DEPARTMENT OF CONSERVATION

THE PAINT LOSS OF CALLMANDER'S STAINED GLASS WINDOWS

An investigation of the prevalence and causes behind the paint loss on Callmander and Svenska Glasmåleri AB's stained glass windows

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ABSTRACT

This MA-thesis investigates the loss of grisaille paint in the stained-glass windows created by the artist Reinhold Callmander and Svenska Glasmåleri AB, with the aim of understanding the prevalence as well as the reasons behind the issue. Stained glass has historically been in the periphery of conservation. This thesis seeks to generate valuable information for both future conservation decision-making and cultural history context. Understanding the reasons for the paint loss can serve as a first step in reducing the risk of further deterioration by raising awareness, highlighting urgency of action and providing information necessary to implement preventive measures. The methods used in this thesis consists of a literature review, condition assessments of Callmander's stained glass in Gothenburg and Varberg, and technical analysis with microscopy, X-ray fluorescence and scanning electron microscopy of glass shards from two of Callmander's windows. Through the condition assessments, the study indicates that paint loss is a common issue amongst Callmander's stained glass windows. Furthermore, the study shows that manufacturing issues are likely responsible for paint loss, possibly due to insufficient firing. To fully establish the cause of paint loss, more research is needed.

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Content

List of words

Badgering – Refers to the method used, to smoothen out grisaille paint before firing. The method is often performed with the use of a badger brush.

Cold paint – Refers to paint which is not fired onto the glass, for example regular oil paint.

Flux – Flux is a component which is added to modify melting and viscosity properties. In this thesis, flux is mentioned as a component of glass. Some older references cited in this work, uses the word “flux” to refer to the glass particles within grisaille paint. However, I chose not to do this, as those particles of glass in turn may contain flux.

Frit – Small glass particles. The particles can be used in both glass-making and as a component in the grisaille paint.

Grisaille paint – In the context of stained glass and this thesis, *grisaille paint* refers to the dark paint made of glass particles, metallic oxides, and additives, which is then fired onto the glass, applied as tracing, matting, or shading. In some references, “vitreous paint” and “black paint” has also been used to describe this type of paint.

Ghost line - A ghost line becomes visible where grisaille paint has disappeared. The ghost line is identified in the glass as a hazy line.

Tracing/trace line – Refers to opaque paint often used as contours. Often the trace line is the first line painted on top of the glass when the image is transferred from a cartoon.

Matting – Refers to an evenly applied layer of grisaille paint, usually for half-tone shadings.

White glass – Refers to uncolored glass.

Releading – Refers to the process of changing old lead cames with new ones in a stained-glass window.

Refiring - Is a restoration method used in the past where grisaille paint is fired onto old panels to retouch paint loss.

Pin holes – Deterioration in from of small holes.

Ruby red- A type of glass, which consists of a clear glass with a red enamel on top.

Sheet glass / plate glass – glass sheets often used for windows.

Stained glass window – A window where the glass is carried by a matrix of led cames and iron bars. The glass is often colored and painted.

1. Introduction

During one of my bachelor courses in 2018 I was assigned to perform a condition assessment of Callmander's stained glass window in the church of *Örgryte Nya*. During my master's internship in 2020 I once again came across one of Callmander's work during the conservation of *the Father's window in Uppsala cathedral*. Both windows suffered severe loss of grisaille paint. After discussions with a college at my internship, it came to light that a third window of Callmander in *Uppsala cathedral, The Son's window,* also displayed the same issue concerning the grisaille paint. Interestingly, other coinciding stained-glass window by *Nuemann & Vogel* in Uppsala Cathedral displayed no signs of paint loss. As *Nuemann & Vogel's* windows are situated next to Callmander's windows and derives from the same period, the question rose whether Callmander's paint loss is directed to his material or manufacture process. Both the windows of *Callmander* and *Nuemann & Vogel* *o*riginates from the end of the 19th-century. In the 19th-century the gothic revival had launched a rejuvenation of the craft and lot of experimentation was made within the field not least concerning the grisaille paint. To date, research has linked many of the paint loss of 19th-century grisaille to faults in manufacture. Research has shown that flaking may be referred to, 1) low firing temperature, 2) to large particle size of pigments 3) high quantity of borax in the paint and 4) wrong flux / pigment ratio (Gilchrist, 2010). In this study windows made by Callmander has been visually investigated in-situ, to realize if the issue of lost grisaille paint is a widespread problem amongst Callmander's stained-glass windows. Secondly, a technical investigation was performed in attempt to determine the potential reasons behind the paint loss. Stained glass windows have been overlooked in heritage conservation for a long time and research of this material is imperative as it is a highly fragile heritage which carries both culturally important, religious, esthetic, and historical values. As an architectural element fragile in nature its exposure to weathering conditions makes it even more vulnerable and in need of care.

1.1 Research aims

This thesis aims to answer whether loss of the grisaille paint is a common issue amongst the artist Callmander's stained-glass windows. Furthermore, the thesis intends to understand the reasons behind the loss of Callmander's grisaille paint. By answering the research question the thesis aspire to generate valuable information for both future conservation decision making and cultural history context.

1.2 Research questions

1) Is loss of grisaille paint common amongst Callmander's stained glass windows?
2) What are the reasons behind the loss of the grisaille paint?

1.3 Limitations

As the focus of this thesis is the grisaille paint, other factors and issues of stained-glass windows will only be mentioned briefly. Certain windows made by Callmander within the area could not be included to the thesis as dates for visits could not be made. The limitation to include windows only from Gothenburg and Varberg is discussed in 3.1.

1.4. Methodology

This academic thesis is an interdisciplinary study combining history and technical analysis. The thesis consists of four parts, a *literature review*, *in-situ assessment*, *technical analysis, result and final discussion*. The thesis presents both primary data (*in-situ assessment and technical analysis)* and secondary data (*literature review*) to answer the research questions. The thesis has a qualitative approach although it partly uses and generates quantitative data.

The literature study aims to introduce the reader to the subject and provide information of the history, potential manufactory methods and materials, previous conservation and history, as well as degradation of grisaille paint on stained glass and case-studies. The literature review will help to introduce the reader to the subject, to understand the reasons behind paint loss of stained-glass windows and to interpret the result.

The in-situ assessments aims to briefly examine the *condition* of each window in-situ. The in-situ assessments are necessary to understand the magnitude of the issue with Callmander's flaking paint. The in-situ assessments are also necessary to realize potential deterioration patterns. The in-situ assessments and its methods are further described in chapter 3.

The technical investigation is necessary to identify the composition of the paint and the glass. The information will be used to address the research questions. The technical analysis consists of Scanning electron microscope (SEM) and X-ray fluorescence (XRF), and microscopy. The methods are described in chapter 4.

1.5 Selection of objects

A selection of objects had to be made for the visual and technical investigation. For the in-situ assessment, a number of Callmander's stained glass windows had to be investigated in situ and for technical investigation a sample suitable for SEM-EDS, XRF and microscopy had to be acquired.

To limit the research, the area of Gothenburg and Varberg was chosen for in-situ assessments, and it was decided that all of Callmander's stained glass windows within the chosen areas would be investigated. The strength to limit the research geographically is that if enough subjects are found, the findings can be interpreted as a representational picture of Callmander's work. The weakness of choosing a specific area is that Callmander's work spans over years and if too few subjects of investigations are found it may be hard to derive conclusions. When it comes to the area it must also be considered that Gothenburg is windy and has a high relative

humidity (RH). As Gothenburg is a city close to the ocean the windows are exposed to both salts and urban pollution from the city landscape.
Gothenburg as a location is important as Callmander lived and worked in the city, and perhaps more information and research subjects are in the reach than anywhere else. The area of Varberg was chosen as they allowed sampling of one of their windows beforehand. In the end, the sampling of Varberg was not conducted, instead discarded glass from two of Callmander's windows in Gothenburg was used to perform two cross sections for the technical analysis.

The windows within the chosen locations were foremost found by using online search engines, but also with help from city antiquarians and stained-glass conservators. Callmander never signed his stained glass, and information concerning stained glass in Sweden online is scarce. All churches and chapels in Gothenburg built in the late 19th-century, were visited and investigated to identify stained glass made by Callmander. In total10 locations were investigated in the in-situ assessments, including: Oscar Fredric's church Werner's villa, Christinae church, Örgryte new church, Fässberg's church, Varberg's church, Sollyckan's church, Jonsered's crhuch, Östra kapellet (the East chapel), and Linnea church. However, two of them could not be confirmed to have glass made by Callmander, Linnea church and Sollyckan's church. The choice was made to still include them, but with certain reservations. Additionally, two locations in the area confirmed to have Callmander's glass could not be investigated, Säve church and a stained glass in the collection of the City museum of Gothenburg.

There is a low possibility that not all Callmander's and Svenska glasmåleri AB's windows within the area were found, as there are no lists or publications covering Callmander's stained glass windows. Windows could have been missed if they were installed in a building constructed earlier than the 19th century, unknown to city antiquarians and conservators, and not present online. It is also noteworthy to mention that many stained-glass windows have been removed as a result of degradation.

2. Literature Study

2.1 Values of stained-glass and grisaille paint

As a mean to introduce the reader to the subject, and to understand the issue of lost paint, it is first necessary to highlight the values of stained glass and its grisaille paint.

A stained-glass window is both an integral part of the architecture and an independent object on its own. As a part of the architecture, the stained-glass window is a part of the construction's historical, cultural, aesthetic, religious, and functional values, as well as its authenticity. This means that if the windows values would be altered the buildings values would be altered too. For instance, a disfigured, or dirty window would have an impact on the building’s aesthetic appearance, as well as the replacement of an original window would change the building's authenticity as original.

On their own a stained-glass window may hold historic, religious, aesthetic, didactic, symbolic values, and authentic importance. A window can be considered a piece of art on its own, carrying the same values as a painting would. The aesthetic values are also connected to the often-present religious values of stained glass, as the design often carries religious iconography. As part of the historic values, we need to consider the history of the stained-glass craftsmanship of Sweden. These artworks are not only a testament to the skills but also proof of how stained glass was made during this era.

The grisaille paint is often crucial to sustain these values, and without it, readability is lost as the flaking turns panels to flat uniformly coloured spaces. The grisaille paint helps to translate and understand the historic meanings, but also increases the religious and aesthetic values, as well as withholding the values of the artist’s original intent. Figure 1 shows two of Callmander’s panels belonging to the *Father’s window* in Uppsala Cathedral. Both panels lost the majority of their grisaille paint, but one of them was re-fired with new paint during a conservation campaign in the 1970s (Andersson, Kvarnström, 2016). The act of refiring is not acceptable in the world of stained-glass conservation today (Corpus Vitrearum, 2016), but in this case, it works as a measuring stick to show the aesthetic difference when grisaille is lost. While the left panel (fig 1) may be interpreted just as a red circle surrounded by green, the right one is instantly identified as a rose. It must also be mentioned that grisaille paint blocks sunlight, and if we compare the two panels in fig 1 we understand that there will be much more transmitted light in the left panel. This is sometimes an issue as the transmitted light may blind the viewer and render the rest of the window less readable.

To sustain the grisaille is not only important for its intrinsic values, but in history it has shown to be critical for the longevity of the window itself, and perhaps the authenticity of the entire construction. In both Varberg Church and Oscar Fredrik, deteriorated windows by Callmander was replaced. Today, it is rare to discard or replace historical windows in Sweden, but as often with historical objects they are more prone to be neglected if their condition is already compromised.

Figure 1. Two stained-glass panels made by Callmander from the Father's window in Uppsala Cathedral. The right one was refired with new grisaille paint in 1970. Photo: Eisfeldt, 2020

2.2 History of stained glass in the 19th century in Europe

To understand the issues of many 19th-century stained-glass windows it is also important to consider the history.

In the 19th-century, the art of producing medieval stained glass was in many ways forgotten. The craft had gradually disappeared since the 16th-century, as a consequence of political disputes, religious clashes, and new style ideals. As the reformation emerged protestants opposed the use of religious images, instigating iconoclasm across Europe (Seddon & Stephens, 1976, p. 142). The thirty years' war and the counter-reformation amidst France and Germany lead to further destruction of liturgic art, and to the destruction of workshops in Lorraine, resulting in a shortage of pot metal glass across the continent (Seddon & Stephens, 1976, p. 142). Throughout the 1800s the destruction continued because the Napoleonic' wars, but also as a consequence of the Enlightenment movement, which continued vandalism and transformed cathedrals to storehouses of hay, and cathedrals of reasons (Seddon & Stephens, 1976, p. 142).
As new style ideals arose with the Renaissance and Baroque the desire for stained glass further decreased. The new fashion consisted of brighter interiors, emphasizing the use of clear glass, instead of the light blocking coloured glass, now considered old and uncivilized (Seddon & Stephens, 1976, p. 142).
While stained glass lost its status, the status of oil paintings rose as it was considered a "higher art form". As a result, new windows were created, predominantly in the form of Heraldry, where the execution of the paint is more comparable with the paint on canvas (Rosewell, 2012).
According to Raguin & Higgins the change of style caused many medieval windows to be replaced (Raguin & Higgins, 2003, p. 168).

As the status and interest was lost, years of mistreat and neglect followed. The devaluation of the craft led to fewer skilled craftsmen which led to further destruction as fewer professionals could perform the repairs (Seddon & Stephens, 1976, p. 142). An example given by Roswell, is the amount of plumber's signatures found on stained glass windows in England, as the plumbers were given the task to repair stained glass solely because of their expertise on lead (Roswell 2012, p. 59). According to Seddon & Stephens neglect was the main reason for loss of medieval stained glass (Seddon & Stephens, 1976, p. 142).

In the 19th-century the craft would experience a rejuvenation as the gothic revival was initiated. The rise of the gothic revival can be traced to several factors, of social, political, and national ideas, fueled by romanticism and new interest of the medieval. In Europe, the industrialization and increased urban population led to cramped living spaces, with polluted smog-filled air. The democratic and socialist values of the Enlightenment called for better standards of living, and many projects of construction and city-planning were launched to improve the conditions. The inhospitable cities created a longing, partly for nature but also for the past without factories. This led to a renewed interest in the medieval, and the Gothic architecture that had previously been neglected was now seen as holy and pure compared to the ”capitalistic” architecture of industrialism (Honour & Fleming, 1982).
The surge of Gothic architecture can also be explained by the need of many states to reinforce their identity and promote their past. Many states considered their heritage to be closer tied to the architecture of medieval Gothic rather than to the Greek and Roman classicism (Honour & Fleming, 1982).

The rapid interest for gothic architecture together with the many restoration projects after the wars in Europe resulted in a great demand for stained glass windows. As a result, several new workshops were established, and more than 80.000 windows were created in the continent (Rosewell, 2012, p. 67).
The largest companies of glass painters were in Germany, Britain, and France, where the workshops exported their painted glass all over the world. One of the largest producers, Xavier and Zettler, who later merged with the Hofkunstanstalt, employed roughly 600 workers (Bengtsson & Bengtsson-Melin, 2014).

As the craft had to be reinvented in the 19th century a lot of experimentation and research had to be conducted. Initially the importance of collectors was monumental for the research. Many of the collectors in both France, England, and

Germany raised an interest, and provided large sets of samples for the contemporary glazier, painters, and researchers to examine and replicate (Raguin & Higgins, 2003, pp. 198-199). The research was also sponsored by royalties and in Germany, Ludwig I played a major part in establishing collections and supporting the domestic craftsmen (Raguin & Higgins, 2003, p. 199). In France Louis Philippe supported the Royal Porcelain Manufactory at Sevres which carried out important research regarding paint with enamels (Campbell, 2006).
In England, research was conducted by many, including William Morris and Charles Pugin, but also Charles Winston Barrister and James Powell (Seddon & Stephens, 1976, p. 146-153). Despite the numerous research endeavors, the fast expansion and high demand of the craft together with the experimentation and lack of knowledge led to many in-built problems.

2.3 Reinhold Callmander and the stained glass in 19th-century Sweden

In Sweden, the 19th-century began with stagnation and mass-migrations to America. The country had dealt with mis growth, cholera, and the aftermath of war resulting in the loss of Finland. Things slowly began to change due to vaccination, peace, and fortuitous harvests, leading to one of the largest population increases of Sweden,1809 to 1850, a building boom and eventually strengthened economy (Bedoire, 2015, p. 12). Despite improvements, the economy, culture and living in Sweden would still be considered marginal by the rest of the Europe (Västerbro, 2019).

As in the rest of Europe the art of producing stained glass had been forgotten in Sweden. Sweden had numerous skilled glassblowers and had since 1740 established a large-scale industry for glassware. Especially in the regions of Småland (Persson & Persson, n.d.). The expansion was made possible partly because of the great access to water and wood but also because the Swedish labour and crown was relatively cheap, making export of cheap quality goods possible. The peak of Swedish glassmaking could be considered the years 1870-1900, as many new Swedish companies were established, amongst these some of

the most well-known, Kosta Boda, Orrefors and Emmaboda. Most of these workshops specialized in glassware and decorative articles, and even though few workshops specialized in glass windows (Persson, n.d.). There were no established glass painters until 1880 and prior to this Sweden's stained-glass was predominantly imported from England and Germany (Sälde, 2003, p. 44). The first glass-painters' firm in Sweden, N.P Ringström was established in 1886 making them Sweden's oldest glass painter and glaziers still active today. Shortly after, in year 1888 a second and a third company, Callmander's Svenska Glasmåleri AB, and Neumann & Vogel's Stockholm's Glasmåleri established.
Despite the Swedish glass production, it seems the glass painters in Sweden continued to import their materials from overseas. The glass panels were most likely imported from Germany and/or England, either blown antique glass or cathedral glass, while the lead and grisaille paint likely was produced domestically (Sälde, 2003, p. 44).

In 1887 Oscar II (1829-1907) inherited the throne as regent of Sweden. Oscar II had a great interest in the Gothic style, mainly inspired by England (Bedoire, 2015). This interest, together with the strengthened economy and need for construction would result in many projects across the country, creating a favorable situation, but sometimes also stressful for craftsmen such as Callmander.

Reinhold Callmander was born in Örebro 1840 and after his early studies in Örebro, 1860-61, he travelled to Stockholm to become an apprentice of the decorative painter, Fredrik Liljeblad. He later continued his studies in the Royal Swedish Academy of Fine arts in Stockholm and eventually received a scholarship from the king, Karl XV (1826-1872) and the queen mother Josefina. (1807 – 1876), to continue his studies abroad, allowing him to travel to Antwerp, Dusseldorf, and Munich (Thomaeus, n.d.)
As Callmander returned to Sweden he settled down in Gothenburg and became a prominent artist and decorative painter creating altarpieces, canvases, and panels paintings.

Gothenburg at this time held a population of 20.000 inhabitants and with its ties to the East Indian company, the city was a nave for Swedish trade. The commerce attracted an aristocracy of philanthropic English and Jewish tradesmen. Amongst them the family, Dickson, Gibson, Carnegie and Hall, who built themself large villas and donated for the erection of many churches around the city (Bedoire, 2015, p. 72). The good economy of the city provided Callmander with numerous works.

In 1884, Callmander designed a stained-glass window for the church of Haga in Gothenburg. (Gullbrandsson, 2013) The architect was Adolf W Edelsvärd, with help from the newly examined architect Adrian Crispin Pettersson, whom Callmander would come to cooperate several times with. After Callmander designed the cartoons for the stained-glass windows in Haga church, they were made by P. G Heinersdorff in Berlin (Gullbrandsson, 2013). Perhaps this is the first time Callmander worked with stained glass, as no earlier work has been found during the writing of this thesis. Unfortunately, the windows were replaced in 1924, due to their bad condition (Gullbrandsson, 2013).
In 1884 Callmander participated in establishing the Art school of Valand, which still is in Gothenburg (Gullbrandsson 2013).
In 1888 Callmander established his own glass painter's studio, Svenska Glasmåleri AB (Guldbrandsson, 2013). He had previously worked as an apprentice for the glazier Magnus Lind, and as he retired, Callmander inherited his workshop. (Tomaeus, n.d.). If Magnus Lind had knowledge of glass-painting is not known. It is neither known for how long Callmander worked with him and whether Callmander learned it from him, nor if he acquired his knowledge of painting glass elsewhere. Svenska Glasmåleri AB grew and at one point the company employed 9 persons (Gullbrandsson, 2013). As Callmander was involved in Valand school it is a possibility that his employees were students from the school (Bengtsson-Melin, 2021, personal conversation). The Company would produce several stained-glass windows across the country until Callmander died 1922, amongst these, the stained glass for Uppsala cathedral.

Paint loss of Callmander's windows began early. In Uppsala cathedral the first signs were reported in 1920 (Kvarnström & Andersson, 2017). In Gothenburg Callmander's windows in the altar of Oscar Fredrik were removed in 1930 (BeBR, 2023). According to a source, Callmander ascribed the problems to the fact that he had been given bad paint by a unjust competitor (Thomaeus, n.d.). This could be one reason for the paint loss. Another reason could be that the work was produced too hastily.
In correspondence between Callmander and the church warden of Uppsala Cathedral, it can be read that the glass painter complained the timeframe of the project was too short. Other times, however, Callmander wrote that he received the cartoons from which he would produce his windows too slowly, and that the lack of work forced him to fire some of his workers (Bengtson & Bengtson-Melin, 2014).

2.4 The making and chemistry of glass

To fully understand the thesis, it's important to understand the basics of glass, how it's made and what it's composed of. The composition plays a significant role not only in understanding the deterioration process, but also in understanding how the windows investigated in this thesis were made.

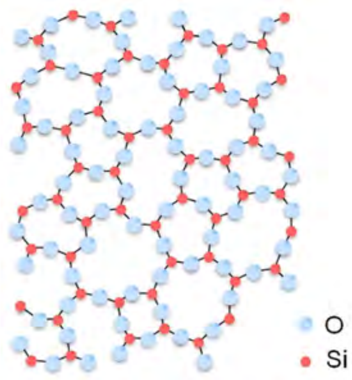

Figure 2. Illustration of the silica-oxygen structure of the glass. Image: Wikimedia commons, 2023

Glass is made by firing sand together with flux, and additives for stability, color and transparency. The sand, which makes the main part of the material consists of silicone dioxide (SiO_2), which forms an amorphous tetrahedral network, where the flux and additives are trapped (Musgraves, Hu, & Calvez, 2019, p. 10). This network can be seen in (Fig 2).

The flux is added to increase viscosity and to lower the melting temperature of the glass. In general flux is made of various alkalis. The historically most common ones are Soda ash (Sodium carbonate, Na_2CO_3) and Potash (Potassium carbonate,

K_2CO_3). Soda ash was made from the ashes of coastal and marine plants, mainly seaweed, whereas potash came from the ashes of wood. In European glass making traditions, potash was particularly important, and was mainly obtained from the ashes of beech, oak and fern. It is worth noting that the alkali content in glasses made with soda ash does not exclusively contain soda, neither does potash glasses contain exclusively potash, instead a mixture of both alkalis can be found in both glass types (Musgraves, et al, 2019, p. 144).

Depending on type of flux, the glass will receive different characteristics. Compared to soda, potash glass is described too be harder to shape, have higher density, faster solidification and “exceptional brilliance” (Corning museum, n,d). Soda on the other hand is mentioned to be more durable against weathering (Davison, 2003, p. 177).

In the 18th century, soda ash with a higher sodium carbonate content was developed, which enhanced the hardness and brilliance of the glass. In the early 19th century, sodium sulfate started to replace sodium carbonate as a flux for sheet glass. The change to sodium sulfate as a flux would not only result in cost savings, but also improve stability, clarity and resistance to environmental factors (Musgraves, et al, 2019 p. 193).

Stabilizers make approximately 10% of a glass batch. The stabilizers prevent the glass from crystallization as it cools make the glass more durable to moist (Davison, 2003, p. 177). A common stabilizer is Lime (calcium oxide (CaO)). When a soda glass contains lime as stabilizer, the glass is referred to as a soda-lime glass. Another example of stabilizer is magnesium oxide (MgO).

Different colors in a glass is decided by metal oxides (Haas, 2005). For example, FeO gives a blue color, Fe_2O_3 brown, Manganese violet-brown, Cobalt blue, Gold red and copper can make the glass both red and green (Davison, 2003, pp. p6-9). As even the smallest amount of metal oxides can affect the tint, there has historically been a challenge to produce clear glass. The two methods used to make clear glass are: *Chemical decolorization* and *Physical decolorization*. The first method, Chemical decolorization, is done by reducing the oxidation of the metals of the glass. This is done by adding nitrates during the firing or by controlling the oxygen levels in the kiln. The second method, physical decolorization, is done by utilizing color theory, neutralizing the tint of the glass with its complimentary color. Physical decolorization will also make the glass greyer and opaquer (Hovmantorp, 2012).

To transform the molten glass into sheet of glass, several methods could be used during the 19th century. The most common method in the end of the century was to produce rolled sheet glass, but also crown glass and cylinder glass was made in smaller quantities (Hovmans torp, 2012).

Rolled glass: The method to produce rolled glass is sometimes known as the Fourcault process after its inventor. The method became common as a method to produce windows in the 19th century (Davison, 2003, p. 118). In short, the molten glass is placed upon a table with walled edges. The glass is then rolled over with a cylinder, often made of copper (Davison 2003, p.130). Rolled glass can sometimes be identified by bubbles in the glass-mass elongated in the direction of the cylinder. Sometimes, the table which the glass is rolled upon has a texture, which is then transferred to the glass.

Crown glass: Early examples of small crown glasses, 150-200 mm has been found in Jerash, Samaria as well as in Chichester and Sussex from year 400. During medieval times the diameter of the glass increased, and together with Cylinder glass it would be the most popular glass used for window making for a long time. The popularity of crown glass decreased as rolled glass became more common in the 19th century, but there were still manufacturers of Crown glass (Davison, 2003 pp. 128-129).

To produce a crown glass, a long hollow metal pipe, known as blowpipe or blow tube is used. On one end, the molten glass is placed, and on the other end, the worker known as a blower breaths air into the pipe, turning the molten glass into a hollow spherical shape. The glass is then transferred to a pontil rod which is placed on the opposite side of the blowers pipe. The sphere which now has a hole, where the blowing glass used to be, is reheated, and rapidly spun with the pontil rod, causing the centrifugal force to turn it into a disc. Because of this glass panels that are blown often receive a characteristic pattern of a circle. In the center of this circle, they are also thicker than in the center part of the disc. The center of a crown glass if often known as, boss, bullion or bull's eye (Davison, 2003, pp. 128-129).

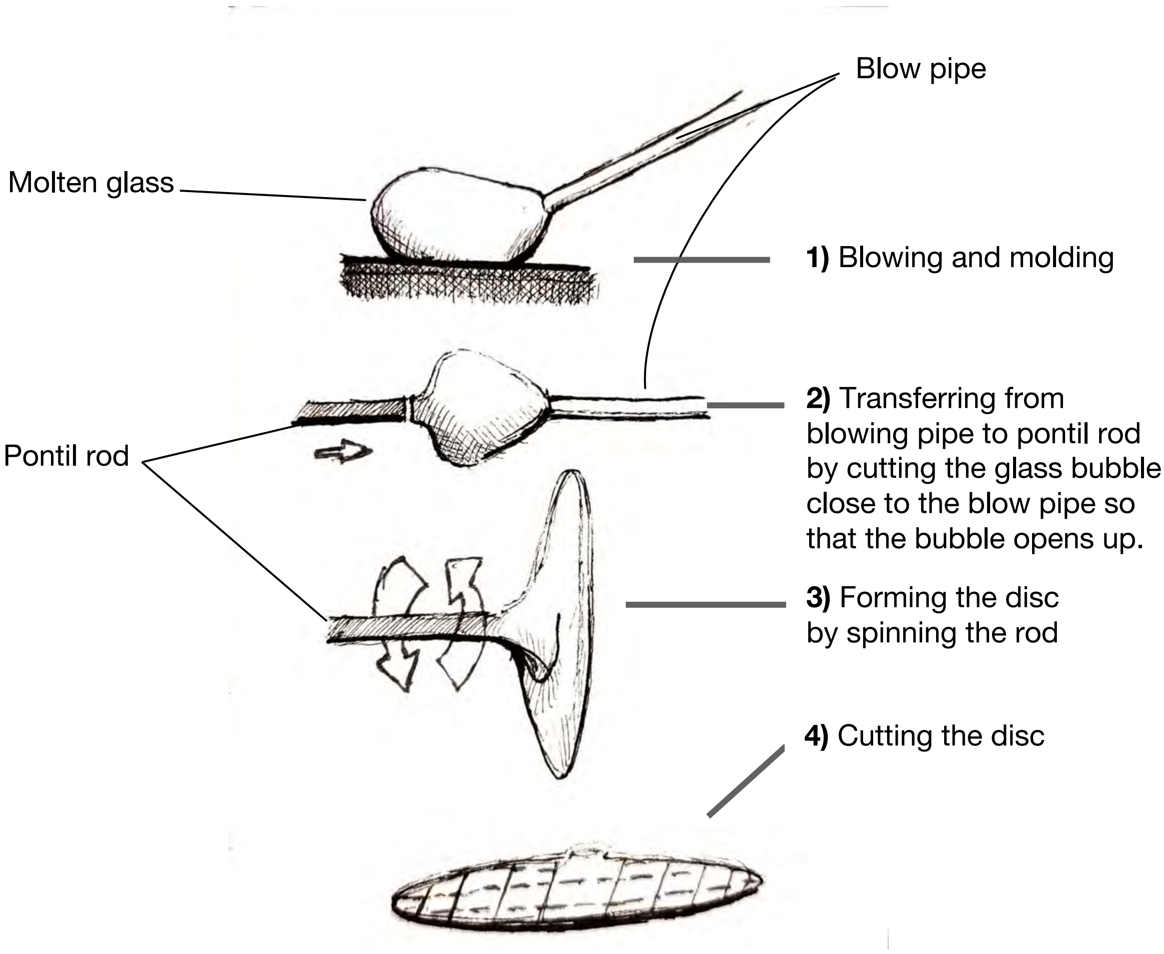

Figure 3. How a crown glass is made. Illustration: Eisfeldt, 2023

Cylinder glass: Cylinder glass is another type of glass made by utilizing a blowpipe, together with crown glass it is one of the most long-lasting techniques, used since the roman times. To produce a cylinder glass, a blowing pipe is first used to turn molten glass into a sphere, the sphere is then placed onto a pontil rod, and swinged back and forth elongating the glass into a cylinder. The cylinder is then cut lengthwise and flattened out. As a result of the production a cylinder glass sheet can sometimes have a difference in thickness lengthwise (Davison, 2003, pp 128-129).

