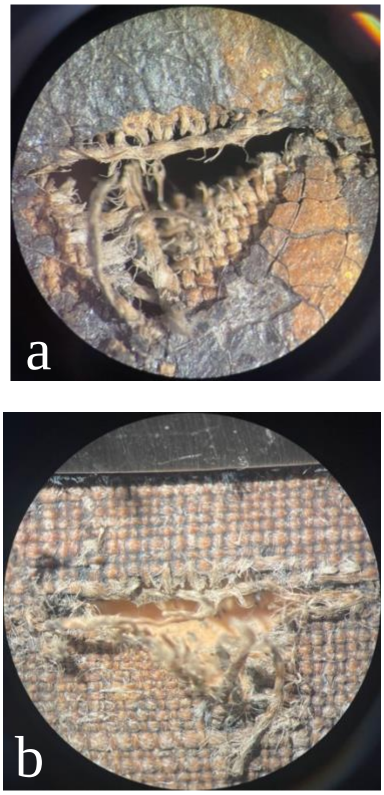

Fig. 38 Tear D, after the removal of patch and adhesive.

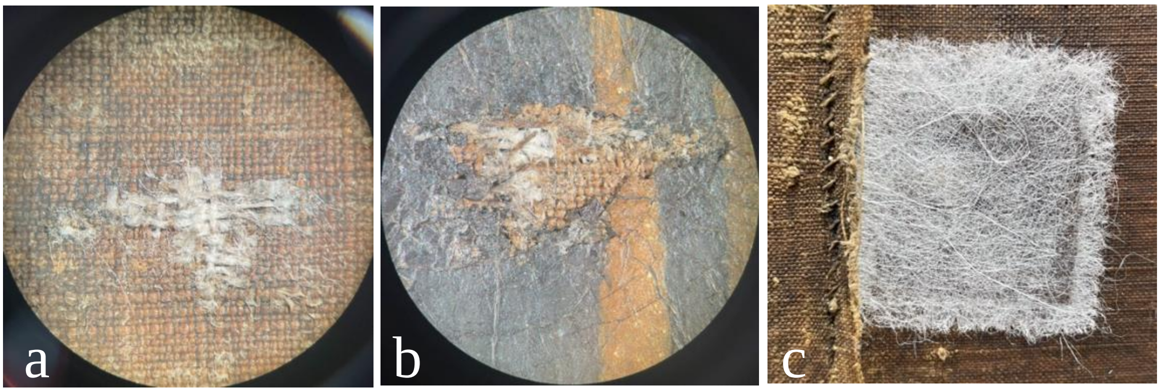

Fig. 39 Left: Tear D, after repairs. A: From the reverse. B: From the front. C: After patching

7.7 Removal from strainer preparation for strip lining

First, the painting was laid face down on a 5 mm thick plastazote foam mat. This was to protect the paint surface and impasto during the following treatments. As described in chapter 3, the paint layers covered the canvas all the way out to the edges. This greatly complicated the process of removing the strainer. The old tacks had been struck far into the canvas and strainer, meaning they had to be dug out. This posed a risk to the paint layers as most tools used in the process could cause damage to the surrounding canvas and paint layer. The only tool found to both fit in underneath the tack heads, as well as being solid enough to dislodge them was a scalpel.

Several measures were tested to ensure the safe and best removal of the tacks. One method was to insert the scalpel behind the canvas, but this also allowed for far less visibility and control over it than when inserted in front of the canvas. Additionally, if the scalpel slipped this could result in a tear, and for this reason, this option was discarded. Another solution was to use Melinex between the scalpel and the paint layer. This worked in cases where the tack was relatively loose or not struck deep, but for the majority of them, it was not possible to fit Melinex behind the tack. This method was partially successful, as some minor paint loss was recorded around some of the tack holes.

After the canvas had been removed from the strainer, the reverse was cleaned. With the paint layers secured by consolidation it could be more thoroughly cleaned using polyurethane sponges. The sponges were successful in their ability to remove the remaining dirt.

After this, the tacking edges were flattened. They were subjected to moisture treatment in the form of strips of blotting paper moistened using misted water to soften the bends so that the canvas could be folded out (Heiber et al., 2020, p. 427). The blotting paper was laid on the tacking edges under pressure for a short time period, before a heated spatula was used to press open the fold. Then, the canvas was weighed down using books over the course of two weeks while the lining canvas was prepared (Heiber et al., 2020, pp. 426–427).

7.8 Strip lining

As noted in chapter 3, the tacking edges were very degraded. There were holes caused by the oxidation of tacks, as well as missing pieces of canvas. Because the tacking edges were originally a part of the motif, the decision was made to not cause further damage and put more holes in these areas by using them as tacking edges. Therefore, it was decided to strip line the canvas as a secondary support.

Additionally, to reduce future paint loss on the tacking edges, it was decided to order a new stretcher that corresponded in size to the canvas size (140.7 cm x 41.8 cm) rather than to the previous sight-size of the motif (139 cm x 36.8 cm). This way, the canvas edges would no longer have to be folded and the strip lining could function as the new tacking edges. This would provide the option of increasing the size of the motif later, or the former tacking edges could be covered with the rabbet of a frame. This option was also discussed with custodians (conservator Thierry Ford and curator Cynthia Osiecki) for approval.

Fig. 40 The canvas edges covered with the 25% BEVA 371 hot sealing adhesive solution

A layer of 25% BEVA® 371 Hot Sealing Adhesive solution[18] was applied to the tacking edges of the canvas (fig. 40). This acted as a general consolidant of the area, ensuring that no more powdery paint would fall off (Bobak, 2003, p. 17). Bobak also used this adhesive layer as a size coat before strip lining, as he noted that sometimes, later varnishing had undermined the bond between original canvas and the strip lining (Bobak, 2003, p. 17).

The chosen lining adhesive was 63.5 µm thick BEVA® 371 film. It was chosen because it is a material that does not penetrate the substrate, instead adhering by nap bond to the surface of the canvas (Nicolaus, 1999, p. 128). BEVA® film is removable by use of acetone, which causes the film to swell. This makes it easily removable without leaving residues on the surface (Kremer Pigmente, n.d.-b). If this cannot be used, heat will soften the adhesive, allowing it to be removed (Berger, 1995, p. 27). During application, BEVA® film does not release harmful solvent vapors, making it a safe adhesive to use also for the conservator (Kremer Pigmente, n.d.-b).

The strips of film were 2.5 cm wide. This is wider than recommended by Bobak, who suggests that the adhesive should be applied no more than 1-1.5 cm onto the original canvas for paintings smaller than 1.3 x 1.3 m (Bobak, 2003, p. 17). However, due to the holes and missing sections it was decided to cover the turnover point with the film.

The canvas used was a polyester sailcloth (269 g/m^2) from Deffner & Johann. It has a high uniaxial stiffness, it is isotropic, resistant to degradation, stress relaxation and changes in relative humidity (RH) (Ackroyd, 2002, p. 5; Young & Jardine, 2012, p. 251). Since the chosen adhesive was a non-impregnating material, it was comparatively less

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[18] The recipe can be found in appendix 4.

stiff and therefore, using a stiffer lining fabric was preferable (Ackroyd, 2002, p. 5). A negative aspect of using polyester sailcloth is the visuals. The fabric is pure white and thus highly contrasting against the original aged canvas. This was an aspect the student chose not to prioritize.

During preparation of the strip lining, the fabric was cut into four pieces about 20 cm wide. The size was to enable stretching onto a temporary loom after the strip lining was completed. The edges of the lining canvas were feathered using a rotary cutter in order to provide a smooth transition to the original canvas, which helps reduce the visibility of the transition point (Bobak, 2003, p. 17). Two layers of BEVA® film was used during the lining. The first was adhered to the original canvas, and the second to the corresponding lining fabric.

The strip lining was performed using a Willard control unit and lining iron 6E. Berger recommended applying BEVA® film at temperatures between 55°C – 65°C, and warned that at temperatures higher than 65°C, the film would pass its glass transition temperature and become liquid, giving it aggressive tack but also allowing it to penetrate cracks in the fabric (Berger, 2000, pp. 94–95). However, heating the iron to 60°C proved inefficient, as the heat did not penetrate well enough through the layers of fabric and adhesive to heat them adequately. The temperature of the iron was set to 70°C, which when measured through the layers provided a temperature of around 61 – 63°C to the adhesive. Using this level of heat was overall undesirable, as heat is a known contributor to chemical reactions, including metal soap formation. On the other hand, it was a necessary treatment to perform due to the condition of the tacking edges.

Fig. 41 During the strip lining

After the strip lining was completed, the painting was stretched onto a temporary loom, on which it remained until after the varnishing. After this, it was stretched onto the new stretcher bars.

7.9 Infilling of paint losses

Fuster-López et al. tested a variety of traditional, commercial and synthetic formulations of fillers. They found that a traditional hide glue-chalk filler without additional additives was the best option as it was able to withstand a wide range of RH fluctuations (30-50%) (Fuster-López et al., 2008, pp. 184–185). A criterion they had for selecting fillers for testing was their ease of removal, using only water and thus avoiding the use of organic solvents (Fuster-López et al., 2008, pp. 184). Therefore, the selected filler for the painting was a traditional filler made from skin glue in distilled water mixed with champagne chalk ($CaCO_3$).

According to Fuster-López, a good filler should have a pigment volume concentration of approximately 65% (Fuster-López, 2020, p. 623). If the PVC is high (over 80%) the filler will be weak, extremely flexible and absorbent, and if the PVC is low the filler will have a high ultimate tensile strength and high stiffness (Fuster-López et al., 2008, p. 182). The filler was made using 13 g champagne chalk mixed with 7% rabbit skin glue[19] to create a 20 mL solution of fill with approximately 65% PVC. The fill was applied to the areas of loss using a small paint brush. Care was taken to ensure as little spill as possible over the edges of the loss. After the fill had dried, distilled water was applied to a cotton swab and excess was removed using blotting paper. This was then rolled over the fill to moisten it, after which a Tiranti 47 modelling tool was used to scrape the fill down and texture it to fit the surroundings. Not all the losses in the painting were filled. Losses that would be visible to the viewer when the painting is displayed, not covered by the rabbet of the frame were filled, whereas losses on the former tacking edges were left unfilled.

Whether to fill before applying any varnish or applying at least one isolation layer between the painting and fill is up to a conservator's preference and the needs of the painting (Burg & Seymour, 2022c, p. 28). In the case of this painting, it would likely have been beneficial to apply an isolation layer before filling, as this would have protected the paint layers better against the filler and water used to remove ghosting[20] (Fuster-López,

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[19] Fuster-López et. al did not specify the concentration of skin glue, so the concentration of skin glue used was the one suggested by Nicolaus (Nicolaus, 1999, p. 238).

[20] Ghosting refers to the white "halo" of excess filling material that often appears around a fill as excess material is removed.

2020, p. 622). Being careful to wipe away excess water from the cotton swabs and waiting until the filler was moist or dry before scraping helped mitigate this issue.

Fig. 42 The painting after cleaning, structural treatments and infilling

7.10 Varnishing

The painting had been varnished in the past and based on the time period in which it originated; it is a work intended to be varnished. The purpose of varnishing a painting is twofold. One is to improve the appearance of a painting by saturating the colors and increasing the gloss (Burg & Seymour, 2022c, p. 6). The other is to protect the paint surface against abrasions, electromagnetic radiation (UV), dirt and gaseous pollution (Matteini et al., 2016, pp. 209–210). The two synthetic varnishes Laropal A-81 and Regalrez 1094 were considered for the painting.

De Witte found that conservators in general prefer varnishes with a high refractive index (RI) (De Witte et al., 1981, p. 81/16/4-3-4–4). The refractive index is a measurement of how much light bends when passing from one medium to another (Burg & Seymour, 2022c, p. 16). The RI of the preferred varnishes was similar to the RI of aged oil paint (1.48 – 1.57) (Burg & Seymour, 2022c, p. 16; Laurie, 1937, pp. 127–129). Having a varnish with similar RI to the binding medium means that the reflections created in the transition between the paint and varnish will be reduced, increasing the clarity of the image (de la Rie, 1987, p. 8). The refractive index is connected to the molecular weight (MW) by an inverse relationship – a high RI generally means a low MW (Berns & de la Rie, 2002, p. 213).

Having low MW means that the molecular chains that make up the resin are shorter. This correlates with a low viscosity, as well as the ability of the varnish to level a surface, which Berns and De la Rie found was very important for the effect of a varnish on a surface (Berns & de la Rie, 2002, p. 215). Surface leveling means that the varnish will fill in the texture of the painting and create a smooth, level surface from which light can reflect evenly (Berns & de la Rie, 2002, p. 212)2/19/2024 11:31:00 AM. This gives it high specular reflection, which makes the surface appear bright and clear, and the colors saturated.

The chosen varnish was Laropal A-81, which is a urea-aldehyde resin. The reason for choosing Laropal A-81 over Regalrez 1094 lay in the difference in properties between the two. Regalrez saturates colors the best but is also very glossy, whereas Laropal A-81 has somewhat less saturation and a lower level of gloss, often described as a satin finish (Goltz et al., 2020, p. 667). If an even matter surface is desired, a microcrystalline wax such as Cosmoloid 80H can be added to the resin(Goltz et al., 2020, p. 670).

Over time, all resins will absorb oxygen. This affects its chemical stability, and additives are usually added to varnishes to mitigate the resulting changes. Tinuvin 292 is a hindered amine light stabilizer (HALS), and is a common stabilizing additive in varnish resins. It acts as an antioxidant by scavenging free radicals in the molecular structure of the resin (Goltz et al., 2020, p. 661). The amount of Tinuvin 292 added to the varnish corresponded to 2% of the weight of the Laropal A81 (Goltz et al., 2020, p. 662).

The varnish was brushed onto the surface using a wide brush. The brushstrokes were evenly applied, and each layer was worked in by first brushing vertically, then horizontally, before finishing with another vertical pass. The advantage of brushing is that it gives a better leveling than spray, which gives it a better gloss and saturation, and likely a better protective effect (Goltz et al., 2020, p. 655). However, it also penetrates deeper into the structure, which can cause degradation of the support or increased rate of metal soap formation. As explained in the literature review, solvent exposure increases ion diffusion, which is a cause of metal soap formation (Hermans et al., 2019, pp. 51–52).

A total of six layers of varnish were brushed onto the painting. Three layers were without wax, followed by three layers with Cosmoloid 80H[21]. This made for a well-saturated surface and a soft, even gloss. The student intended to mimic the original level of gloss that was on the painting before cleaning, as shown in table 17.

Despite the advantages of brushing, when considering the research question and the fact that the painting was strip lined, the varnish should ideally have been applied by spray. Spray application penetrates less into the structure of the painting than brushing, and is less likely to affect the lining adhesive (Goltz et al., 2020, pp. 657, 670). In the case of the *Still-life*, the lining adhesive did come loose in some spots after varnishing and had

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[21] The varnish recipe can be found in appendix 4.

to be reheated and re-adhered. The reason spraying was not performed was that the tools for doing so were not available in the student atelier.

7.11 Visual reintegration

Prior to the visual reintegration of paint losses, a simple digital retouching was done using Adobe photoshop to make a preliminary assessment of what level of visual reintegration would be necessary for each fill in the painting (fig. 43). The colors were applied in layers, first using a dead color resembling the canvas, at which point some fills along the edges were appropriately muted, then black for the black half and red for the red half, which muted several more, and lastly imitative retouches for the major losses in the motif. The reason for making this study was that the time for visual integration was very limited. The student would not be able to complete all areas to a satisfactory level of imitation, and by making the digital study, the areas that needed to be prioritized could quickly be identified. Fig. 43 shows the digitally retouched painting, and the prioritized losses are labeled A-E.

Since the painting had already been varnished, the varnish functioned as an isolating layer between the fills and the retouching layers. This sealed the fills, ensuring that the retouches would not sink (Digney-Peer et al., 2020, p. 632), and protected the original paint layers from the retouches.

Fig. 43 The digitally retouched painting, with the losses of highest priority labeled.

Gamblin Conservation Colors were used for the visual reintegration. These were specifically designed for conservation use by Robert Gamblin in collaboration with René de la Rie, the Getty Institute and the National Gallery in Washington, D.C. in the late 1990s (Dunkerton, 2010, p. 94). The pigments are bound in Laropal A-81, which has an RI of 1.503 (Burg & Seymour, 2022c, p. 33). This is similar to aged oil paint, and it was the same resin used for varnishing. This means that the binder is likely to reflect light very similarly to the original paint film and varnish, which increases the likelihood of achieving successful retouches (Digney-Peer et al., 2020, pp. 640–641).

Ideally, using the same pigments as the original materials is best for creating accurate, invisible retouches, but in some cases these are unavailable due to toxicity, being replaced with others or expense (Digney-Peer et al., 2020, p. 636). Additionally, many pigments have variable compositions, meaning that different batches may have slightly different colors, or changes in manufacturing may have resulted in pigments that look different than before. One more aspect is useful to consider; metamerism. This is an effect where colors that look identical under one light source look different under another (Burg & Seymour, 2022c, p. 50). Metameric matching is most common in azurite blue and copper-based greens (Digney-Peer et al., 2020, p. 638; Staniforth, 1985). These particular colors were not found in the *Still-life*, but being aware of the issue is nonetheless helpful.

As mentioned above, the time available for the visual reintegration was limited. Based on the digital sketch, the most important areas had been identified and those were chosen for the highest priority. It was decided to use gouache to paint all the fillings yellow gray to match the canvas in order to make them less visible, before focusing on the imitative visual reintegration of the major losses in the motif. The visual reintegration was not complete at the time of finishing the thesis and will be completed by the end of February.

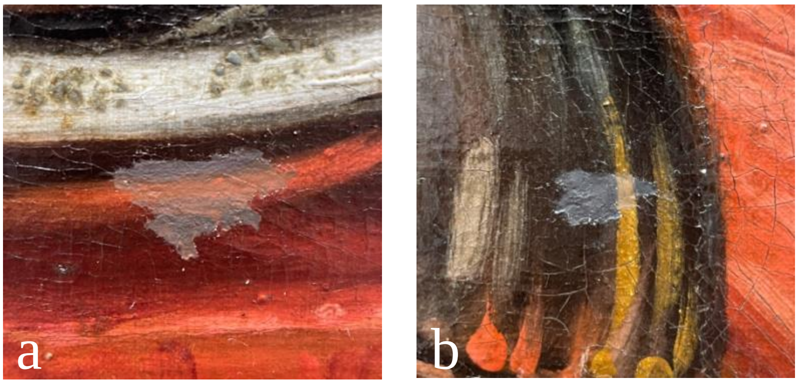

Fig. 44 Two of the retouches after the first layer of retouching using gouache. Subsequent layers will be applied using Gamblin Conservation Colors.

8 Conclusion and further treatment

8.1 Aims, objectives and the research question

The overall aim of the project was to complete a conservation treatment that improved the current condition of the painting, as well as took into consideration its long-term preservation. The condition of the painting did improve during treatment, as loose paint was re-adhered and the repaired tears increased the structural stability of the canvas. The tacking edges were reinforced and the presence of acidic compounds in the canvas were reduced, as shown by the increase in pH after treatment. Additionally, the appearance of the painting was greatly improved by removing the discolored varnish and applying a new one.

Fig. 45 The painting on 17.02.24, after varnishing and initial visual reintegration.

The research question asked whether treatment can be performed in a way that does not increase the rate of metal soap formation, and what measures can be taken to achieve this. Additionally, there were two related objectives: developing a method for cleaning that enabled a total cleaning, and considering if there were treatments were other concerns would be more important than preventing further metal soap formation.

The performed treatment did enable a total cleaning of the varnish layers, but the complex crust found on the surface underneath the varnish and the sensitivity encountered in the paint layers made it impossible to clean the paint surface in an ethical way given the constraints of a masters’ thesis.

The measures taken to not increase the rate of metal soap formation included limiting the exposure to solvents by using solvent gels, using heat and moisture only where necessary and controlling their effect, for example by binding moisture in a gel or blotting paper, and choosing an adhesive option that did not require the use of heat. It is likely impossible to perform a conservation treatment of a painting that in no way makes use of these three factors, but it is possible to perform treatments that limit their use. This is, however, not just dependent on materials and methods available to the conservators, but also the composition and condition of the painting itself. The older and more damaged a painting is, the more challenging it becomes to treat it in such a minimalistic way. This ties into a concept discussed in *1.4 Ethical framework*: minimal intervention. Minimal intervention can be summarized as an "attitude of rational restraint" (Villers, 2004, p. 4), and this is, in essence, what the research question is asking of the conservator. The most significant takeaway from this is that the most important factor in preventing metal soap formation in artworks is to maintain a stable environment for the painting, in which the rate of metal soap formation will naturally be reduced as a consequence of it not being exposed to environmental risk factors.

8.2 Limitations

In the introduction the limits placed on the project were described. Challenges appearing during the project, such as the polysaccharide gels not having the desired effect made it necessary to push these boundaries in order to be able to complete the project. If more time had been available, furthering the gel research into synthetic gels, such as Pemulen, Nanorestore® gels and Borax would have been ideal. Seeing the advantages of rigid gels over non-rigid ones, more research into this topic would also have been useful.

Additionally, situations were encountered where new information came to light after a completed treatment. Significantly, the research led by Hannah Flock into adhesives for tear mending was only found after the tear mending was complete. Flock et. al suggested that different adhesives should be used depending on the type of joint to be made. The traditional Heiber adhesive was still recommended for overlap bonds with fiber intermingling (Flock et al., 2023, p. 240), but for butt joints, the most common joint in the *Still-life*, sturgeon glue mixed with cellulose fibers such as Arbocel BWW 40 (Flock et al., 2023, pp. 240–241)[22] was recommended. Had this been known prior to tear mending, these adhesives would have been used instead.