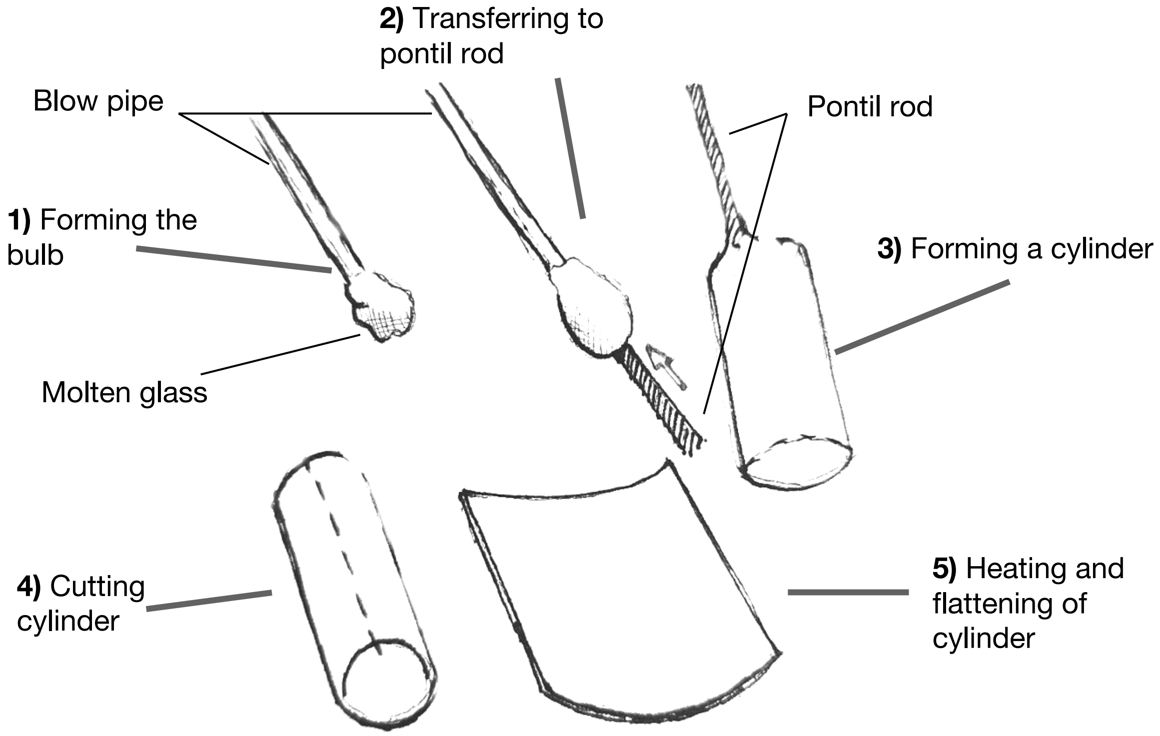

Figure 4. How a cylinder glass is made. Illustration: Eisfeldt, 2023

Float glass: Float glass is the most used method to produce for windows today. As float glass was developed in the middle 20th century, it is irrelevant for this thesis, and not mentioned further.

2.5 How grisaille paint was made in the 19th-century

At the time of this thesis no records concerning the manufacture of Callmander's paint could be found. A source mentions Callmander blaming ”bad paint acquired from a competitor” as the reason for his paint loss (Thomaeus, n.d.). Whether this is true or whether he pointed the blame at someone else is questionable.
The market for grisaille paint and paint supplies was well established in Europe at this time. The grisaille paint within Sweden was probably produced domestically while glass panels were imported from abroad (Sälde, 2014). Whether Callmander produced his own paint or if he bought it is not known.

Even though no specific information regarding Callmander's grisaille paint was found, sources from the 19'th century may give information to how Callmander's grisaille paint may have been made.

Grisaille paint of today, the 19th century, and medieval times are very similar. but as the craft was revived in the 19th-century a lot of experimentation concerning the material and method was conducted (Gilchrist, 2010).

In Fromberg's book "Painting on glass" from 1851 and M.A Gessert's "Rudimentary treatise on the art of painting on glass" 1851, the processes of manufacturing stained glass is described.

In short, the paint consists of pigments made of metal oxides, particles of low-melting glass (often led glass), and a carrier made of either oil, acetic acid or water with gum arabicum. The paint is then applied onto a glass panel and fused onto it by firing.

The first step of producing the paint is to mix the grounded glass and pigments. These two components could be mixed in two ways, and both are described by Gessert and Fromberg from 1851. The first method is to simply mix the grounded glass and pigments in solid form. Once mixed, the mixture could then be mixed with oil, water or acetic acid and applied onto the substrate glass and fired (Fromberg, 1851, p. 25) and (Gessert ,1851 p. 7). In the second method the grounded glass and pigments in solid form is instead placed in a crucible. The crucible is then placed in a kiln until the mixture begins to bubble. It is then withdrawn from the kiln and poured into a vessel surrounded by cold water. This procedure would first fuse the grounded glass and pigments and then split them into small fragments (sometimes called ”frits"). The second method has a significant advantage according to Fromberg and Gessert. When the pigments consist of metallic oxides with a considerably high melting point, the temperature needed to properly fuse them with the ground glass can sometimes exceed the temperature of the substrate glass tolerance and break it. By fusing pigments and ground glass separately in the crucible in before, a higher temperature can be employed, ensuring that the flux and pigments fuse properly together first. They can then be grounded and fired onto the substrate glass with a lower temperature (Fromberg, 1851, p. 25) and (Gessert ,1851 p. 7).

Both pigment and grounded glass had to be made into fine particles. For this a mortar made of porcelain was used, and if a finer result was sought after, a heavier mortar would be used. If the particles were too finely grinded the paint could risk cracking after firing, the reason for this, however, is not mentioned (Fromberg, 1851, p. 25).

The pigments and ground glass, were then mixed with a carrier to apply the paint. Examples of carrier solvents are water and gum arabicum, different types of oil such as lavender or linseed, but also turpentine, acetic acid (sometimes as white vinegar with gum arabicum), or urine, and egg white which was used during medieval times (Grieco, 2014, p 101). According to Gessert, the most suitable is “rectified oil of turpentine, somewhat thickened with standing, and to which a little lavender is added” (Gessert, 1851, p. 47).

Each carrier solvent had different purposes. For example, sugar is tacky but can be used as trace lines, turpentine is water resistant, and lavender is suitable for softening shadows, diluting, and creating realistic representations (Grieco, 2014, pp. 105-106).

The mixing of the pigment, carrier solvent and flux was done by piling the pigments and flux on a tray or plate, and then gently adding the right amount of carrier and mixing them together. If gum arabicum was used, it could be mixed dry together with pigments and flux first, (*the dry-to-dry method)* or it could be mixed with the water, and then applied to the wet pigment and flux (*wet-to-wet method)* (Gilchrist, 2010).

Depending on the vehicle solvent the paint is preferred for different purposes. Commonly, the pigments diluted with oil was first applied for trace lines, and as it dried, water-based paint could be painted on top without the two layers mixing. This way, acetic acid could also be used, as it does not mix with either oil or water as dried, allowing up to three layers of subsequent paint (Reytinens, 1983).
A panel could also be painted and fired several times, by first painting one layer, then fire it, and then paint and fire again. This could be repeated at least three times, but generally less firing is recommended, as more firings require more time, may provide bad results, and adds a greater risk that the glass may break. If the paint was applied too thickly it would also fall off after the firing.
For trace lines a brush with longer hair was often used. Generally, the glass was painted on top of the cartoon which carried the plan/sketch of the full work. After painting, a hog brush could be used to either smoothen out the paint or to remove paint to create effects. As the paint dried, it was common to use wooden sticks, quill, needles or use the back of the pencil to scrape off the paint from the glass before firing. The dried paint surface could also be stippled with a brush (Reytinens, 1983).

Fromberg and Gessert also describe the kiln used for firing the paint. The described kiln consists of three different chambers, one lower where the ashes vent, one middle where the fire was, and one upper chamber where the muffle and glass opening could be found. To light this kiln wood which did not cause dark smoke was preferred, and a wood which could burn evenly (Gessert, 1851, p 55). Coal was also used at this time but not preferred as the sulphur, could have a bad effect on

the paint (Gilchrist, 2010). The reason for this is not mentioned, but it may be because sulphur creates acids that could damage the glass (Davison, 2003, p. 191). After placing the wood in the kiln and putting it to the fire it is important that the temperature changes do not occur too fast, or too slow. Gessert mentions two methods used by glass painters to monitor the temperature. One was to view the muffle to see whether or when it turned red. Another was to use test glass to see when it melted. Thermometers were also available; however those were not deemed trustworthy (Gessert, 1851, p. 59).
Reyntiens also mentioned that glazier had to use their eyes rather than temperature meters, as most glass and paints react differently to the heat. (Reyntiens 1983)

2.6 Deterioration of glass

Glass is susceptible to many types of deterioration, and it's important to consider that damage on glass is both permanent and irreversible (Davison, 2003). The material can be deteriorated by mechanical or chemical factors.

The mechanical factors may include abrasion from improper cleaning, forceful impact resulting from vandalism, birds colliding with the panes or even strong winds. Rapid and significant temperature changes may also cause expansion or contradiction within the material, leading to breakage.

Chemically, the glass can deteriorate either as the silica structure is weakened or as the alkalis are leached from the glass structure. Alkalis are leached due to hydrolysis, which occurs as the glass is exposed to moisture, causing the alkalis to slowly leach out of the structure until equilibrium between the glass and moisture is reached. Several factors affect the rate at which leaching occurs. (Davison, 2003, p. 206)

The primary reason for leaching may be the composition of the glass itself. If the glass is poorly made or contains large number of alkalis, the leaching will be increased. The effect of leaching has been particularly noted in potash glass.

Additionally, the effect of leaching has been noted to increase if the moisture has a low pH value. A low pH value may result from the use of improper cleaning, pollutants in the air, or as byproducts of fungi and bacterial growth (Fink, 2017 p. 202). The leaching of alkalis may lead to a formation of a gel-like layer on the surface and is sometimes identified by a hazy cloudy appearance (Davison, 2003, p. 191). In professional conservation terminology, the leaching of alkalis is often referred to as weathering, but everyday language, it is sometimes called glass sickness (Davison, 2003, p. 191).

A common pollutant that can lower the pH value of moisture is Sulphur dioxide (SO2). The pollutant is usual in urban areas due to traffic but also in churches due to burning candle lights. According to Davison 2003, there is no research indicating that Sulphur dioxide alone causes degradation of glass. However, in conjunction with water it can form acids which have the potential to corrode the glass, leading to the development of crusts on the glass surface (Davidson, 2003, p. 191).

In addition to lowering the pH, and increasing the rate of weathering, accumulations of pollution and dirt is known to cause other issues on glass.
Dirt which sticks to the windows due to thermal diffusion and moisture, provides a breeding ground for microorganisms and fungi, which can cause staining and etching on the glass, and further lowering the PH (Fink, 2017, p. 202), biocorrosion may also leave a white opalescent film on the glass (Fink 2017, p. 218).

At last, accumulations of dirt also disfigure the appearance of a window, which decreases its aesthetic values.

2.7 Deterioration of grisaille paint

Grisaille paint can degrade for a variety of reasons, many of which work together. One of the main reasons behind deterioration is inherent issues created during manufacture due to the use of wrong materials or production. If pigment grains are too large, or if the paint has too low pigment to flux ratio, the paint will be soft and

consist of granular layers, which can eventually lead to pulverization of the paint. A good pigment to flux ratio is between 1:3 to 1:2. A second issue may be the presence of too much borax (Gilchrist, 2010).
Borax is an ionic compound of sodium and borate, which was commonly used as a flux. The negative effect of Borax was mentioned around 1880 by William Morris in correspondence with George Howard. Morris wrote that Borax was to blame for the paint turned water-soluble after firing (Vidimus, 2023).
Despite Morris statement, Borax continues to be used even today (Gilchrist, 2010). The use of Borax can be found in Fromberg's and Gessert's book from the 19th century, as well as Reyntiens book, from 1983.

Grisaille paints with a significant amount of alkalis may pose another threat of degradation. As the paint consists of ground glass, the presence of alkali makes it susceptible to corrosion, a phenomenon sometimes referred to as "glass sickness". This occurs when moisture leaches alkali ions and forms an alkali-solution which dissolves the silicate network. The corrosion can manifest as formation of pitting but may also soften the paint and make it susceptible to further degradation Corrosion may also cause the paint to powder or darken. Depending on the paint and glass composition, it will be more or less prone to leaching. This can be seen as certain stained-glass windows are in good condition despite being exposed for hundred years. Typically, potash-glass is more sensitive to this type of corrosion than glass made with sodium (Gilchrist, 2010, p. 36).

The medium chosen for applying the paint may also impact the paint's longevity. Excessive use of gum arabicum during the process can result in a tacky paint surface that may scale when fired. Similarly, using vinegar as a medium can make the paint more susceptible to weathering as compared to using water-based paint (Grieco, 2014).

The properties of the substrate glass are also important. If the substrate glass has a significantly higher thermal expansion coefficient than the paint, the paint will adhere badly as it won't be able to merge. This will manifest in a delamination of the paint layer. The different thermal expansion coefficient may also create in-build stress, especially in historic potash-silicate glass, which may lead to cracks in the grisaille paint (Palomar et al, 2019). The thermal expansion properties also matter as the stained-glass window is exposed to heat, especially as dark grisaille may become significantly warmer in the sun than transparent glass. (Palomar et al, 2019).

Misfiring is another issue which may occur when painting glass. If grisaille paint is fired at too low temperature, the insufficiently fired paint turns porous, permeable, and granular, and may not adhere to the glass (Gilchrist, 2010). The degradation of paint often begins with small micro-fractures parallel to the surface (Verita, et al, 2005). On the contrary, if the paint is fired too long or at too high temperature, the paint and glass will react to the temperature by forming gas (Verita, et al, 2005). As the gas emits it forms holes in the paint layer and alters its stabilization (Gilchrist, 2010).

In addition to the manufacturing process, the condition and longevity of the paint is also influenced by climate and external agents of deterioration. Humidity plays a significant role in the leaching of alkali-ions (Gilchrist, 2010, pp 100). Higher humidity increases the exchange of ions as equilibrium is increased. The leaching is further increased if the moisture is acidic (Gilchrist, 2010, p. 100). High humidity may also enable dirt and dust to stick to the window, especially due to effects of thermodiffusion.

Great variation in temperature is another climate related agent of deterioration, causing paint layers with different thermal expansion properties than the substrate glass to delaminate (Bernardi, 2008).

Dirt is also a factor that affects the condition of the paint layer on stained glass windows. Dirt commonly consists of various airborne particles, including dust and soot, which often stick to the window due to the thermodiffusion. In addition to altering the visual appearance of the window, dirt can have negative effects on the condition of the paint. As dirt is hygroscopic, it increases the humidity levels and create an environment that is ideal for the growth of microorganisms. Dirt and air pollutants combined with humidity may also form acids which in turn can deteriorate both substrate glass and paint layer (Davison & Newton, 2003). Over time, dirt gets sedimented to the surface and harder crusts may form (Koob, 2006). The removal of dirt can also be damaging to the glass. Physical forces may abrade or completely remove fragile grisaille paint while cleaning solvents can cause leaching of ions in the glass structure or dry out the glass.

2.8 Previous conservation and restoration methods on lost paint

For this thesis it is important to identify past conservation and restorations actions on the windows investigated in-situ. Previous restoration and conservation methods can indicate what deterioration agents the window has been exposed too. Furthermore, certain restoration actions can remove the original paint from the glass.

Historically, the options for dealing with paint loss have included refiring, cold painting, consolidation, or as in certain cases, to replace the entire glass. In modern times, painted glass has often been placed behind the original to recreate the lost images.

Refiring is a technique where new grisaille paint is fired onto areas of paint loss. The technique was at least used until 1970 in Sweden, as some of the panels on the Father's window in Uppsala Cathedral was refired at that time. Today, the technique is not practiced due to ethical reasons (Kvarnström Andersson, 2017).

Initially the technique may have been used as it was considered to restore the artist's original intent, and with that the authenticity of the window. The action was also more durable than retouches made with cold paint and could therefore have been seen as a good option.
Today, the technique is considered unethical for several reasons. Original material is considered as a part of an object's authenticity in contemporary conservation

ethics. Since refiring may transform original glass due to its heat and replace original paint it can therefore be questioned. The action is also completely irreversible, which goes against the conservation principle of *re treatability*. Furthermore, refiring goes against the principle of *minimum intervention*, as today, other non-invasive methods can be used to restore lost esthetics.
Finally, refiring also imposes a risk, as the temperature used when firing may crack the glass.

Replacing entire glass panels that lost its grisaille has also been practiced. Like refiring it can be considered to remove authenticity of the window as historic values and the value of the original material is replaced by esthetic and symbolic values. Replacing a panel with a new one, could however be considered reversible if the original glass is kept safely stored.

Cold paint is another method used to retouch lost paint. The word “cold” is used as the paint is not fired into the glass. Historically oil paint has been used for cold paints. Cold paint is not as invasive as refiring, however the treatment is not very lasting, as the oil paint quickly falls off (Vidimus, n.a).

Today, painted backing plates are generally used to restore the esthetic values after a paint loss. Backing plates are generally painted clear glass attached on the backside of the stained glass window. An example of the use of backing plates can be seen in chapter 2.8.

Beside active conservation and restoration process, preventive conservation has also been used, optimizing the climate for the window

2.9 Conservation of the ”son’s window” a lancet window made by Callmander in Uppsala Cathedral

The Son’s window was installed during the great restoration of the Uppsala Cathedral by Helgo Zetterwall, and was one of many windows installed during the restoration 1885-1893 (Bengtson, Bengtson-Melin, 2014). At first the work to produce the stained glass windows, was appointed to the German firm*, Heinersdorff & Co*, but after disagreements concerning the price the work was eventually appointed to Reinhold Callmander. Even though Callmander was a skilled painter, his design was considered ”too expensive”, and the architect Agi Lindegren who came to be responsible of much of the indoor restoration, designed the windows. The design was painted onto a carton, which then was sent to Gothenburg where Callmander and the newly established Svenska Glasmåleri AB produced the windows. In letters sent between Lindegren and Callmander, the frustration of Callmander can be read. Callmander was stressed as the Cathedral would reopen and Lindegren did not send him the cartoons quickly enough. As a result, Callmander finished some of the cartoons himself, resulting in him also being responsible for the design (Bengtson, Bengtson-Melin, 2014).

The windows of Uppsala Cathedral were finished in time, but unfortunately some of the paint of Callmander’s windows had already in year 1920 been lost to the degree that some inscriptions were unreadable. Since then numerous conservation and restoration efforts have been employed, 1968, 1974 and 2006 (Kvarnström & Andersson, 2017). Interestingly, it can be noted that the stained-glass windows made by *Nuemann & Vogel* also located in Uppsala cathedral, on the very same wall, and added only few years after Callmander’s windows, does not show the same issues regarding paint loss. That the condition of the grisaille between Callmander’s and Nuemann & Vogel’s windows differ, may point towards a material issue within Callmander’s stained glass, as they have been subjected to the same environment for approximately the same time.

The conservation project of the Sons window was initiated in year 2012, and it can be examined in detail in the article Retouching the past by Kvarnström & Andersson, 2017 (Bengtson, Bengtson-Melin, 2014).The project began before Uppsala domkyrkas glasmålningsateljé had been established in 2013, and the first steps of the conservation project was therefore initiated by the Cathedral studios in Canterbury as they performed a trial conservation and started the de-installation of the Sons window.

At this time the window had severe paint loss which had seriously discarded the readability and disfigured faces and hands of the figures. At parts the loss had almost created a type of ”negative” image (fig 5). Moreover, the texts had also turned unreadable. Beside paint loss, the windows had problems with several past restorations. The restorations had been performed with cold paint. Paint had also been consolidated with epoxy. The paint consolidated with epoxy had started to delaminate and hang loose from the panels. Other panels had during previous restoration been replaced with new ones, infills where neither the glass nor the paint entirely matched the color of the originals. In total there were around 70 infills with paint, and 20 without (Kvarnström & Andersson, 2017).

Figure 5. Photo with transmitted light, showing a panel of the Son's window in Uppsala Cathedral, before conservation. Photo: Uppsala domkyrkas glasmålningsateljé, 2014

To approach the issue, Uppsala domkyrkas glasmålninigsateljé together with the administrative county board, which is responsible for the monumental cultural heritage within the county, searched for the most suitable and ethical continuation within the guidelines of Corpus Vitrearum Medii Aevi (CVMA). At first the issue concerning the retouched paint and lost grisaille was discussed. As a part of the windows history, would the retouches be preserved? And was the paint loss also a

part of the windows history? Would the window lose a part of its authenticity and history if this was retouched? It was also decided that the least invasive would be to act with minimal intervention - cleaning, mending cracks in glass and lead cames, reinstall panels, and add copper wires for support.
As the investigation continued, it was realized that most of the infills were in the borders of the stained glass where they could easily be replaced without harming the lead network. It also came to realization that the state of the epoxy paint was too bad to consolidate. Furthermore, the epoxy paint had been painted to emulate a matt grisaille with the function to block the light. As much of the epoxy paint was lost, it therefore in a sense had lost some of its function as it no longer blocked the sunlight, blinding the eye of the viewer and rendering other panels of the window less visible. Apart from this the panels were also discoloured and incorrectly repainted, sometimes with discolored glass (Kvarnström & Andersson, 2017).

To address the question, a seminar was held together with an advisory group including experts, art historians and conservators. At this meeting it was decided that the infills which were visually disturbing could be retouched with tracing lines, and that the former infills with mismatched color would be replaced - partly as their purpose was lost, partly as it was not original material but also, because it had shown most of them were in borders and it could be done without harming original material. The new panels were dated, signed, and the old ones were stored. At the seminar it was also decided that hands, faces and inscriptions would be" retouched" by backing plates painted with trace lines of grisaille paint (fig 6). The result of a first test can be seen in figure 7 and 8. The backing plates where not sealed, to not create a microclimate. It was also decided that a

Figure 6, Backing glass made for the panel shown in fig 5. Signed "UDGA 2014". Photo: Uppsala domkyrkas glasmålningsateljé, 2014 protective glass would be placed on the outside, to halt the deterioration. Based on research the glass was installed to give an area between protection glass and original ventilated with indoor air (Kvarnström & Andersson, 2017).

Figure 7. Photo of the panel in reflective light, backside, after conservation and with a painted backing glass for the face and hands. Photo: Uppsala domkyrkas glasmålnings ateljé, 2014

Figure 8. Photo of the panel in transmitted light, frontside, after conservation and with a painted backing glass for face and hands. Photo: Uppsala domkyrkas glasmålnings ateljé, 2014

3. History and In-situ assessment of Callmander's stained glass windows in Gothenburg and Varberg

3.1 Method and objective

The objective with the in-situ assessment is to gain understanding of the subject's material, condition, and site, to understand the extent and reasons behind Callmander's lost grisaille paint. Identification of the material and the characteristics of the paint and substrate glass may provide information on how the windows were made and what the future deterioration may be. Characteristics may be the colour of the grisaille, the brushwork, the thickness, the smoothness, or granularity. To understand the paintwork aesthetically it is also helpful to predict what a missing motif may have looked like and anticipate the paint loss. To describe and understand the placement of each window is necessary to understand its potential agents of deterioration. The assessments will focus on the condition of the grisaille and substrate glass, but also other parts will be mentioned briefly, as they may indicate agents of deterioration which also could affect the paint. Previous conservation treatments and restorations are not always documented and if they are, the documentation might sometimes not describe all the taken actions. It is necessary to find traces of previous conservation, especially treatments of the grisaille paint, to fully understand the deterioration of Callmander's paint. Every window was examined with ocular investigation and documented with the camera of a Fairphone 3, and Sony alpha 290 with a 18-55 SAM lens. For Christinae church a handheld microscope Jiusun 2k HD was also used.

3.2 Christinae's church

3.2.1 History of Christinae's church

The Christinae's church in Gothenburg, also known as "Tyska kyrkan" (The German church) is located in central Gothenburg, Norra Hamngatan 16. The history of the church begins in 1623 as a wooden chapel was built for the city's Dutch and German inhabitants to practice their religious worship. As the chapel was destroyed in a fire 1699, the current Christinae church was constructed. The history of the church’s stained-glass windows begins in 1879 when Wilhelm Röhs and Carin Röhs donated two glass paintings on each side of the church’s choir depicting Petrus and Paulus. The glass paintings were designed by Callmander and manufactured by C.F Eberling. During a restoration of the choir in year 1899 five more stained-windows were added, made by Callmander and Svenska Glasmåleri AB. In 1901 the company was commissioned to produce additionally six more windows installed in the nave (Göteborgds stift, n.d.). Data from the National Heritage Board’s data base for built heritage, (BeBR, n.d.-a) confirms that the two first windows were manufactured by glazier C.F Eberling. In search for more information regarding a glazier known as C.F Eberling no information is found. Instead, a C.F Eberling who worked as an architect in Gothenburg during the end of the 19th century is found. If the architect and glazier is not the same person, they would be namesakes living in the same city during the same time. It was not unusual that architects did design windows in that era. In Vasagatan 15, another building designed by the architect C.F Eberling, there is unpainted but colored stained glass (BeBR, n.d.-a).

Another important piece of the church history is that the first two windows were added in 1879. Before Svenska Glasmåleri AB was formed in 1888. Callmander did design windows before he formed Svenska Glasmåleri AB, for example the stained-glass windows of Haga Church in Gothenburg. Although, no information of him as a manufacturer prior 1888 has been found for this thesis. Consequently, the first two windows Paulus and Petrus cannot be used as a mean to understand Callmander’s material and methods.

Since the installation of the windows three separate restorations has been performed. In Sweden’s National Heritage Board’s data base of built heritage (BeBR), the first restoration of the windows is mentioned in year 1962. The reason which led to the intervention nor the extent of it is not mentioned, neither is it mentioned whom performed the conservation (BeBR, n.d.-a).

The second conservation year 1978 was induced as a bomb detonated at the neighbouring town hall, leading to the shattering of many windows, and a total of 360 broken glass panes (Sidén, 2020).

The restoration of the windows was led by N.P Ringströms Glasmästeri (BeBR, n.d.-a). During the conservation work N.P Ringström mended broken glass sometimes with leadcames and sometimes with epoxy glue. The most damaged glass was replaced with new glass from Germany and Belgium (Sidén, 2020). The third conservation intervention was made in 2013 as a part of a larger façade restoration. This restoration was performed by Kåltorp's glasmästeri but certain glasses with severe paint loss was sent to Germany and treated by Derrix glass studio. According to Erik Norberg, part-owner at Kåltorp's glasmästeri many of the windows paint loss could be directed to bad retouches performed during the 1962 restoration (Ödesjö, 2012). L.B antik and opalecent glas AB was also involved in the restoration 2013, responsible for painting new glasses (Ödesö, 2012). One of the glasses which later will be technically examined in this thesis, is one of the original glass panes made by Callmander from one of the windows. The glass named as *glass B* in this thesis was discarded during the façade restoration 2013 (Informant 1, 2019).

3.2.2 In-situ assessment Christinae's church

The church has twelve stained-glass windows, four on each side of the nave (fig 9 - 16) and four in the choir (fig 17 - 20). The altar points towards the east and the windows have protective glazing possibly from the 2013 restoration. The paintwork consists of matting for shadows and tracing for outlines and text. What can be seen without ladder, is that all grisaille is painted on the inside of the glass.

At first glance the grisaille paint appeared to be in good condition, perhaps because so many glass panels was replaced due to the explosion in year 1978. Especially for the windows near the choir, the condition was good. The bottom part of these window were situated in eye level, were only small areas of paint loss and pitting could be found, (fig 21 and 22) the upper part however could not be investigated up close. The windows in the nave showed greater signs of deterioration, possibly as they were further away from the explosion and therefore had more original glass left. For these windows especially the tracing had in places lost significant amount of paint, ranging from pinholes to entire areas of 5 x 5 cm. The characteristics of the loss was much like the paint loss of the windows in Uppsala cathedral of Callmander. With a circular pattern, possibly adhering from small pits (fig 24, 25). The loss was not uniform, and for example certain panels could have a deterioration on the upper part while the panel next to it only had deterioration on the lower. With the handheld microscope the paint appeared to be quite granular (fig 26 and 27).

There was some dirt on the window, and perhaps a cleaning would reveal more areas of loss. Apart from this, certain marks of corrosion could be found on the grisaille. The substrate glass was in good condition, apart from minor scratches. It was difficult, to for certain, distinguish the original glass from the glass of the 1972 and 2013 restorations. There was slight change in colour for certain glass panels, and it could be assumed some of the slightly odd ones were not original. Furthermore, it could be assumed that most of the original would be further away from the choir which was closest to the 1972 explosion. It was also difficult to distinguish possible retouches both from 1962 and 2013 from original paint. Since refiring is not used in conservation anymore it could be assumed that the grisaille paint is not from the 2013 conservation. Especially as the characteristics of the loss and paint have similarities with Callmander's paint in Uppsala cathedral.

Figure 9. Photo of the window depicting St Petrus. Photo: Eisfeldt, 2022

Figure 10. Photo of the window depicting St Marcus. Photo: Eisfeldt, 2022

Figure 11. Photo of the window depicting Johannes. Photo: Eisfeldt, 2022

Figure 12. Photo of the window depicting Esaias. Photo: Eisfeldt, 2022

Figure 13. Photo of the window depicting St, Paulus. Photo: Eisfeldt, 2022

Figure 14. Photo of the window depicting David. Photo: Eisfeldt, 2022

Figure 15. Photo of the window depicting st Matheus. Photo: Eisfeldt, 2022

Figure 16. Photo of the window depicting st Lucas. Photo: Eisfeldt, 2022

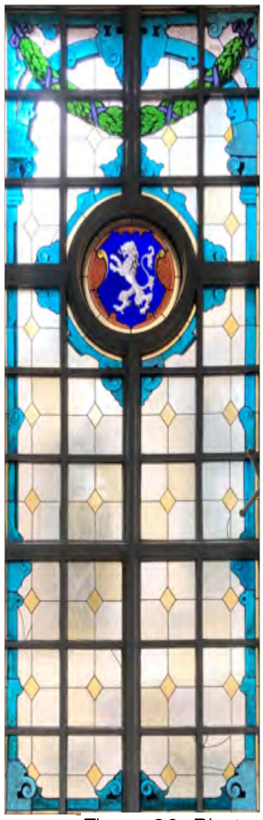

Figure 17. Photo of the red window in Christiane church's choir. Photo: Eisfeldt, 2022

Figure 18. Photo of the green window in Christiane church's choir. Photo: Eisfeldt, 2022

Figure 19. Photo of the purple window in Christinae church's choir. Photo: Eisfeldt, 2022

Figure 20. Photo of the blue window in Christinae church's choir. Photo: Eisfeldt, 2022

Figure 21. A panel of the red window in the church's choir with paint loss in the dark trace lines. Photo: Eisfeldt, 2022

Figure 22. A panel of the red window in the church's choir. Paint loss of the dark trace line can be seen in the panel's bottom left and top right. Photo: Eisfeldt, 2022

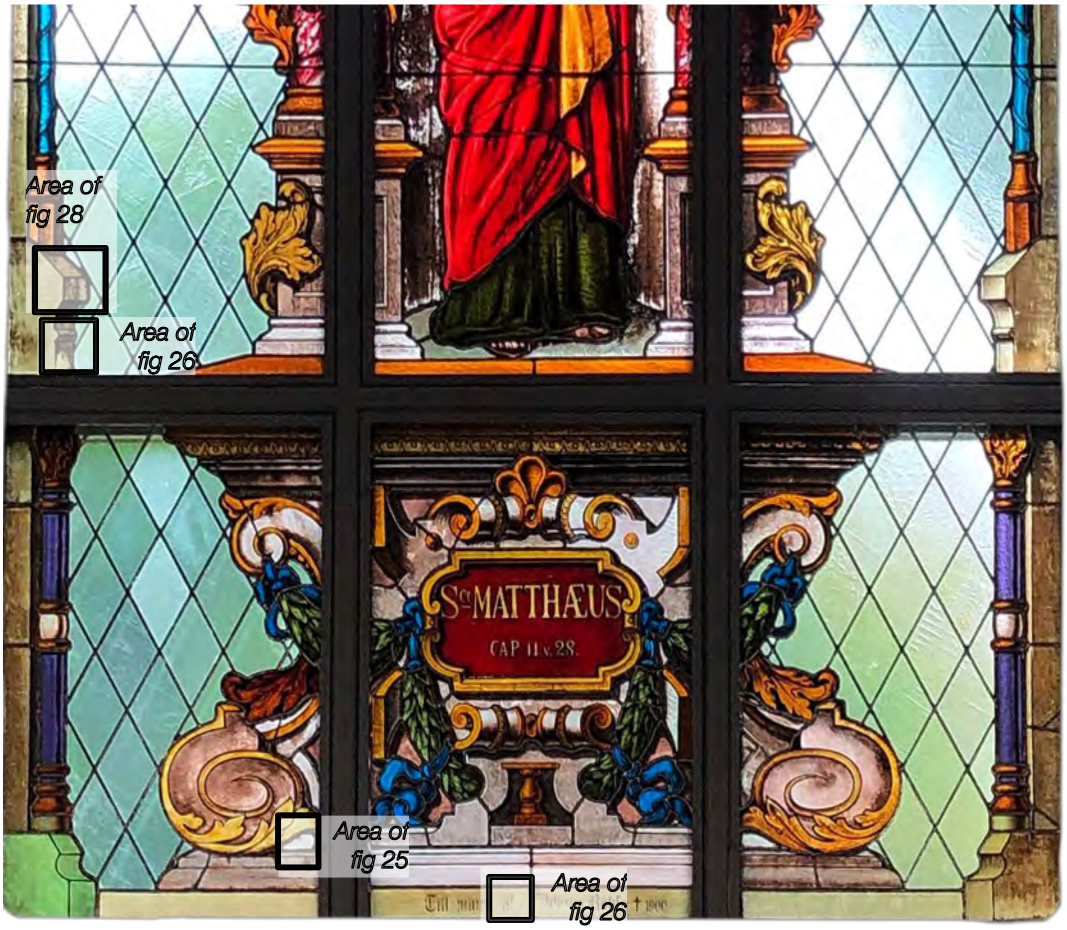

Figure 23. Photo of the window of St, Matheus. Photo: Eisfeldt, 2022

Figure 24. Photo of the window of St, Matheus showing paint loss. Photo: Eisfeldt, 2022

Figure 25. Photos on a second area of the window of St, Matheus showing paint loss. Photo: Eisfeldt, 2022

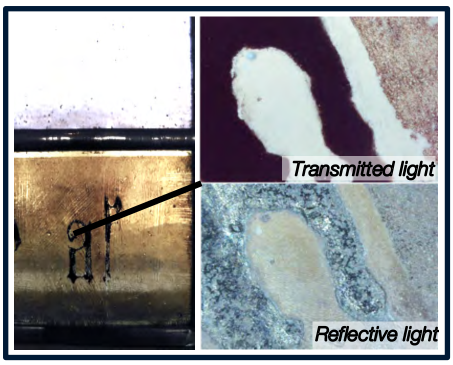

Figure 26. Photos taken with hand-held microscope on Matheus showing paint loss on St Matheus. Photo: Eisfeldt, 2022

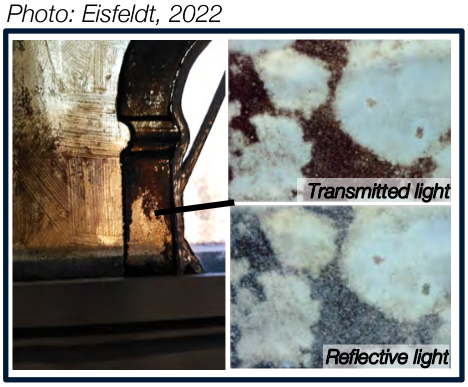

Figure 27. Photos taken with hand-held microscope on a second area of St, Matheus showing paint loss. Photo: Eisfeldt, 2022

3.3 Fässberg's church

3.3.1 History Fässberg's church

Fässberg's church is located in Central Mölndal, on the hill known as "Baazberget", address Terrakottagatan 3. The architect behind the church is Adrian Crispin Pettersson, who collaborated with Callmander in several projects. The construction of Fässberg Church was completed the 4th December 1887, only two and a half years after Pettersson finished his first sketches (Svenska kyrkan Mölndal, 2020). The church's history shows a lingering battle against moisture, with the first problem arising only 10 years after the church's opening. Extensive restoration of both walls and roof has then occurred 1917, 1947, 1973, 1995 (BeBR, n.d.-b). In Sweden's National Heritage Board's data base of built heritage, only one intervention concerning the windows are mentioned, in year 1947-1948, when a window in the choir was walled up (BeBR, n.d.-b). No restoration work concerning the windows is mentioned in the guide folder where all other restorations are mentioned (Svenska kyrkan Mölndal, 2020). Neither was any information regarding interventions on the windows mentioned during my visit at the church.

3.3.2 In-situ assessment Fässberg's church

The church has three rose windows and six lancet windows. The six lancet windows are located three on each side in the nave. Where three are facing to west and three to the east. The lancet windows have an ornament pattern made of a dark trace lines (fig 28 and 29). On the lancet windows a lot of grisaille paint have vanished (fig 30 and 31). The paint loss is not uniform, and for each panel the grisaille has vanished on different locations of the glass. The paint is perceived as quite granular. Beside the paint, the windows are in fairly good condition. The glass condition is without remarks, and the lead is without cracks and only shows minor corrosion. No difference was noted between the windows of the west and the east wall.

The grisaille paint on the three rose windows, located east, west and north, were more difficult to investigate, as their placement was high. However, it can be seen from afar that the grisaille has disappeared at several places (fig, 32 and 33). Perhaps, the panels with red substrate glass have slightly more paint loss, but it is difficult to anticipate. Reasons behind this could be that the red colour absorbs more heat from the sunlight causing them to flake more. It could also be that the red substrate glass had a too high melting point for the vitreous paint to fully fuse. It could also be that the red glass pieces were fired simultaneously and with a slightly low temperature. No difference in deterioration could be made whether the windows were located to the east, south or north.

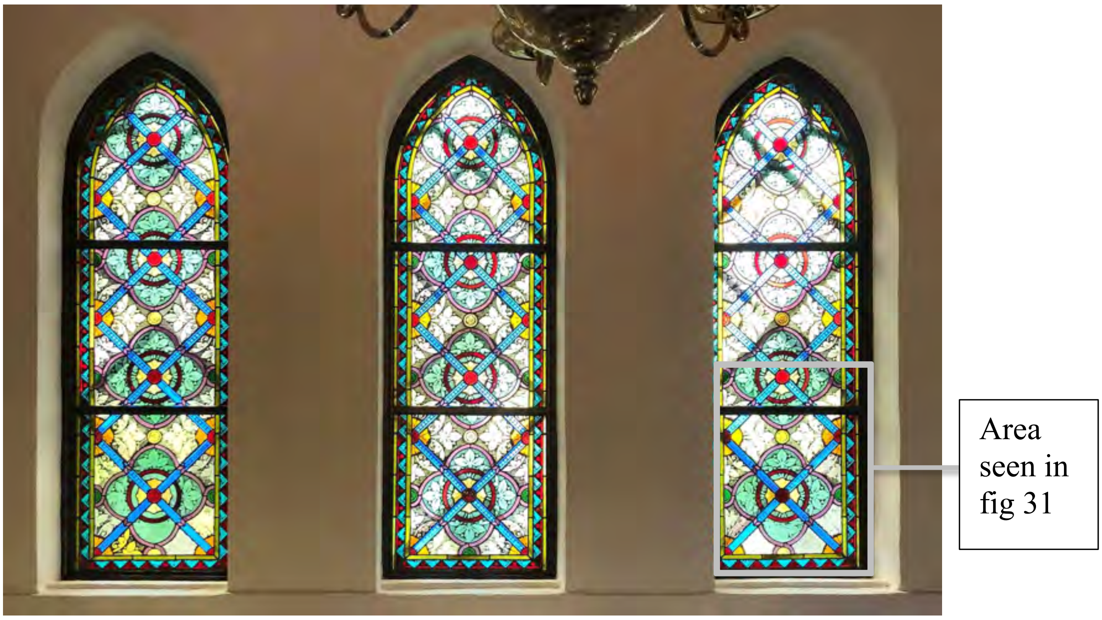

Figure 28. Photo of the three windows on the west wall of Fässberg's church. Photo: Eisfeldt, 2022

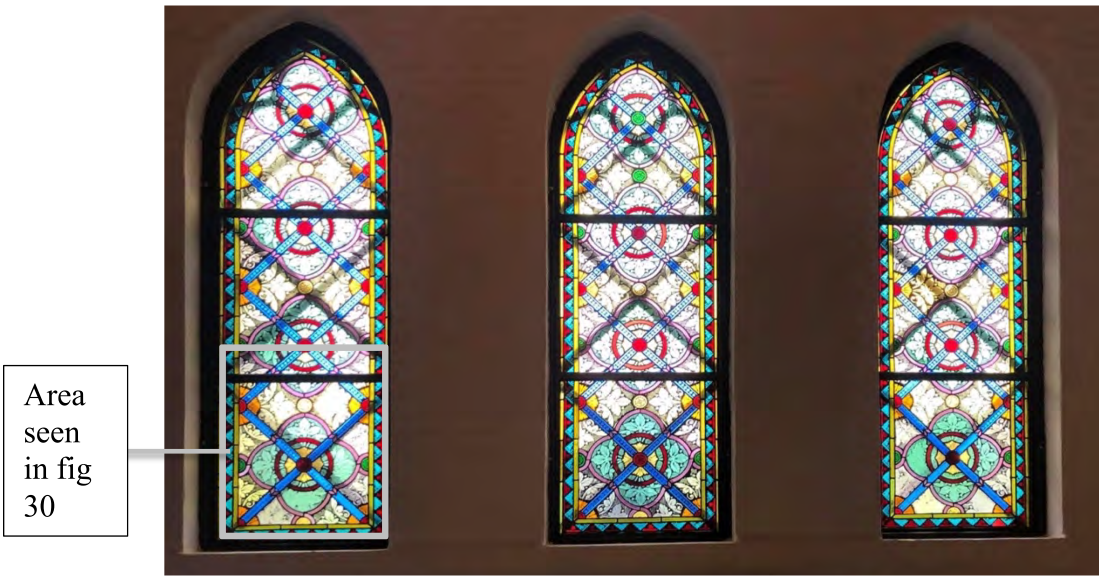

Figure 29. Photo of the three windows on the east wall of Fässberg's church. Photo: Eisfeldt, 2022

For the windows in the nave, the paint loss was perceived to appear quite randomly, this can be seen in figure 30 and 31, where some panels with the most paint loss are situated next to the ones in the best condition.

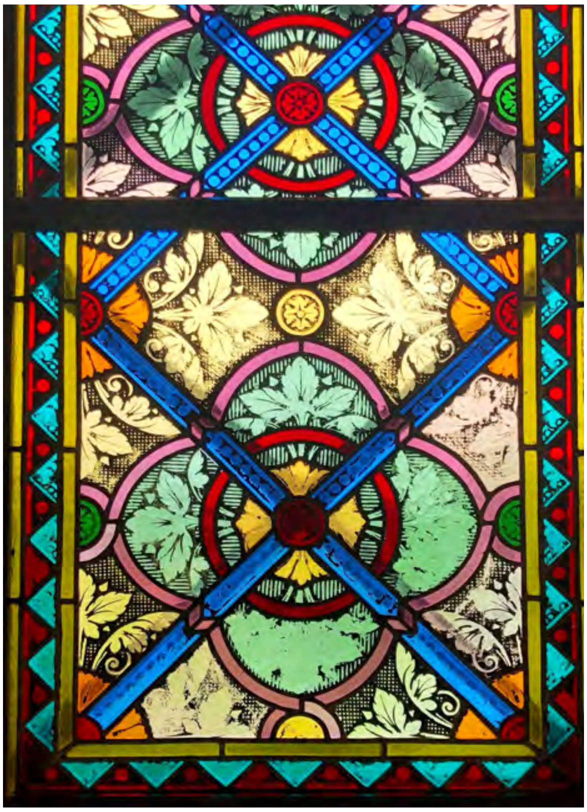

Figure 30. Photo of the bottom of the left window in figure 29. Photo: Eisfeldt, 2022

Figure 31. Photo of the bottom right window in figure 28. Photo: Eisfeldt, 2022

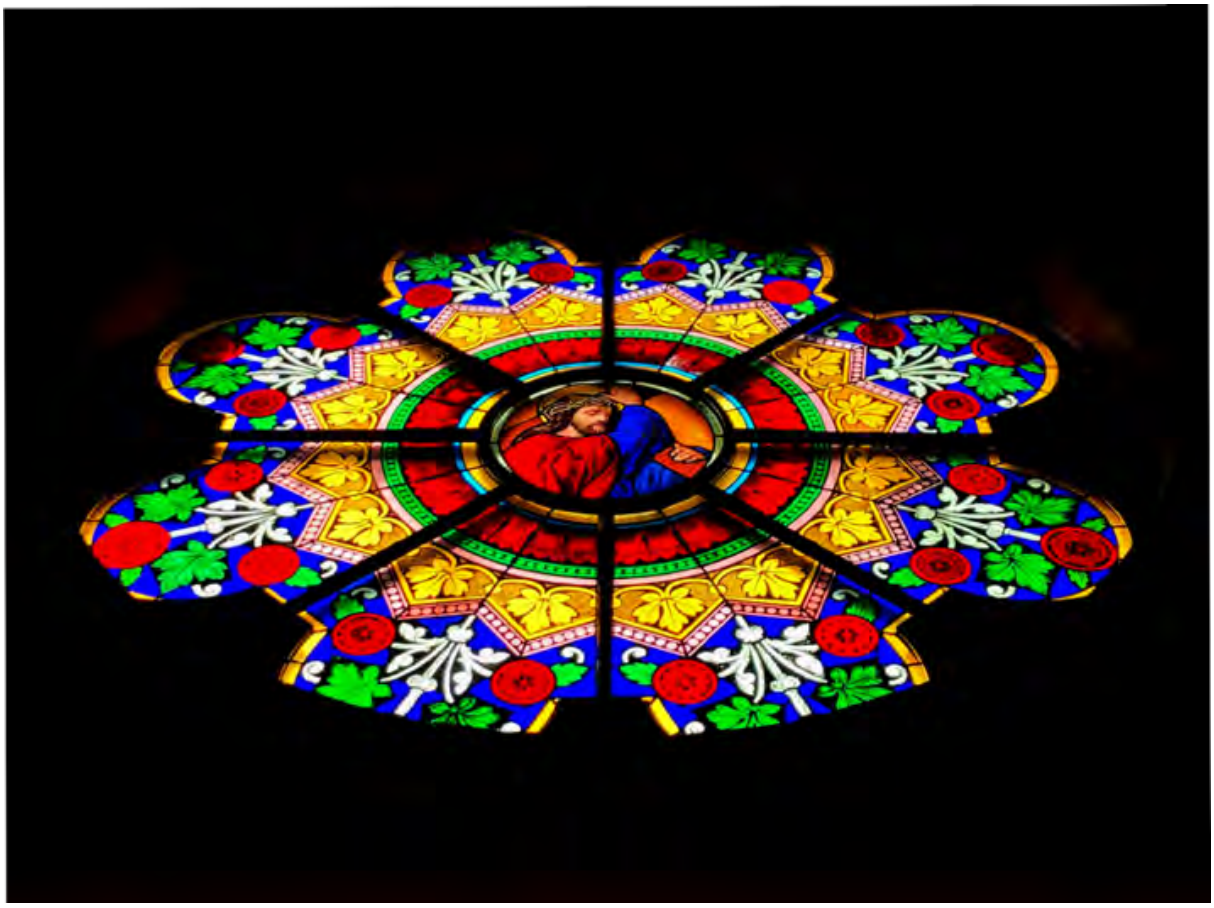

Figure 32. West rose window of Fässberg's Church. Photo: Eisfeldt, 2022

Figure 33. East rose window of Fässberg's Church Photo: Eisfeldt, 2022

3.4 Örgryte new church

3.4.1 History of Örgryte new church

The church, Örgryte new church, was built between 1888-1890 upon the hill known as “Svalberget” in Gothenburg, Lennart Svegelius väg 10. The construction was initiated by donations from David Lundström, James Dickson, David Carnegie and Oscar Ekman. The architect was once again Adrian Crispin Peterson, with builder F.O Peterson. According to the church’s documents, Callmander and Svenska Glasmåleri AB produced 17 windows which were acquired by the church 1889. In the Church’s own record, it is mentioned that in year 1937 the lead cames were replaced (Inventarieföreteckning, 2013).
In 1951 five windows were discarded. The reason for this was that a new altarpiece was acquired, and the windows was considered as “disturbing” (Svenska kyrkan, n.d.-a). In Sweden’s National Heritage Board’s data base of built heritage it is mentioned that the four rose windows, were moved from the choir to their current position in 1952, and that “the rest” of the windows were stored in a storage facility (BeBR, n.d.-c). In 2016 a facade conservation led by Tegelfogen AB was initiated (Tegelfogen, n.d.). The project included plans to restore the rose windows, but were halted as asbestos was discovered in the joints (Informant 1, 2023).

3.4.2 In-situ assessment Örgryte new church

The church has 6 lancet windows and 6 painted rose windows, although only 4 could be inspected (fig 35 - 38). The glass of the rose windows seems to be inverted, as the grisaille paint is facing outwards on each of the glass panels. Furthermore, the brown pupils painted on (fig 40) are painted on the inside of the glass, whereas historically pupils are almost always painted on the surface facing the outside to give the image more depth. The reason that the glass is inverted is perhaps because there is a protective glass on the outside and the initial idea was that this would protect the paint. No information regarding a conservation/restoration project where this would have happened was found in the church documentation, but likely the change was made in 1952 when the four rose windows were moved to their current location.

The church has a long history with issues regarding its climate. The issues can be connected to its use of material and construction, but also due to its location, being on the top of a hill, where the wind from the ocean brings moist and salt. The church's documentation of restoration shows a pattern where most damages are directed to the south, while the north is quite protected and stable. For the windows no difference between the south and north is observed. Overall, a few cracks can be found in the glass,and on the lead cames there are some corrosion, and small cracks, but nothing immediate. The lead cames are also covered with a modern type of window putty. The windows felt quite clean, however small stains of wall paint could be found on one of the rose windows. The grisaille paint felt quite stable with some exceptions. Pin-holes and tiny dots of paint loss was found uniformly on all windows and different panels, mostly in the dark tracing paint, but some holes can also be found on the grisaille which is transparent brown. The worst affected parts were the circular glass panels (fig 41), but the flaking of these panels can be considered minor compared to other of Callmander's stained glass windows examined during this thesis. No flakes which had fallen of could be seen beneath the window, perhaps it has been recently cleaned.

Figure 34. The lancet windows in the choir of Örgryte new church. Photo: Eisfeldt, 2022

Figure 35. The north-east rose window of Örgryte's new church. Photo: Eisfeldt, 2022

Figure 36. The south-east rose window of Örgryte's new church. Photo: Eisfeldt, 2022

Figure 37. The shouth-west rose window of Örgryte's new church. Photo: Eisfeldt, 2022

Figure 38. The north-west, rose window of Örgryte's new church. Photo: Eisfeldt, 2022

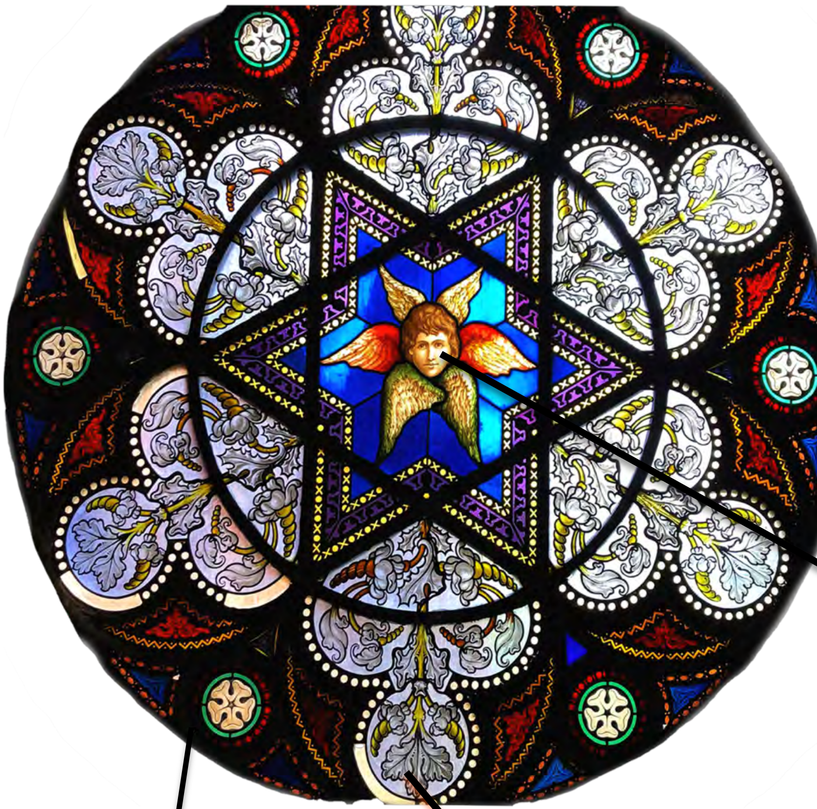

Figure 39, The north- west window of Örgryte's new church. Location of detailed images. Photo: Eisfeldt, 2022

Figure 40. The eyes of the north- west window, depicted on the inside of the glass. Photo: Eisfeldt, 2022

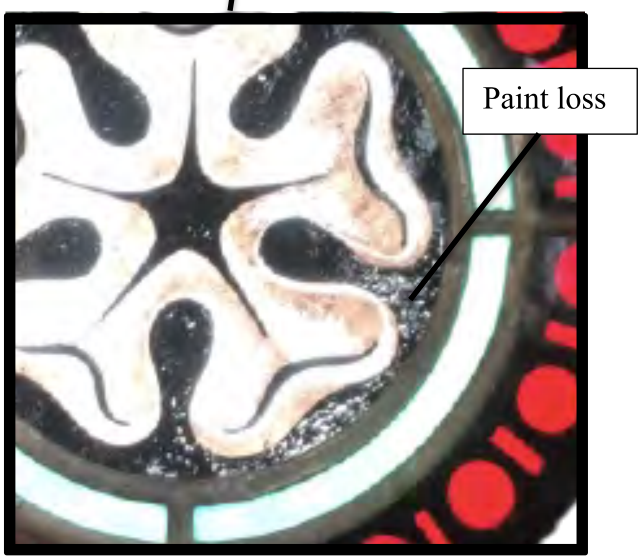

Figure 41. Example of one of the roundels with paint loss. Photo: Eisfeldt, 2022

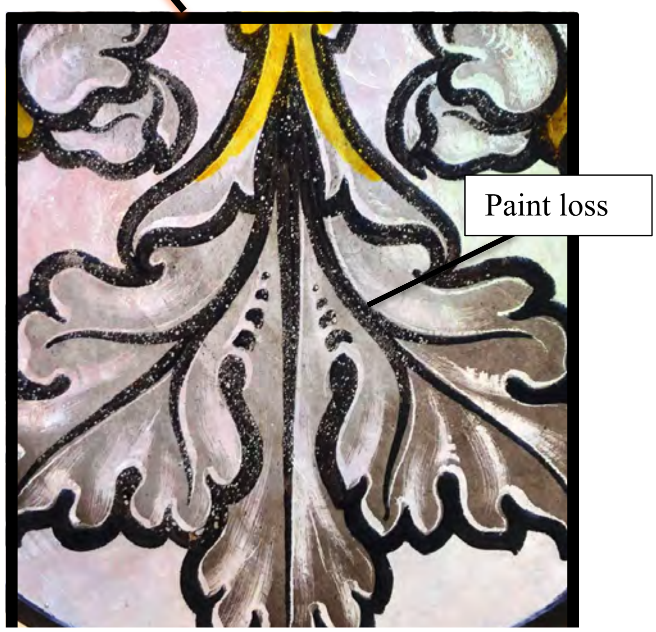

Figure 42. Example of loss in form pin-holes found on the rose windows. Photo: Eisfeldt, 2022

3.5 Oscar Fredrik’s church

3.5.1 History of Oscar Fredrik’s church

The Church of Oscar Fredrik is located in the centre of Gothenburg near Järntorget on the address Oscar Fredriks Kyrkogata 1. The church named after the Swedish king Oscar II opened on the easter day of 1893. The architect behind the construction was the Swedish architect Helgo Zetterwall, known for his new-gothic restoration in Lund- and Uppsala Cathedral. Zetterwall and Callmander had previously worked together during the restoration of Uppsala Cathedral 1886-1994, and he appointed Callmander to create rose windows in the aisle and transept windows in the choir. Today, only two rose windows of Callmander and Svenska Glasmåleri AB remains in the church. The stained-glass windows for the choir, was replaced in 1930 by windows designed by the artist Alberth Eldh. ”Accordingly Callmander’s windows did not ”withstand the wind, rain and weather” (Svenska kyrkan, 2021). The windows designed by Alberth Eldh was likely produced by N.P Ringström (BeBR, n.d.-d). Albert Eldh had in a previously restoration year 1913-1915 performed paintings on walls, ceilings and in the choir and side chapels. The 1913-1915 restoration is mentioned to have been led by architect C.F Ebeling (BeBR, n.d.-d). Possibly the same C.F Eberling, named as a producer of windows for Christinae church above. In 1970 one of the rose windows were painted black, as its light were considered too blinding. The overpaint was removed in 1978 (Svenska kyrkan, n.d-b). Between 2019 and 2020, Studio Västsvensk Konservering (SVK) undertook conservation work on the walls and ceilings of the church, acting as subcontractor for FO Petterson & Söner (Västra Götalands Regionen, n.d). In year 2023 Tegelfogen AB has initiated a conservation of the exterior of the church. Once again Blyfönsteriet AB led by Sussane Marlow has been commissioned to perform the conservation of the windows (Informant 1, 2023).