8.3 Further research

The result of the research project in the thesis showed that on a varnish as complex as this one, polysaccharide-based solvent gels do not produce the adequate results.

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[22] The recipe tested by Flock et al. was a 25% solution of sturgeon glue with added cellulose fibers 20:1 by weight.

This does not mean that these gels cannot be used for varnish removal, but they are more likely to be effective when used for aqueous treatments. At the same time, gels, especially rigid gels have such great potential advantages in terms of moisture retention and minimal clearance after use that further research into this topic could be very interesting.

In terms of the metal soaps, there were several aspects that could be pursued further. No literature could be found on the role of arsenic in metal soap formation, though it likely played a role in the unique aggregation of soaps found in this painting (fig. 10). This could form part of a project to further investigate "risk factors" for metal soap formation, as arsenic is a common metal in pigments.

Additionally, the presence of lead soap crusts could be researched further. All crusts encountered in literature (Klaassen et al., 2019; Sawicka et al., 2014; Van Loon et al., 2010, 2011). The crusts encountered in literature contained sulfur, which this one did not appear to contain. This could be a misinterpretation of SEM-EDX results, but it could also be a phenomenon that warrants further study.

Finally, a lot of research is being done on water sensitivity in modern oil paintings, but the presence of water sensitivity in such an old painting proved difficult to understand. More research into the cause of this sensitivity could be of aid in treating other paintings showing similar sensitivities.

8.4 Further treatments and care

If the painting is to be displayed, the visual reintegration should be completed.

Using the information gained from this project, similar conservation treatments could be carried out on the two companion pieces (fig. 15, 16), ideally with further examination and analyses carried out that could build on what was learned here. Relevant analyses would include pXRF to gain an overview of the pigments present, and if indications of orpiment are found, SEM-EDX analysis of samples from such areas could be used to compare the three paintings.

In addition to the recent conservation treatments undertaken, preventive measures are the most important factors in terms of both limiting further formation of metal soaps, and the overall preservation of the painting. Thus, it is recommended that the painting is kept in a controlled and stable environment, where the painting is not subjected to extreme or fluctuating temperatures and major shifts in relative humidity (RH) (Noble, 2019, pp. 16–17).

9 References

9.1 Literary references

Ackroyd, P. (2002). The structural conservation of canvas paintings: Changes in attitude and practice since the early 1970s. *Studies in Conservation*, *47*(Supplement-1), Article Supplement-1. https://doi.org/10.1179/sic.2002.47.Supplement-1.3

Ackroyd, P., & Villers, C. (2003). The Problem with Minimalism. In M. Bustin & T. Caley (Eds.), *Alternatives to Lining* (pp. 9–14). UKIC/BAPCR.

Aguado, E., Bianchi, C., & Ibáñez, M. G. (2023). *Assessment of the acidity and salinity of hydrosensitive painted surfaces: Reliable pH and conductivity data for designing cleaning strategies and scientific models*. ICOM CC 20th triennial conference, Valencia.

Appelbaum, B. (1987). Criteria for Treatment: Reversibility. *Journal of the American Institute for Conservation*, *26*(2), Article 2. https://doi.org/10.2307/3179456

Appelbaum, B. (2010). *Conservation treatment methodology*. B. Appelbaum.

Bailey, G., Chen, J. J., Correa, C., Cutajar, J., Guidera, S., Heumiller, K., House, R., Keller, A., Kriss, D., Kronkright, D., Ludvigsen, L., Mikesell, M., Nosek, B., Ruiz-Molina, M., Schmidt, P., & Weldon, M. (2022). Infrared Reflectography (IRR). In L. Elledge, S. Kang, & S. Russo (Eds.), *AIC wiki*. https://www.conservation-wiki.com/wiki/Infrared_Reflectography_(IRR)

Barbisan, S. (2018). Tip: Local Cleaning with Gels: Acknowledging the Challenges and Successes. In *Book and Paper Group Annual* (Vol. 37, pp. 152–155). American Institute for Conservation of Historic and Artistic Works. https://cool.culturalheritage.org/coolaic/sg/bpg/annual/v37/bpga37-24.pdf

Berger, G. A. (1995). Letter to the editor (on the reversibility of BEVA bonds). *The Picture Restorer*, *7*, 26–28.

Berger, G. A. (2000). *Conservation of paintings: Research and innovations*. Archetype.

Bergström, I. (1956). *Dutch still-life painting in the seventeenth century* (Repr.1983). Hacker Art Books.

Berns, R. S., & de la Rie, E. R. (2002). *The relative importance of surface roughness and refractive index in the effects of varnishes on the appearance of paintings*. ICOM Committee for Conservation 13th Triennial Meeting Rio de Janeiro 20-27 September 2002, Rio de Janeiro. https://www.icom-cc-publications-online.org/2218/The-relative-importance-of-surface-roughness-and-refractive-index-in-the-effects-of-varnishes-on-the-appearance-of-paintings

Bezur, A., Lee, L., Loubser, M., & Trentelman, K. (2020). *Handheld XRF in Cultural Heritage. A practical workbook for Conservators.* J. Paul Getty Trust and Yale University.

Bobak, S. (2003). The Limitations and Possibilities of Strip-Lining. In M. Bustin & T. Caley (Eds.), *Alternatives to Lining* (pp. 15–20). UKIC/BAPCR.

Boon, J. J., Hoogland, F. G., & Keune, K. (2007). Chemical Processes in Aged Oil Paints Affecting Metal Soap Migration and Aggregation. In *AIC Group Specialty Postprints: Papers Presented at the Thirty-fourth Annual Meeting of the American Institute for Conservation of Historic & Artistic Works Providence, Rhode Island June 16-19, 2006* (Vol. 19, pp. 16–23). American Institute for Conservation of Historic and Artistic Works.

Boon, J. J., Weerd, J. van der, Noble, P., Keune, K., & Wadum, J. (2002). Mechanical and chemical changes in Old Master paintings: Dissolution, metal soap formation and remineralization processes in lead pigmented ground/intermediate paint layers of 17th century paintings. In *ICOM Committee for Conservation 13th Triennial Meeting Rio de Janeiro Preprints* (Vol. 1, pp. 401–406). James & James (Science Publishers) Ltd. https://www.icom-cc-publications-online.org/2207/In-their-own-words--painting-conservation-and-restoration-in-19th-century-America-according-to-the-artists-and-restorers-who-recorded-their-practices-and-beliefs

Bråthen, I. (2023). Nedbrytning av grundering og fargelag på lerretsmalerier som følge av metallsåpedannelse. In *Eksamensbesvarelse, KONS4042*. Universitetet i Oslo.

Bucklow, S. (1997). The description of craquelure patterns. *Studies in Conservation*, *42*(3), Article 3. https://doi.org/10.1179/sic.1997.42.3.129

Bucklow, S., Stoner, J. H., & Rushfield, R. (2020). The classification of craquelure patterns. In *Conservation of Easel Paintings* (2nd ed., pp. 295–301). Routledge.

Burg, J. M. van den, & Seymour, K. (2022a). *Dirt and Dirt Removal (Dry and Aqueous Cleaning)* (K. J. van den Berg, Ed.; Vol. 1). Cultural Heritage Agency of the Netherlands. https://english.cultureelerfgoed.nl/publications/publications/2022/01/01/dirt-and-dirt-removal

Burg, J. M. van den, & Seymour, K. (2022b). *Varnish Removal* (K. J. van den Berg, Ed.; Vol. 2). Cultural Heritage Agency of the Netherlands. https://english.cultureelerfgoed.nl/publications/publications/2022/01/01/varnish-removal

Burg, J. M. van den, & Seymour, K. (2022c). *Varnishing and Inpainting/Retouching* (K. J. van den Berg, Ed.; Vol. 6). Cultural Heritage Agency of the Netherlands. https://english.cultureelerfgoed.nl/publications/publications/2022/01/01/varnishing-and-inpainting

Burg, J. M. van den, & Seymour, K. (2023). *Consolidation of Paint and Ground* (K. J. van den Berg, Ed.; Vol. 3). Cultural Heritage Agency of the Netherlands.

Byrne, A. (1991). Wolbers Cleaning Methods: Introduction. *AICCM Bulletin*, *17*(3–4), 3–11. https://doi.org/10.1179/bac.1991.17.3-4.001

Caple, C. (2000). *Conservation Skills: Judgment, Method and Decision making*. Routledge.

Carden, M. L. (1991). Use of Ultraviolet Light as an Aid to Pigment Identification. *APT Bulletin: The Journal of Preservation Technology*, *23*(3), 26–37. https://doi.org/10.2307/1504337

Casanova-González, E., Maynez-Rojas, M. Á., Mitrani, A., Rangel-Chávez, I., García-Bucio, M. A., Ruvalcaba-Sil, J. L., & Muñoz-Alcócer, K. (2020). An imaging and spectroscopic methodology for in situ analysis of ceiling and wall decorations in Colonial missions in Northern Mexico from XVII to XVIII centuries. *Heritage Science*, *8*(1), Article 1. https://doi.org/10.1186/s40494-020-00434-8

Casini, A., Chelazzi, D., & Baglioni, P. (2023). Advanced methodologies for the cleaning of works of art. *Science China Technological Sciences*, *66*. https://doi.org/10.1007/s11431-022-2348-7

Casoli, A., Di Diego, Z., & Isca, C. (2014). Cleaning painted surfaces: Evaluation of leaching phenomenon induced by solvents applied for the removal of gel residues. *Environmental Science and Pollution Research*, *21*(23), 13252–13263. https://doi.org/10.1007/s11356-014-2658-5

Centeno, S. A., & Mahon, D. (2009). The Chemistry of Aging in Oil Paintings: Metal Soaps and Visual Changes. *The Metropolitan Museum of Art Bulletin*, *67*(1), 12–19.

Chelazzi, D., Fratini, E., Giorgi, R., Mastrangelo, R., Rossi, M., & Baglioni, P. (2018). Gels for the Cleaning of Works of Art. In *ACS Symposium Series* (pp. 291–314). https://doi.org/10.1021/bk-2018-1296.ch015

Cooper, A., Burnstock, A., van den Berg, K. J., & Ormsby, B. (2014). Water Sensitive Oil Paints in the Twentieth Century: A Study of the Distribution of Water-Soluble Degradation Products in Modern Oil Paint Films. In K. J. van den Berg, A. Burnstock, M. de Keijzer, J. Krueger, T. Learner, A. de Tagle, & G. Heydenreich (Eds.), *Issues in*

Contemporary Oil Paint (pp. 295–310). Springer International Publishing. https://doi.org/10.1007/978-3-319-10100-2_20

Cotte, M., Checroun, E., De Nolf, W., Taniguchi, Y., De Viguerie, L., Burghammer, M., Walter, P., Rivard, C., Salomé, M., Janssens, K., & Susini, J. (2017). Lead soaps in paintings: Friends or foes? *Studies in Conservation*, *62*(1), 2–23. https://doi.org/10.1080/00393630.2016.1232529

Cremonesi, P. (2013). Rigid Gels and Enzyme cleaning. In M. F. Mecklenburg, A. E. Charola, & R. J. Koestler (Eds.), *New Insights into the Cleaning of Paintings: Proceedings from the Cleaning 2010 International Conference, Universidad Politécnica de Valencia and Museum Conservation Institute* (pp. 179–184). Smithsonian Institution Scholarly Press. https://doi.org/10.5479/si.19492359.3.1

Cremonesi, P. (2016). Surface cleaning? Yes, freshly grated Agar gel, please. *Studies in Conservation*, *61*(6), 362–367. https://doi.org/10.1179/2047058415Y.0000000026

Cremonesi, P., & Casoli, A. (2017). Thermo-reversible rigid agar hydrogels: Their properties and action in cleaning. In L. V. Angelova, B. A. Ormsby, J. H. Townsend, & R. Wolbers (Eds.), *Gels in the conservation of art* (pp. 19–28). Archetype Publications.

de Carbonnel, K. V. (1980). A Study of French Painting Canvases. *Journal of the American Institute for Conservation*, *20*(1), 3–20. https://doi.org/10.2307/3179678

de la Rie, E. R. (1987). The Influence of Varnishes on the Appearance of Paintings. *Studies in Conservation*, *32*(1), 1–13. https://doi.org/10.2307/1506186

de Visser, M., & Odlin, L. (2017). Pemulen emulsions for the removal of overpaint, discoloured remains of lining adhesive, and remnants of older varnish layers on a 17th century group portrait. In L. V. Angelova, B. A. Ormsby, J. H. Townsend, & R. Wolbers (Eds.), *Gels in the conservation of art* (pp. 187–192). Archetype Publications.

De Witte, E., Goessens-Landrie, M., Goethals, E. J., Van Lerberghe, K., & van Springel, C. (1981). *Synthesis of an acrylic varnish with high refractive index*. 81/16/4.

Digney-Peer, S., Thomas, K., Perry, R., Townsend, J., & Gritt, S. (2020). The imitative retouching of easel paintings. In J. H. Stoner & R. Rushfield (Eds.), *Conservation of Easel Paintings* (2nd ed., pp. 626–653). Routledge.

Dillon, C. E., Lagalante, A. F., & Wolbers, R. C. (2014). Acrylic emulsion paint films: The effect of solution pH, conductivity, and ionic strength on film swelling and surfactant removal. *Studies in Conservation*, *59*(1), 52–62.

Dunkerton, J. (2010). Retouching with Gamblin Conservation Colors. In R. Ellison, P. Smithen, & R. Turnbull (Eds.), *Mixing and matching: Approaches to retouching* *paintings* (pp. 92–100). Archetype publications.

E.C.C.O. (2003). *ECCO professional guidelines II: Code of Ethics*. E.C.C.O. European Confederation of Conservator-Restorers Organisations. https://www.ecco-eu.org/wp-content/uploads/2021/03/ECCO_professional_guidelines_II.pdf

False-color image processing. (2023, May 2). *AIC Wiki*. https://www.conservation-wiki.com/wiki/False-color_image_processing

Fife, G. R. (2011). *'Pack Mentality: The development of Tissue Gel Composite Cleaning at SRAL.'* ICOM Committee for Conservation 16th Triennial Meeting Lisbon Portugal 19-23 September 2011, Lisbon.

Fife, G. R. (2017). Moving on up: A review of Results from SRAL's tissue-gel composite approach. In L. V. Angelova, B. A. Ormsby, J. H. Townsend, & R. Wolbers (Eds.), *Gels in the conservation of art* (pp. 257–261). Archetype Publications.

Flock, H., Demuth, P., Diebels, S., & Jägers, E. (2023). The Thread-by-Thread Tear-Mending Method: New Insights into the Choice of Adhesivees and Their Application. In C. Schwarz, I. McClure, & J. Coddington (Eds.), *Conserving Canvas* (pp. 234–245). Getty Conservation Institute. https://www.getty.edu/publications/conserving-canvas/v-adhesives/29/

Folch, M. O. (2011). *Non-destructive condition assessment of painting canvases using NIR spectrography*. Universitat de Barcelona.

Franken, M. (2017). Sixty years of thread counting. In C. R. Johnson (Ed.), *Counting Vermeer: Using Weave Maps to Study Vermeer's Canvases, RKD Studies*. RKD studies. https://countingvermeer.rkdstudies.nl/3-sixty-years-of-thread-counting/33-thread-density/#fn1

Frey, F., Heller, D., Kushel, D., Vitale, T., & Weaver, G. (2017). *The AIC guide to digital photography and conservation documentation* (J. Warda, Ed.; 3rd ed.). the American Institute for Conservation of Historic and Artistic Works.

Frøysaker, T., & Liu, M. (2013). Extended Abstract Noninvasive Assessments of Cleaning Tests on an Unvarnished Oil Painting on Canvas by Edvard Munch. In *New Insights into the Cleaning of Paintings: Proceedings from the Cleaning 2010 International Conference, Universidad Politecnica de Valencia and Museum Conservation Institute*. Smithsonian Institution. https://repository.si.edu/handle/10088/20498

Fuster-López, L. (2020). Filling. In J. H. Stoner & R. Rushfield (Eds.), *Conservation of Easel Paintings* (2nd ed., pp. 604–625). Routledge.

Fuster-López, L., Mecklenburg, M. F., Castell-Agustí, M., & Guerola-Blay, V. (2008). Filling materials for easel paintings: When the ground reintegration becomes a structural concern. In J. Townsend, G. Heydenreich, T. Doherty, & J. Ridge (Eds.), *Preparation for Painting: The Artist's Choice and its Consequences* (pp. 180–186). Archetype Publications. https://repository.si.edu/handle/10088/35985

Gel. (n.d.). In *Encyclopaedia Brittanica*. Retrieved January 14, 2024, from https://www.britannica.com/science/gel

Gellan Gum. (n.d.). CP Kelco. Retrieved September 17, 2023, from https://www.cpkelco.com/products/gellan-gum/

Gettens, R. J., & Mrose, M. E. (1954). Calcium Sulphate Minerals in the Grounds of Italian Paintings. *Studies in Conservation*, *1*(4), 174–189. https://doi.org/10.2307/1505020

Getty Conservation Institute. (2023, October 8). *Making an Agarose Gel in a Microwave and Preparing an Agarose Plug*. Youtube. https://www.youtube.com/watch?v=V490KuFsU4k

Giraud, T., Gomez, A., Lemoine, S., Charlene, P., Raimon, A., & Guilminot, E. (2021). Use of gels for the cleaning of archaeological metals. Case study of silver-plated copper alloy coins. *Journal of Cultural Heritage*, *52*, 73–83. https://doi.org/10.1016/j.culher.2021.08.014

Goltz, M. von der, Proctor, R. G., Whitten, J., Mayer, L., Myers, G., Hoenigswald, A., & Swicklik, M. (2020). Varnishing as part of the conservation treatment of easel paintings. In J. H. Stoner & R. Rushfield (Eds.), *Conservation of Easel Paintings* (2nd ed., pp. 654–675). Routledge.

Graaff, J. H. (1981). Hydroxy propyl cellulose, a multipurpose conservation material. In *ICOM Committee for Conservation 7th Triennial Meeting Ottawa Canada 21-25 September 1981* (p. 81/14/9-1-81/14/9-7). International Council of Museums. https://www.icom-cc-publications-online.org/3689/Hydroxy-propyl-cellulose-a-multipurpose-conservation-material

H. Bukowskis Konsthandel (Stockholm). (1928). *No. 267, 1928: Förteckning över en synnerligen värdefull samling oljemålningar, skulpturer, möbler, textilier, keramik, glas, metallföremål, silver m.m., som tillhört framlidne grosshandlaren Hilmer Åberg. Samlingarna försäljas genom Aktiebolaget H. Bukowskis Konsthandel å auktion i lokalen Arsenalsgatan 2, torsdagen den 13 och fredagen den 14 sept. [1928], f. m. kl. 11-1; e. m. från kl. 2.30*. Bibliothèque de l'Institut National d'Histoire de l'Art, collections Jacques Doucet. http://bibliotheque-numerique.inha.fr/idurl/1/67338

Hackney, S. (2020). *On canvas: Preserving the structure of paintings*. Getty Conservation

Institute.

Hayem-Ghez, A., Ravaud, E., Boust, C., Bastian, G., Menu, M., & Brodie-Linder, N. (2015). Characterizing pigments with hyperspectral imaging variable false-color composites. *Applied Physics A*, *121*(3), 939–947. https://doi.org/10.1007/s00339-015-9458-8

Heiber, W. (2003). The Thread-by-Thread Tear Mending Method. In M. Bustin & T. Caley (Eds.), *Alternatives to Lining* (pp. 35–47). UKIC/BAPCR.

Heiber, W., Tomkiewicz, C., Scharff, M., & Levenson, R. (2020). Tear mending and other structural treatments of canvas paintings, before or instead of lining. In J. H. Stoner & R. Rushfield (Eds.), *Conservation of Easel Paintings* (2nd ed., pp. 406–439). Routledge.

Hermans, J. J., Keune, K., Van Loon, A., & Iedema, P. D. (2019). Toward a Complete Molecular Model for the Formation of Metal Soaps in Oil Paints. In F. Casadio, K. Keune, P. Noble, A. Van Loon, E. Hendriks, S. A. Centeno, & G. Osmond (Eds.), *Metal Soaps in Art: Conservation and Research* (pp. 47–67). Springer International Publishing. https://doi.org/10.1007/978-3-319-90617-1_3

Hinde, L. (2013). Pemulen and xanthan gels: Properties and applications. *The Picture Restorer*, *43*, 35–37.

Hughes, A. (2017). Measurement of Surface pH of Paper Using Agarose Gel plugs: A feasibility study. In L. V. Angelova, B. A. Ormsby, J. H. Townsend, & R. Wolbers (Eds.), *Gels in the conservation of art* (pp. 62–66). Archetype Publications.

Iannuccelli, S., & Sotgiu, S. (2010). Wet Treatments of Works of Art on Paper with Rigid Gellan Gels (R. King, Trans.). *The Book and Paper Group Annual*, *29*, 25–39.

IIC-American Group. (1968). *The Murray Pease Report and Code of Ethics for Art Conservators*. IIC-American Group. https://www.culturalheritage.org/docs/default-source/resources/governance/organizational-documents/murray-pease-report.pdf?sfvrsn=1cb60339_10

Infrared radiation imaging. (2022, February 28). AIC Wiki. https://www.conservation-wiki.com/wiki/Infrared_radiation_imaging

Johnson, C. R. (2017). Exploiting Weave Maps. In C. R. Johnson (Ed.), *Counting Vermeer: Using Weave Maps to Study Vermeer's Canvases, RKD Studies*. RKD studies. https://countingvermeer.rkdstudies.nl/6-exploiting-weave-maps/61-weave-matches/

Kanth, A., Singh, M., & Pandey, S. C. (2018). Optimizing the rigidity of Gellan and Agar gels for cleaning sensitive acrylic emulsion painted surfaces. *International Journal of Conservation Science*, *9*(3), 451–462.

Keune, K., & Boevé-Jones, G. (2014). Its Surreal: Zinc-Oxide Degradation and Misperceptions in Salvador Dalí’s Couple with Clouds in Their Heads, 1936. In K. J. van den Berg, A. Burnstock, M. de Keijzer, J. Krueger, T. Learner, A. de Tagle, & G. Heydenreich (Eds.), *Issues in Contemporary Oil Paint* (pp. 283–294). Springer International Publishing. https://doi.org/10.1007/978-3-319-10100-2_19

Kielland, T. (1929). *Årbok 1928/29*. Kunstindustrimuseet. https://urn.nb.no/URN:NBN:no-nb_digitidsskrift_2019051681238_001

Klaassen, L., van der Snickt, G., Legrand, S., Higgitt, C., Spring, M., Vanmeert, F., Rosi, F., Brunetti, B. G., Postec, M., & Janssens, K. (2019). Characterization and Removal of a Disfiguring Oxalate Crust on a Large Altarpiece by Hans Memling. In F. Casadio, K. Keune, P. Noble, A. Van Loon, E. Hendriks, S. A. Centeno, & G. Osmond (Eds.), *Metal Soaps in Art: Conservation and Research* (pp. 263–282). Springer International Publishing. https://doi.org/10.1007/978-3-319-90617-1_15

Kleiner, F. S. (2018). *Gardner’s Art through the Ages: A Global History*. Cengage Learning.

Kremer Pigmente. (n.d.-a). *Technical data sheet for 63700-63712—Klucel—Hydropropylcellulose*. Kremer Pigmente. Retrieved September 27, 2023, from https://www.kremer-pigmente.com/elements/resources/products/files/63700-63712e.pdf

Kremer Pigmente. (n.d.-b). *Technical data sheet for BEVA® 371 FILM (thick, 65 μm)*. Retrieved February 5, 2024, from https://www.kremer-pigmente.com/elements/resources/products/files/87051e.pdf

Laurie, A. P. (1937). The refractive index of a solid film of linseed oil rise in refractive index with age. *Proceedings of the Royal Society of London. Series A - Mathematical and Physical Sciences*, *159*(896), 123–133. https://doi.org/10.1098/rspa.1937.0061

Leroux, M. (2016). Soft matter: Gel development for conservation treatment gellan gum and Nanorestore Gel®. *The Book & Paper Group Annual*, *35*, 43–47.

MacBeth, R., & Breare, C. (2020). The technical examination and documentation of easel paintings. In J. H. Stoner & R. Rushfield (Eds.), *Conservation of Easel Paintings* (2nd ed., pp. 302–321). Routledge.

Maheux, A. F. (2015). Cross-disciplinary uses for gellan gum in conservation. *The Book & Paper Group Annual*, *34*, 69–79.

Maranesi, G. (2017). Using rigid gellan gel for the stratigraphic cleaning of a canvas painting. In L. Angelova, B. Ormsby, J. Townsend, & R. Wolbers (Eds.), *Using rigid gellan gel for the stratigraphic cleaning of a canvas painting / Giacomo Maranesi, Gels in the* *conservation of art* (pp. 129–131). Archetype Publications Ltd.

Marriott, S., Brough, J., & Saltmarsh, P. (2010). Material Focus: Lascaux 4176 Medium for Consolidation. *The Picture Restorer*, *37*, 34–35.

Martínez-Casado, F. J., Rodríguez-Cheda, J. A., Ramos-Riesco, M., Redondo-Yélamos, M. I., Cucinotta, F., & Fernández-Martínez, A. (2019). Physicochemistry of Pure Lead (II) Soaps: Crystal Structures, Solid and Liquid Mesophases, and Glass Phases – Crystallographic, Calorimetric, and Pair Distribution Function Analysis. In F. Casadio, K. Keune, P. Noble, A. Van Loon, E. Hendriks, S. A. Centeno, & G. Osmond (Eds.), *Metal Soaps in Art: Conservation and Research* (pp. 227–239). Springer International Publishing. https://doi.org/10.1007/978-3-319-90617-1_13

Matteini, M., Mazzeo, R., & Moles, A. (2016). *Chemistry for Restoration: Painting and Restoration Materials*. Nardini Editore.

Mazzuca, C., Micheli, L., Carbone, M., Basoli, F., Cervelli, E., Iannuccelli, S., Sotgiu, S., & Palleschi, A. (2014). Gellan hydrogel as a powerful tool in paper cleaning process: A detailed study. *Journal of Colloid and Interface Science*, *416*, 205–211. https://doi.org/10.1016/j.jcis.2013.10.062

Measday, D., Walker, C., & Pemberton, B. (2017). A summary of ultra-violet fluorescent materials relevant to Conservation. *Australian Institute for the Conservation of Cultural Material National Newsletter*, *137*. https://aiccm.org.au/network-news/summary-ultra-violet-fluorescent-materials-relevant-conservation/

Michalski, S. (1991). Paintings: Their Response to Temperature, Relative Humidity, Shock, and Vibration. In M. F. Mecklenburg (Ed.), *Art in Transit: Studies in the Transportation of Paintings*. National Gallery of Art.

Mühlethaler, B., & Thissen, J. (1993). Smalt. In A. Roy (Ed.), *Artists' Pigments. A Handbook of Their History and Characteristics* (Vol. 2, pp. 113–131). National Gallery of Art/ Archetype publications ltd.

Muñoz Viñas, S. (2005). *Contemporary theory of conservation*. Elsevier Butterworth Heinemann.

Nicolaus, K. (1999). *The restauration of paintings* (C. Westphal, Ed.). Könemann. http://archive.org/details/restaurationiere0000nico

Noble, P. (2019). A Brief History of Metal Soaps in Paintings from a Conservation Perspective. In F. Casadio, K. Keune, P. Noble, A. Van Loon, E. Hendriks, S. A. Centeno, & G. Osmond (Eds.), *Metal Soaps in Art: Conservation and Research* (pp. 1–22). Springer International Publishing. https://doi.org/10.1007/978-3-319-90617-

1_1

Noble, P., Boon, J. J., & Wadum, J. (2002). Dissolution, Aggregation and Protrusion: Lead soap formation in 17th century grounds and paint layers. *ARTMATTERS - Netherlands Technical Studies in Art*, *1*, 46–61.

Noble, P., Van Loon, A., & Boon, J. J. (2005). Chemical changes in old master paintings II: darkening due to increased transparency as a result of metal soap formation. In *ICOM Committee for Conservation 14th Triennial Meeting The Hague 12-16 September 2005* (pp. 496–503).

Odegaard, N. (2005). *Material characterization tests for objects of art and archaeology* (2. ed.). Archetype Publications.

Osmond, G., & Carter, A. (2013). Extended Abstract—The Effect of Conductivity on Water Solubility: Cleaning a Modern Chinese Oil Painting. In M. F. Mecklenburg, A. E. Charola, & R. J. Koestler (Eds.), *New Insights into the Cleaning of Paintings: Proceedings from the Cleaning 2010 International Conference, Universidad Politécnica de Valencia and Museum Conservation Institute* (pp. 115–118). Smithsonian Institution Scholarly Press. https://doi.org/10.5479/si.19492359.3.1

Petukhova, T., & Bonadies, S. D. (1993). Sturgeon Glue for Painting Consolidation in Russia. *Journal of the American Institute for Conservation*, *32*(1), 23–31. https://doi.org/10.2307/3179649

Plahter, U. (2004). *Materials and Technique* (Vol. 2). Archetype.

Rizzo, A., & Burnstock, A. (2003). A review of the effectiveness and effects of deacidification of linen, cotton and flax canvas after 17 years of natural ageing. In M. Bustin & T. Caley (Eds.), *Alternatives to Lining* (pp. 49–55). UKIC/BAPCR.

Romano, C. (2022). Paint Consolidation. In A. Schaffer & C. Gostowski (Eds.), *AIC Conservation wiki*. https://www.conservation-wiki.com/wiki/Paint_Consolidation

Rota, E., Bozzi, C., Cremonesi, P., & Lucchini, A. (2021). Study of the Best Methodology for Measuring Surface pH of Linen Canvas. *Studies in Conservation*, *66*(6), 313–320. https://doi.org/10.1080/00393630.2020.1838711

Russick, S., Dobrowolski, N., Nosek, B., & Williams, R. (2018). Gellan gum tips. *The Book & Paper Group Annual*, *37*, 162–164.

Sánchez-Ledesma, A., Muro-García, C., & Gayo-García, M. D. (2013). Effects of Commercial Soaps on Unvarnished Painted Surfaces: A Pilot Study for Their Assessment. In M. F. Mecklenburg, A. E. Charola, & R. J. Koestler (Eds.), *New Insights into the Cleaning of Paintings: Proceedings from the Cleaning 2010*

International Conference, Universidad Politécnica de Valencia and Museum Conservation Institute (pp. 185–196). Smithsonian Institution Scholarly Press. https://doi.org/10.5479/si.19492359.3.1

Sawicka, A., Burnstock, A., Izzo, F. C., Keune, K., Boon, J. J., Kirsch, K., & van den Berg, K. J. (2014). An Investigation into the Viability of Removal of Lead Soap Efflorescence from Contemporary Oil Paintings. In K. J. van den Berg, A. Burnstock, M. de Keijzer, J. Krueger, T. Learner, A. de Tagle, & G. Heydenreich (Eds.), *Issues in Contemporary Oil Paint* (pp. 311–332). Springer International Publishing. https://doi.org/10.1007/978-3-319-10100-2_21

Scott, C. L. (2012). The use of agar as a solvent gel in objects conservation. *AIC Objects Specialty Group Postprints*, *19*, 71–83.

Soldano, A., & van den Berg, K. J. (2014). Investigation into the Surface Conductivity of Water-Sensitive Modern Oil Paints. In K. J. van den Berg, A. Burnstock, M. de Keijzer, J. Krueger, T. Learner, A. de Tagle, & G. Heydenreich (Eds.), *Issues in Contemporary Oil Paint* (pp. 407–417). Springer International Publishing. https://doi.org/10.1007/978-3-319-10100-2_27

Soppa, K. (2022). Flaking paint on absorbent canvas: Approach, possibilities and challenges. *International Journal of Conservation Science*, *13*(1), 1567–1582.

Staniforth, S. (1985). Retouching and Colour Matching: The Restorer and Metamerism. *Studies in Conservation*, *30*(3), 101–111. https://doi.org/10.2307/1505925

Stavroudis, C. (Director). (2013, October 31). *Measuring Surface pH and Conductivity Using Water Drop and Agarose Plug Methods*. https://www.youtube.com/watch?v=bOqZEE7Kb8Y

Stavroudis, C. (2017). Gels: Evolution in Practice. In L. V. Angelova, B. A. Ormsby, J. H. Townsend, & R. Wolbers (Eds.), *Gels in the conservation of art* (pp. 209–217). Archetype Publications.

Steger, S., Eggert, G., Horn, W., & Krekel, C. (2022). Are cellulose ethers safe for the conservation of artwork? New insights in their VOC activity by means of Oddy testing. *Heritage Science*, *10*(1), Article 1. https://doi.org/10.1186/s40494-022-00688-4

Stols-Witlox, M. J. N. (2014). *Historical recipes for preparatory layers for oil paintings in manuals, manuscripts and handbooks in North West Europe, 1550-1900: Analysis and reconstructions* [PhD, Universiteit van Amsterdam]. https://dare.uva.nl/search?identifier=d857e372-47a7-4afe-aa70-df209368ee9d

Storbritannia Conservation Unit. (1992). *Science for conservators: Vol. 1 : An introduction to materials: Vol. Vol. 1*. Conservation Unit of the Museums & Galleries Commission in conjunction with Routledge.

Stuart, B. (2007). *Analytical techniques in materials conservation*. John Wiley & Sons.

Sutherland, K. (2013). Solvent Leaching Effects on Aged Oil Paints. In M. F. Mecklenburg, A. E. Charola, & R. J. Koestler (Eds.), *New Insights into the Cleaning of Paintings: Proceedings from the Cleaning 2010 International Conference, Universidad Politécnica de Valencia and Museum Conservation Institute* (pp. 1–243). Smithsonian Institution Scholarly Press. https://doi.org/10.5479/si.19492359.3.1

Townsend, J., Jones, R., & Stonor, K. (2007). Lead Soap Aggregates in Sixteenth- and Seventeenth-Century British Paintings. In *AIC Group Specialty Postprints: Papers Presented at the Thirty-fourth Annual Meeting of the American Institute for Conservation of Historic & Artistic Works Providence, Rhode Island June 16-19, 2006* (Vol. 19, pp. 24–32). American Institute for Conservation of Historic and Artistic Works.

Udina, R. (2021). *Reversibility and the right conservation treatment* (pp. 201–210).

Vallieres, J. (2013). *Gellan Gum: Investigating Applications as a solvent gel (poster summarizing thesis)* [Master thesis, Queens University]. https://www.queensu.ca/art/sites/artwww/files/uploaded_files/posterJaymeVallierescopy.pdf

Van Loon, A., Hartman, L. E., van den Burg, J., Haswell, R., & Pottasch, C. (2019). The Development of an Aqueous Gel Testing Procedure for the Removal of Lead-Rich Salt Crusts on the Surface of Paintings by Giovanni Antonio Pellegrini (1675–1741) in the “Golden Room” of the Mauritshuis. In F. Casadio, K. Keune, P. Noble, A. Van Loon, E. Hendriks, S. A. Centeno, & G. Osmond (Eds.), *Metal Soaps in Art: Conservation and Research* (pp. 283–296). Springer International Publishing. https://doi.org/10.1007/978-3-319-90617-1_16

Van Loon, A., Noble, P., & Boon, J. J. (2010). The formation of complex crusts in oil paints containing lead white and smalt: Dissolution, depletion, diffusion and deposition. *Postprints SEM 2010, London 9–10 September 2010*.

Van Loon, A., Noble, P., & Boon, J. J. (2011). White hazes and surface crusts in Late Rembrandt paintings. In *Preprints for the ICOM Committee for Conservation 16th Triennial Meeting Lisbon Portugal 19-23 September 2011* (pp. 1–10). Critério Artes Gráficas, Lda.; ICOM Committee for Conservation. https://www.icom-cc-publications-online.org/1148/White-hazes-and-surface-crusts-in-Late-Rembrandt-paintings

Villers, C. (2004). Post minimal intervention. *The Conservator*, *28*(1), 3–10. https://doi.org/10.1080/01410096.2004.9995197

Vodret, R. (2016). Note Introduttive sulla tecnica esecutiva di Caravaggio/ Introductory Notes on Caravaggio's technique of Execution. In R. Vodret, G. Leone, M. Cardinali, M. B. De Ruggieri, & G. S. Ghia (Eds.), *Caravaggio: Opere a Roma: Tecnica e stile: Saggi/ Works in Rome: Technique and style: Essays* (Vol. 1, pp. 16–51). SilvanaEditoriale.

Volk, A., & van den Berg, K. J. (2014). Agar – A New Tool for the Surface Cleaning of Water Sensitive Oil Paint? In K. J. van den Berg, A. Burnstock, M. de Keijzer, J. Krueger, T. Learner, A. de Tagle, & G. Heydenreich (Eds.), *Issues in Contemporary Oil Paint* (pp. 389–406). Springer International Publishing. https://doi.org/10.1007/978-3-319-10100-2_26

Wetering, E. van de. (1997). *Rembrandt. The Painter at Work*. Amsterdam University Press.

Wolbers, R. (2017). Gels, green chemistry, gurus and Guides. In L. V. Angelova, B. A. Ormsby, J. H. Townsend, & R. Wolbers (Eds.), *Gels in the conservation of art* (pp. 3–10). Archetype Publications.

Wolbers, R. C., Stavroudis, C., & Cushman, M. (2020). Aqueous methods for the cleaning of paintings. In J. H. Stoner & R. Rushfield (Eds.), *Conservation of Easel Paintings* (2nd ed., pp. 526–548). Routledge.

Young, C. (2003). The Mechanical Requirements of Tear Mends. In M. Bustin & T. Caley (Eds.), *Alternatives to Lining* (pp. 55–58). UKIC/BAPCR.

Young, C., & Jardine, S. (2012). Fabrics for the twenty-first century: As artist canvas and for the structural reinforcement of easel paintings on canvas. *Studies in Conservation*, *57*, 237–253. https://doi.org/10.1179/2047058412Y.0000000007

9.2 Archival References

Nasjonalmuseet for kunst, arkitektur og design. *Innkjøps-og gaveprotokoll for Kunstindustrimuseet i Oslo 1876-1960.* AeL0010. Dokumentasjonsarkivet, Oslo.

Nasjonalmuseet for kunst, arkitektur og design. *Katalogperm for Kunstindustrimuseet i Oslo. KIM-1001*. Perm: Heb-L0063. Dokumentasjonsarkivet, Oslo.

«Styremøte 12. oktober 1928» i Nasjonalmuseet for kunst, arkitektur og design. *Aa-Styreprotokoller for Kunstindustrimuseet i Oslo 1926-1960.* Aa 0003. Dokumentasjonsarkivet, Oslo.

10 Figures

Fig. 46 National Museum inventory no. 10219A before treatment.

Fig. 47 The painting on 17.02.24 after most treatments were completed, except retouches

Fig. 48 The painting in UV light, before treatment

Fig. 49 The painting in UV light, after treatment apart from visual reintegration.

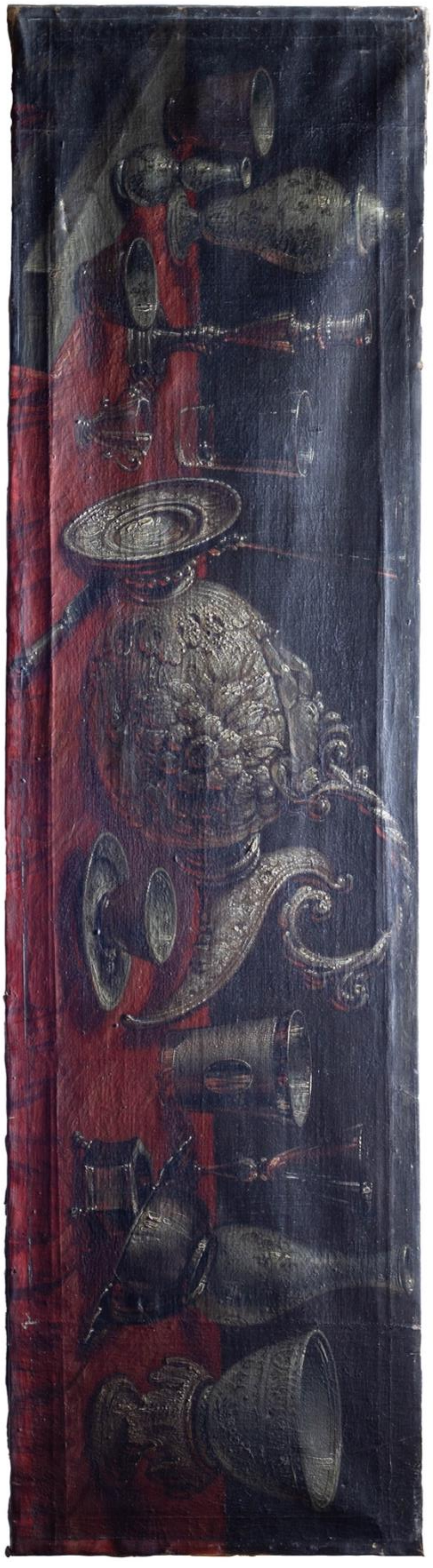


Fig. 50 The painting in raking light before treatment

Fig. 51 The painting in IR light before treatment

Fig. 52 The painting using FCIR processing before treatment

Fig. 53 X-ray radiograph of the painting before treatment

Fig. 54 The reverse of the painting before treatment.

Fig. 55 The reverse of the painting after all treatments except visual reintegration.

11 Tables

Table 7 The complete thread density measurements

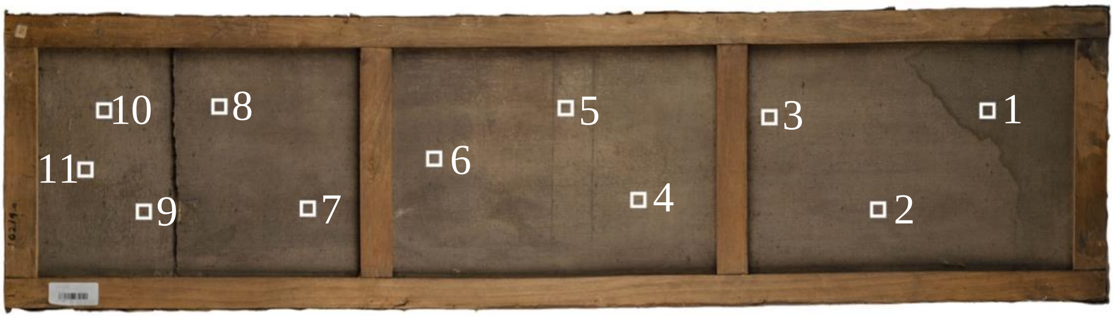
	Threads per 1 cm^2	
Measurement spot	**Vertical**	**Horizontal**
Canvas A		
1	25	26
2	23	26
3	23	25
4	27	24
5	25	23
6	25	26
7	23	25
8	24	23
Average:	**24,375**	**24,5**
Canvas B		
9	27	23
10	29	24
11	24	25
Average:	**26,67**	**24**
		

Table 8 The Biuret test

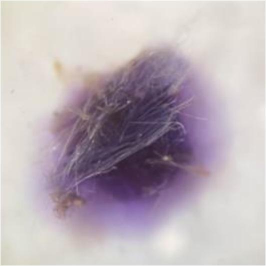
	Before	**After**	**Result**
Ground layer	 40×	 40×	No color change on the ground, but it reacted with the NaOH. Note the slight blue tinge on canvas fiber.
Adhesive from the patch	 20×	 20×	Immediate purple color formation, which means that the adhesive likely contains protein.