3.5.2 In situ assesment of Oscar Fredrik's church

As Callmander's window in the choir was removed due to ”flaking paint” only two rose windows of Callmander remains in the church. The west (fig 43) and the south fig (45). From the ground, it is clear that one of the blue glasses of the west window has been replaced and that a large amount of grisaille paint in the red and yellow panels is lost. (Fig 43, 44) The south window also showed signs of paint loss, however as the windows are situated high up on the wall a more detailed condition assessment proved difficult.

Figure 43. The west rose window of Oscar Fredrik's church.
Photo: Eisfeldt, 2022

Figure 44. The west rose window of Oscar Fredrik's church. In the photo paint loss is visible, and can be seen especially on the upper side of the window. Photo: Eisfeldt, 2022

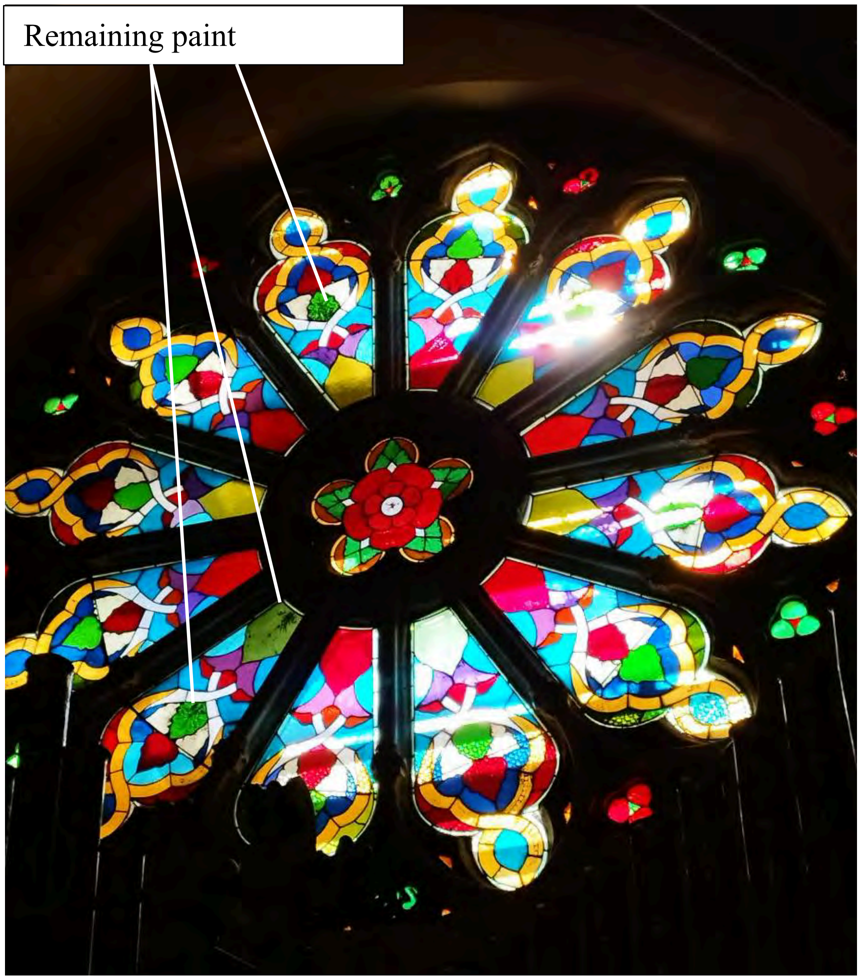

Figure 45. The south rose window of Oscar Fredric's church with paint loss visible from distance. Photo: Eisfeldt, 2022

3.6 Jonsered church

3.6.1 History of Jonsered's church

The church is located in Jonsered with the address Anna-Stinas lid. It was built with donations from William Gibson (1783-1857) between 1858 and 1860. The design was made by architect Adolf Wilhelm Edelswärd (1824-1919). In year 1897 the church was remodeled and given a choir designed by the architect Yngve Rasmussen. By Rasmussen Reinhold Callmander was appointed to design four windows (BeBR, n.d.-e). In 1927 the middle window was covered with a wooden board (BeBR, n.d.-e).

3.6.2 In-situ assessment Jonsered's church

In Jonsered's church there are three windows (fig 46, 47, 48) in the choir which were all investigated. The windows have a lot of areas with lost paint. Most notable is the loss of the dark grisaille tracing used for decorative patterns on the yellow panels. The loss in these areas is similar to previous windows investigated, where the loss occurs in a circular pattern. Major loss of paint can also be seen in the faces, especially on the right window (fig 49, 50). The loss in this window is similar to the loss in *the Son's window* in Uppsala cathedral seen in chapter 2.8, where the paint had varnished and created a ”negative” image as dark grisaille paint turned to transparent spaces. Looking closely at the window, both washes, matts and tracelines of grisaille has vanished, in difference to some of the other windows in this thesis where only the tracing had disappeared. The paint loss in Jonsered Church can be seen on top of all the different colored glasses and different shades of grisaille, including dark black, reddish brown and grey brown. Apart from the lost grisaille the windows were in good condition, without cracks or corrosion on the lead. The windows also felt very clean, some pits and scratches could be seen on the substrate glass.

Figure 46. The left window in the choir of Jonsered church. Photo: Eisfeldt, 2022

Figure 47, The right window in the choir of Jonsered church. Photo: Eisfeldt, 2022

Figure 48. The middle window in the choir of Jonsered church. Photo: Eisfeldt, 2022

Figure 49. The right window in the choir of Jonsered church. Areas of paint loss are marked with dotted pink lines. Photo: Eisfeldt, 2022

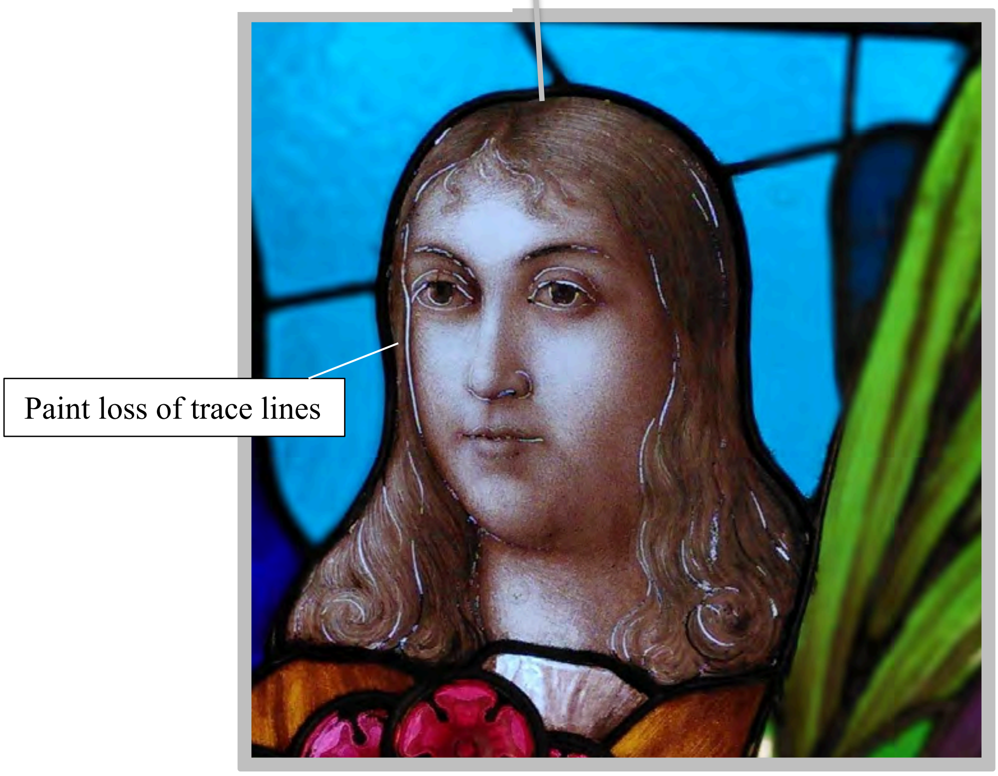

Figure 50. The middle window in the choir of Jonsered church. Close-up on the face. Photo: Eisfeldt, 2022

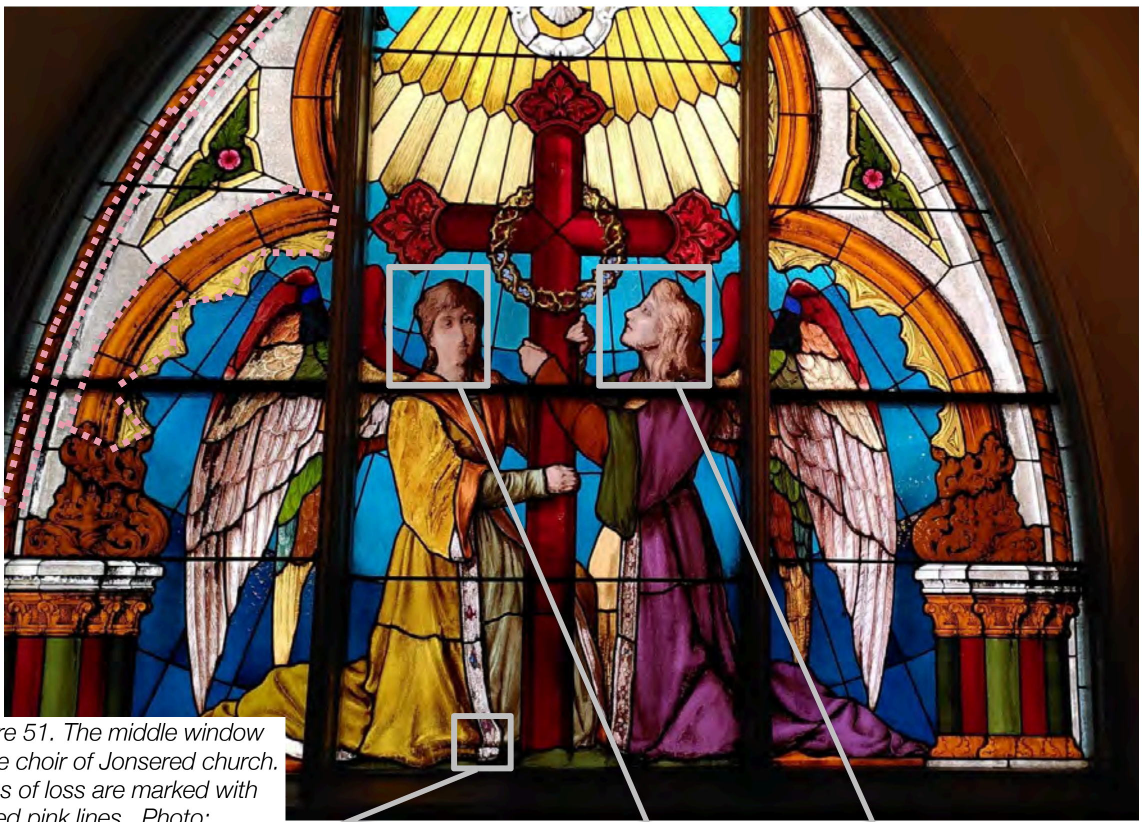

Figure 51. The middle window in the choir of Jonsered church. Areas of loss are marked with dotted pink lines. Photo: Eisfeldt, 2022

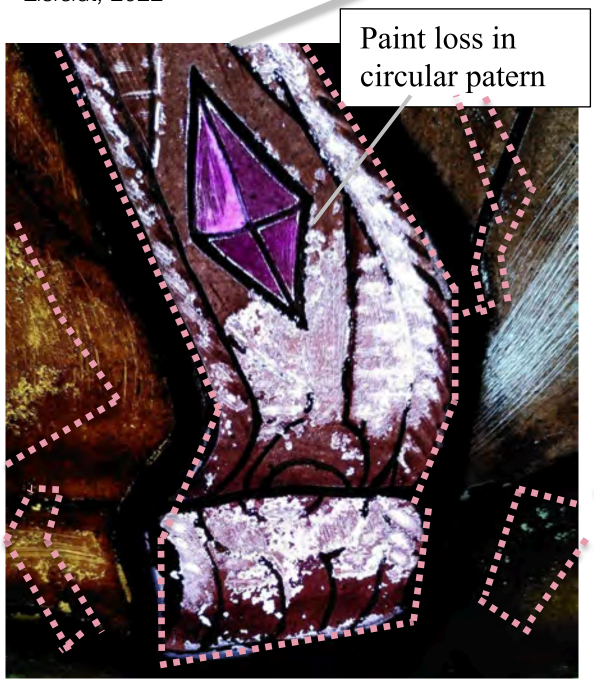

Figure 52. Circular paint-loss in the matting of glass in the middle window in the choir of Jonsered church. Areas of loss are marked with dotted pink lines. Photo: Eisfeldt, 2022

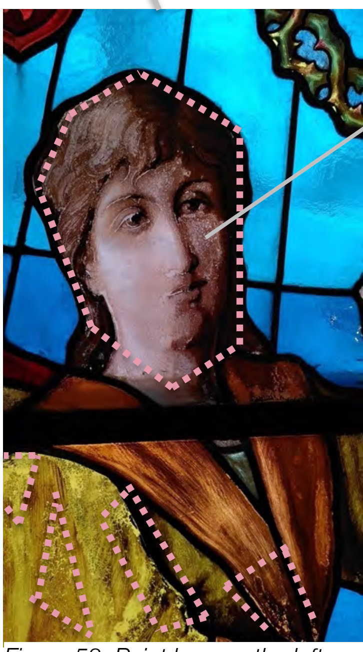

Figure 53. Paint loss on the left character of the middle window in Jonsered church. Areas of loss are marked with dotted pink lines. Photo: Eisfeldt, 2022

Figure 54. Paint loss of matting and tracing of the right character of the middle window in the choir of Jonsered church. Areas of loss are marked with dotted pink lines. Photo: Eisfeldt, 2022

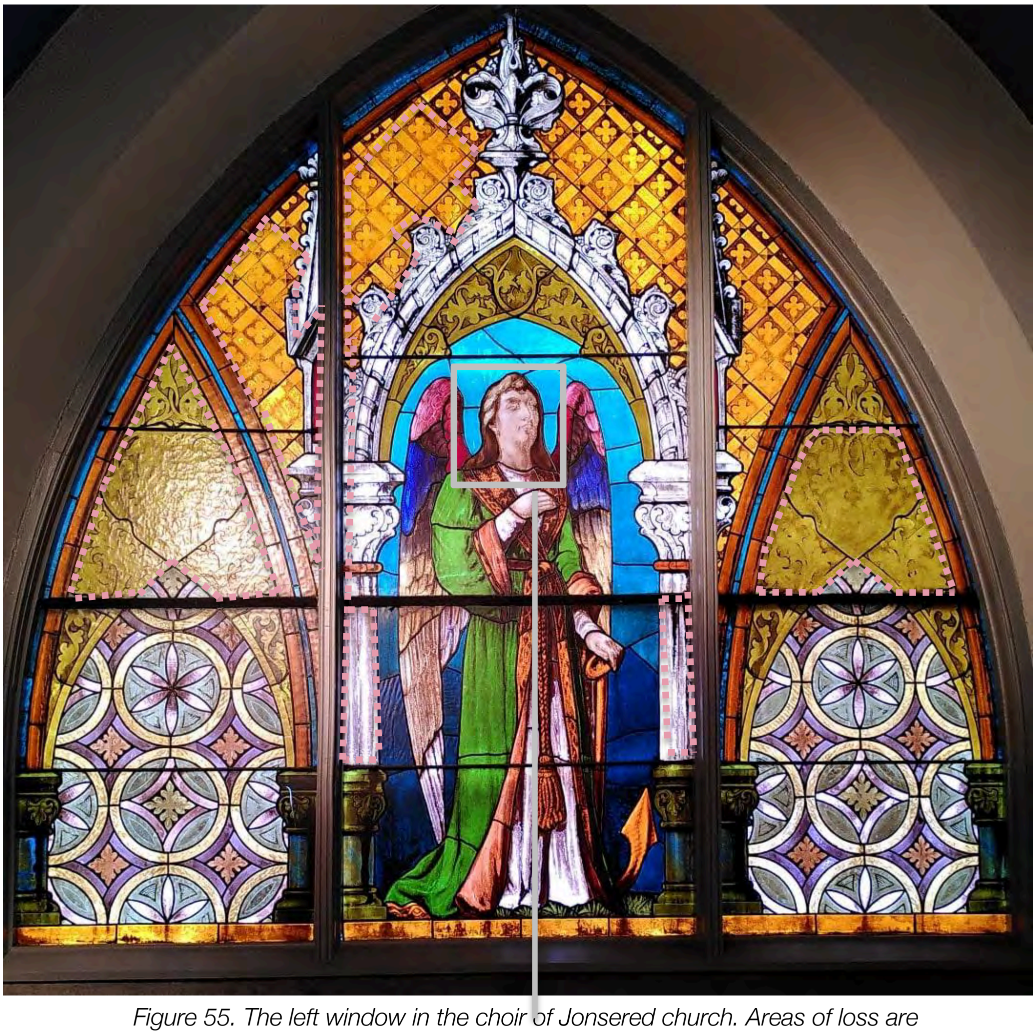

Figure 55. The left window in the choir of Jonsered church. Areas of loss are marked with dotted pink lines. Photo: Eisfeldt, 2022

Figure 56. Photo of face with severe paint loss in the left window in the choir of Jonsered church. Photo: Eisfeldt, 2022

3.7 Linnea's church

3.7.1 History of Linnea's church

Linnea's church is located in central Gothenburg at Linnegatan 35. The church was inaugurated the 20th november 1903 and was Gothenburgs second Baptist church. Today the church is working with charity and shelter for homeless. It is not certain who made the windows of the church as no records were found. However, there are certain things that points towards Callmander, as he was the only active glass painter in Gothenburg, but also as the style is similar, as well as the material, (glass and lead cames). It is not known however if the windows were added during the construction of the building, especially as there are outers windows placed outside of the stained-glass. Added later however, it may be argued that the style would be different.

3.7.2 In-situ assessment Linnea's church

The three windows (fig 57) are painted with dark grisaille for trace lines and lighter stippled grisaille for shadings. The purple, yellow and blue glass are very similar to the ones of Jonsered. Stylistically the depictions of the characters are slightly different compared to the ones in Christinae's church and Örgryte's new church, as they appear a little flatter with less washes. Also, the detail of the hair is different than to other of Callmander's work. The lowest panels ornament style, however, has many similarities with Callmander's. The window also shares the same type of lead cames. Behind the stained-glass windows there are other exterior windows. The exterior windows consist of unpainted coloured glass in their lowest part (fig 58). The interior windows or the stained glass (fig 57) has a dark brown red and a black dark grisaille.

The windows are very dirty, (fig 59, 60) due to thermo-diffusion and years of attracting pollution, dust, and candle smoke. Apart from the dirt, the condition seems to be good, perhaps as they are protected by the exterior windows. Looking closely at the grisaille many small cracks could be found in the paint. The paint layer also felt quite granular and at certain places pinholes could be found. The substrate glass did not seem to have any cracks, but due to the dirt layer it was difficult to fully examine its condition. It is also possible that much of the painted details and shadows would appear if the glass was cleaned.

Figure 57. The three lancet windows in the choir of Linnea Church
Photo: Eisfeldt, 2022

Figure 58. The outer window of the Linnea church. Photo: Eisfeldt, 2022

Figure 59. Close-up photo of the left window of the Linnea church. Photo: Eisfeldt, 2022

Figure 60. Photo of the dirt of the left window of the Linnea church. Photo: Eisfeldt, 2022

3.8 Varberg's church

3.8.1 History of Varberg's church

The church of Varberg located in central Varberg, Kyrkogatan 2, was built year 1769-1772 by Friedrich August Rex (BeBR, n.d.-f). During a restoration 1890-91 it is claimed that windows by Reinhold Callmander was installed (Börjesson, 2005, pp. 62-63). In year 1960 the register claims that all of Callmander's windows were replaced by four windows by artist Johan Thomas Skovgaard (BeBR, n.d-f). When visiting the church, it is easy to identify the four windows by Skovgaard as they have a modern esthetic, but also as they are signed. Behind the altar there is a fifth stained glass with a very different style, much like the style of Callmander. Apart from the style, the material such as glass, paint and lead cames, are similar to other windows of Callmander. It may therefore be possible that the 1930 restoration did not remove all windows, but saved the stained glass hidden behind the altar.

Especially as Skovgaard only installed four windows, and there are five within the church building. Two of the discarded windows made by Callmander can be seen in fig 61.

Figure 61. Interior photo of Varberg's church, where two of Callmander's windows which today are discarded can be seen. The date of the photo is unknown. Photo: Riksantikvarieämbetet, n.d

3.8.2 In-situ assessment of Varberg's church

The window (fig 62) situated on the church's east wall consists of Cathedral glass and a lead network. It is painted with a dark grey, almost black grisaille. The paint seems to be quite thinly applied.

The lead seems quite new and is in good condition without any corrosions and cracks. The substrate glass was in good quality, with only few pits with and no salt percipitation nor iridescence. The paintwork, however, has a large amount of paint loss (Fig 63, 64) The paint loss can be found on all the glasses, and by eye, it seems the orange glasses has lost more paint than the yellow ones (fig 62). This might be explained by coincidence, but also by uneven firing, or the different characteristics of the substrate glass pieces. Furthermore, it could be stated that what grisaille is left, feels quite secure. No flakes were found under the window which may indicate that the window does not flake momentarily. Neither were any running stains from the paint found on the glass.

Figure 62. The stained glass window of Varberg's church.
Photo: Eisfeldt, 2022

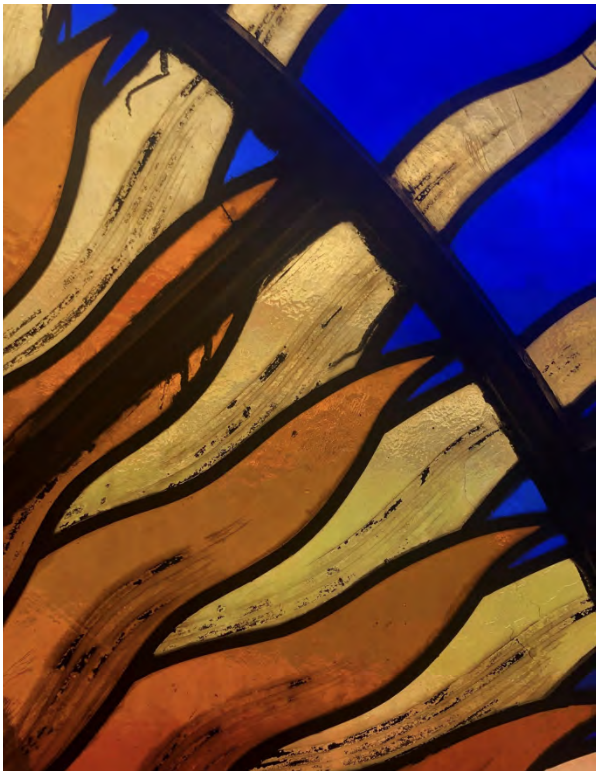

Figure 63. Paint-loss of Callmander's stained glass in Varberg's church. Photo: Eisfeldt, 2022

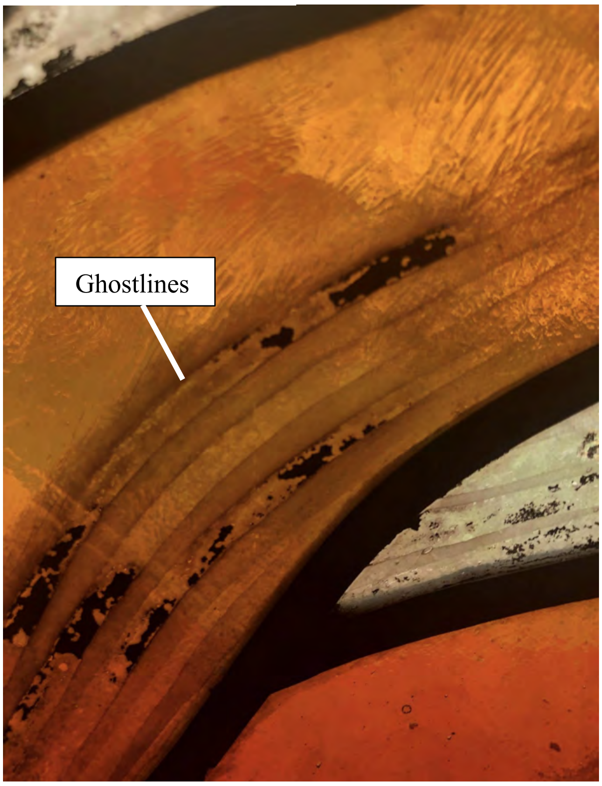

Figure 64. Paint loss and ghostlines of Callmander's window in Varberg's church. Photo: Eisfeldt, 2022

3.9 Sollyckan’s church

3.9.1 History of Sollyckan’s church

Sollyckan’s church located in Varberg, Förenings gatan 54, was built in 2005 by design of architect Jerk Altons. The church belongs to the same congregation as Varberg’s Church (Svenska kyrkan, n.d.-c). Inside of the building entrance, two stained glass panels are kept in a wall indoors between two rooms. As the style and material resembles the style of Callmander, it is possible that they were relocated during the removal of Callmander’s windows in Varberg’s Church.

3.9.2 In-situ assessment of Sollyckan’s church

The windows consists of cathedral glass painted with a dark, almost black grisaille tracing. The glass and lead cames are in fairly good condition but the paintwork has lost much of its paint. The paint loss has occurred quite uniformly and cannot only be ascribed to one type of glass. Just like many other of Callmander’s windows, the paint seems to lose adhesion with the glass by circular patterns (fig 66)

Figure 65. One of the two windows in Solyckan’s church. Photo: Eisfeldt, 2022

Figure 66. Close-up on the paint loss of the window shown in figure 65. Photo: Eisfeldt, 2022

3.10 Wernerska villan

3.10.1 History of Wernerska villan

Wernerska villan is a private residence located in central Gothenburg, Storgatan 26. The residence was built in year 1886 for Carl Wijk and his wife Emma Helena Röhss. The architect was Adrian Crispin Peterson who took inspiration from villas in the northern Germany. At first the house was known as the Wijska palatset, but later it would change its name as the Werner family took over (HIGAB, n.d.). The windows of Callmander were likely acquired during the construction. No prior history of conservation of the windows could be found, but in the beginning of this thesis the windows had been temporarily moved and treated for bulging by Blyfönsteriet AB in Alingsås. During the treatment also lead was mended and putty was added. The windows showed almost no signs of paint loss in the grisaille paint (Informant 1, 2021).

Figure 67. The four windows located in the Wernerska villan. Photo: Higab, 2021

3.10.2 Visual assessment of the windows of Werners villa

In total there are 4 windows in Wernerska villan (fig 67) As the panels recently were treated for bulging only one was inspected (fig 68). The window was still being treated and therefore investigated at the studio of Blyfönsteriet AB in Allingsås. Beside bulging the panel was in good condition. No signs of deterioration could be seen of the grisaille paint except small pinholes. The windows had been protected by exterior glass on their original site.

Figure 68. One of the windows from the Wernerska villan treated for bulging by Blyfönsteriet AB in Alingsås. Photo: Eisfeldt, 2022

3.11 Östra kapellet

3.11.1 History Östra kappelet

Östra kapellet on Östra Kyrkogården in Gothenburg, address: Bagaregården 742:9 nr 3, Nobelplatsen 7 was designed by architect J H Strömberg in 1861. The Rose window of Östra Kapellet is placed on the west side of the chapel. No information regarding the windows can be found in BeBR, nor any online sources. The window was identified with the help of city antiquarian (Informant 2, 2021, personal conversation) as one of Callmander's windows. In 2018 the building was struck by lightning which caused a fire (Silén, 2020). After the fire the rose window was treated by Blyfönsteriet AB. Blyfönsteriet AB, had to carefully move the rose window out of its framework to perform cleaning, replacing of lead on the edges of all 9 panels, bridging of glass cracks with lead in 6 places, removal and reinstallation of 11 glasses which had to be mended with glue, replacement of 8 severely damaged glass and Blyfönsteriet AB also removed silicon mendings from previous conservations (Informant 1, 2023).