Table 9 Chemical spot tests for binding medium identification

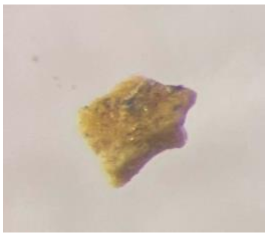
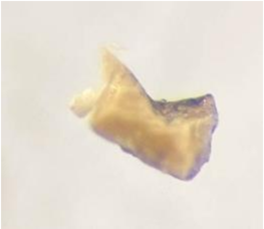
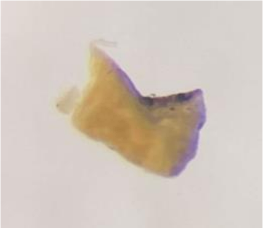
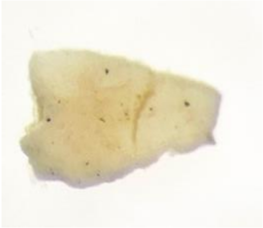
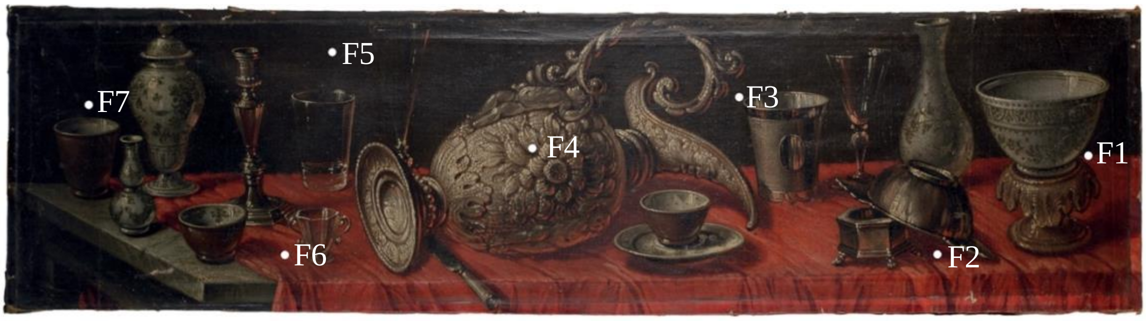
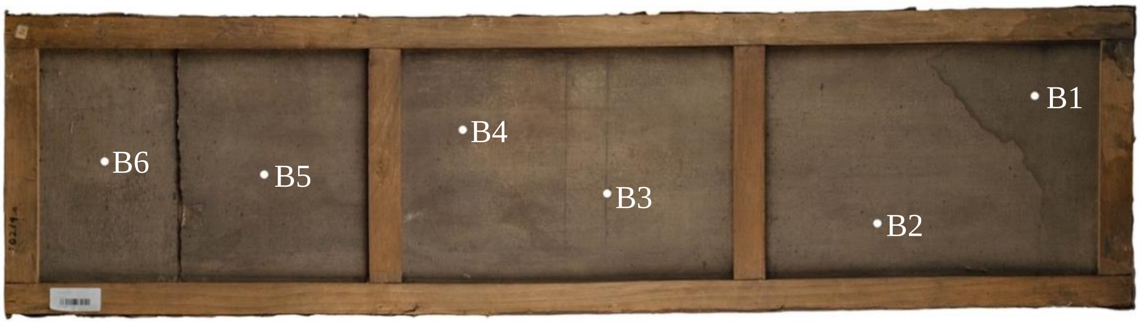
Tested with	**Before (picture)**	**After (picture)**	**Result**
Distilled water 1 drop from pipette	 16,3×	 16,3×	No reaction
Ethanol 4 drops from pipette	 50 ×	 50×	No reaction
Aqueous alkali (NaOH) 2 drops from pipette	 40×	 40×	Immediately saponified, indicative of an oil-based ground.

Table 10 Complete pH and conductivity measurements

	Before cleaning		**After cleaning**	
Location	**pH**	**Conductivity**	**pH**	**Conductivity**
F1	5.66	1 µS/ cm	6.64	31 µS/ cm
F2	5.93	9 µS/ cm	6.33	0 µS/ cm
F3	5.78	7 µS/ cm	6.26	0 µS/ cm
F4	6.00	11 µS/ cm	6.1	0 µS/ cm
F5	6.24	7 µS/ cm	6.16	2 µS/ cm
F6	6.36	1 µS/ cm	6.29	1 µS/ cm
F7	6.03	8 µS/ cm	6.24	1 µS/ cm
Average	**6.05**	**7,1 µS/ cm**	**6.29**	**5 µS/ cm**
B1	6.05	16 µS/ cm	6.04	17 µS/ cm
B2	6.07	15 µS/ cm	5.83	11 µS/ cm
B3	4.79	36 µS/ cm	5.39	13 µS/ cm
B4	5.25	144 µS/ cm	5.29	11 µS/ cm
B5	5.17	14 µS/ cm	5.87	4 µS/ cm
B6	5.56	16 µS/ cm	6.12	4 µS/ cm
Average	**5.48**	**40,1 µS/ cm**	**5.75**	**10 µS/ cm**





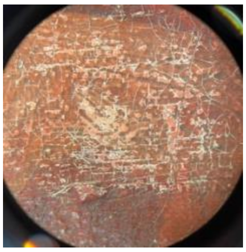
Tables

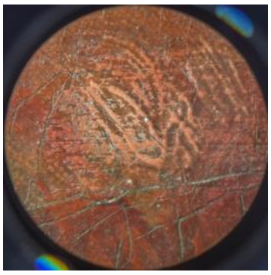
Table 11 Solvent testing

Solvent	**Application method**	**Result**	**Assessment**
Isopropanol	Cotton swab: 20 rolls	Dissolution noted after 7 rolls	Suitable, but to entirely remove the varnish required more than 20 rolls.
Ethanol	Cotton swab: 20 rolls	Dissolution noted after 5 rolls	Suitable
Acetone	Cotton swab: 20 rolls	Dissolution noted after 3 rolls	Suitable

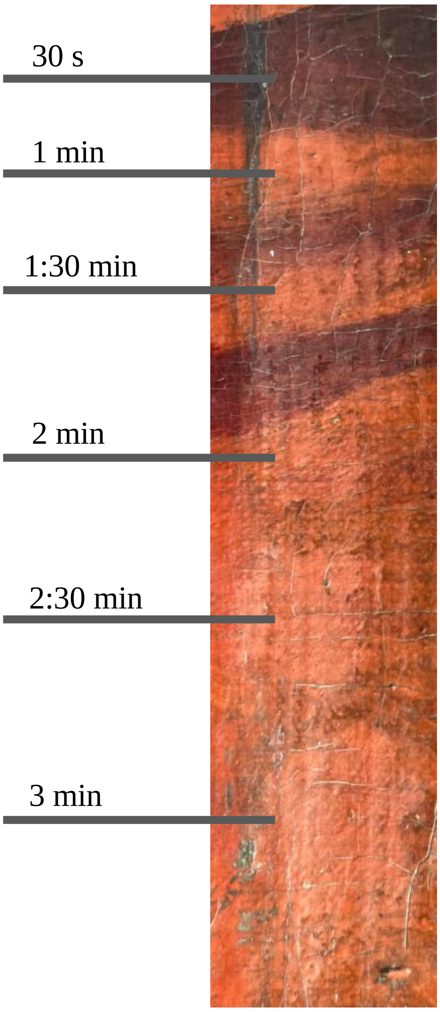
1. Isopropanol
2. Ethanol
3. Acetone

Table 12 Gel testing

Gelling agent	**Tested solvent**	**Gelling agent %**	**Texture**	**Duration**	**Effect on the surface**
Xanthan	Ethanol 50% in distilled water	2%	Thick, flowing.	3 min	 Before clearing: No moisture on the reverse. After clearing: A damp spot.
	Ethanol 50% in distilled water	2%	-	5 min	 Before clearing: No water on the reverse. After clearing: A damp spot.
	Ethanol 50% in distilled water	3%	Very thick, sticky.		Not tested on the surface. Did not dissolve properly in the given timeframe, but upon observation the following day it had properly dissolved.

Klucel® G	Ethanol	3%	Very runny		Not tested on the surface. Too runny, was thickened before testing.
	Ethanol	4%	Thick, but flowing texture.	1 min	 Before clearing: No wet spot visible on the reverse. After clearing: A damp spot.
	Ethanol	4%	-	3 min	 Before clearing: No wet spot on the reverse. After clearing: A damp spot. Very uneven varnish removal.
Gellan	Ethanol 20% in distilled water	3%	4 mm thick. Rigid, but fell apart easily. Quite wet.	3 min	 A very wet spot visible on the reverse. Hardly any effect on the varnish. Left

					moisture on the paint surface.
Agar	Ethanol 20% in distilled water	3%		3 min	A wet spot on the reverse. No effect on the varnish. Left moisture on the surface.
	Acetone 20% in distilled water	3%		3 min	 A wet spot on the reverse. Very ineffective on the varnish. Left moisture on the surface.
Carbopol® EZ 2-Ethomeen® C25	Acetone		Thick, quite rigid. Comfortable working consistency, does not slip. Leaves a lot of residues, difficult to remove without a lot of clearing.	30 s 1 min 1:30 min 2 min 2:30 min 3 min	30 s: Slight solvent dissolution. No dirt pickup. 1 min: Some varnish dissolution. Some dirt pickup. 1m 30s: Some varnish dissolution. Some dirt pickup. 2 min: Quite a lot of varnish dissolution. Some dirt pickup. A lot of varnish remains on the surface.

					2m 30s: Good varnish dissolution. A lot of dirt pickup. Some varnish remains on the surface. 3 min: Very good varnish dissolution. A lot of dirt pickup. Some varnish spots remain.
Carbopol® EZ 2-Ethomeen® C25	80% acetone/ 20% benzyl alcohol		Thick, quite rigid. Very little flow, does not Leaves a lot of residues.	 No wet spot from the gel, but the clearing left a lot of moisture on the reverse.	

				30 s: Some varnish dissolution. Some dirt pickup. Very uneven. 1 min: Some varnish dissolution. Some dirt pickup. 1:30 min: Good varnish dissolution. Some dirt pickup. Uneven removal. 2 min: Good varnish dissolution. A lot of dirt pickup. Some varnish spots remain. 2:30 min: Very good varnish dissolution. A lot of dirt pickup. Some remaining spots of varnish. 3 min: Very good varnish dissolution. A lot of dirt pickup. Hardly any spots. Too much clearing risks picking up red and yellow pigment.

Table 13 Testing of cleaning agents

Cleaning method	**Application method**	**Result**	**Assessment**
Distilled water	Cotton swab	Over varnish: no effect	Likely cleaned before, minimal soil present.
		On tacking edge: some effect.	Not effective enough
		After varnish removal: no effect, immediate pigment removal on red and yellow.	
Triammonium citrate (TAC) 1%	Cotton swab	Over varnish: very little effect.	Likely cleaned before, minimal soil present.
		On tacking edge: good effect. After 10 rolls: pigment removal on red.	Suitable on black half, may be used on red with extreme care.
		After varnish removal: Effective on black, white and brown. Immediate pigment removal on yellow. After 10 rolls: pigment removal on red.	Suitable on black half of the painting, with care to avoid red.
TAC 1%	Klucel® G	After varnish removal: Effective on black, white and brown. Immediate pigment removal on yellow upon removal of the gel. Clearing with deionized water caused immediate pigment removal on red.	Suitable on black half of the painting, with care to avoid red.
TAC 2%	Cotton swab	After varnish removal:	Not suitable

		Effective on black, white and gray. Immediate pigment removal on red, brown and yellow.	
TAC 2%	Klucel® G	After varnish removal: Effective on black, white and brown. Immediate pigment removal on red.	Not suitable
NH_4OH, pH 7,7	Cotton swab	After varnish removal: No effect on the dirt. Immediate pigment removal on red. Not tested on yellow.	Not suitable
Triton X-100 1% in deionized water	Cotton swab	After varnish removal: No effect on the dirt. Immediate pigment removal on red.	Not suitable
Citric acid pH 6,5 buffered with NaOH and deionized water	Cotton swab	After varnish removal: No effect on dirt, pigment removal on red.	Not suitable.

Tables

Table 14 Numerical evaluation of the tested solvents and cleaning agents

No pigment loss						**Pigment loss**					
Good effect		Medium		Minimal		Good effect		Medium		Minimal	
Even	**Uneven**	**Even**	**Uneven**	**Even**	**Uneven**	**Even**	**Uneven**	**Even**	**Uneven**	**Even**	**Uneven**
6	5	4	3	2	1	-1	-2	-3	-4	-5	-6

Interpretation taken from Frøysaker et al. 2013:122

Colors							
Color area / Solvent /Cleaning agent	Blue decoration on porcelain (0201)	Red tablecloth light (0601)	Red tablecloth dark areas	Brown ceramic (0701)	Black background (0801)	Yellow bowl mount	White porcelain (0903)
Free solvent isopropanol	1	1	1	1	1	1	1
Free solvent ethanol	3	3	3	3	3	3	3
Free solvent acetone	5	5	5	5	5	5	5
Carbopol® EZ 2-Ethomeen® C25 acetone gel	3	3	3	3	3	-	3

Carbopol® EZ 2-Ethomeen® C25 acetone benzyl alcohol gel	5	5	5	5	5	5	5
Distilled water	1	1	1	1	1	-5	1
NH_4OH, pH 7,7	1	-1	-3	-1	1	-1	1
TAC 1%	4	-3	-3	4	4	-1	4
TAC 2% in Klucel® G and deionized water	6	-1	-6	-6	6	-6	6
Triton X-100 1% in deionized water	1	1	2	1	1	-6	1
Citric acid pH 6,5 buffered with NaOH and deionized water	1	1	1	1	1	-6	1

Table 15 Structure of the paint layers and summary of research findings

Color	Color - no.	#	Location	Technique[23]	Layer structure	Opacity[24]	FCIR	pXRF[25]	Cross-section and SEM-EDX	Possible pigments
Blue	0201	1	Decoration on the three white vases, inside the brown cups and bowls	4. D 3. D 2. M	4. Blue 3. Black/ dark blue 2. White 1. Ground[26] 0. Canvas	4. T 3. O 2. O	Red	**As**, **Co**, **K**, *Si*, *Ni*	-	Smalt

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[23] Mch – monochrome, M – modelled, D - Drawn

[24] O – opaque, T – transparent

[25] Organized by likely **probably major elements**, present in lesser quantities, and *minor/trace amounts* (Bezur et al., 2020, p. 153)

[26] Points 1. and 0. will only be mentioned on the first row, but are present in all structures.

Yellow	0401	2	Bowl mount, far right	5. D 4. M 3. M 2. M	6. White 5. Light yellow 4. Yellow 3. Black 2. Dark brown	6. O 5. O 4. O 3. O 2. O		**As**, Fe, Pb, Ca	**As, S**, Fe,	Orpiment, yellow earth pigment
Red	0601	3	Tablecloth, main	3. M 2. M	3. Light red 2. Red	3. O 2. O	Yellow	**Hg**, Fe, S	-	Vermillion, red earth pigment?
	0602	4	Tablecloth, shadows	3. M 2. M	3. Dark red 2. Medium dark red	3. O 2. O	Orange	**Hg**, Fe, S	-	Iron-based red on top of vermillion
	0603	5	Tablecloth, hanging off the edge	5. M 4. M 3. M 2. M	5. Light red 4. Dark, cold red 3. Medium dark red 2. Red	5. O 4. O 3. O 2. O	Yellow in the light areas, orange in the dark areas	**Hg**, Fe, S	-	Vermillion (light red), iron pigment (dark red)
Brown	0701	6	Porcelain cup far left, small cup, cup on saucer	5. D 4. M 3. M 2. M	5. Highlights 4. Cold light brown 3. Dark brown 2. Brown	5. O 4. O 3. O 2. O		-	-	

Black	0801	7	Background to the left of the possible pentimento	2. Mch	2. Black	2. O		**Pb**, Ca,	-	Organic pigment, likely charcoal
	0802	8	Background to the right of the possible pentimento	2. Mch	2. Black	2. O		Pb, Ca	-	Organic pigment, likely charcoal
	0803		Upturned bowl, octagonal spice box, candlestick, knife, beaker	5. D 4. M 3. M 2. M	5. White highlights 4. Reflected light (white or red) 3. Black 2. Dark gray	5. 4. 3. 2.				
White	0901	9	Tabletop	4. 3. 2.	4. Highlights 3. Dark gray 2. Gray	4. O 3. O 2. O		Pb, Ca	-	Lead white
	0902	10	Table side and leg	4. 3. 2.	4. Highlights 3. Black 2. Dark gray	4. O 3. O 2. O		Pb, Ca	-	Lead white
	0903	11	White porcelain vases, inside of brown cups	5. D 4. 3. M 2. M	5. White highlights 4. C 3. Black 2. Gray	5. O 4. T 3. O 2. O		Pb, Fe, O	-	Lead white

	0904	12	Glasses	4. D 3. D 2. M/D	4. White highlights 3. Red shine 2. Gray contour	4. O 3. O 2. O		-	-	
	0905	13	Ewer	6. D 5. M 4. M 3. M 2. M	6. Highlights 5. Light contrast – gray and red 4. Black 3. dark gray 2. Medium gray	6. O 5. O 4. O 3. T 2. O	Red areas: Yellow White areas: white, red-tinted white	Pb, As, Fe, Kr, Hg Co, K, S -	-	Lead white, organic charcoal black, likely some smalt mixed in with the white

Key:

Violet - 0100
Blue - 0200
Green - 0300
Yellow - 0400
Orange - 0500
Red - 0600
Brown - 0700
Black - 0800
White - 0900
Skin tone - 1000
Metal - 1100

Table 16 Color measurements

Location	**Before treatment**		**After cleaning**		**After varnishing**	
Bowl mount (0401)	S 7010-Y30R	●	S 3030-Y20R	●	S 3040-Y10R	●
Red tablecloth (0601)	S 6030-Y80R	●	S 2060-Y80R	●	S 2060-Y90R	●
Brown ceramics (0701)	S 8505-Y80R	●	S 7010-Y70R	●	S 7020-Y60R	●
Black background (0801)	S 8500-N	●	S 8005-Y20R	●	S 8505-Y20R	●
Tabletop (0901)	S 6010-G70Y	●	S 4005-R80B	●	S 4010-R90B	●
White porcelain (0903)	S 7005-G80Y	●	S 4010-R90B	●	S 3010-R90B	●
Ewer (midtone) (0905)	S 7010-Y30R	●	S 5010-Y30R	●	S 5010-Y30R	●

Table 17 Gloss measurements

Location of measurement	Before treatment	After cleaning	After varnishing
Black background (0801)	50	2	50
Red tablecloth (0601), left of the ewer	50	12	75
Red tablecloth (0601), right of the ewer	50	30	75
Brown cup (far left) (0701)	50	6	50
Porcelain bowl (far right) (0903)	50	2	50
Ewer (0905)	50	2	50

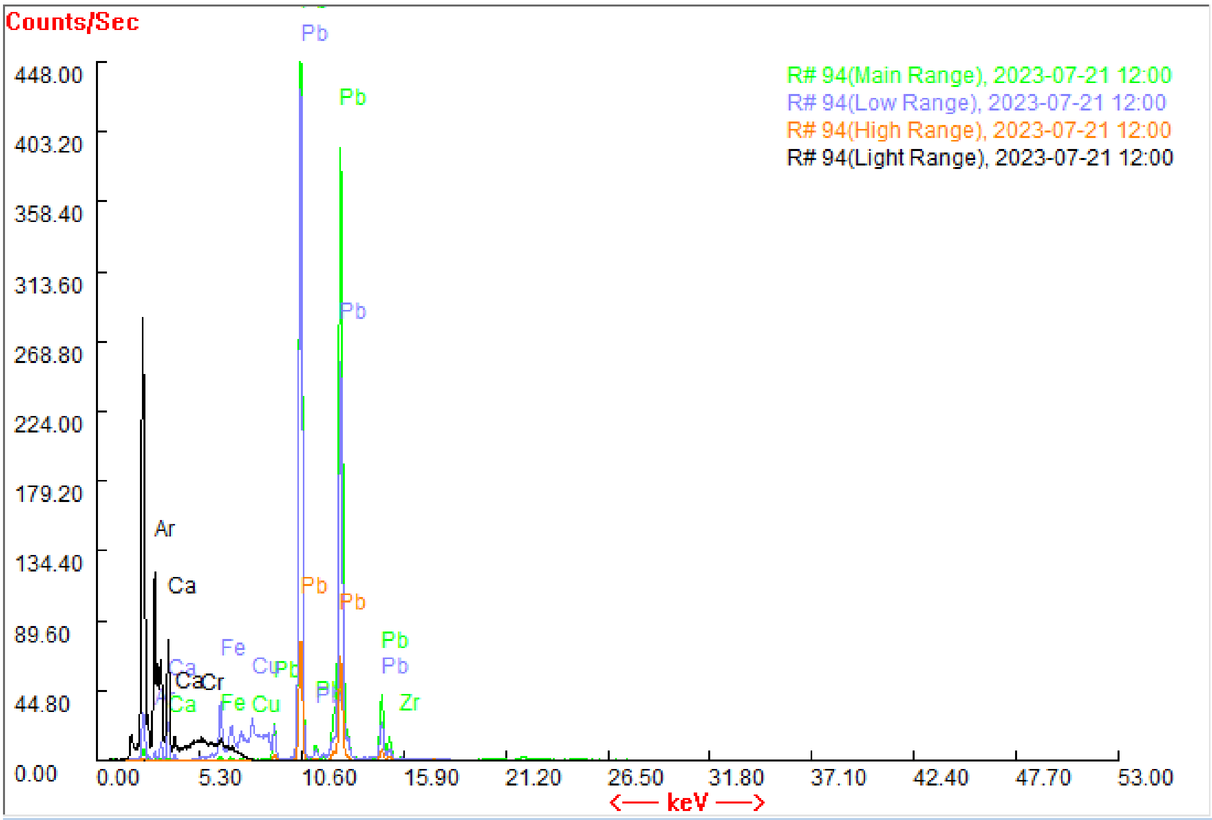
Gloss rating guide from the Norwegian Color Senter AS Natural color system (NCS) gloss scale	
Gloss type	**Gloss value**
Full matt	2
Matt	6
Semi-matt	12
Satin	30
Semi-glossy	50
Glossy	75
High gloss	95

12 Appendices

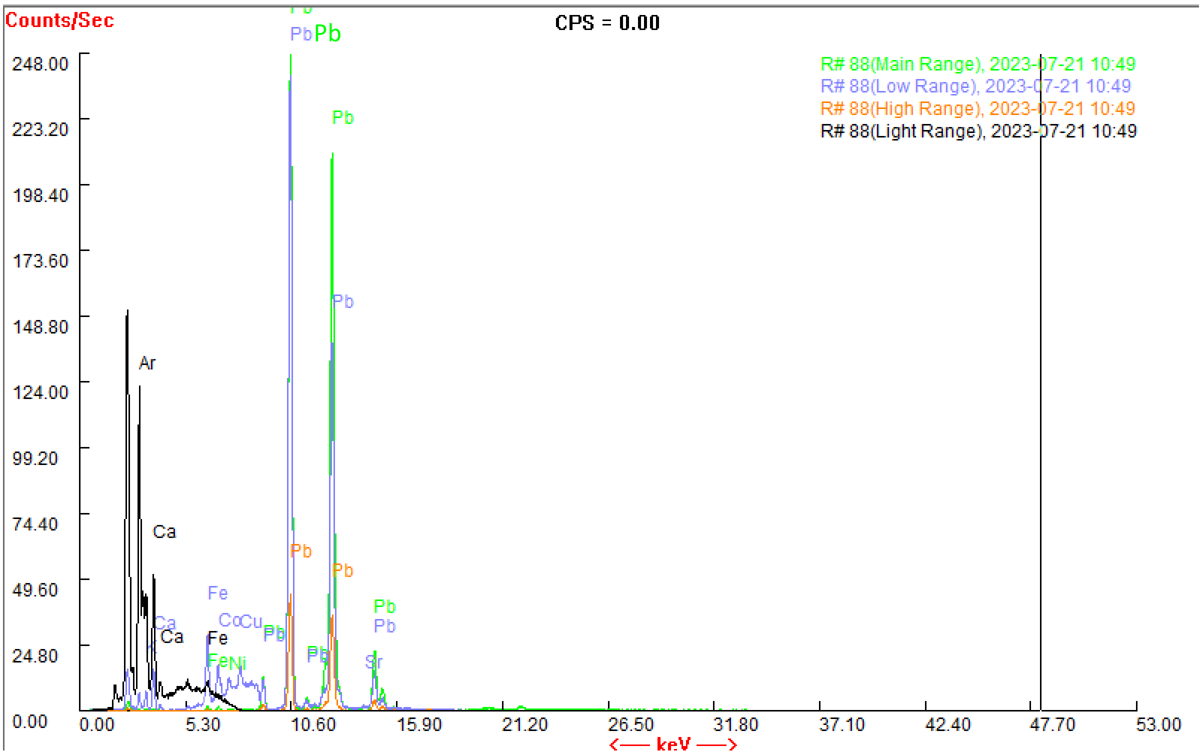
1: pXRF spectra

Locations of pXRF measurements.