Figure 69. Photo taken during restoration of the rose window of the East chapel 2018. Photo: Marlov, 2018

3.11.2 In-situ assessment of Östra Kappelet

The window (fig 70) could only be inspected from below where it could be seen that the window suffered from severe paint loss of the grisaille. A closer examination of the window was impossible due to the distance.

Figure 70. Photo of the Rose window in the East chapel
Photo: Eisfeldt 2022.

4. Technical investigations of Callmander's paint

The technical investigation consists of microscopy, stereomicroscopy, XRF, FR microscopy of two samples, and scanning electron microscope of two cross sections. The technical investigation begins with a description of the objects to be investigated (4,1) followed by a description of the methods, (4.2) and finally the results are presented in chapter 5.

4.1 Description of objects for technical investigation

For the technical investigation two original shards of painted glass made by Callmander given by Blyfönsteriet AB in Alingsås were investigated. The two glasses are in the thesis named A and B and are presented below.

4.1.1 Description of glass A

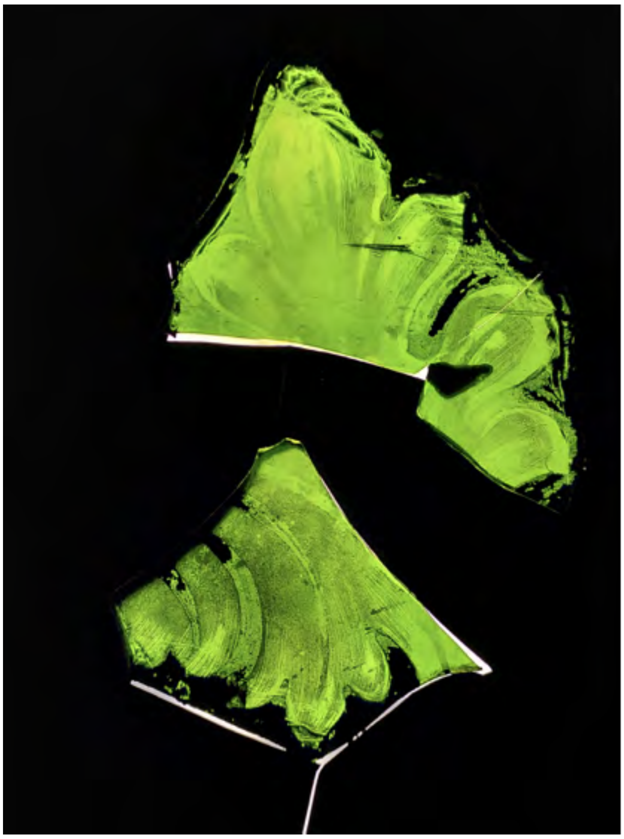

Figure 71. Photo of glass A in transmissive light. Photo: Eisfeldt, 2021

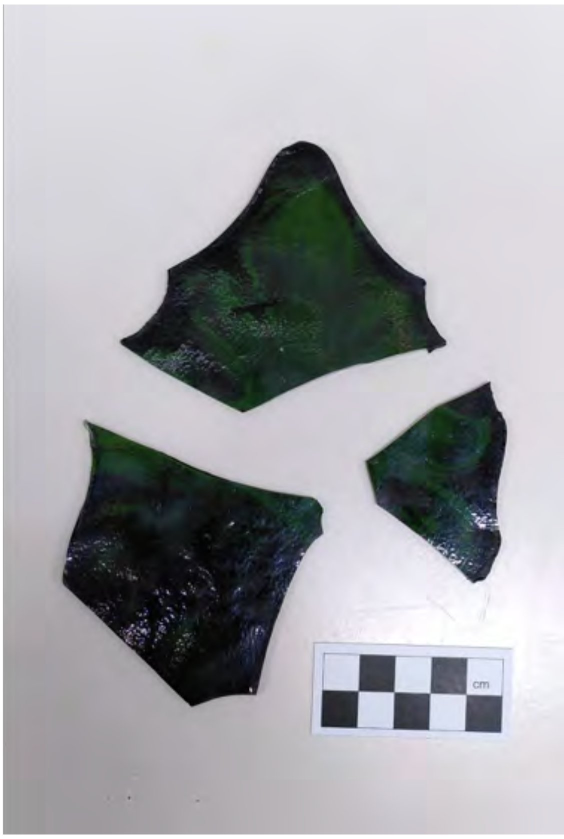

Figure 72. Photo of glass A with reflective light. Photo: Eisfeldt, 2021

Glass A (fig 71, 72) originates from the rose window of Östra Kapellet (described in 3.11) in Gothenburg and was discarded from the chapel as it was severely broken. The piece measures 130 x 95 x 2 mm. The glass is a green cathedral glass painted with a tracing of dark grisaille. The grisaille paint has been applied with a brush and then softened with a badger brush before firing. The glass is cracked and has only three pieces remaining. The grisaille paint has major paint loss, and in the middle ghost lines. The paint loss has occurred rather uniformly apart from the edges, where most of remaining paint can be seen, perhaps because it was protected by the lead cames. The grisaille which is left on the sample seems fairly stable. It can be seen that the loss of grisaille occurs in circular patterns, similar to the examined windows. On the shard there is also epoxy glue from a past restoration treatment. Apart from that there are no signs of previous conservation of the glass.

4.1.2 Description of glass, B

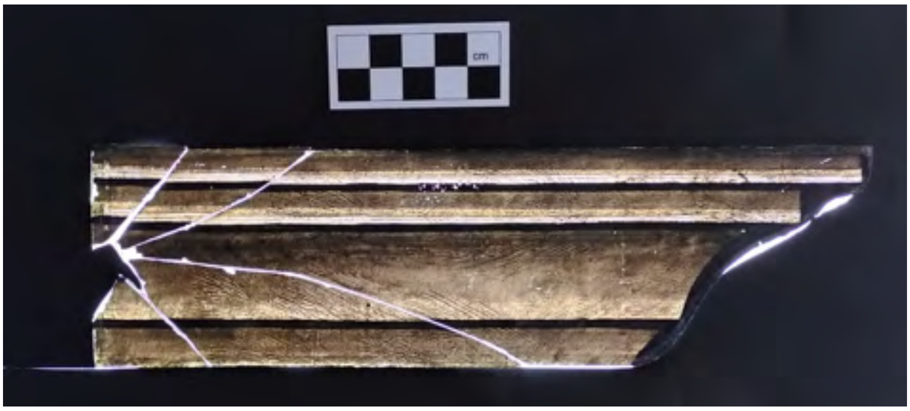

Figure 73. Photo of glass B in transmissive light. Photo: Eisfeldt, 2021

Figure 74. Photo of glass B with reflective light Photo: Eisfeldt, 2021

Figure 75. Photo of Lucas in Christinae's church. Photo: Eisfeldt, 2021

The second glass, B (fig 73, 74) was originally a part of one of the lancet windows in Christiane's church in Gothenburg, described in chapter (3.2) The glass was discarded in 2013, as it was cracked and had lost parts of its material (Informant 1, 2019). The measurement of the piece is 240 x 65 x 2,5 mm. The glass is a clear cathedral glass. The grisaille paint consists of tracing and matting, depicting a part of architecture, on either the windows of Lucas or Johannes. At parts the grisaille has been scraped off before the burning to create artistic effects. Beside the cracks the glass is in considerable good condition. No flaking can be found, except small pinholes. The glass carries no signs of previous conservations treatments such as refiring, or consolidation.

4.2 Technical investigation methods

4.2.1 Preparation of Cross sections

Taking samples is an irreversible and destructive action. To ethically justify the sampling, it was conducted on shards that has earlier been discarded and replaced from their original windows due to extensive breakage and loss. To further minimize the damage of original material, the sampling was conducted in a careful approach, with a sample size of 2x2mm. The areas of sampling were selected with optical microscope (OP) Leica s9i to find suitable areas. The samples were acquired with a glasscutter and small plyer. Areas for sampling can be seen in fig 76 and 77

The samples were then named and placed inside a form with nametag and embedded with *technowhite 2000 LC from Kulzer* (epoxy resin). The epoxy resin was then hardened inside a UV-light box.

Residues from the technowhite was removed with acetone and the samples were wet-polished with sandpaper with particle size from 400 – 4000 p. Finished result can be seen in fig 78.

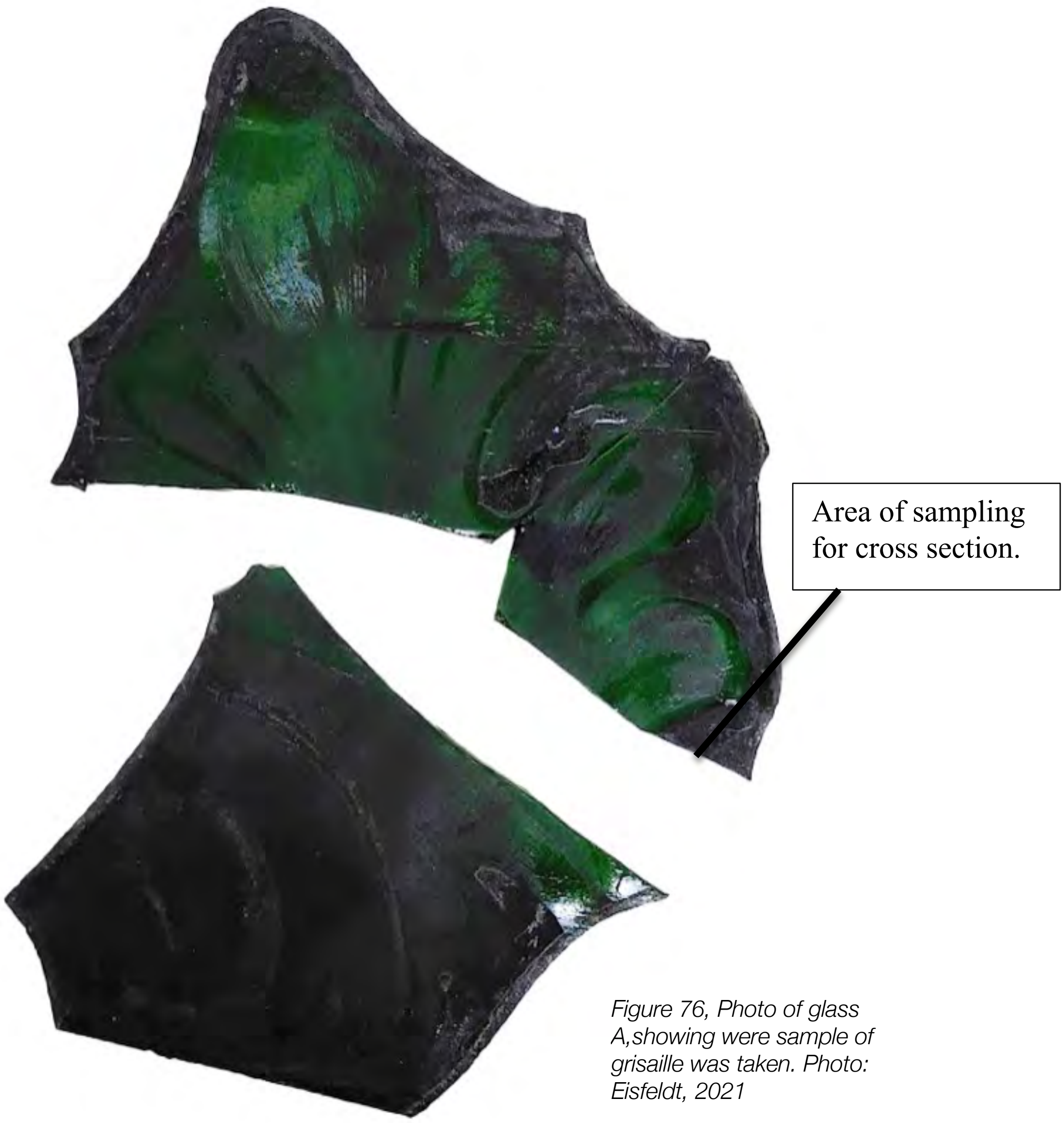

Figure 76, Photo of glass A,showing were sample of grisaille was taken. Photo: Eisfeldt, 2021

Figure 77. Photo of glass B showing where sample of grisaille was taken. Photo: Eisfeldt 2021

Figure 78. The two samples for cross section embedded in technowhite 2000. Photo: Eisfeldt, 2022

4.2.2 Microscopy method

Initially a stereomicroscope equipped with a Leica S7i camera was used at Gothenburg university. The stereo microscope was used for a first identification of the samples and areas suitable for further investigation at the Swedish National Heritage Board. A Stereo Microscope with a Leica microscope S9i was used to investigate the glass shards before sampling. On the cross sections a Nikon Eclipse LV100ND fitted with a Nikon Digital sight 10 camera was used with objective 10-50x and fluorescence microscopy (FR) with objective 10-50x.

4.2.3 XRF method

As a method to quickly identify elements within the glass X-ray fluorescence was used. The XRF is a non-destructive tool which can identify elements heavier than sodium and lighter than uranium (Horiba, 2023). It works by sending X-rays towards a small area. As the electrons of each atom of the area are excited, they will emit X-rays, called fluorescent or secondary X-rays. As each element has their own distinctive fluorescent the element can be identified. (Thermo Fischer, n.d.). The result from the XRF is displayed as a graph, where on the X axis, the different elements can be discovered and the Y the intensity of each peak. Certain elements

may display several peaks, as energy from more than one electron, backscatter. Certain elements may also block others, and / or share peaks with other.
To get the best result possible, it is therefore necessary to perform many tests to strengthen the result, and then compare the graphs to realize if they display the same type of elements. It is also necessary to realize that the results have a percentage of difference, and sometimes they may only be a finger pointing to the actual composition.
For this investigation a Artax 800, Mo X-ray tube with polycapillary lens, from Bruker was used at the Swedish National Heritage Board with a voltage of 50 KV and a current of 600 microA.

First the XRF was used to perform analysis on three different areas for the two samples. The analysis was made on the thickest area of paint, a thinly applied area, and directly on the glass. For each type of area three different spots were analyzed and compared.
At last, a line scan was performed on sample B.

4.2.4 Sem method

The SEM provides magnified images and elemental mapping of samples by measuring backscattered electrons (University of Melbourne, n.d.) which enables us to analyze the composition of the grisaille paint. The SEM has proved to be a useful tool for previous studies o grisaille paint, for example in the study of historic grisaille paints by Carmona (Carmona, 2006) and in the study of paint loss in 19^{th}-century grisailles by Gilchrist (Gilchrist, 2010).
In this study a JEOL JSM-IT500 (SEM/EDS) at the Swedish National heritage board, was used. As glass does not conduct electricity, samples had to be sputtered in gold or carbon coating. For this a 6 nm gold coating was used.

5. Results Technical investigation

5.1 Microscopy

5.1.1 Glass A – Result of optical microscopy on surface with Leica S7i

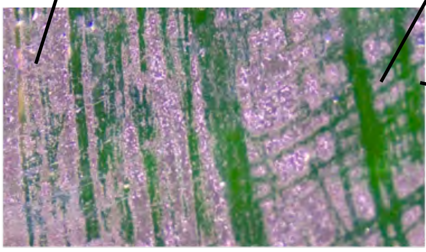

Figure 79, The surface structure that is left where the grisaille paint is lost. Marks from badgering can be seen in the right part of the image. Photo: Eisfeldt, 2021

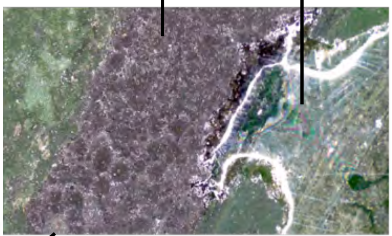

Figure 80. Residues from epoxy mending and circular pattern on top of the paint Photo: Eisfeldt, 2021

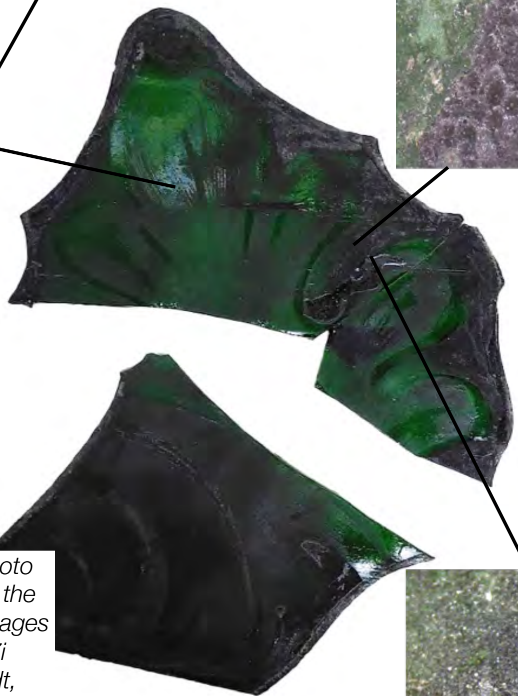

Figure 81. Photo of glass A for the position of images from Leica s7i Photo: Eisfeldt, 2021

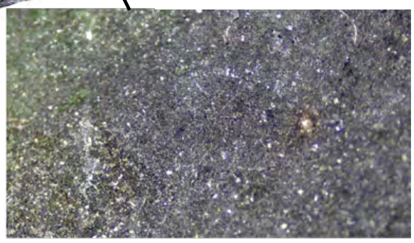

Figure 82. The surface structure of the paint Photo: Eisfeldt, 2021

In the Leica S7i microscopy in Gothenburg, it was visible that the surface of sample A, was perceived as rather porous and granular (fig ,79, 82). Furthermore, many white circular patterns could be found in the grisaille (fig 80). Perhaps, these could be corrosion, or dirt, or the beginning of paint loss. The study could not detect any iridescent stains on the glass surface, which can be related to atmospheric pollutants (Corrêa Pinto, 2017). Neither can any indication of melting on the substrate glass, which would indicate a high firing temperature during the application of grisaille be found.

5.1.2 Glass A – Result of FR microscopy image with Nikon EclipseLV100ND fitted with Nikon digital sight 10

In FR microscopy the cross section of Sample A shows a large number of bubbles in the grisaille paint (fig 83, 84) It is also visible that the paint is quite inhomogeneous and granular. There is also a notion that the grisaille and the glass is not very fused together, as the interface between the paint and substrate is rather sharp. At places, there also seem to be cracks in the interface between paint and substrate. In fig 84, There is also a type of layer on top of the grisaille paint, possibly a corrosion or gel layer.

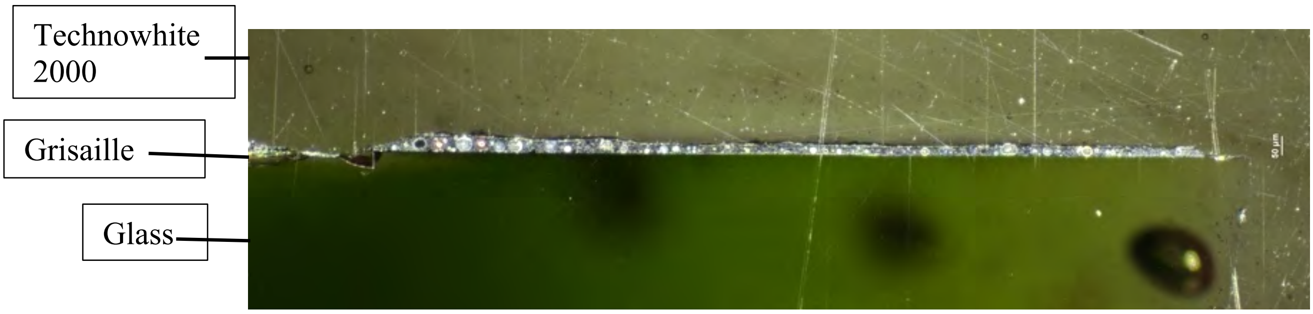

Figure 83. Microscope image of the cross section. The scale bar seen to the right is 50 µm.
Photo: Eisfeldt, 2022

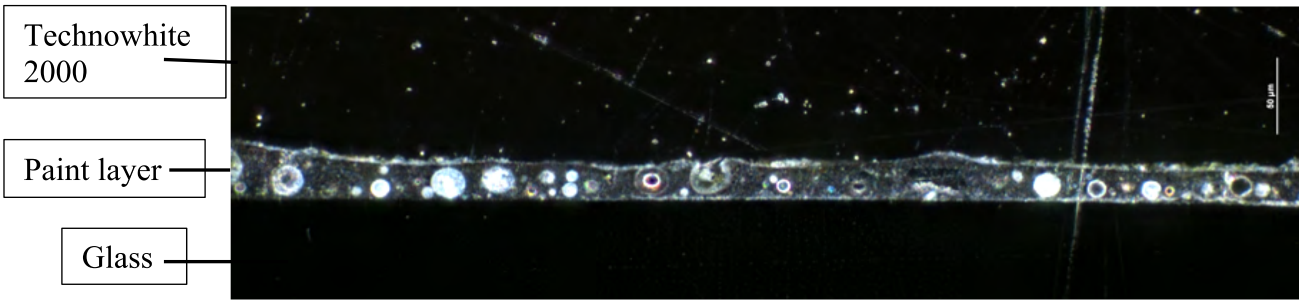

Figure 84. Microscope image of the cross section. The scale bar seen to the right is 50 µm
Photo: Eisfeldt, 2022

5.1.3 Glass B – Result of optical microscopy on surface with Leica S7i

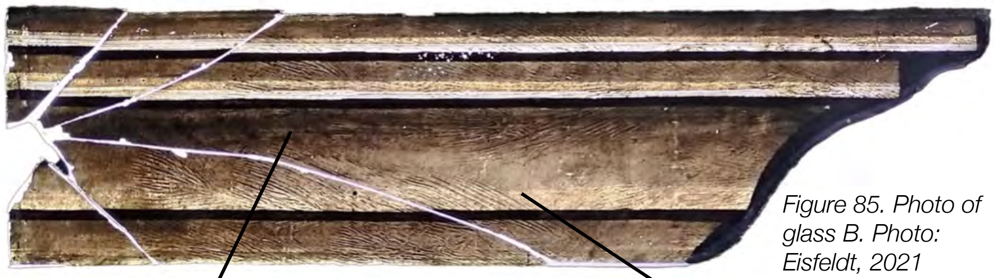

Figure 85. Photo of glass B. Photo: Eisfeldt, 2021

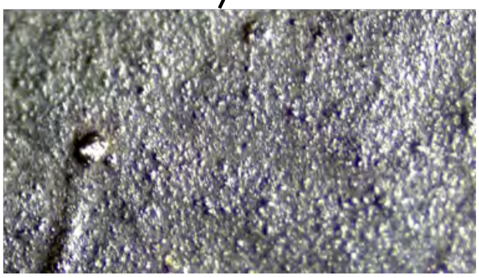

Figure 86. Microscope image 1 of the surface of glass B. Photo: Eisfeldt, 2021

Figure 87. Microscope image 2 of the surface of glass B. Photo: Eisfeldt, 2021

In stereo microscope glass B's grisaille was much different to glass A (fig 86, 87). The grisaille of the B sample looks despite its granularity coherent and well fused. Under microscope, no more signs of pitting could be found except, few which could already be seen by eye. Neither could any signs of corrosion be found in this magnitude.

5.1.4 Glass B – Result of FR microscopy image with Nikon EclipseLV100ND fitted with Nikon digital sight 10

In the FR microscopy (fig 88) it is visible that the paint layer of sample B is thinner and does not have as many bubbles as sample A. The B sample also looks more homogenous. As in sample A, sample B also shows a distinct interface between grisaille and substrate glass.

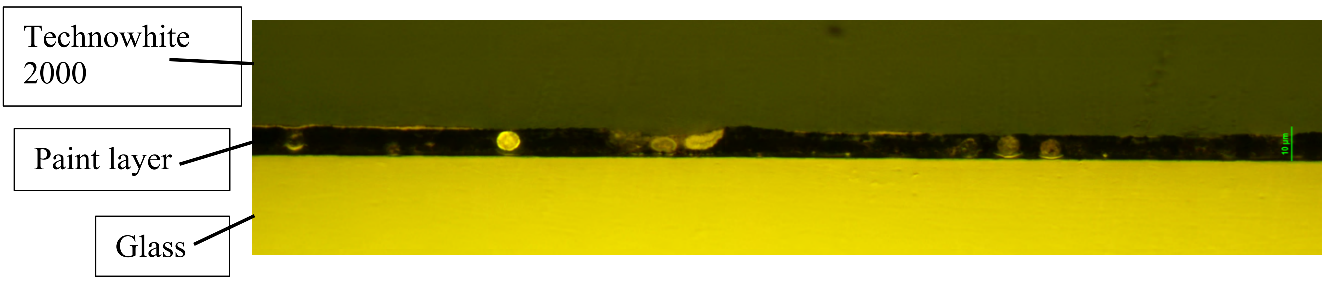

Figure 88. FR microscopy image with Nikon EclipseLV100ND fitted with Nikon digital sight 10 on cross section from glass B. The measuring scale bar seen to the right is 10 µm Photo: Eisfeldt, 2022

5.2 XRF-Result

5.2.1 Glass A XRF-Result

The green glass on sample A was the first to be analyzed. Three tests performed on the green glass had the same peaks and were transformed into one single graph (fig 89). The test showed high peaks on, calcium (Ca), chromium (Cr) and copper (Cu), but also lower peaks of iron (Fe) and lead (Pb). The high peak of Ca may indicate that Ca has been used as a stabilizer. The Cr and Cu is possibly what makes the green tint. The Fe may be explained as impurities of the sand. Other small peaks such as titanium (Ti), and zink (Zn) may also be explained due to impurities in raw material. potassium (K) could either be impurity or an indication that the flux potash. The high silica (Si) peak was very expected and resembles the Si structure of the glass.

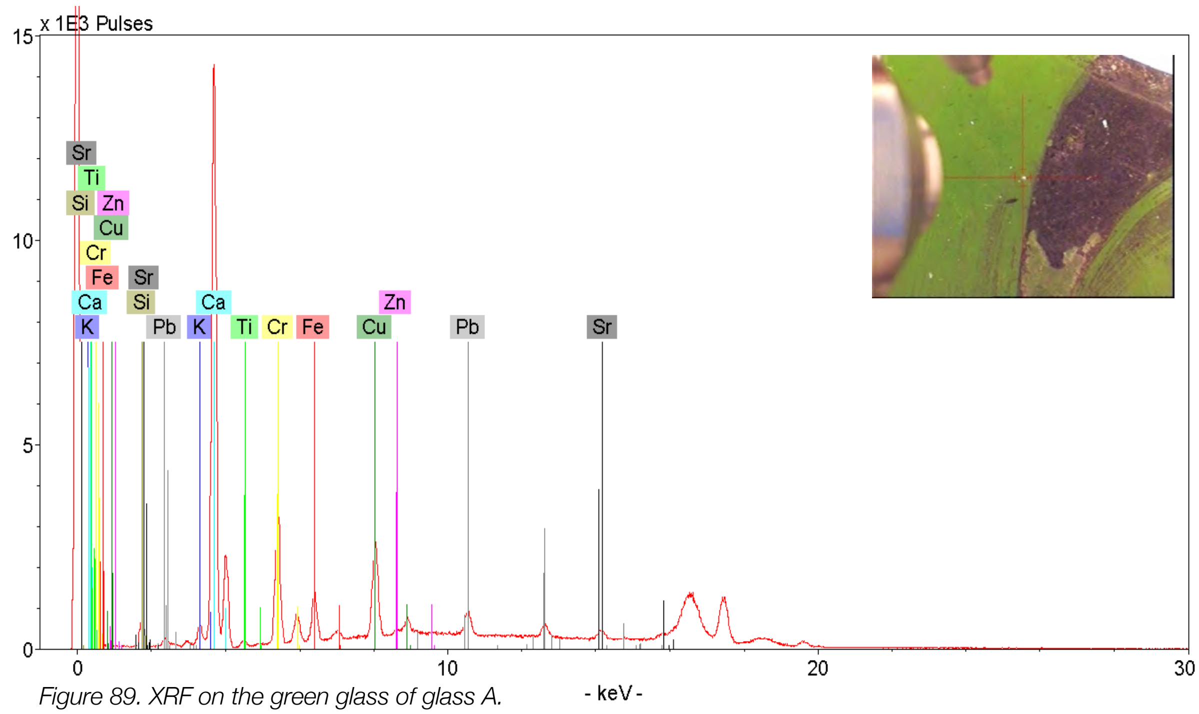

Figure 89. XRF on the green glass of glass A. Graph: Eisfeldt, 2022

For the black paint on the green glass, (fig 90) the result showed a lot of lead and cobalt (Co), but also some iron, magnesium (Mn) copper and zink (Zn). Just as in the former graph the combination of the three tests was combined into one graph as the they had the same peaks. The Lead Pb was much anticipated as it is often the type of glass chosen as frit in the grisaille paints, due to its low glass transition temperature (Tg). cobalt was sometimes used to enhance the darkness in grisaille paints. Fe is also typical for both dark and brown grisailles (Pradell, 2015). Apart from frit the lead could also be traces from the lead cames.