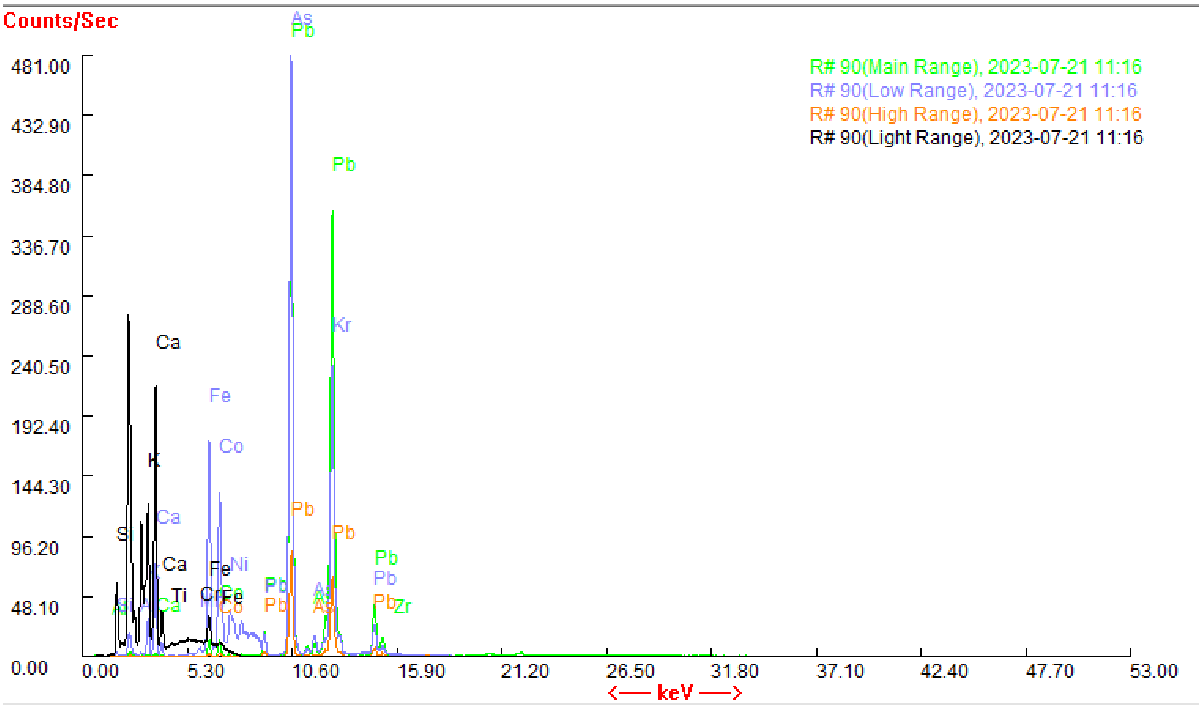
1 – Background



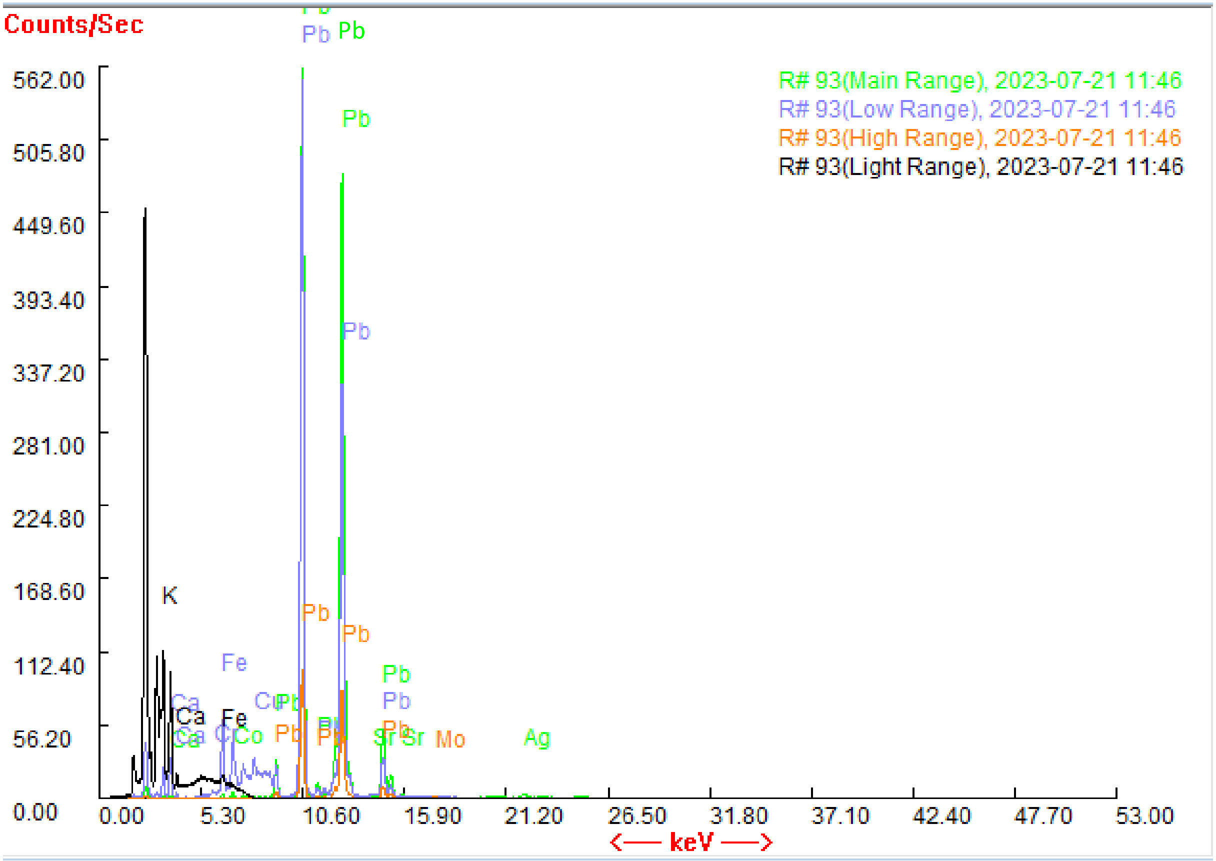
2 – White on lidded vase



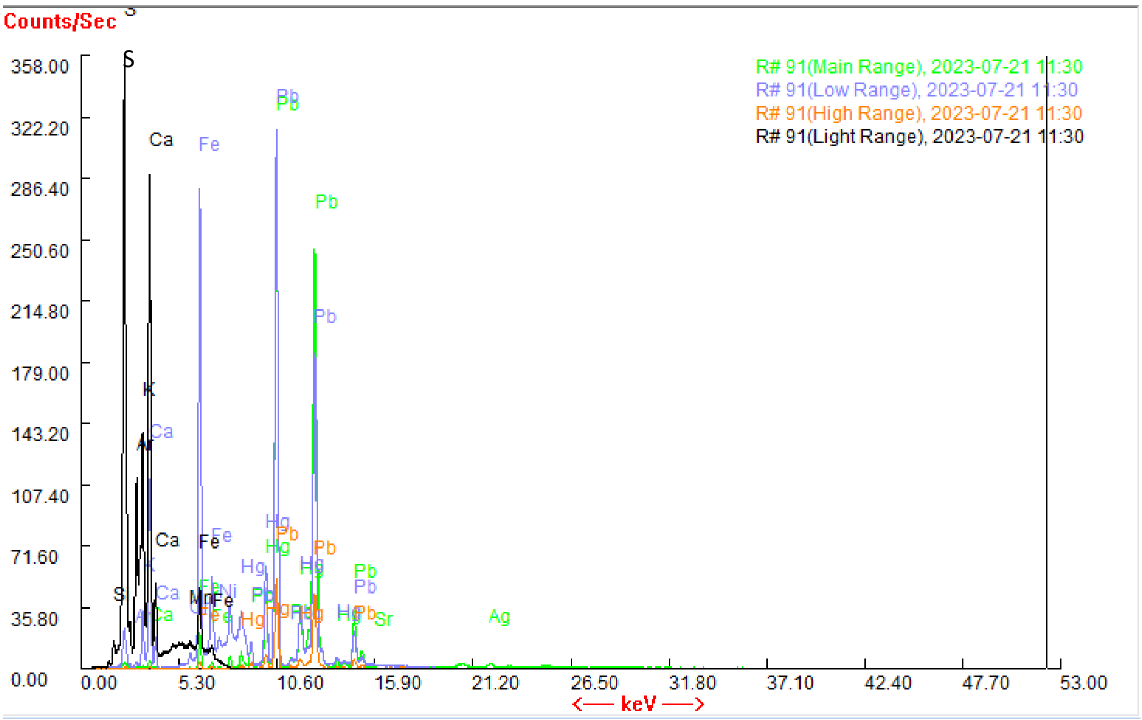
3 – blue décor on lidded vase



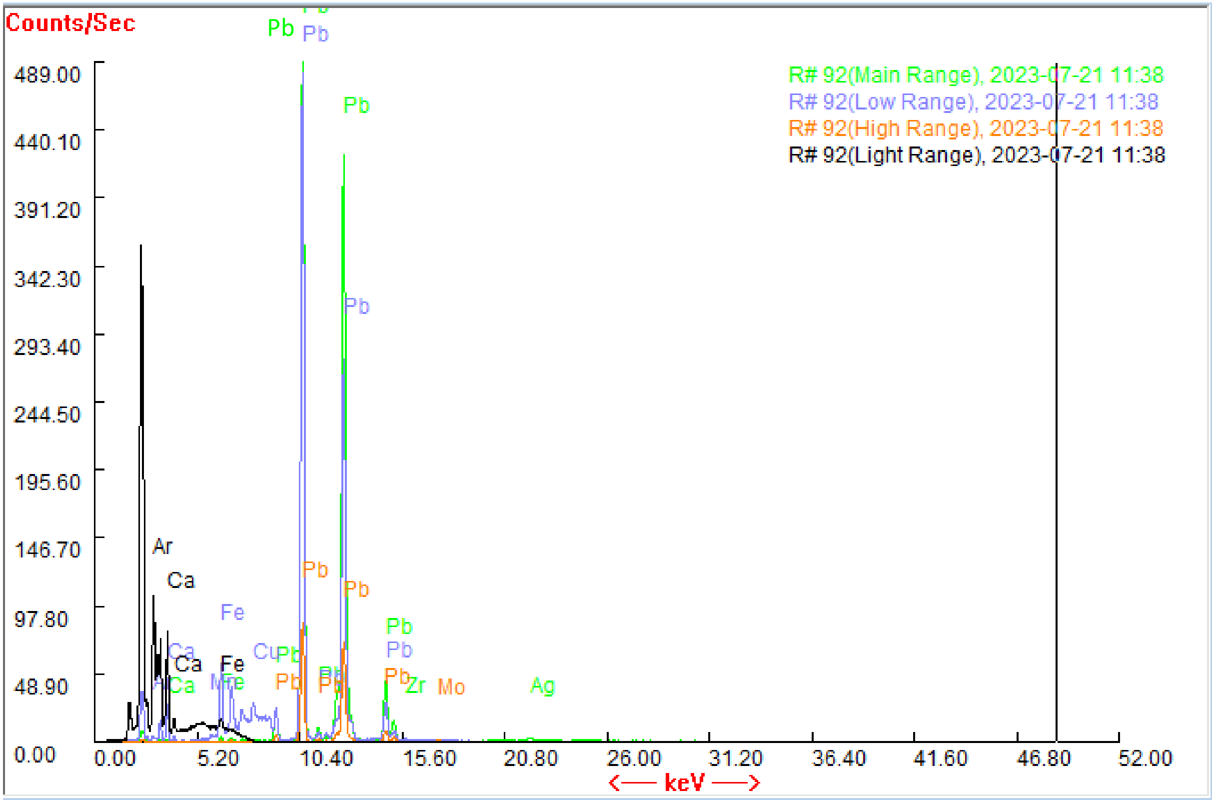
4 – tiny vase



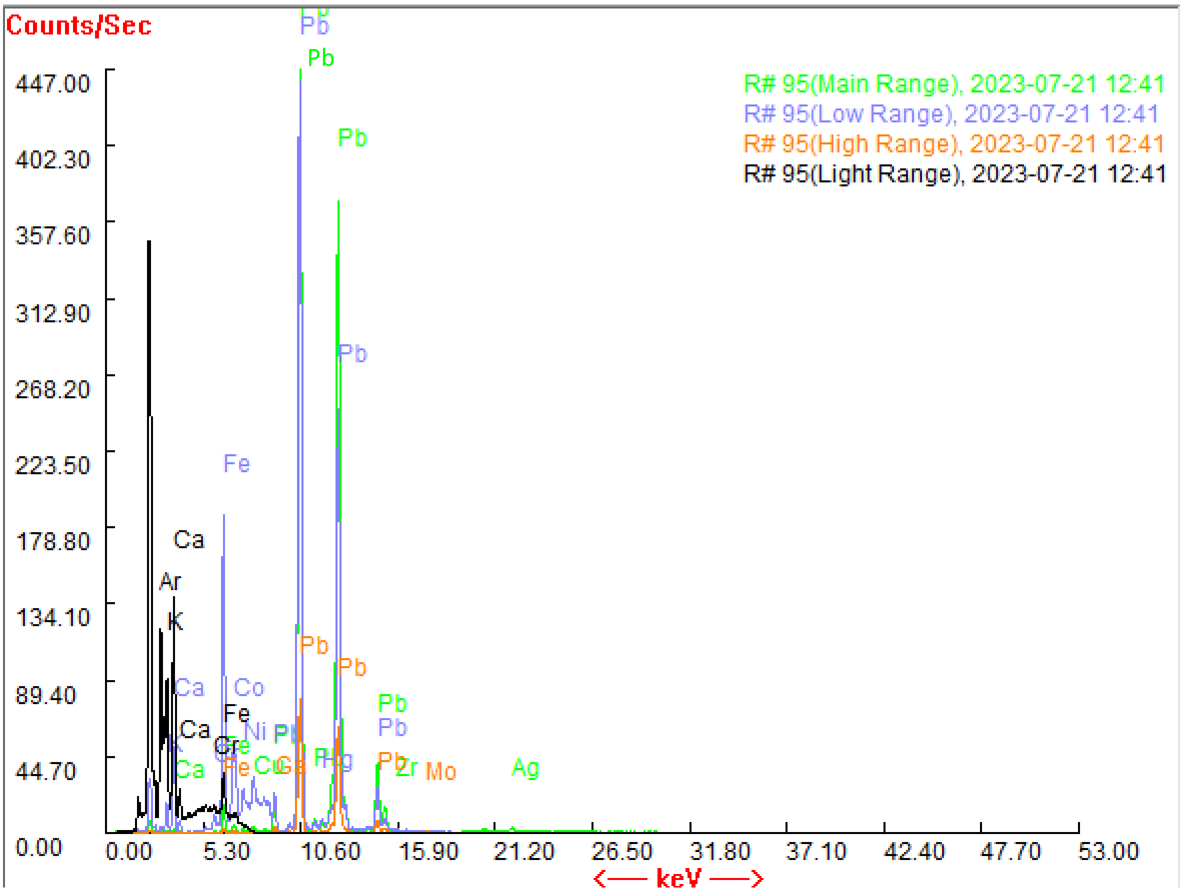
5 – Tablecloth, shadow



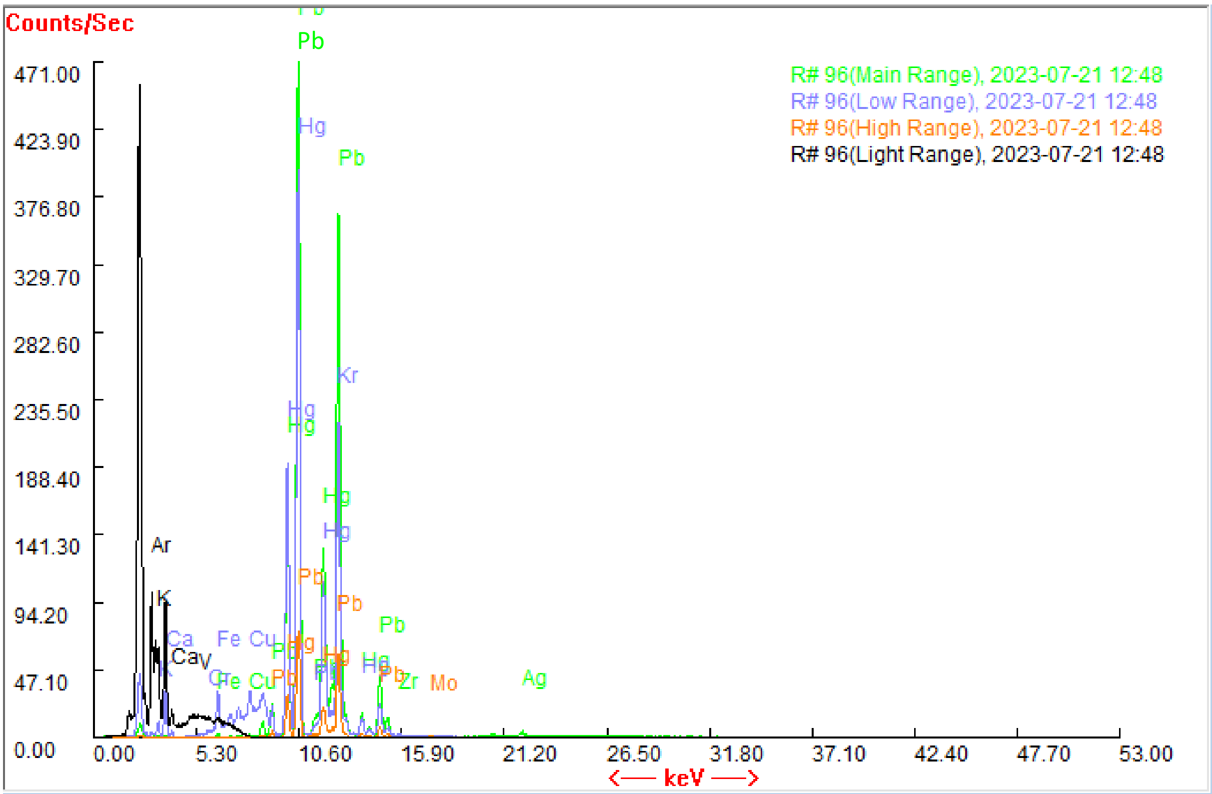
6 – Table



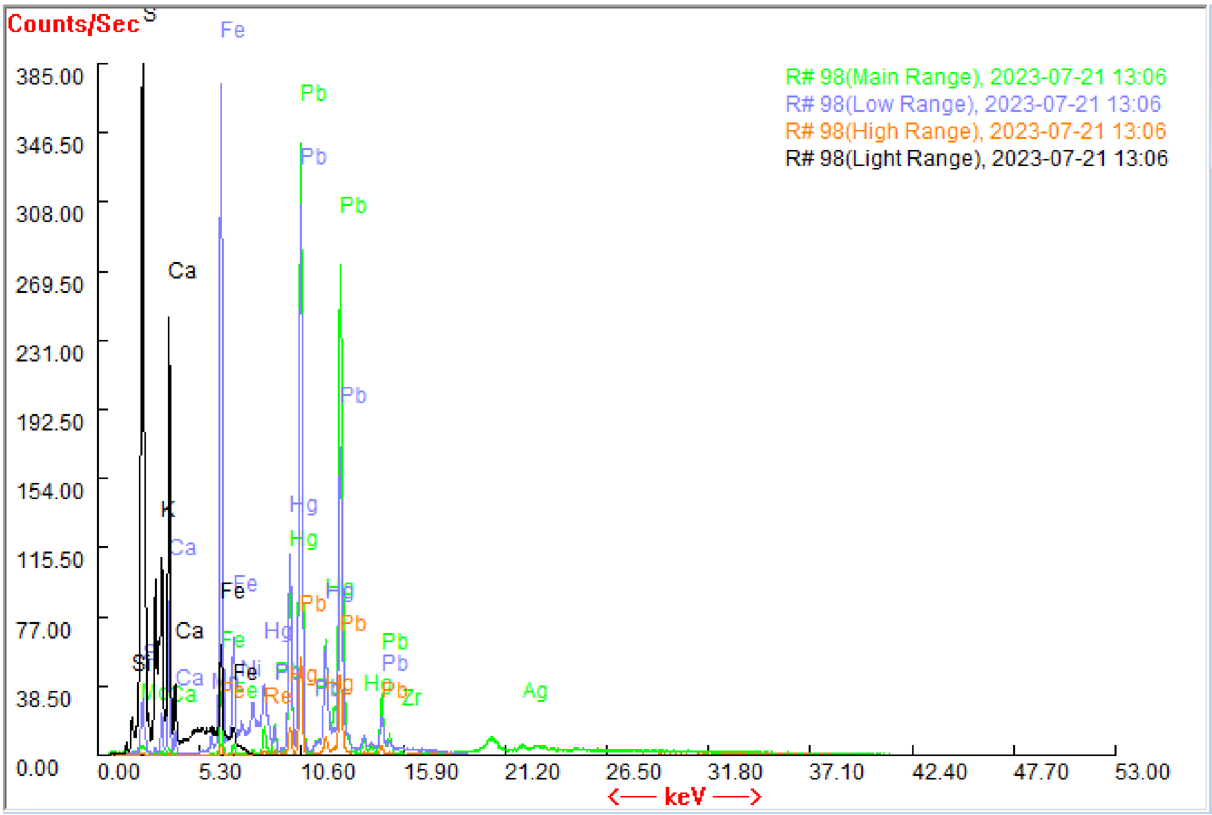
7 – Candlestick



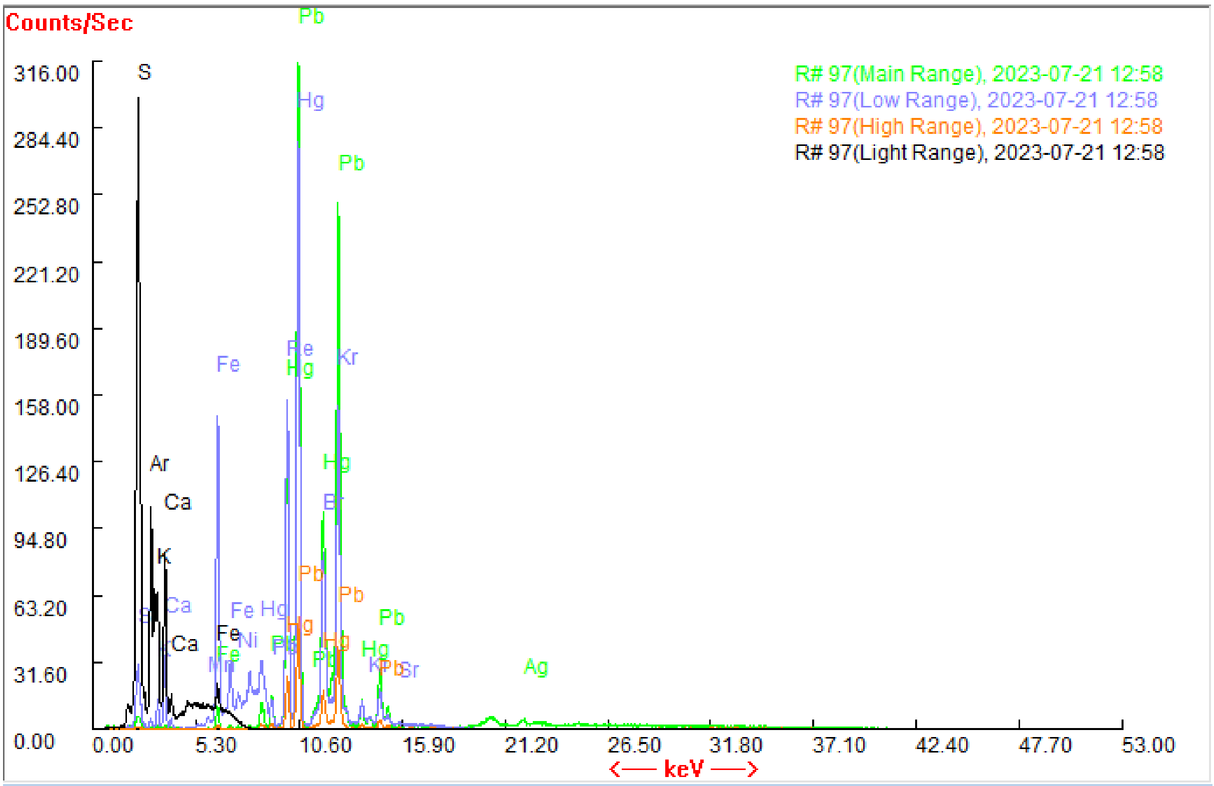
8 – Tablecloth light



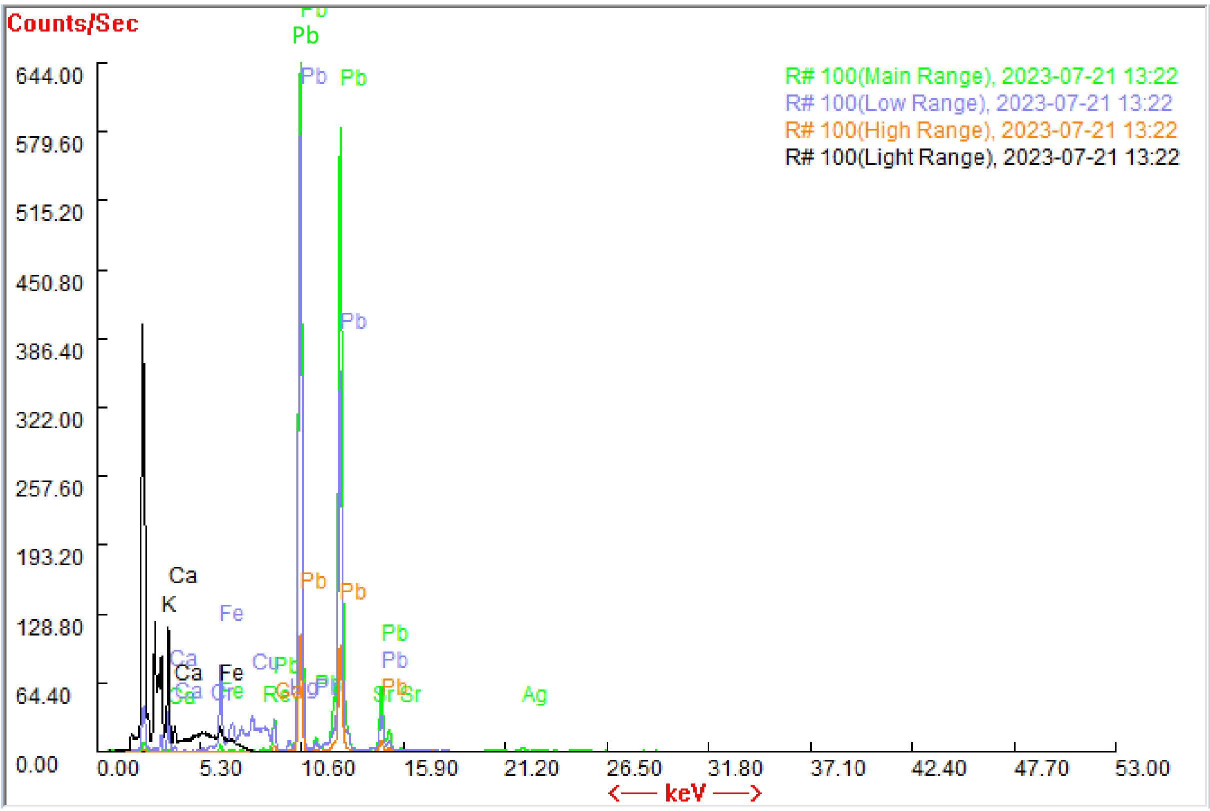
9 – Tablecloth edge shadow



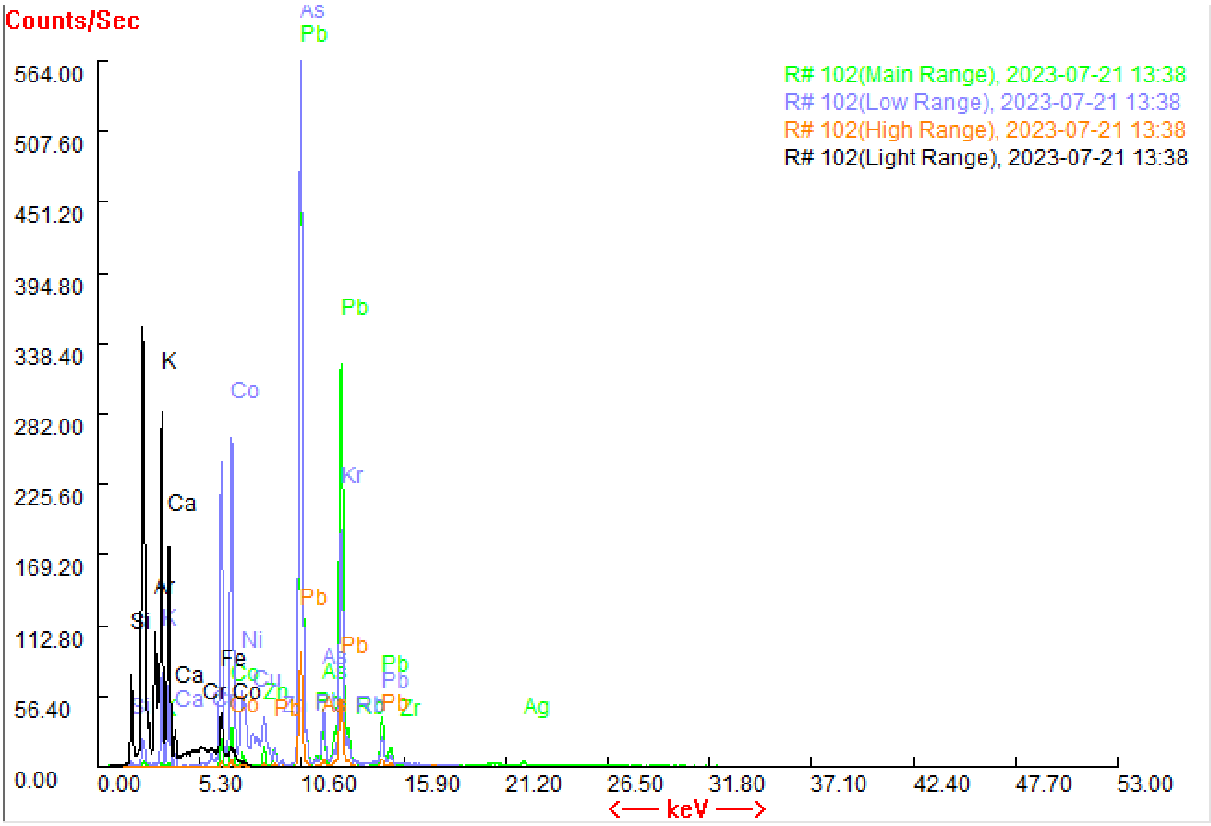
10 – Tablecloth edge light



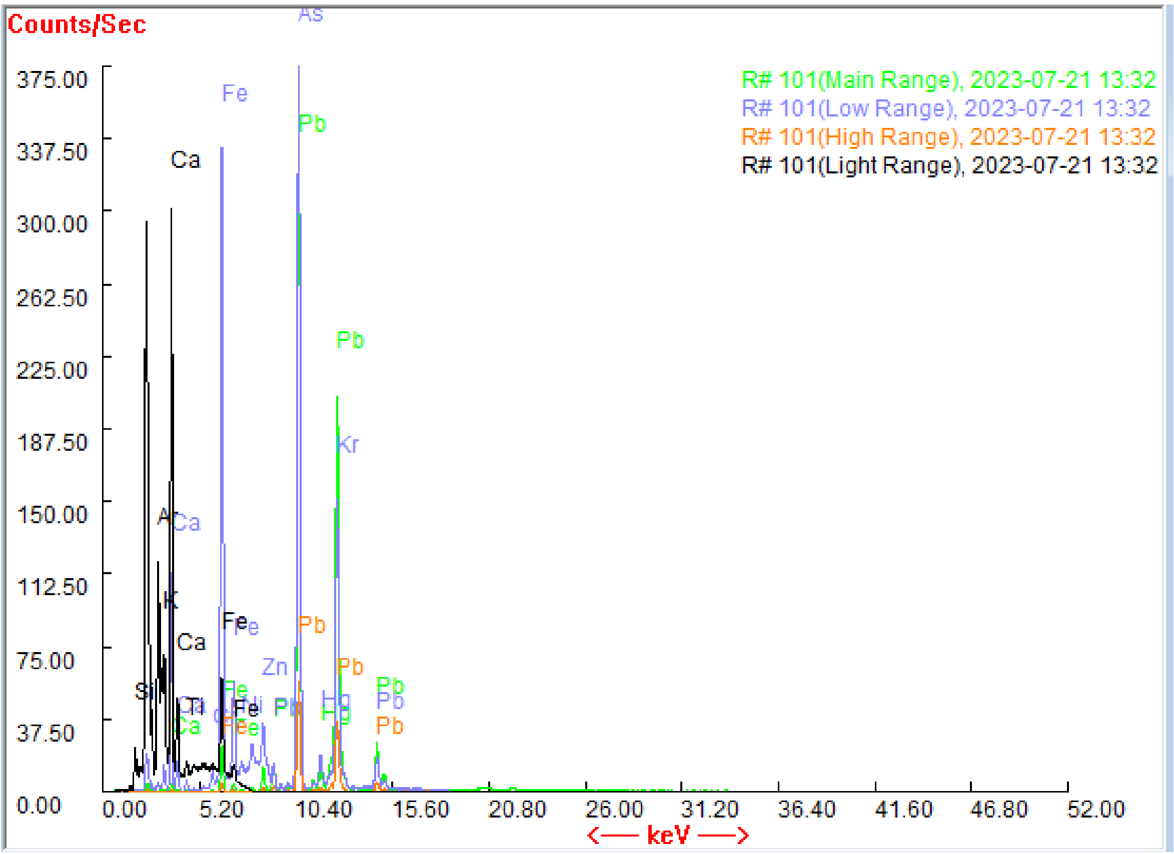
11 – Ewer



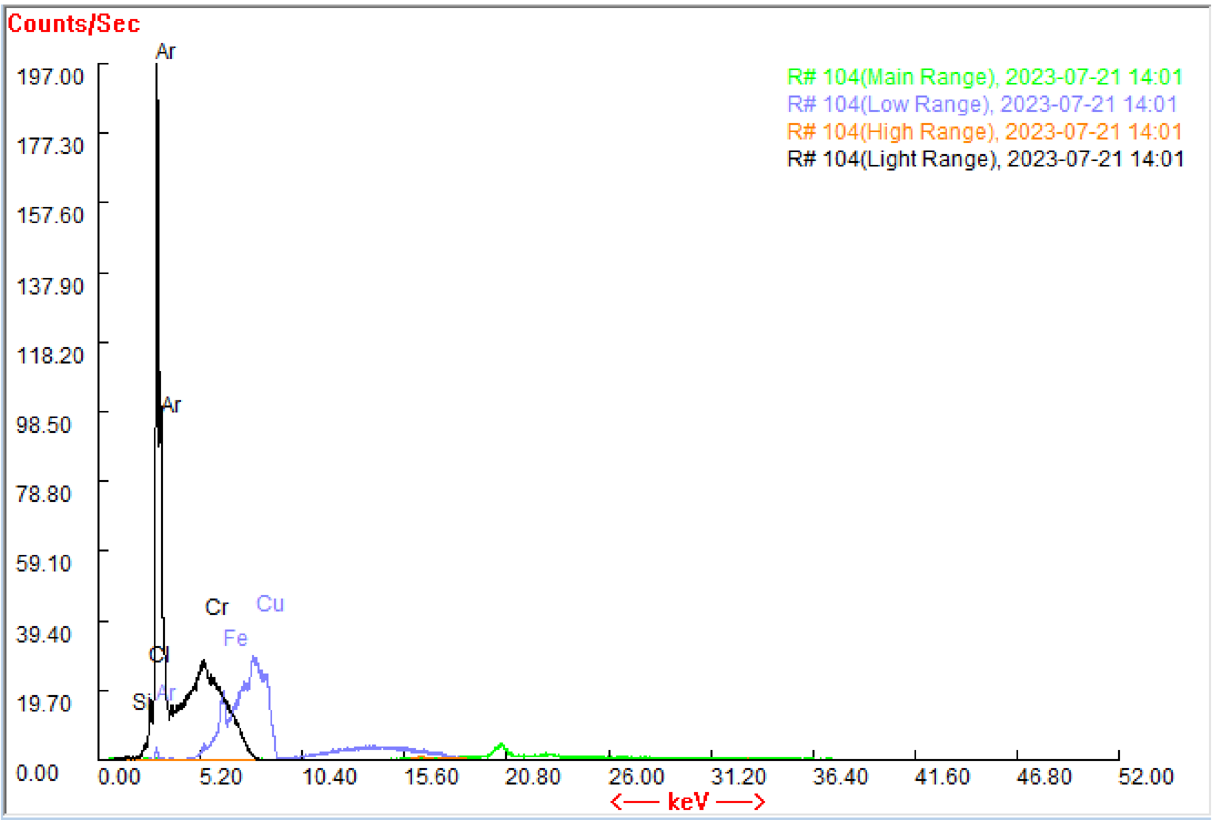
12 – Blue décor on the right-hand side bowl



13 – Bowl mount

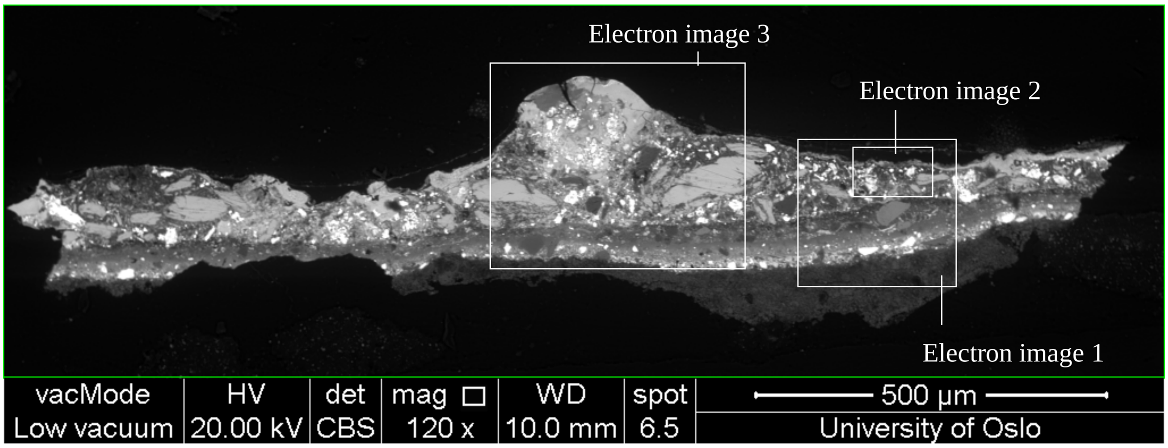


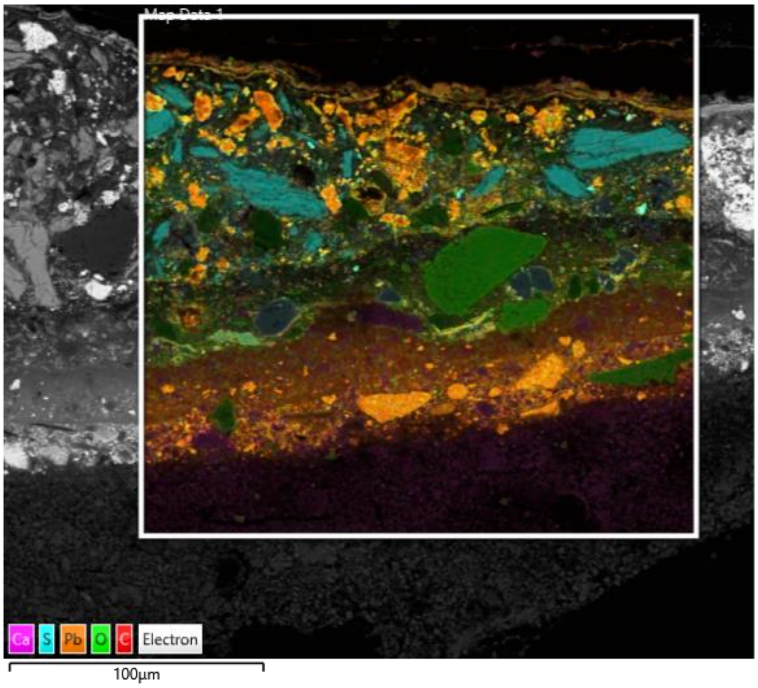
14 – Ethafoam reference



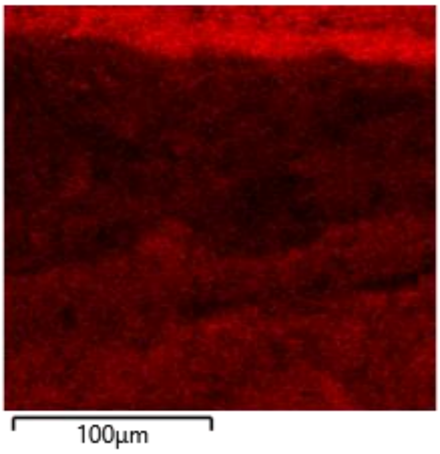
2: SEM-EDX analysis results

Electron image 1

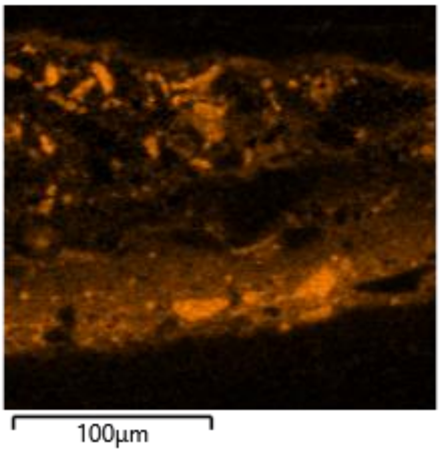




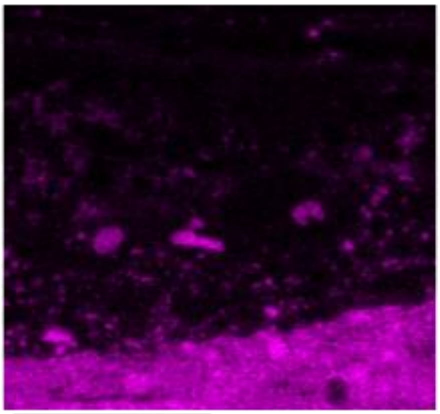
C K series



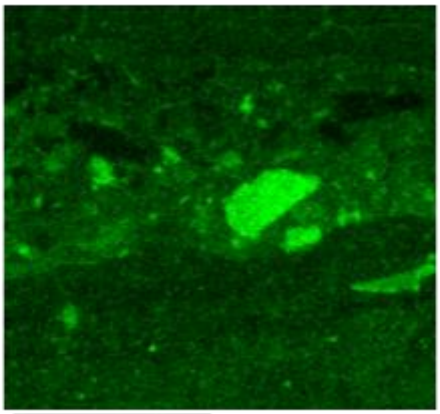
Pb M series



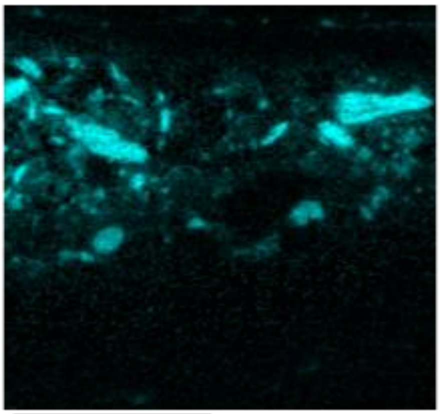
Ca K series



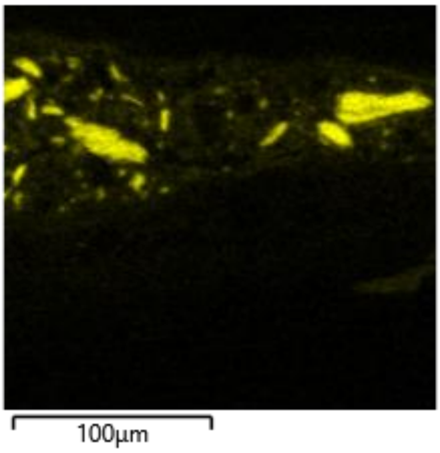
O K series



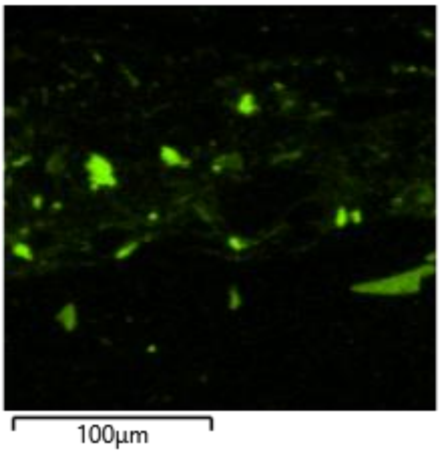
S K series



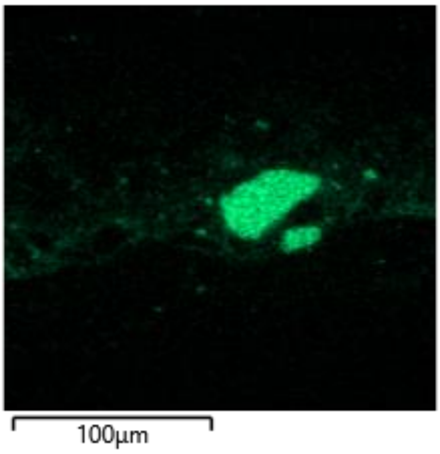
As L series



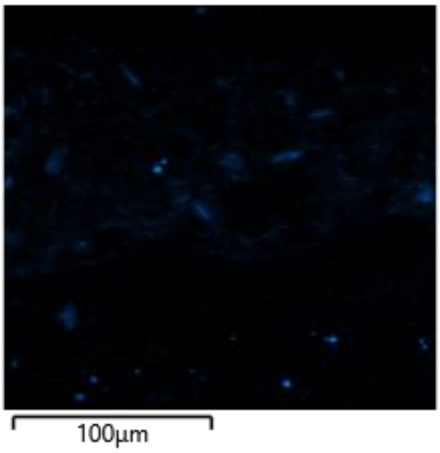
Si K series



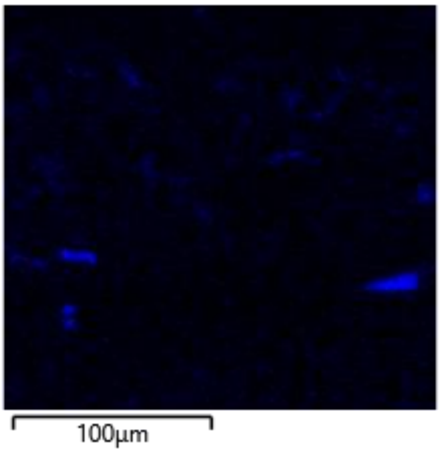
Fe K series



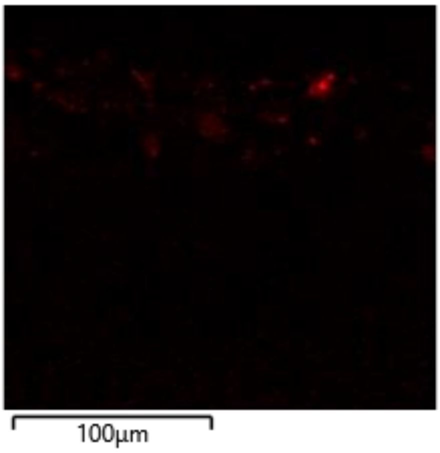
Al K series



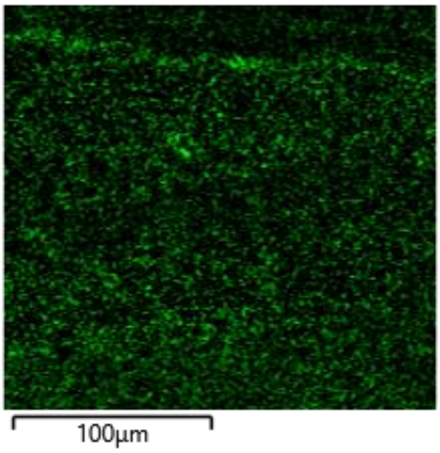
K K series



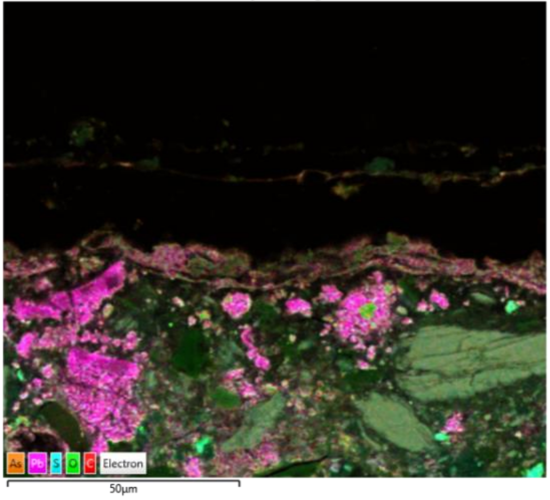
Sn L series

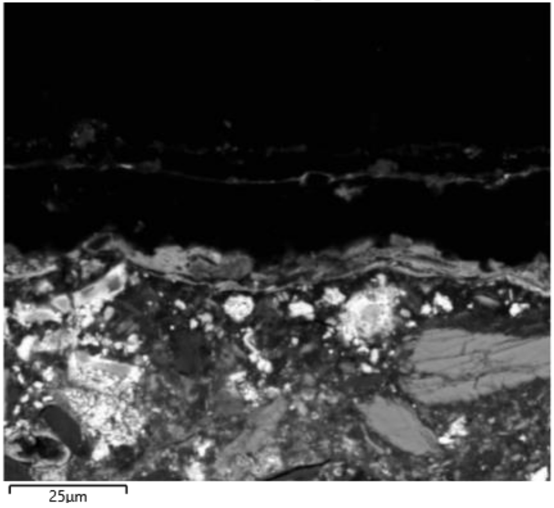


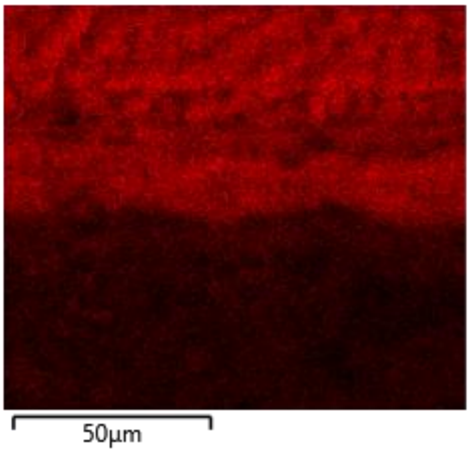
Cl K series

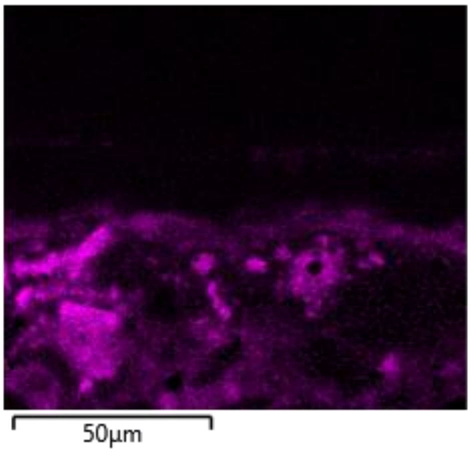


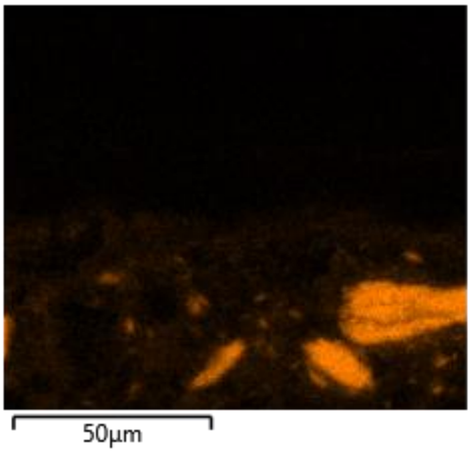
Electron image 2 – Potential metal soap crust