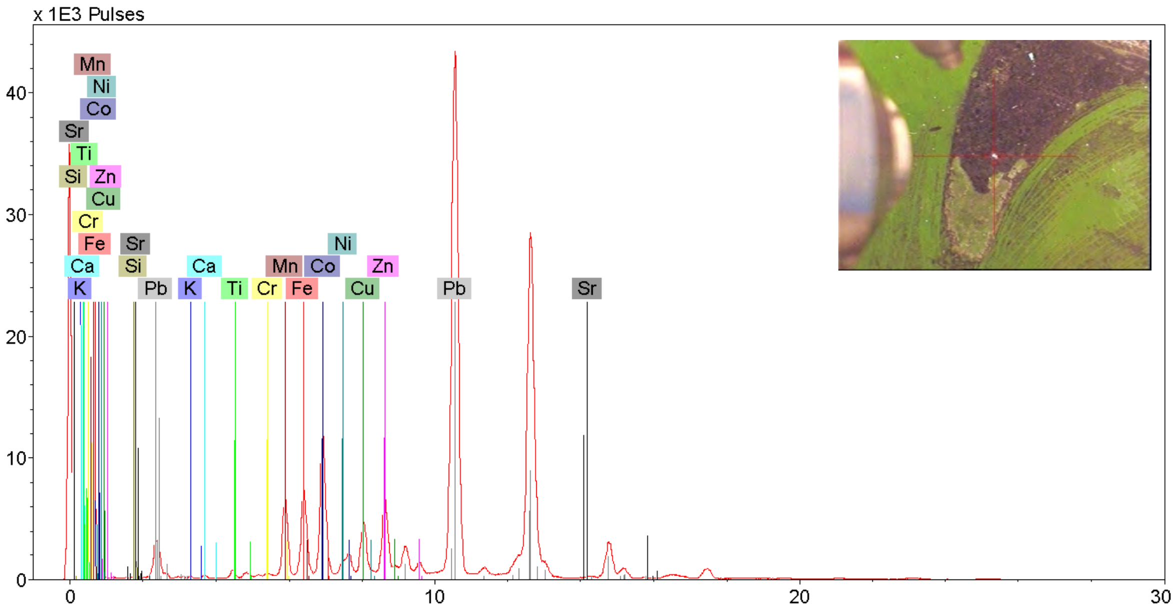

Figure 90. XRF on the dark paint of glass A. Graph: Eisfeldt, 2022

The test shows the graph on the thin black paint (fig 91). Likely some elements from the substrate glass became visible as well forming the peak of calcium and chromium, however we do also see the same elements as in the thicker dark paint. Likely it’s the same type of paint investigated in figure 90.

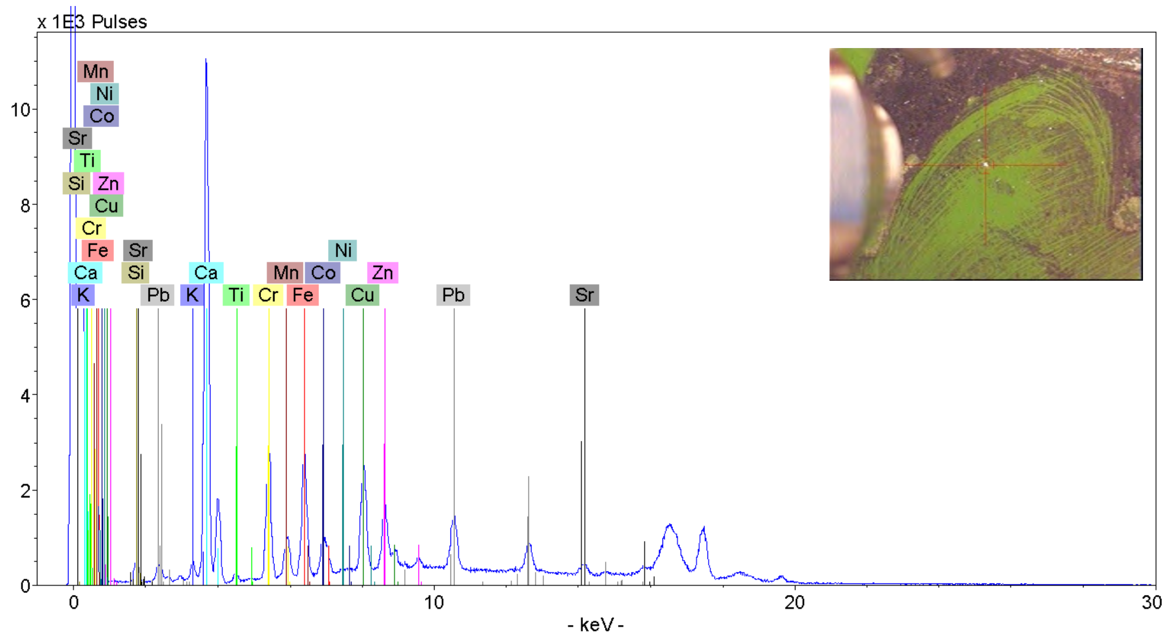

Figure 91. XRF on the thin dark paint of glass A. Graph: Eisfeldt, 2022

5.2.2 Glass B XRF-Result

Figure 92 shows the combined graph for the three tests on the dark paint of glass B. The three tests where all corresponding and had the same peaks. In the test we can determine that the dark paint on B has high peaks of lead, but also some manganese, iron, cobalt, zink and copper. Similarly, to the dark paint of glass A.

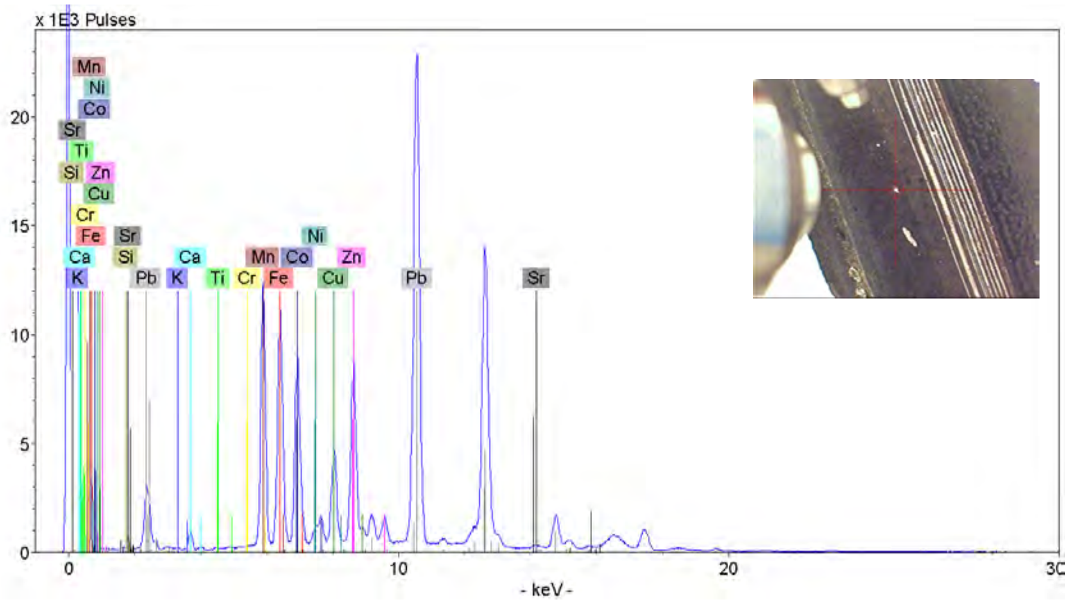

Figure 92. XRF on the dark paint of glass B. Graph: Eisfeldt, 2022

In figure 93 the analysis was performed at one of the lines where the paint had been scraped off before fusing the pigments. The test showed mostly manganese some calcium, and a little bit of iron and copper. manganese can sometimes be added in attempt to make a glass clearer or as a stabilizer (Baldwin, 1985). Iron and copper may have been added as pigments but could also derive from the sand.

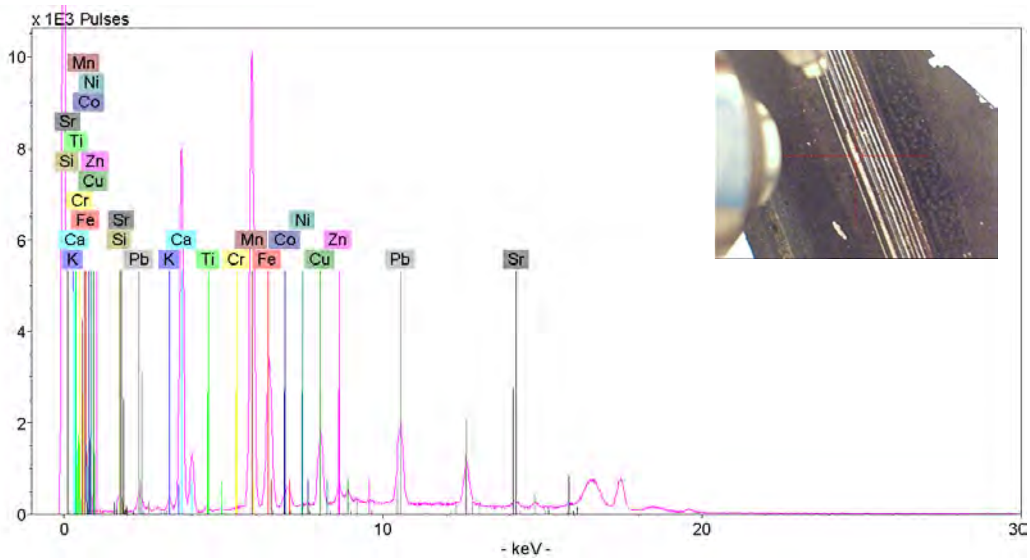

Figure 93. XRF on the area with scrapped of paint of glass B. Graph: Eisfeldt, 2022

The last two graphs were acquired with a line scan on glass B. Figure 94 shows the elements for the entire line, while figure 95 shows where each corresponding element was found. In figure 95 we clearly see the difference between glass and grisaille. We can also get a notion of how the elements of the glass has merged with the elements of the grisaille, between 0.25 nm and 0.3 nm.

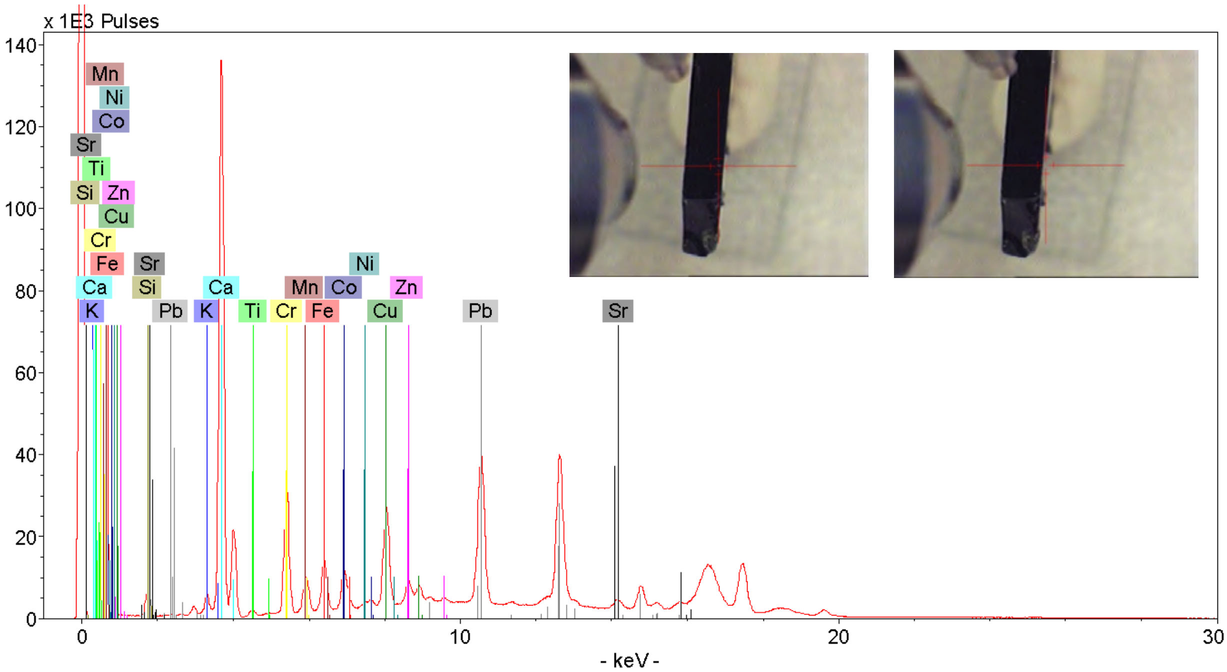

Figure 94. XRF line scan on the edge of glass B, examining both paint and substrate glass, collective graph. Graph: Eisfeldt, 2022

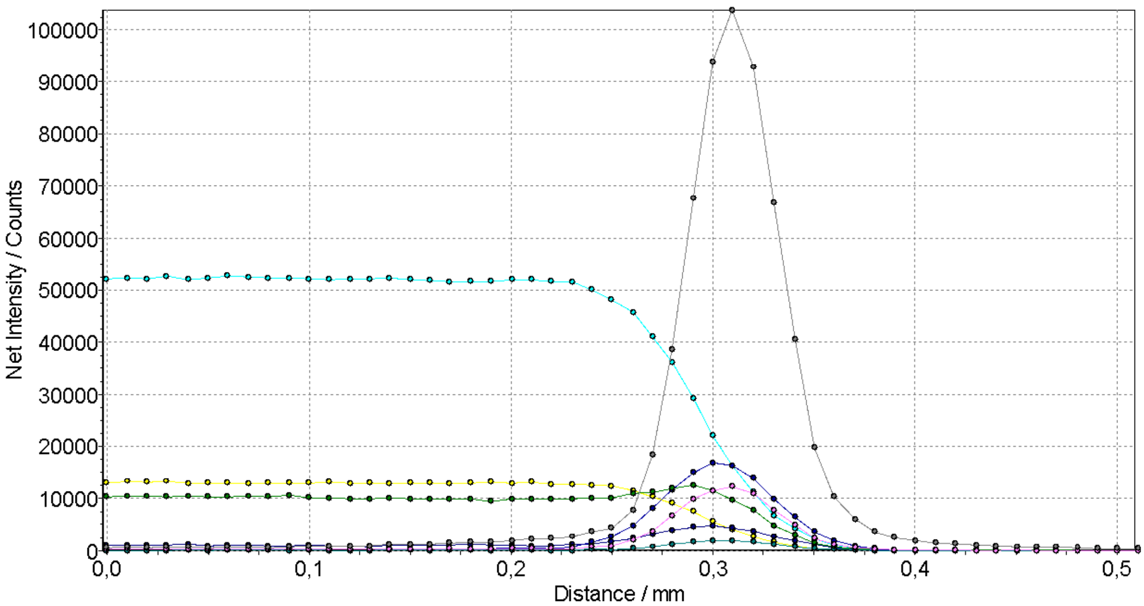

Figure 95. XRF line scan on the edge of glass B, examining both paint and substrate glass. The first peak starting from 0.0 shows the glass and the second peak shows the grisaille paint. Graph: Eisfeldt, 2022

5.3 SEM-EDS results

5.3.1 SEM-EDS result glass A

In the SEM-EDS image (fig 96) there is a clear visual difference between substrate glass and grisaille. As there is no interrereference line visible between the two mediums, it may indicate that the two mediums have not fused properly. With SEM-EDS it was also revealed that the grisaille has high levels of, cobolt, arsenic, iron and lead. As none of these elements are present in the substrate glass it could indicate that no ion diffusion has occurred, which in turn could indicating insufficient firing. Contrary to this, the SEM-EDS also shows a number of bubbles (fig 96), which can be an indication of high firing, as high temperatures form (Verita, et al, 2015). The bright areas seen around the bubbles, indicate heavy elements, as heavy elements backscatter more electrons, the elemental mapping shows it is re-deposition of lead, arsenic and sulphur (fig 97, 98).

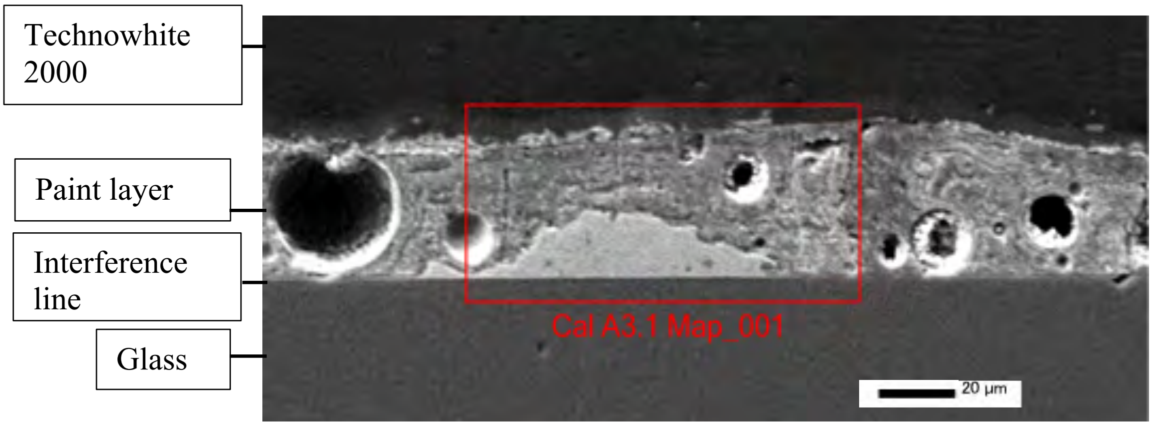

Figure 96. Image of SEM-EDS map 001of the cross section of glass A. magnification x550. The scale bar is 20 µm. Image: Eisfeldt, 2022

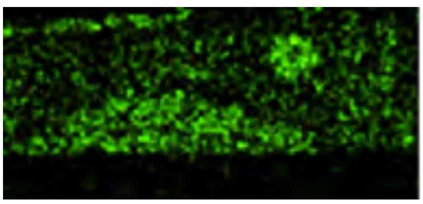

Figure 97. Elemental map of arsenic of map 001 of glass A, shown in fig 96. Image: Eisfeldt, 2022

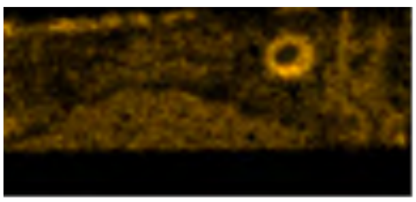

Figure 98. Elemental map of sulphur of map 001 of glass A, shown in fig 96. Image: Eisfeldt, 2022

With the SEM images it is hard to see the pigments grains, which makes it hard to realize their size and shape. As grains of iron oxides in the grisaille paint receive “rounder” characteristics, if they are subjected to higher temperature (Pradell, 2015) it could have given more information regarding the firing. In retrospective, perhaps a higher contrast in the SEM-EDS, would have been suitable for this purpose.

The thin white line in the surface layer of the grisaille indicates heavy elements, which perhaps is a result of leaching of metals (fig 99). There is also crust-like formation on the surface, perhaps as a result of corrosion.

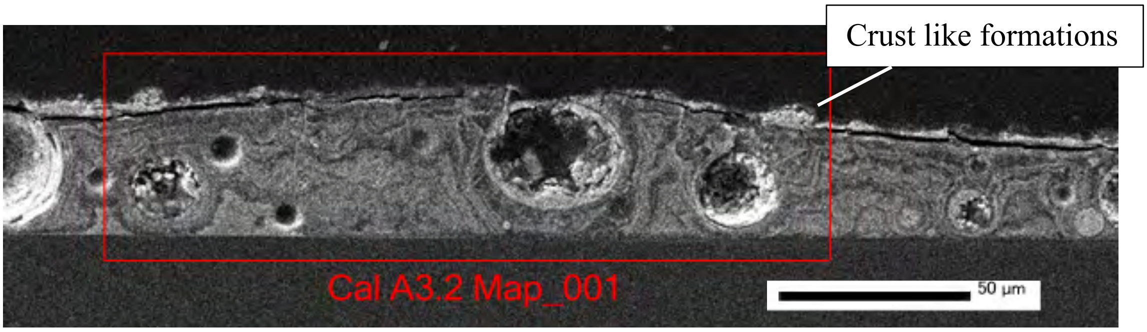

Figure 99. Image of SEM-EDS map 001of the cross section of glass A. Magnification x450. The scale bar is 50 µm. Image: Eisfeldt, 2022

Furthermore, the results, verifies the result from the XRF investigation, as they show the occurrence of the same elements. In the SEM-EDS investigation there was no occurrence of boron. Boron is a very light element and is sometimes difficult to detect. However, as no traces were found during the investigation, it could be safe to assume that the element is not present in the sample. The SEM-EDS also showed calcium on all maps for glass A, amongst these (fig 103). For one map, it also showed potassium (fig 102). The potassium could be an indication that the glass is a potash glass, but it could also be due to impurities in the raw material. In the SEM lead (Pb) was also visible in the paint of glass A (fig 101) which further indicates that the paint was made with frits of lead glass.

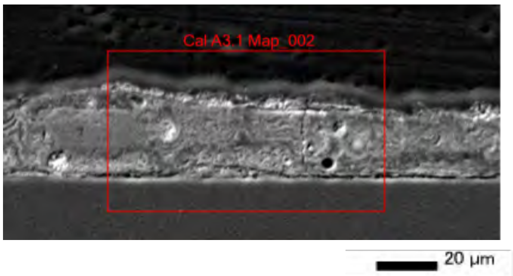

Figure 100. Image of SEM-EDS map 002 of the cross section of glass A. Magnification is x800. The scale bar is 20 µm. Image: Eisfeldt, 2022

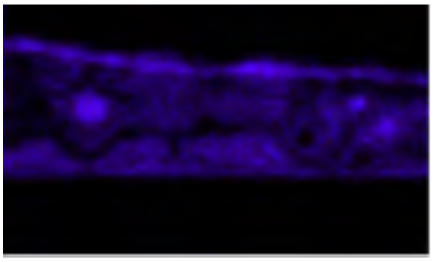

Figure 101. Elemental map of lead of map 002 of glass A. Image: Eisfeldt, 2022

Figure 102. Elemental map of potassium of map 002 of glass A. Image: Eisfeldt, 2022

Figure 103. Elemental map of calcium of map 002 of glass A. Image: Eisfeldt, 2022

Figure 104. Elemental map of sodium of map 002 of glass A. Image: Eisfeldt, 2022

The Sem-EDS also shows the presence of silica. If the grains of pigments were more visible, they could be compared with the amount of Si in the paint, to anticipate the pigment to flux ratio in volume. To draw these kinds of conclusions according to the image is however difficult and not reliable, as different elements emits different amounts, but also, because the image is only two-dimensional.

5.3.2 SEM-EDS result glass B

In Sample B a lot of iron, aluminum, cobalt, lead, and manganese is detected in the paint layer. The iron, manganese and cobalt, has likely been added as pigments. Manganese can be added as MnO_2 pyrolusite, and iron as FeO_2 or FeO_3, the cobalt could be added as a mean to enhance the black color of the grisaille (Pradell, 2015).

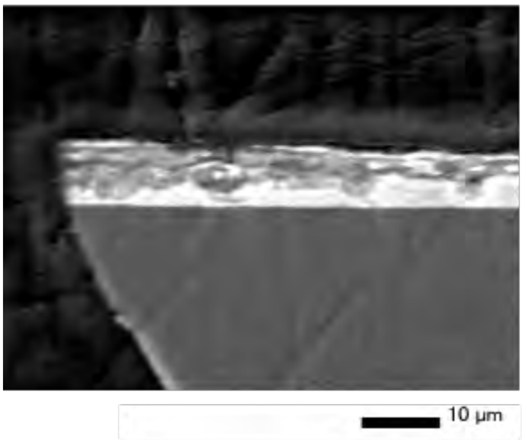

Figure 105. Image of SEM-EDS map 005 of the cross section of glass B. Magnification x1900. The scale bar shown at the bottom is 10 µm. Image: Eisfeldt, 2022

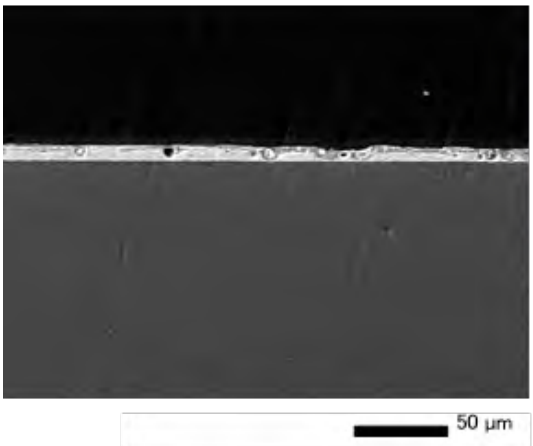

Figure 106. Image of SEM-EDS map 004 of the cross section of glass B. Magnification x550. The scale bar is 50 µm. Image: Eisfeldt, 2022

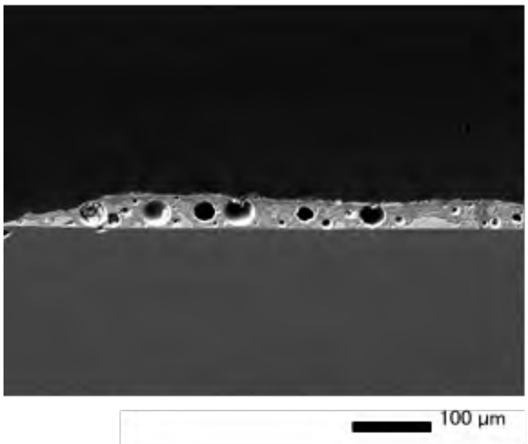

Figure 107. Image of SEM-EDS map 004 of the cross section of glass A. Magnification x190. The scale bar is 100 µm. Image: Eisfeldt, 2022

As in sample A, sample B also has a clear difference between substrate glass and grisaille, (fig 105, 106) perhaps indicating insufficient firing. Compared to sample A, by viewing the mapping of the elements there is a notion, that sample B is slightly more homogenous than the sample A. Sample, B, also seem to have less bubbles (fig 106,107). As in the microscope it can also be seen in the SEM that the paint layer of Sample B is thinner than the paint layer of sample A.

The SEM-EDS shows there is potassium present in both substrate glass and paint layer (fig 110) which could indicate the glass is a potash glass, there is also sodium and calcium present (fig 109, 111). Sodium could contrary indicate that the glass is a soda glass, however it must be noted that potash glass also contains some sodium (Musgraves, et al, 2019 p. 144). Calcium was sometimes added as a stabilizer (Davison 2003, p. 107) the glass could therefore be a lime-potash glass.

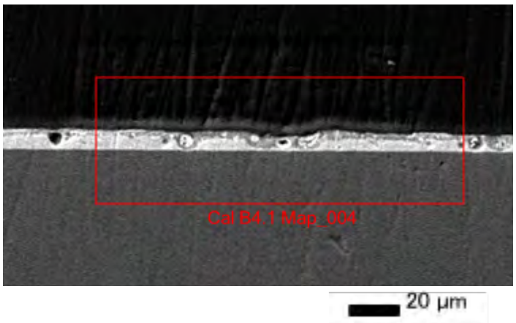

Figure 108. Sem map 004 of glass B. Magnifiication x550. Scale bar 20 µm. Image: Eisfeldt, 2022

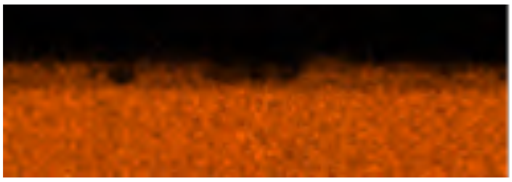

Figure 109. Elemental map of sodium of map 004 of glass B. Image: Eisfeldt, 2022

Figure 110. Elemental map of potash of map 004 of glass B. Image: Eisfeldt, 2022

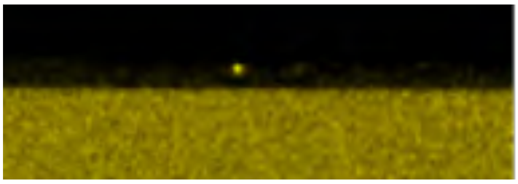

Figure 111. Elemental map of calcium of map 004 of glass B. Image: Eisfeldt, 2022

6. Final discussion and conclusion

There are many factors, both external and internal, that cause grisaille paint on stained glass to deteriorate. As many factors work in conjunction, it is sometimes difficult to pin-point only one reason for the loss of paint.

That the paint loss in Callmander's work can be directed to in-built issues is however likely. The literature review revealed that many 19th-century stained glass windows suffer from paint loss due to faulty materials and manufacturing processes (Gilchrist, 2010, pp. 116-117). This is often attributed to the revival and relearning of the craft, which led to the use of inappropriate materials, as well as the high work rate brought on by the great demand for stained glass windows. Since Callmander's work is from the same era, manufacturing-related paint loss is a possibility. Additionally, correspondence between Uppsala Cathedral and Callmander suggests that he was also subjected to high work intensity at times (Bengtsson & Bengtsson-Melin, 2014).

The literature study also points to cases where Callmander's windows began to lose paint within only 20 years of installation. This further supports the possibility of manufacturing issues, since windows made correctly should last longer. Especially as *Neuman & Vogel*'s window in Uppsala Cathedral, situated on the same wall as one of Callmander's windows and installed only a few years later, did not have the same issues (Kvarnström & Andersson, 2017). That the *Neuman & Vogel*'s window are in good condition while Callmander's are not, is a strong indication that the issue lies in Callmander's production and material. A source mentioned in the literature review that Callmander blamed "bad paint" for the paint loss. If this is true, it reinforces the idea that the material was the reason behind the paint loss (Gullbrandsson, 2013).

Based on the visual assessment it could be concluded that the majority of Callmander's windows had issues regarding their paint. The prevalence that such a large amount of his work had the same issue may further suggest that manufacturing issues contributed to the paint loss. During the visual assessment it was also observed that the paint loss could not be localized to specific parts of the windows. Instead, the loss seemed to occur randomly, sometimes with the most degraded panels located next to the ones in the best condition. The observation further reinforces the idea that the paint loss was caused by issues in material or manufacturing process rather than climate. Since a deterioration pattern as a result of climate alone, should possibly show a larger deterioration on weather exposed parts and on west windows facing the ocean. The randomness of the paint loss could be stemming from either misfiring of certain panels, or due to unevenly grinded or mixed pigments. Apart from human errors, the misfiring could be explained by issues with the kiln or the temperature measurements, preventing the paint and substrate glass to fuse.

During the technical investigation, glass shard A and B showed very different conditions. Glass B was stable and barely showed paint loss, while glass A had severe paint loss and possible paint corrosion. In the technical investigation, it was realized in FR microscopy and SEM-EDS that the paint of glass A had larger pigments, significantly more bubbles and were less homogenous than the paint on glass B. That the paint of A contains more bubbles could indicate that the paint was fired at a high temperature, according to Verita et al, if paint is fired at a too high temperature, it can flake and become very unstable (Verita et al, 2015), which could explain the paint loss in Callmander's windows In microscopy no signs of melting were found on the substrate glass, which may contradict the paint being subjected to too high temperature. Especially if the substrate glass is soda-lime glass with a melting point of 700 °C (Martin, 2006), since grisaille is fired around 650-700 °C (Machado, 2022). Potash glass has a higher melting point between 900-1400 °C (Stern, 2017). The results of the XRF analysis showed peaks of potassium for both glass A and B which could indicate that the two glasses are potash glasses. In SEM-EDS potassium was found for glass A on one of three maps, and glass B for two of two, which could further indicate that the two glasses are potash glass. However, the SEM-EDS also detected sodium in both glass A and B which instead could indicate that the two glasses are soda glasses. According to Davison, some potassium can be found in soda glasses and some soda can be found in potash glasses (Davison, 2003, p 172). As the quantity of potassium and soda is hard to derive from the results of SEM-EDS, it is not possible to fully confirm, whether the glass samples are made with potash or with soda.

In microscopy of cross sections, a very sharp line between paint and glass could be seen, perhaps indicating that the paint and substrate glass had not fused very well. In the SEM-EDS investigation it was further visible that not many elements of the paint had mixed with the elements of the substrate glass, which could further indicate insufficient firing.

Since there are potential indicators of both insufficient firing and too hard firing it is hard to draw conclusions. Perhaps it could be suggested that the firing was conducted with a high temperature under a short time. This could possibly explain that the paint has numerous gas bubbles, while there were no signs of melting on substrate glass. The reason for this could be that Callmander was trying to work faster, by firing the paint at a higher temperature under shorter time.

Another possible explanation to the contradicting gas bubbles and signs of insufficient firing could be that the substrate glass has too high Tg in combination with insufficient firing. This could happen if the substrate glass is a potash glass. If the glass has to high Tg while the temperature is too low, the glass won't allow the paint to stick. If the paints instead had a much lower Tg perhaps it could explain the paint forming bubbles while the substrate glass was not melting, preventing the two to fuse properly.

When analyzing the composition of the paint in XRF and SEM-EDS, both sample A and B had similar composition. In the SEM results there were no evidence of Boron, which has been implicated as a reason for paint loss in other studies. boron can be very challenging to detect in SEM-EDS due to its low atomic weight (Gilchrist, 2010). Given that no signs of boron were detected in neither of the tests conducted, it should however be safe to assume that the element is not present in Callmander's paint.

In SEM-EDS the B sample seems to have slightly higher content of pigment than the A sample. Too high content of pigment compared too flux, may cause instable paint and paint loss. The difference in ratio is difficult to anticipate and the ratio of pigments seems just slightly more increased in glass A. A higher ratio of pigments in the paint of glass A could be explained because the ornament design of glass A could be considered to require more opaqueness than the depicted cloth in glass B.

Although the darkest part of the cloth in glass B was tested in the SEM-EDS, and it too was perceived as opaque by the eye. If Callmander bought the paint, it's no surprise they are similar in composition, considered the company did not change paint over time. Perhaps the slight difference of pigment to flux ratio could be explained by uneven grinding or Callmander himself adding more pigment to a paint in attempt to make it darker and more opaque for the most dark parts of his depictions. There are also signs of corrosion, which could indicate glass sickness, this could be possible if the glasses has a high content of alkali due to high percentage of Na och K. Signs of corrosion could also be due to the firing, as insufficient firing can make the glass more prone to corrosion as well. Finally, it was revealed that the paint layer in glass A was thicker than the paint layer in glass B. The thickness of grisaille paint layer could have an impact on the paint's longevity, and could perhaps explain the numerous and uneven paint loss seen in many of Callmander's stained glass windows. However, according to Pradell, 2016 the thickness of grisaille paints can vary between 10 and 100 µm micrometer, which would put glass A with approximately 20 µm and B with approximately 40 µm, on the thinner side of the spectrum (Pradell, 2016).

In conclusion it was realized that many of Callmander's stained glass had an issue regarding paint loss in their grisaille paint. Perhaps this is only an issue within Gothenburg and Varberg, but probably it's a widespread issue as so many examples were found. When it comes to the reason behind the paint loss, most information points towards a manufactural issue. The exact cause is however hard to determine but could be related to firing as there are signs of both insufficient firing and too hard firing, or the paint being to thick. Perhaps a technical investigation of a larger set of glasses could give more detailed information. Especially if the results were compared with technical results from the works other artists. Another future project could be to try to re-create Callmander's paint. This could be made by matching the elements found in the samples. The recreated paint could then be applied in different manners and put in an aging chamber. The result could then be compared to his original glasses. In the future it could also be interesting to re-visit the windows documented in this study, to observe how the condition changes with time by comparing photos.

List of equipment

Microscopy

Nikon Eclipse LV100ND fitted with a Nikon Digital sight 10 camera was used with objective 10-50x and fluorescence microscopy (FR) with objective 10-50x. (Swedish national heritage board)

Jiusun 2k HD – handheld microscopy

Leica S9i (Swedish national heritage board)

Leica S7i (Gothenburg University)

Scanning electron microscope

JEOL JSM-IT500 (SEM/EDS) (Swedish national heritage board)

X-ray fluorescence

Artax 800, Mo X-ray tube with polycapillary lens, from Bruker was used at the Swedish National Heritage Board with a voltage of 50 KV and a current of 600 microA. (Swedish national heritage board)

<u>Photography</u>

Fairphone 3

Sony alpha 290 fitted with a 18-55 SAM lens

Materials

Material *techno white 2000 LC from Kulzer* (epoxy resin).

List of figures

Figure 100. Image of SEM-EDS map 002 of the cross section of glass A. Magnification is x800. The scale bar is 20 µm. Image: Eisfeldt, 2022

Figure 101. Elemental map of lead of map 002 of glass A. Image: Eisfeldt, 2022

Figure 102. Elemental map of potassium of map 002 of glass A. Image: Eisfeldt, 2022

Figure 103. Elemental map of calcium of map 002 of glass A. Image: Eisfeldt, 2022

Figure 104. Elemental map of sodium of map 002 of glass A. Image: Eisfeldt, 2022

Figure 105. Image of SEM-EDS map 005 of the cross section of glass B. Magnification x1900. The scale bar shown at the bottom is 10 µm. Image: Eisfeldt, 2022

Figure 106. Image of SEM-EDS map 004 of the cross section of glass B. Magnification x550. The scale bar is 50 µm. Image: Eisfeldt, 2022

Figure 107. Image of SEM-EDS map 004 of the cross section of glass A. Magnification x190. The scale bar is 100 µm. Image: Eisfeldt, 2022

Figure 108. Sem map 004 of glass B.Magnifiication x550. Scale bar 20 µm. Image: Eisfeldt, 2022

Figure 109. Elemental map of sodium of map 004 of glass B. Image: Eisfeldt, 2022

Figure 110. Elemental map of potash of map 004 of glass B. Image: Eisfeldt, 2022

Figure 111. Elemental map of calcium of map 004 of glass B. Image: Eisfeldt, 2022

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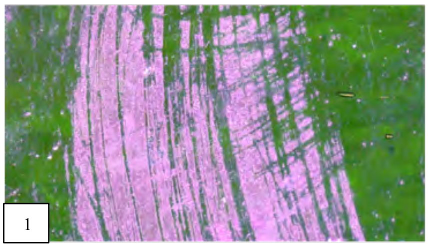
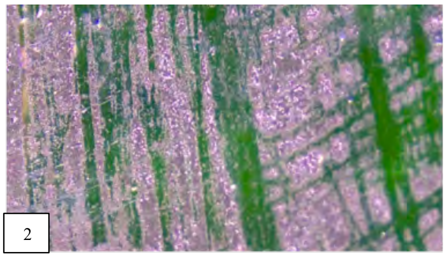
Non-printed scources

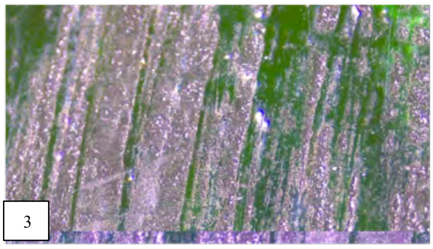
Informant 1: Susanne Marlow, Antiquarian and specialist in stained glass, Blyfönsteriet AB, Personal conversation, 6-05-2021 and 12-05-2023.

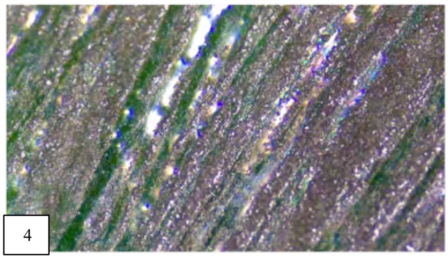
Informant 2: Karin Nordström, Antiquarian, Museum of Gothenburg, Personal conversation, 24-05-2021.

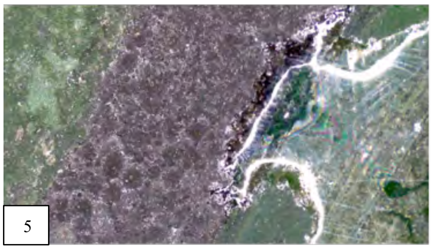
Appendix 1, microscopy with leica s71

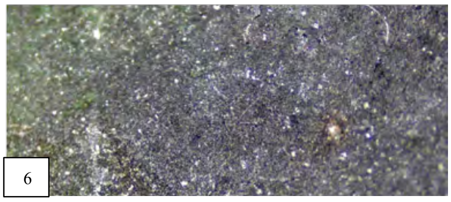


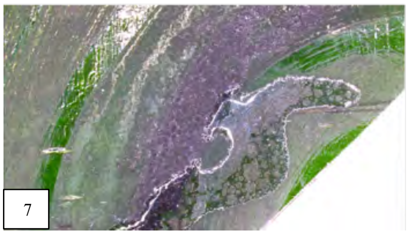




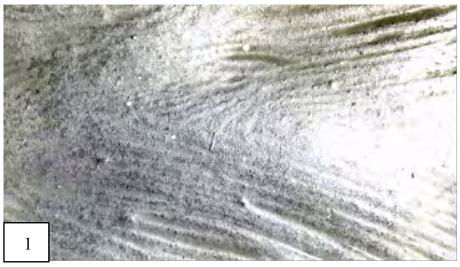


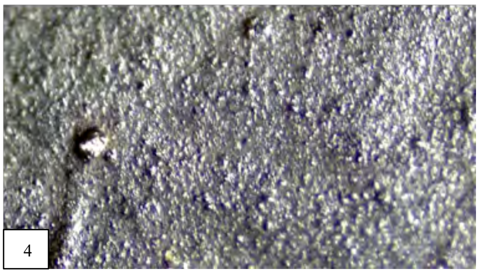






Microscopy with Leica S7I, Sample B areas of investigation





Appendix 2, Provtagnings protokoll

Providentifikationskod
RAÄ Dnr 2021-3126 **Objektnummer** Se nedan **Löpnummer** Se nedan

Frågeställning
Att förstå sammansättningen i Callmanders svartlodsfärg i syfte att hitta orsaken bakom det färgbortfall som drabbat flertalet av hans målningar.

Planerade analyser

Mikroskopi, Flourescens mikroskopi 10x-50x, Svepelektronmikroskop (SEM), och µ-XRF mikro-röntgenfluorescens.

Hantering efter analys
Skärvor returneras till ägare (Blyfönsteriet AB) genom Victor Eisfeldt. Två tvärsnittsprover bevaras hos Riksantikvarieämbetet (RAÄ).

Benämning: Glasskärvor. En härstammar från Östra kapellet i Göteborg (prov A) och den andra från Tyska Kyrkan i Göteborg (Prov B)
Identifierande: R. Callmander
Datering: : (1888 -1922)
Plats: Blyfönsteriet AB, Allingsås

Ansvarig
Tillståndsgivare Susanne Larsen (Blyfönsteriet AB)
Ägare Susanne Larsen (Blyfönsteriet AB
Kontaktperson Victor Eisfeldt
Adress Lilla Regementsvägen 14
41527 Göteborg
Telefonnummer 07032367761 **E-post** victor.eisfeldt@gmail.com

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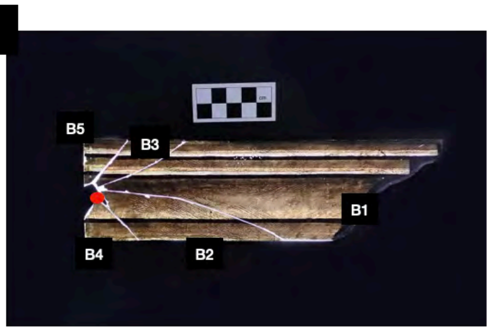
Prov

Provtyp: Glasskärvor, bemålat glas.
Trivialnamn: Bemålat glas
Kemiskt namn: N/A
Källa: Susanne Larsen

A

B



Provplats:

Fig 1, och fig 2, foto av prov A och B, där respektive skärva är numrerad och platser för provtagning markerade med rött.

Foto av prov:

Fig 3, foto av prover Cal B4.1 och Cal A3.1.

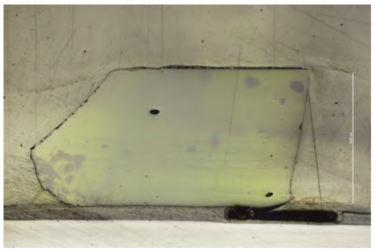
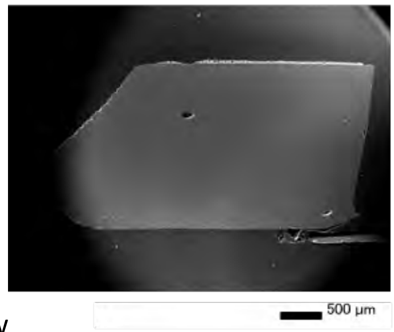
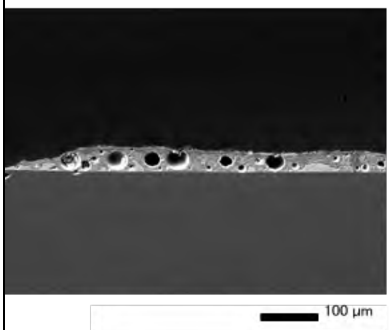
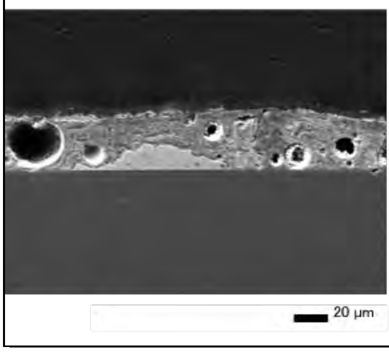
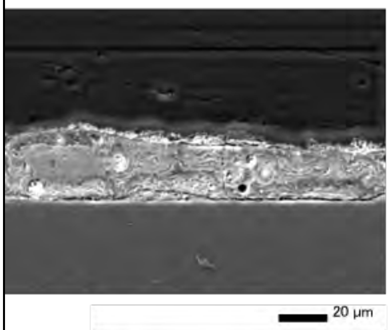


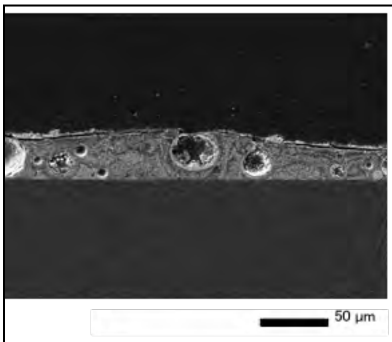
Fig 3, Foto av Cal B4.1 och Fig 4, foto av Cal A3.1.

Beskrivning av prov: Tvärsnitt från skärvor av bemålat Katedralglas. Tvärsnitten är placerade i epoxy.
Metod provtagning: Inledningsvis användes ett Stereomikroskop Si9 Leica. Mikroskopet användes för att dokumentera och identifiera lämpliga ytor för tvärsnitt. Tvärsnitt utfördes med hjälp av glasskärare och tång. Tvärsnitten var ca 2x2 mm, Tvärsnitten placerades i en provform som fylldes med Technovit, (UV-härdande epoxy) i syfte att fästa tvärsnitten. I provformen placerades även en lapp där tvärsnitten namngavs. Tvärsnittet från A kallades Cal A3.1 och tvärsnittet från B fick namnet B4.1 Efter UV-härdning, torkades en fet yta som bildats på epoxyns ytskikt bort med acetone. Tvärsnitten våtslipades sedan med våtslippapper upp till 4000 p gradering.
Förhållanden vid provtagning: Provtagning utfördes inomhus med skyddsutrustning i laboratorium under normala förhållanden.
Iakttagelser vid provtagning: N/A
Rekommenderad förvaring före analys: Analys av prover påbörjades omgående.
Övrigt: N/A

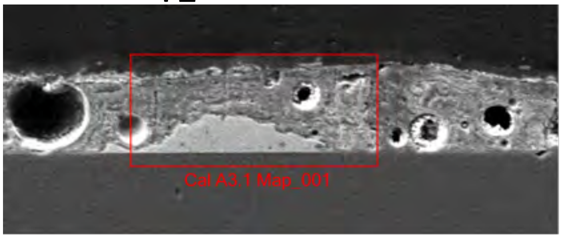
Appendix 3, SEM-EDS, National Heritage board

SEM-EDS analysis CAL A.3.1	Samples
 Cal A3.1 overview	
Cal A3.1 area of interest 1 Sem_SED_004 	
Cal A3.1 area of interest 2 Sem_SED_005 	**Map_001**

Cal A3.1 area of interest 3 Sem_SED_002 	**Map_002**
Cal A3.2 area of interest 4 Sem _SED_001	**Map_001** **Map_002**

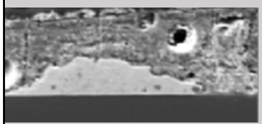
 Signal SED Landing Voltage 20.0 kV WD 10.1 mm Magnification x450 F.O.V. 284.4 x 213.3 µm Probe Current Std. 50.0 Scan Rotation 0.0° Vacuum Mode HighVacuum	

Cal A3.1 Map_001

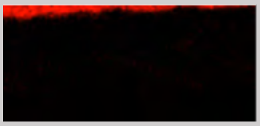


Signal SED, Landing Voltage 20.0 kV, WD 10.2 mm
Magnification x550, Vacuum Mode HighVacuum

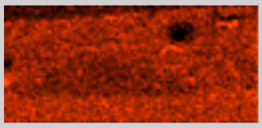
IMG



C-K

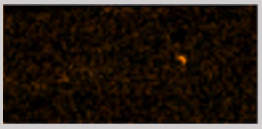


O-K

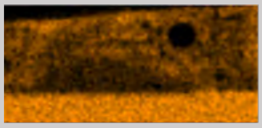


Na-K

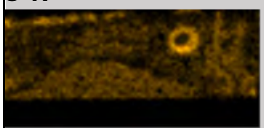
Al-K



Si-K

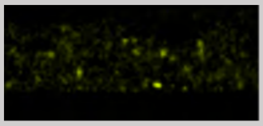


S-K



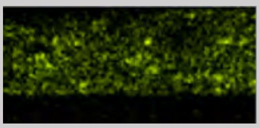
Ca-K

Mn-K

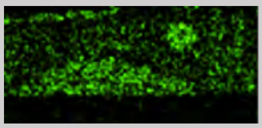


Fe-K

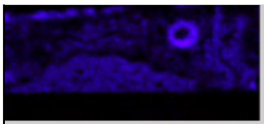
Co-K



As-K



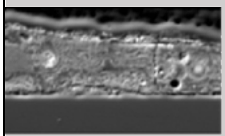
Pb-M



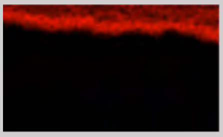
Cal A3.1 Map_002

Signal SED, Landing Voltage 20.0 kV, WD 10.0 mm
Magnification x800, Vacuum Mode HighVacuum

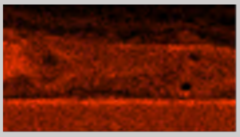
IMG



C-K



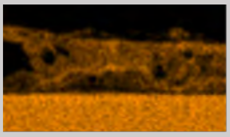
O-K



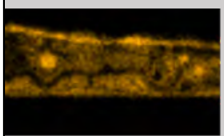
Na-K

Al-K

Si-K



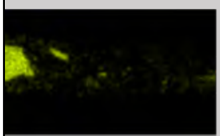
S-K



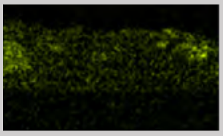
K-K

Ca-K

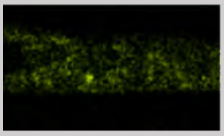
Mn-K



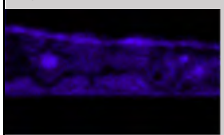
Fe-K



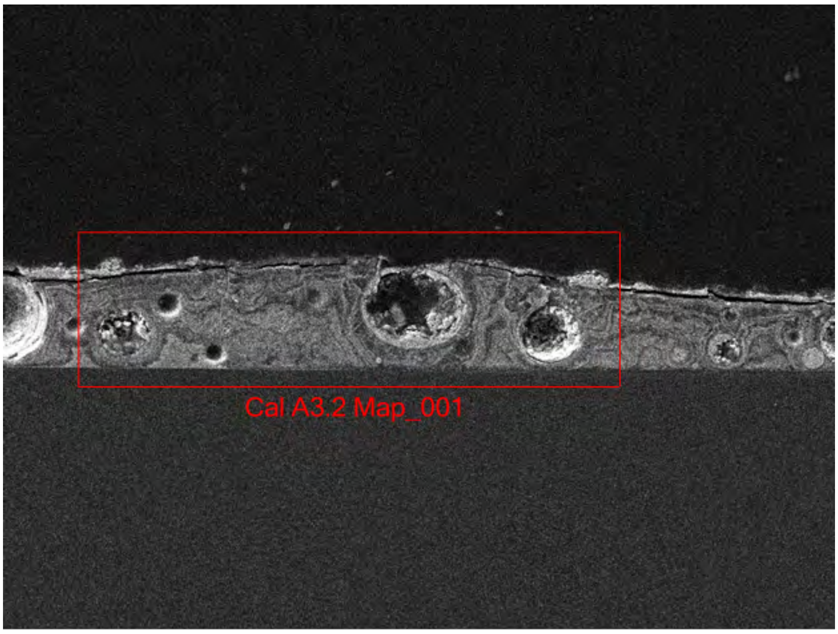
Co-K



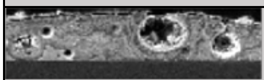
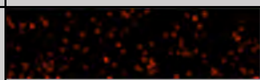
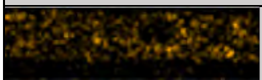
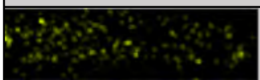
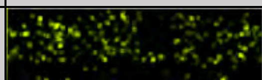
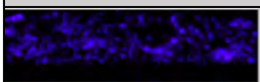
Pb-M



Cal A3.2 Map_001

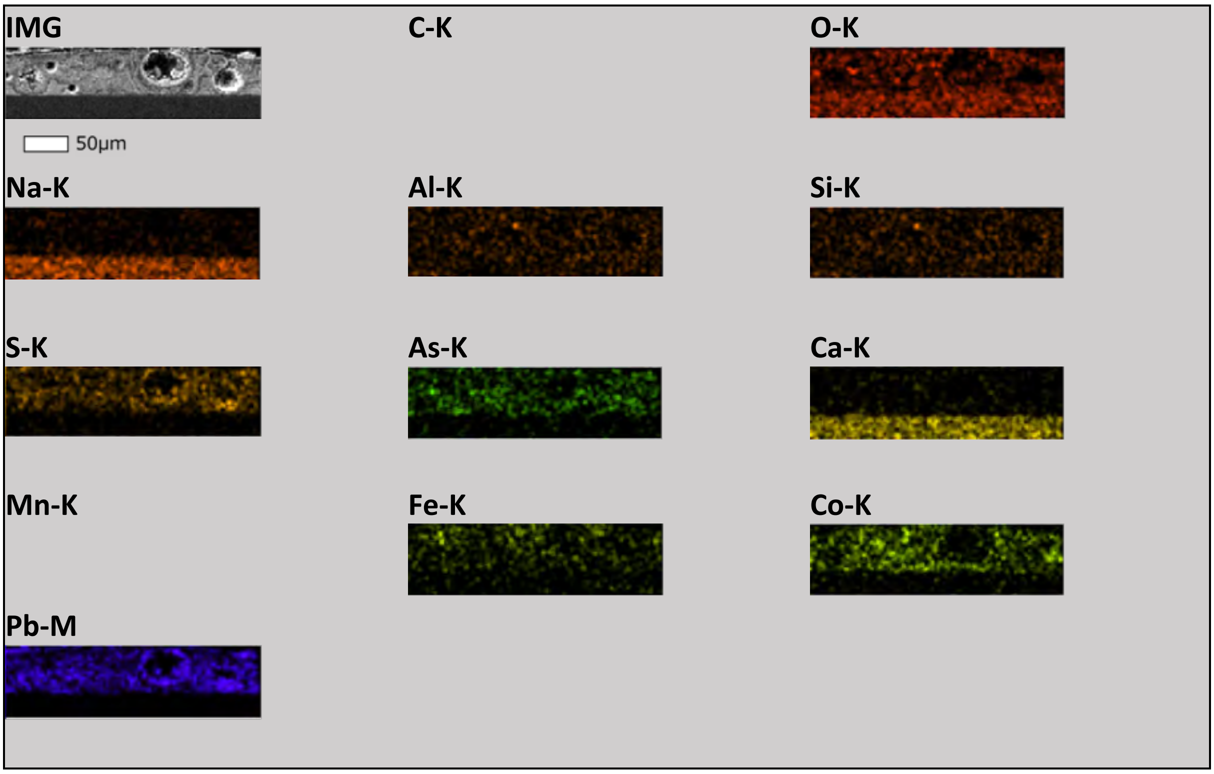


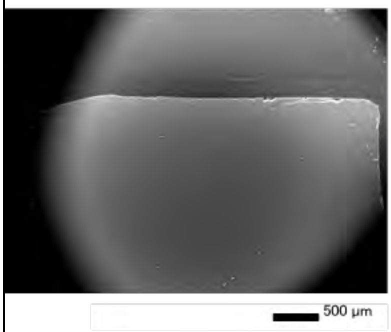
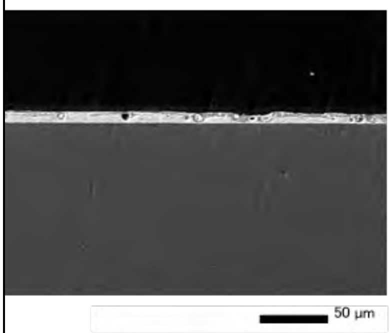
Signal SED, Landing Voltage 20.0 kV, WD 10.1 mm
Magnification x450, Vacuum Mode HighVacuum