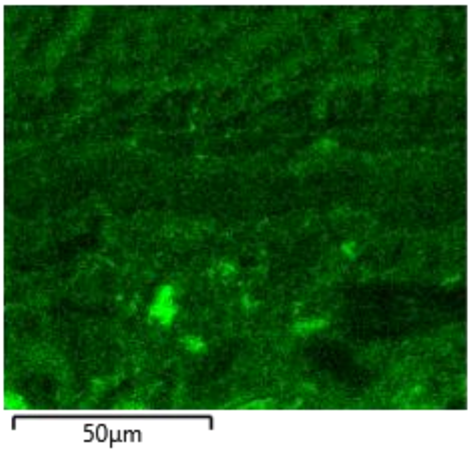

EDS Layered Image 2

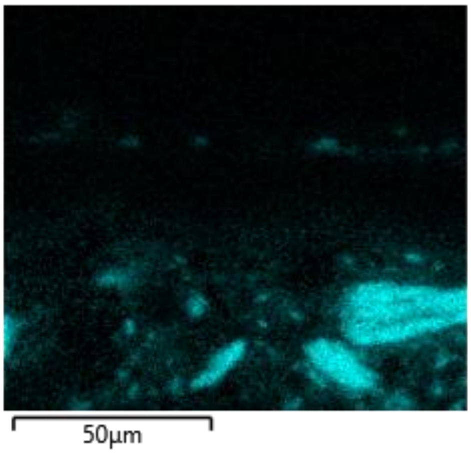

Electron Image 2


C K series

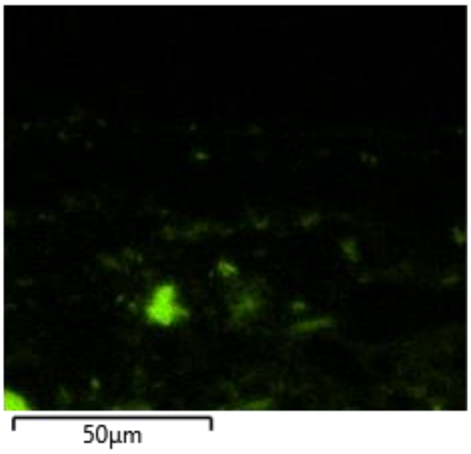

Pb M series


As L series

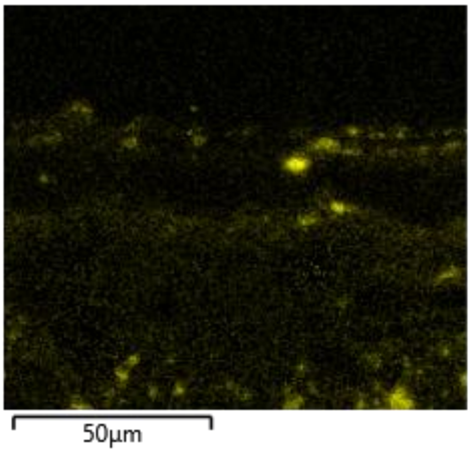

O K series



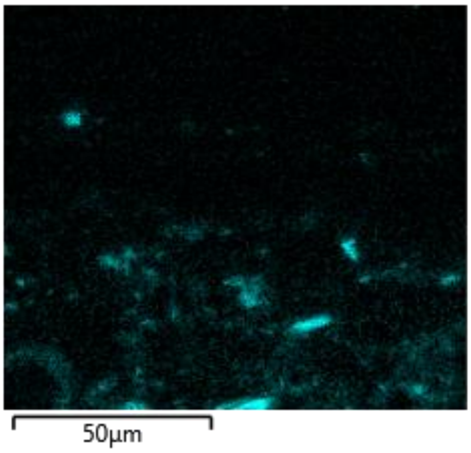
S K series



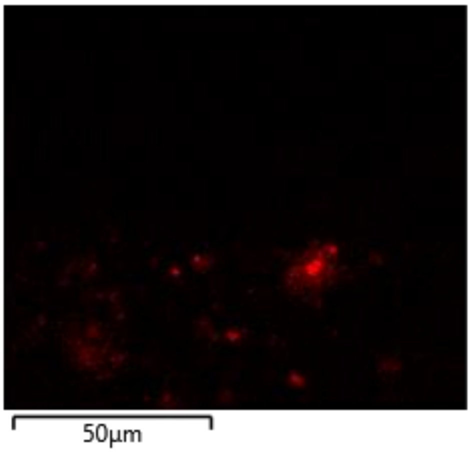
Si K series



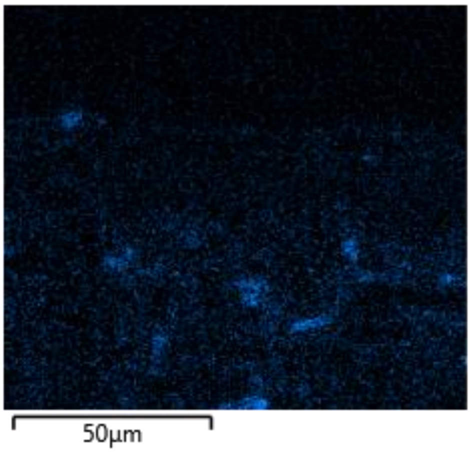
Ca K series



Al K series

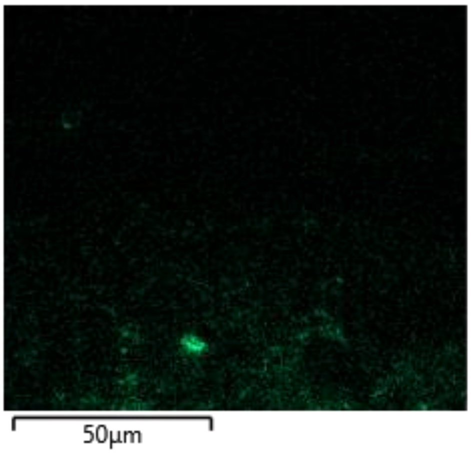


Sn L series

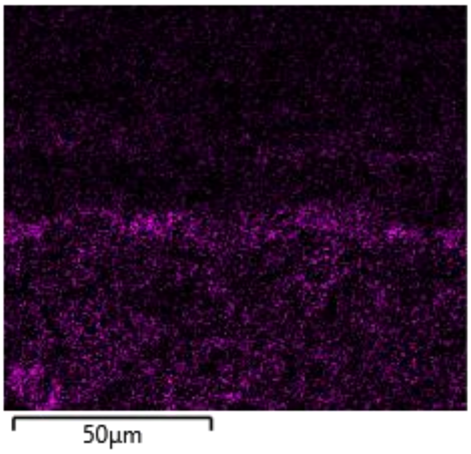


K K series

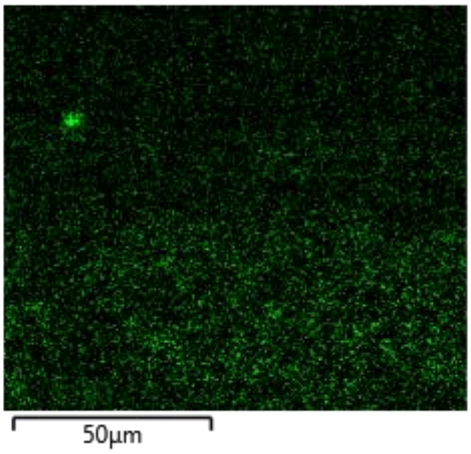
Fe K series



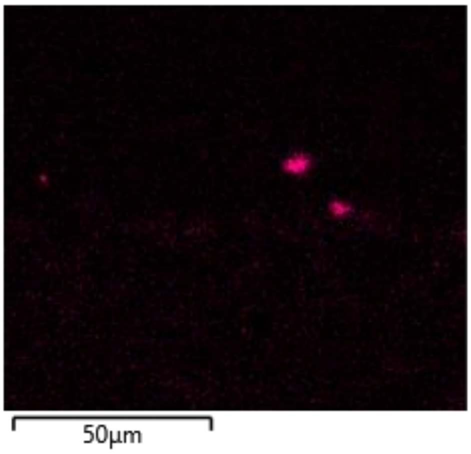
Cl K series



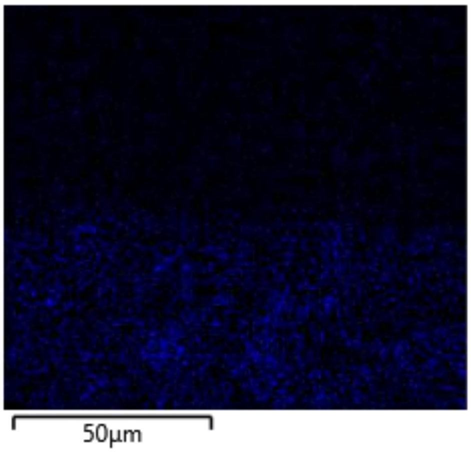
Na K series



P K series

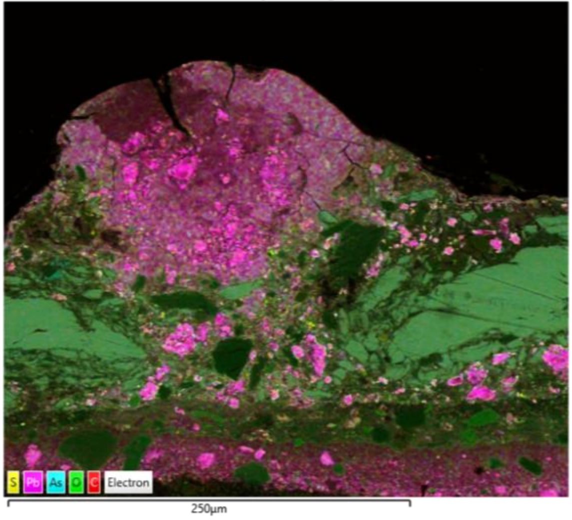


Zn K series

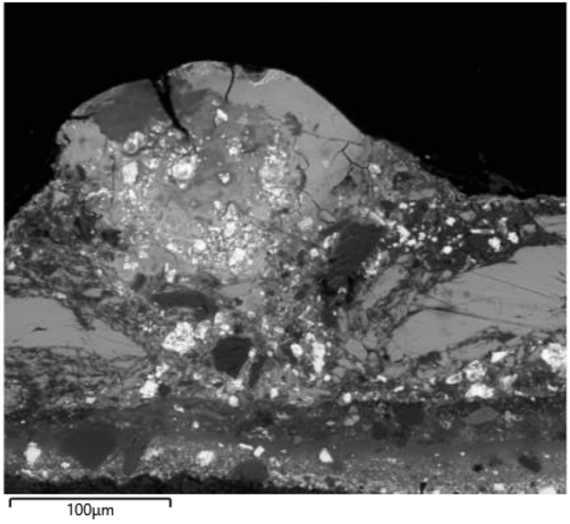


Electron image 3

EDS Layered Image 3



Electron Image 3



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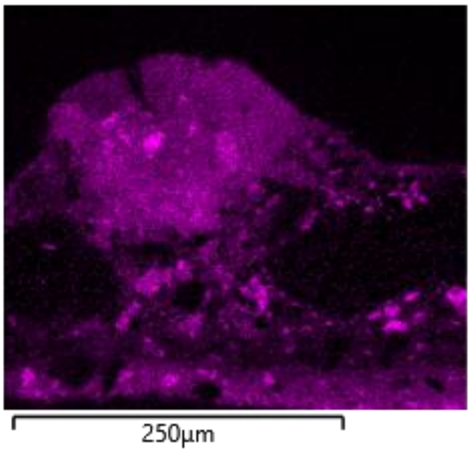

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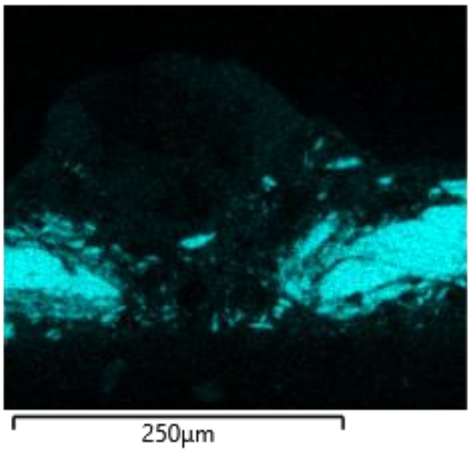
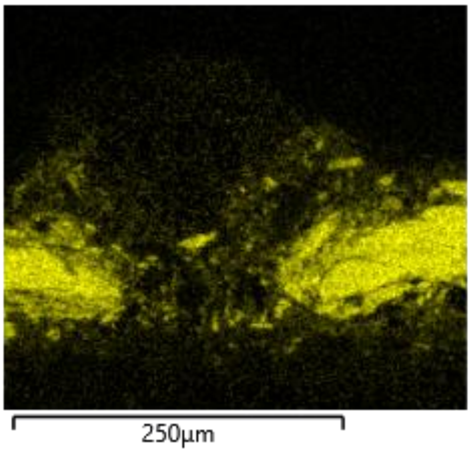
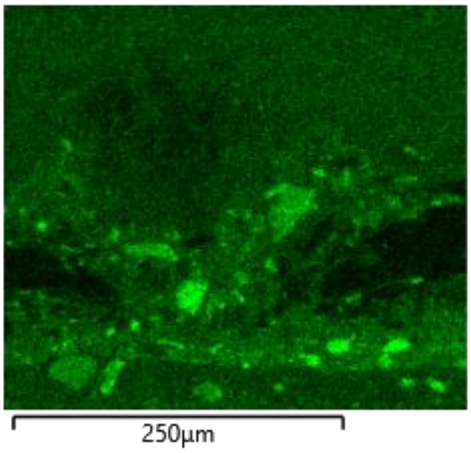
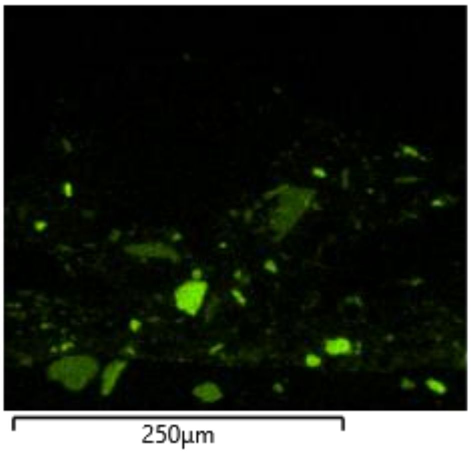


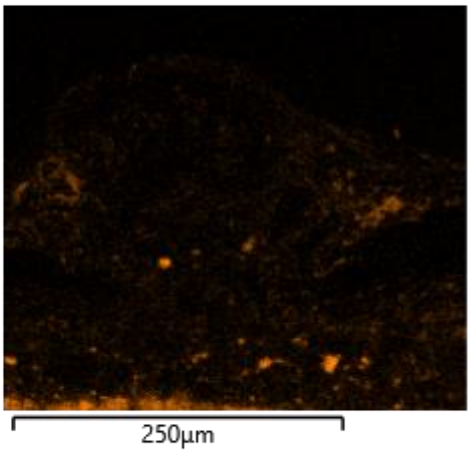
S K series



O K series




Si K series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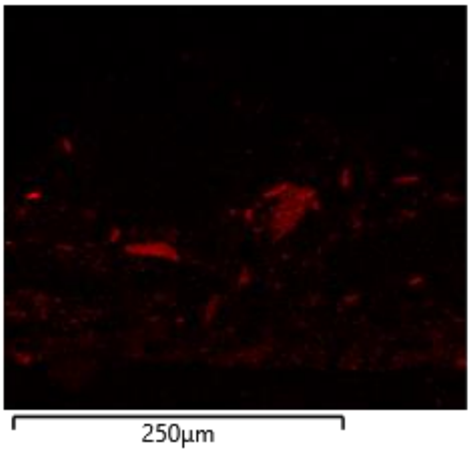
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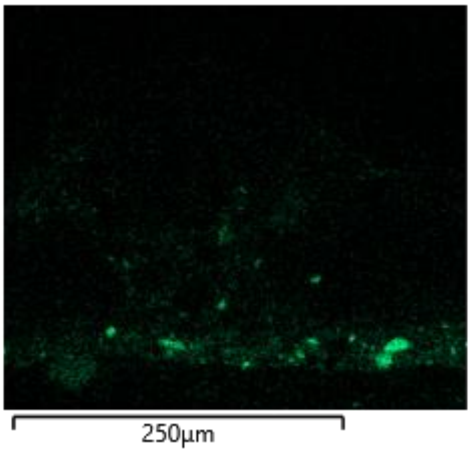
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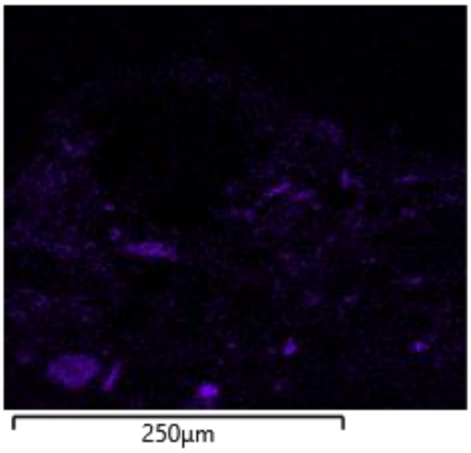
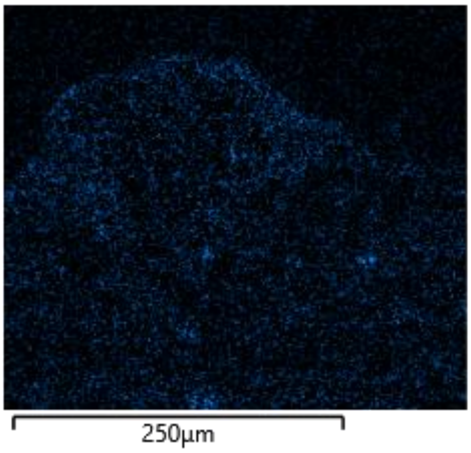
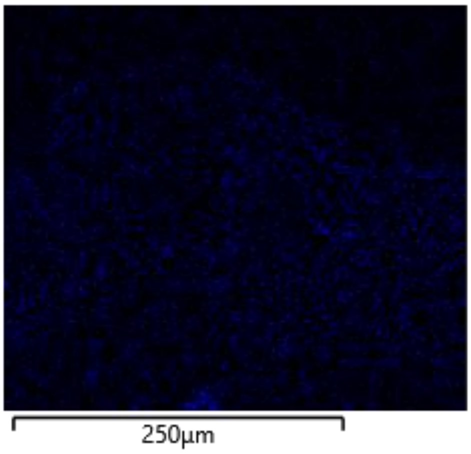
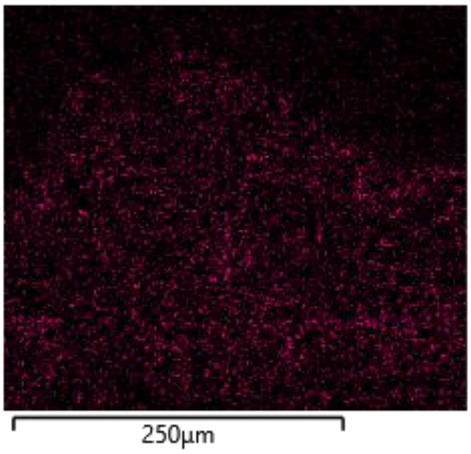

K K series


Cl K series


Na K series


Zn K series

3: Overview of analyses, treatments and time usage

Table 18 Examination and analytical techniques

Technique	**Instrument**	**Date**	**Duration**
Painting received		07.06.23	
X-ray	ICM CP120 by Teledyne ICM	30.06.23	2 h
Pre-treatment visible light photography.	Canon EOS 550D, CLE Design Ltd. Vertical luminaire model HF3695	03.07.23 21.07.23	2 h
Pre-treatment ultraviolet light photography	Canon EOS 550D, CLE Design Ltd. UV Vertical luminaire model UVVTL436	03.07.23	20 min
Alternate light photography 1 Infrared 1 2 Infrared 2 3 False Color infrared 4 Ultraviolet fluorescence	ARTIST® camera by Art Innovation	04.07.23	3 h
Thread counting	Thread counter	21.07.23	1 h
pXRF analysis	Niton™ XL3T GOLDD+ by Thermo Scientific™	21.07.23	4 h
Visual examination	Visual observation Leica MZ12 stereomicroscope	23.08.23 24.08.23 08.09.23 12.09.23	9 h
Gloss measurements	Norwegian Colour Senter AS Gloss scale	23.08.23 18.01.24 13.02.24	40 min
Ground layer binding medium test	Leica MZ12 stereomicroscope	31.08.23 01.09.23	1 h

Biuret test for protein	Leica MZ12 stereomicroscope	14.09.23	20 min
pH and conductivity testing	Horiba Laquatwin conductivity meter Horiba Laquatwin pH meter	08.09.23	4 t
Solvent tests for varnish removal	Cottom swab Isopropanol Ethanol Acetone	21.09.23	3 h
Sample removal	Leica MZ12 stereomicroscope Scalpel	04.10.23	1 h
Cross-section preparation	EasySection Technovit 2000 resin Technovit 2000 varnish Ethanol Sandpaper FEMA 320, 500, 800, 1000, 2400, 4000 Micromesh 6000, 8000, 12000 grit	30.10.23 – 01.11.23	5 h
Dirt cleaning tests	Triton X TAC Cotton swab	01.11.23 – 02.11.23	1 h
SEM-EDX	SEM: FEITM ESEM Quanta™ 450. EDX: OXFORD instrument X- MAX50	10.11.23	5 h
Total			42 h, 20 min

Table 19 Treatments and interventions performed

Interventions	Materials and equipment	Date	Duration
Demounting painting from decorative picture frame	Scalpel Pliers Melinex	26.06.23	40 min
Loose soil cleaning from back of painting	Vacuum Soft brush Polyurethane sponges	21.09.23 16.11.23	2 h 30 min
Varnish removal	Acetone, free solvent Acetone-benzyl alcohol Carbopol gel Acetone Carbopol gel	10.10.23 –31.10.23	83 h
Consolidation of loose paint flakes	Brush, Lascaux medium for consolidation Lascaux medium for consolidation	12.10.23 – 31.10.23	3 h
Dirt/ crust removal from the motif	TAC 1% Klucel® G	01.11.23 – 06.11.23	1 h 30 min
Patch removal	Distilled water Cotton swab Scalpel	07.11.23	10 min
Tear repairs	Sturgeon glue 20% Wheat starch 10%	08.11.23 – 16.11.23	15 h

	Entomological needles on sticks Microscope Bit of linen canvas Scissors		
Demounting canvas from strainer	Scalpel	16.11.23	2 h
Patching	BEVA® 371 film 25.4 µm Hollytex fabric Willard control unit and heated spatula 4E.	26.11.23 – 30.11.23	4 h
Strip lining and mounting to temporary stretcher	BEVA® 371 solution BEVA® 371-film 63.4 µm Polyester sailcloth Willard control unit and lining iron 6E.	27.11.23 – 01.12.23	7 h
Filling	Rabbit skin glue Champagne chalk Tiranti no 47 modelling tool Scalpel Distilled water	05.12.23 –14.12.23	
Varnishing	Laropal A-81 resin Shellsol A Shellsol T Tinuvin 292 Cosmoloid 80H	18.01.24 – 12.02.24	2 h

Visual reintegration	QOR aquarelle set Talens Gouache set Gamblin Conservation Colors Small brushes	14.02.24 – end of February 2024	2 h +
Mounting to new stretcher	Stretcher bars Canvas pliers Staples Staple remover Keys	17.02.24	5 h
Total			128 h 50 min

4: Recipes

Agarose-gel 3% (Rota et al., 2021, p. 319).

1.5 g agarose
50 mL distilled water

The agarose was added to the distilled water and stirred. Then put in the microwave for 30 seconds. Make sure the container is tall and made of plastic, so the agarose has room to expand when heated. After the first round, heat up in 10 second increments until the agarose is dissolved and the solution begins thickening. Let cool, but make sure to add a lid to the container to prevent evaporation.

When cool, reheat the solution in the microwave, as agar-family gels gel better when better when heated twice (Giraud et al., 2021, p. 74). When it is all melted, pour the agarose in an appropriate mold, and aim for a thickness of 45 mm (Rota et al., 2021, p. 319).

Directions followed were provided by Chris Stavroudis in a video by the Getty Institute (Getty Conservation Institute, 2023)

Carbopol® based gel

(Recipe provided during course given by Heather Galloway. Other mixing options can be found in the article “Gels: Evolution in Practice” by Chris Stavroudis (2017, p. 212)

1 g Carbopol® EZ
10 mL Ethomeen® C-25
50 mL desired solvent

5. 50 mL acetone for the acetone gel or
6. 40 mL acetone/ 10 mL benzyl alcohol for the acetone/benzyl alcohol gel

5-8 mL distilled water

Mix Carbopol® EZ and Ethomeen® C-25 well before adding solvent or solvent mixture. Mix together.
Add the water little by little until the mixture gels to a desired consistency. You may not need all the water.

4%(w/v) Klucel® G in ethanol

0.4 g Klucel® G
~10 mL ethanol

Add 0.4 g Klucel® G to a small amount of ethanol. Fill the container up to 10 mL.

Xanthan gel

Mix ethanol and distilled water in a 1:1 solution. For a 10 mL solution of xanthan gel, 0.2 g xanthan is

5 mL distilled water ethanol
0.2 g xanthan

Triammonium citrate 1%

0.1 g Triammonium citrate (TAC)
Deionized water
Total volume 10 mL

The TAC was dissolved in water, then the container was filled to a total volume of 10 mL

Gellan-ethanol gel

0.3/ 3 g gellan gum powder
80 mL water
0.032 g calcium acetate
20 mL ethanol

Heated to 90 °C using the same procedure as agarose gel, although not double heated. When the gel had cooled to less than 78 °C, ethanol was added.

Citric acid

0.1 g citric acid
Deionized water

Fill to a total volume of 10 mL

Triammonium citrate 1% in Klucel® G

0.5 g TAC
Deionized water
Fill to a total volume of 50 mL
2 g Klucel® G was added to the mixture and stirred.

Triton X 1%

0.1 g Triton X
Deionized water

Fill to a total volume of 10 mL

BEVA 371 dilute solution

1 part BEVA
3 parts white spirit

Mix together via stirring.

Sturgeon/ wheat starch paste glue

(Heiber, 2003, p. 44; Heiber et al., 2020, p. 407)

20% sturgeon glue in distilled water
10% wheat starch paste in distilled water
Mix 1:1.

For 10 mL finished glue:
1 g sturgeon glue
5 mL distilled water

Dissolve in low heat. Heiber suggests max. 40°C when using the finished mixture, while Petukhova writes max. 60°C when making the glue (Heiber, 2003, p. 44; Petukhova & Bonadies, 1993, p. 24). A higher temperature causes sturgeon glue to lose its adhesive qualities.

0.5 g wheat starch
5 mL distilled water

Mix together
When both mixes are dissolved, combine them in a suitable container and shake it a bit for them to mix properly.

Laropal A81 varnish (Goltz et al., 2020, p. 667)

14 g Laropal A81
43 g Shellsol A100
43 g Shellsol T
0,28 g Tinuvin 292 (2% of the weight of the resin (Goltz et al., 2020, p. 662))

(0,7 g Cosmoloid H80, a microcrystalline wax)

The first step was to crush the beads of Laropal A81. This increased the surface and thus the speed of dissolution.

Shellsol A and Shellsol T were mixed 1:1 during stirring. Laropal A81 was added bit by bit. Lastly, after it was dissolved, Tinuvin 292 was added.

If adding Cosmoloid H80, the mixture should be heated to 70 °C before adding the wax. The amount of wax is adjustable depending on the desired gloss level of the varnish.

Chalk-glue filler (Fuster-López, 2020, p. 623)

1.5 g rabbit skin glue
20 mL distilled water
13 g champagne chalk

Mix together the rabbit skin glue and water under low heat to make a 7% rabbit skin glue solution (Nicolaus, 1999, p. 238).

Add 13 g champagne chalk to make a ~20 mL solution of filler with approximately 65% PVC.