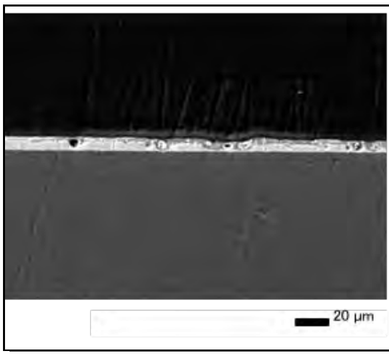
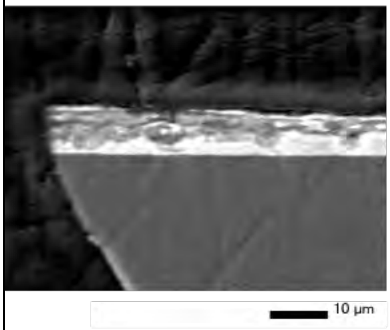
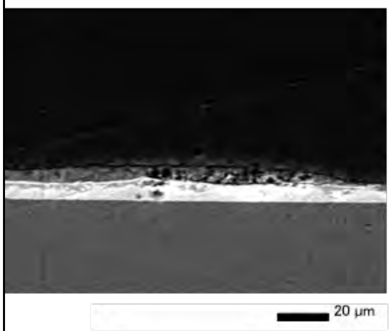
IMG	C-K	O-K
		
Na-K	**Al-K**	**Si-K**
		
S-K	**K-K**	**Ca-K**
		
Mn-K	**Fe-K**	**Co-K**
		
Pb-M		
		

Cal A3.2 Map_002

Signal SED, Landing Voltage 20.0 kV, WD 10.1 mm
Magnification x450, Vacuum Mode HighVacuum

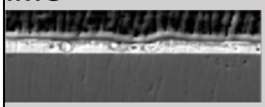
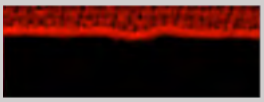
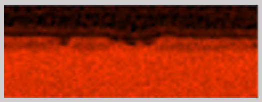


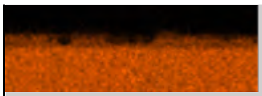
SEM-EDS analysis CAL B.4.1	**Samples**
Cal B4.1 overview Sem_SED_001  Signal SED Landing Voltage 20.0 kV WD 10.2 mm Magnification x30 F.O.V. 4.267 x 3.200 mm Probe Current High 50.0 Scan Rotation 0.0° Vacuum Mode HighVacuum	
Cal B4.1 area of interest 1 Sem_SED_002  Signal SED Landing Voltage 20.0 kV WD 10.5 mm Magnification x450 F.O.V. 284.4 x 213.3 μm Probe Current High 50.0 Scan Rotation 0.0° Vacuum Mode HighVacuum	
Cal B4.1 area of interest 2 Sem_SED_003	**Map_004**

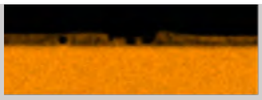
 Signal SED Landing Voltage 20.0 kV WD 10.4 mm Magnification x550 F.O.V. 232.7 x 174.5 µm Probe Current High 50.0 Scan Rotation 0.0° Vacuum Mode HighVacuum	
Cal B4.1 area of interest 3 Sem_SED_004  Signal SED Landing Voltage 20.0 kV WD 10.5 mm Magnification x1,900 F.O.V. 67.37 x 50.53 µm Probe Current High 50.0 Scan Rotation 0.0° Vacuum Mode HighVacuum	**Map_005**
Cal B4.1area of interest 4 Sem _SED_005  Signal SED Landing Voltage 20.0 kV WD 10.5 mm Magnification x850 F.O.V. 150.6 x 112.9 µm Probe Current High 50.0 Scan Rotation 0.0° Vacuum Mode HighVacuum	**Map_006**

Cal B4.1 Map_004

Signal SED, Landing Voltage 20.0 kV, WD 10.4 mm
Magnification x550, Vacuum Mode HighVacuum

IMG	C-K	O-K
		
Na-K	Al-K	Si-K



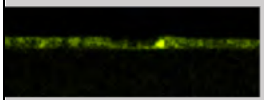


K-K

Ca-K

Mn-K

Fe-K



Rb-L

Pb-M

Cal B4.1 Map_005

Signal SED, Landing Voltage 20.0 kV, WD 10.5 mm
Magnification x1900, Vacuum Mode HighVacuum

IMG

C-K

O-K

Na-K

Al-K

Si-K

S-K

Cl-K

K-K

Ca-K

Mn-K

Fe-K

Co-K

Pb-M

Cal A3.2 Map_001

Signal SED, Landing Voltage 20.0 kV, WD 10.1 mm

Magnification x450, Vacuum Mode HighVacuum

IMG	C-K	O-K
Na-K	**Al-K**	**Si-K**
S-K	**K-K**	**Ca-K**
Mn-K	**Fe-K**	**Co-K**
Pb-M		

Cal A3.2 Map_002

Signal SED, Landing Voltage 20.0 kV, WD 10.1 mm
Magnification x450, Vacuum Mode HighVacuum

IMG	C-K	O-K
Na-K	**Al-K**	**Si-K**
S-K	**As-K**	**Ca-K**
Mn-K	**Fe-K**	**Co-K**
Pb-M		

Appendix 4, XRF Instrument report

SWEDISH NATIONAL HERITAGE BOARD
RIKSANTIKVARIEÄMBETET

Date of analysis 2022-04-21
Analyst Kaj Thuresson

Datum 2022-04-21
Dnr RAÄ-2021-3126
Fyndnr. na
Löpnr: na
Handläggare: Kathrin Hinrichs Degerblad

µ- XRF Instrument Report

Sample Identification Code

RAÄ Dnr 2021-3126 Object no. A1-A3, B1-5

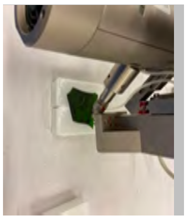
Sample Callmander glass, A3 and B4

Description of sample Shards made of cathedral glass with grisaille paint / vitreous paint. One of the glasses are inpainted with green colour.

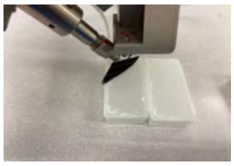
Age 1880-1920

Material Glas with grisaille paint.

Point of analysis photo and description of where on sample analysis done including overview photo if necessary for orientation



A2



B3

Purpose

The purpose of the analysis is to understand the composition of Callmanders painted glass. The result will then be used in a multidisciplinary thesis aiming to understand the paint loss connected to many of his stained glass.

Method

Sample preparation N/A

Riksantikvarieämbetet
Artillerigatan 33
Box 1114
621 22 Visby
Tel 08-5191 8000
E-post riksant@raa.se
Hemsida www.raa.se
Org.nr 202100-1090
Plusgiro 59994-4
Bankgiro 5052-3620

Instrument Parameters

- [X] µ-XRF Artax 800, Mo X-ray tube with polycapillary lens, Bruker; Berlin, Germany
  - [X] single point analysis (spot size <100µm)
  - [X] line scan (lateral resolution <100µm)
  - [X] elemental 2D mapping
  - [ ] quantification, MQuant Calib, Bruker; Berlin, Germany
  - [ ] quantification with standards

SWEDISH NATIONAL HERITAGE BOARD
RIKSANTIKVARIEÄMBETET

Voltage 50 KV

Current 600 µA

Scan time per point 7-10 s

Number of measurement points: Single point x 3, Line 52, Map XXX

Spot distance: Line 0,01 mm, Map XXX mm

Scan area

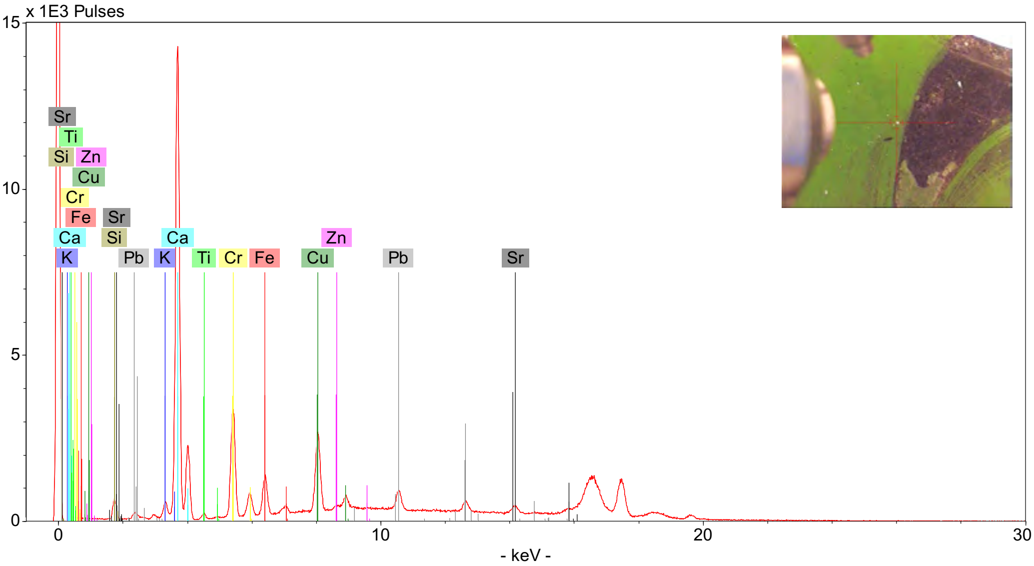
Total scan time

Filter [X] no filter [ ] Al 315 µm [ ] Mo 12.50 µm [ ] other ____________

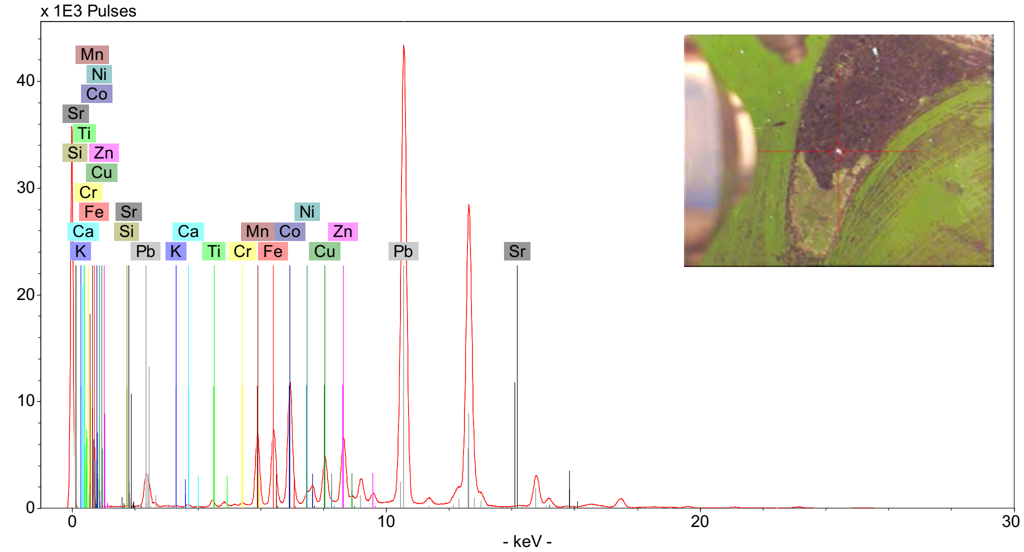
Lens 0.060

Atmosphere [X] air [ ] He for light element detection

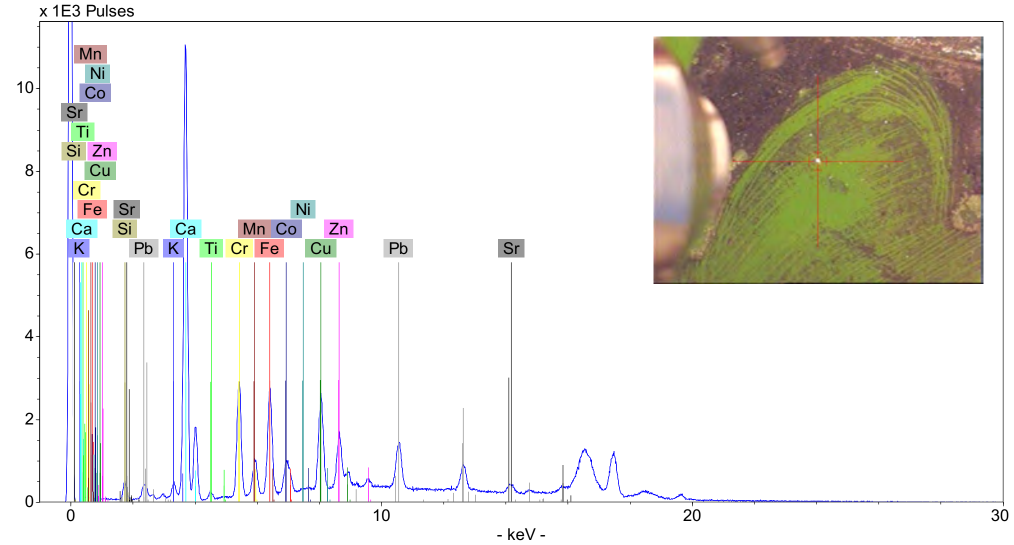
Qualitative Results



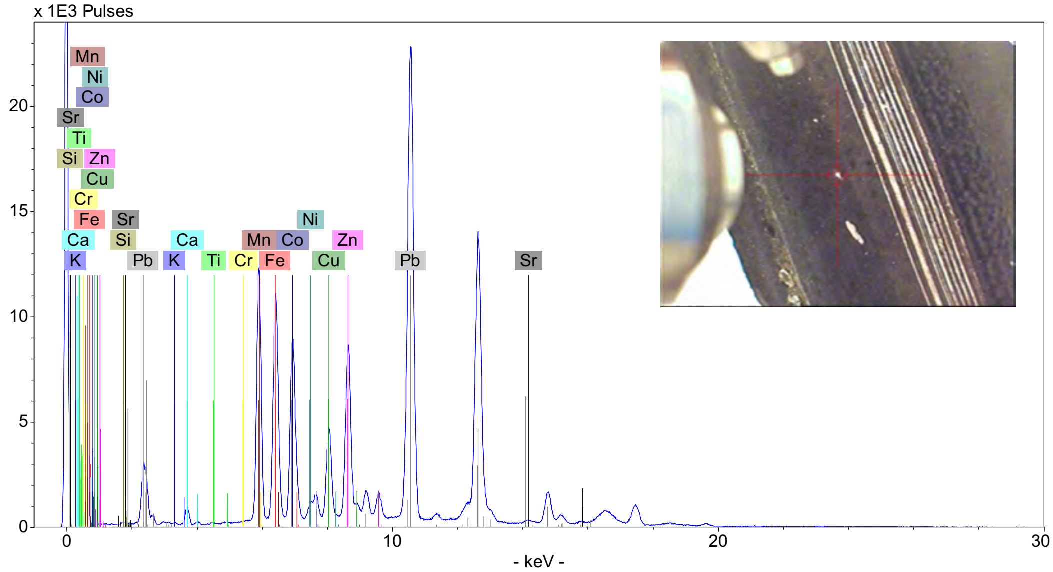
A2 grönt glas: Mest Ca, Cr och Cu. Lite Fe och Pb



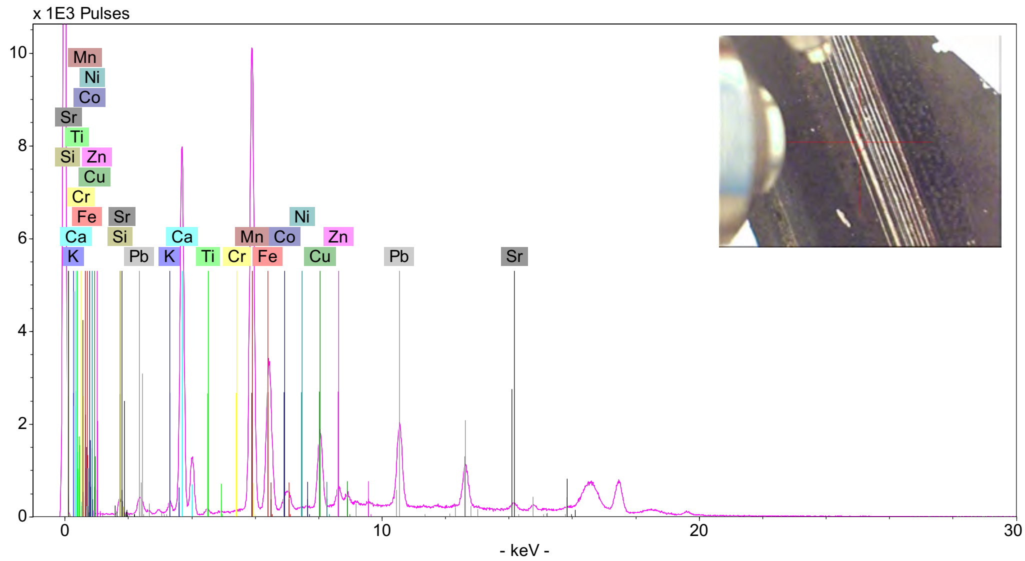
A2 svart: mest Pb och Co, ganska mycket Fe, Mn, Cu och Zn



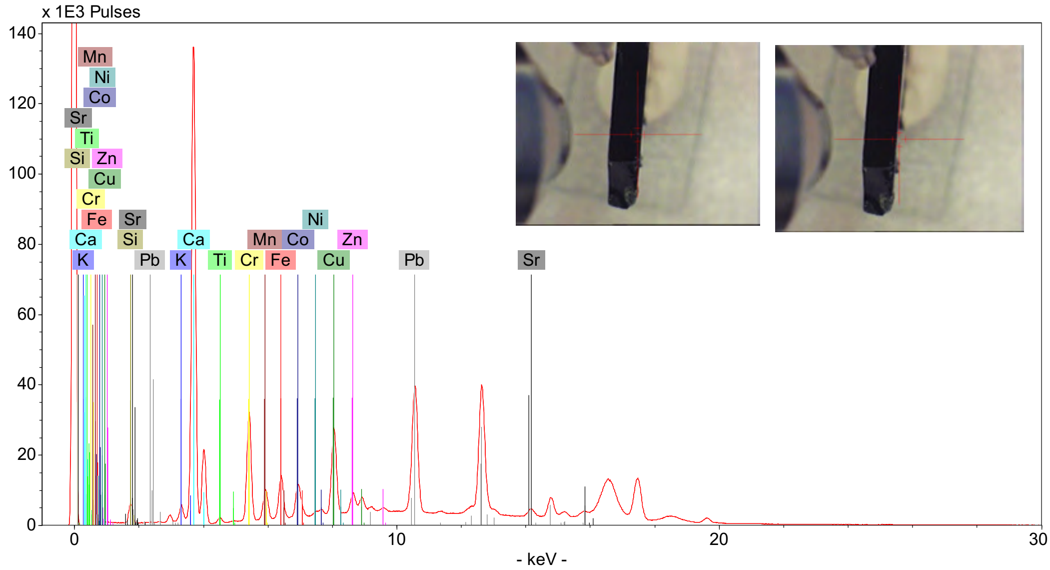
A2 tunt svart: Mest Ca, ganska mycket Cr, Fe och Cu, lite Co, Mn, Zn och Pb



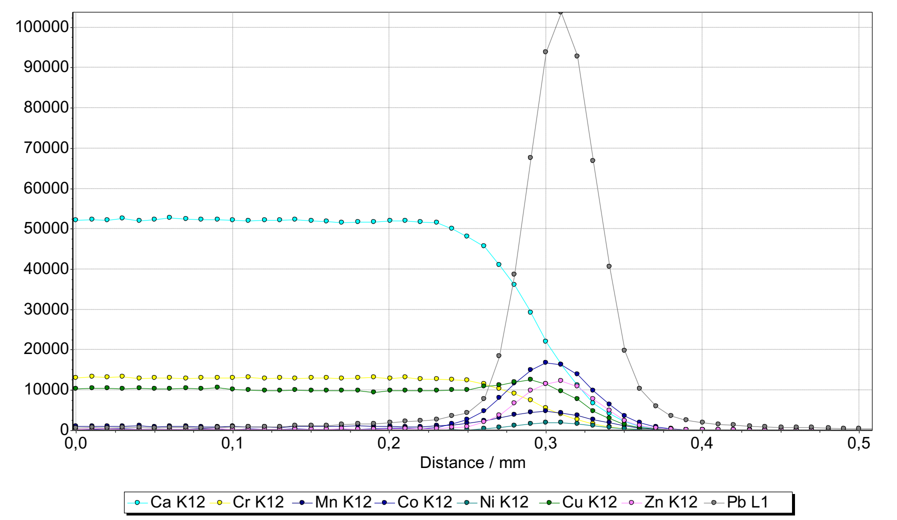
B3 svart: Mest Pb, Ganska mycket Mn, Fe, Co, Zn och Cu

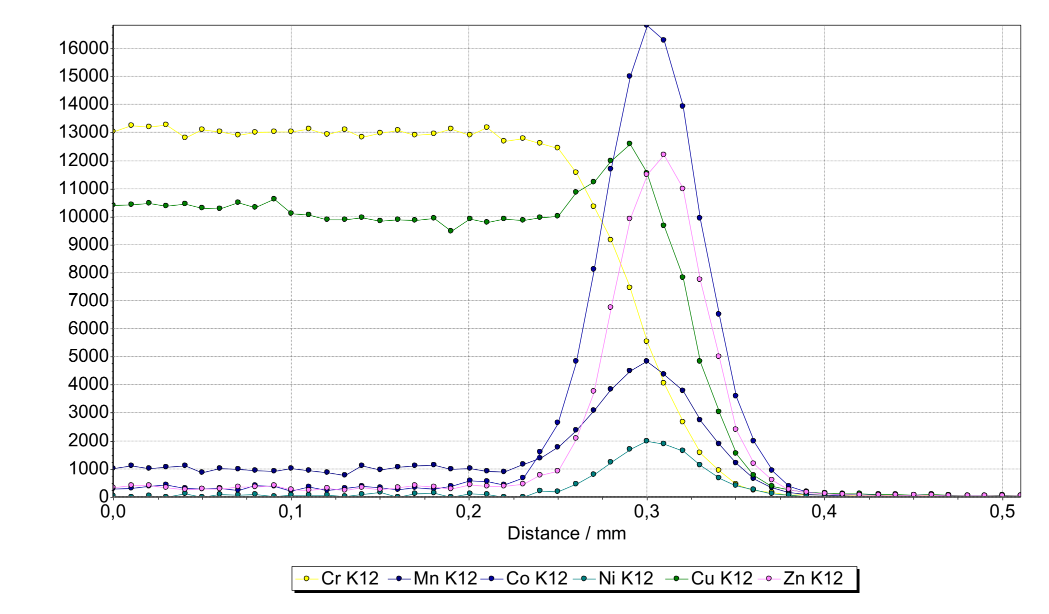


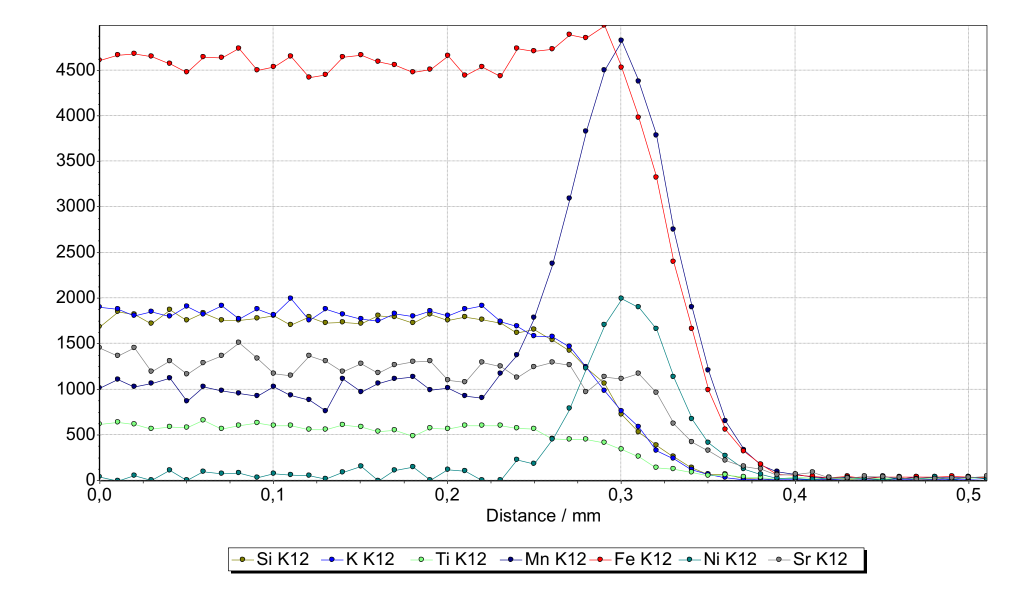
B3 vit: Mest Mn och Ca, lite Fe och Cu

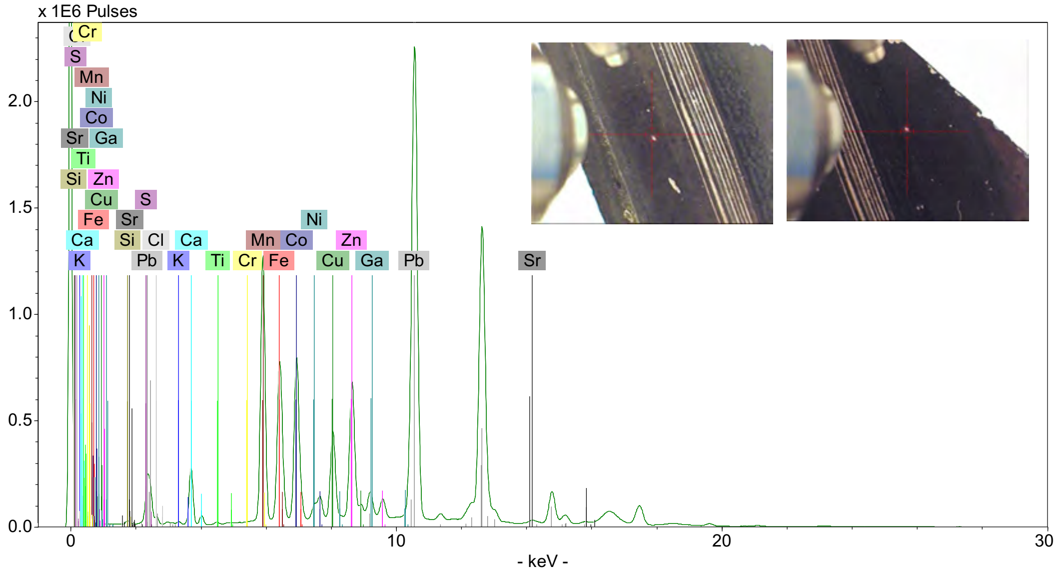


Accu line A3 cross section:




16000
15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0,0
0,1
0,2
0,3
0,4
0,5
Distance / mm
Cr K12
Mn K12
Co K12
Ni K12
Cu K12
Zn K12


4500
4000
3500
3000
2500
2000
1500
1000
500
0
0,0
0,1
0,2
0,3
0,4
0,5
Distance / mm
Si K12
K K12
Ti K12
Mn K12
Fe K12
Ni K12
Sr K12



B3 Map1

Mapping Results

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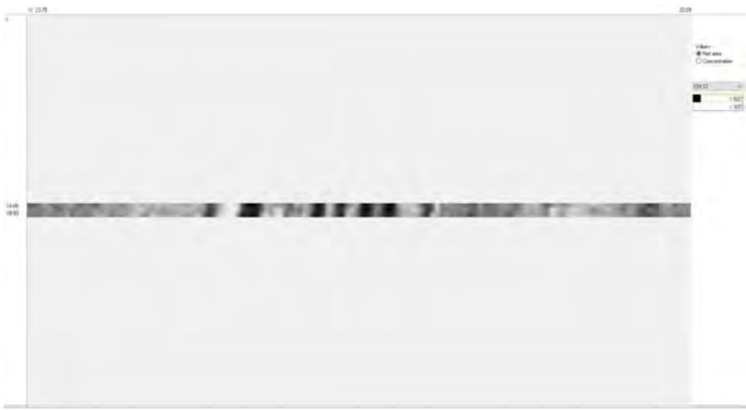

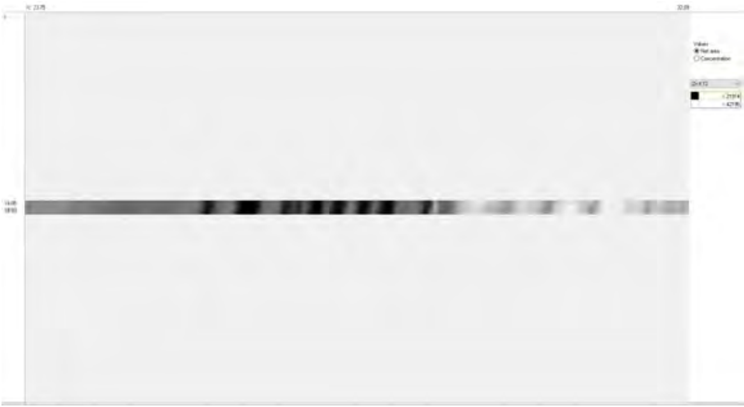

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