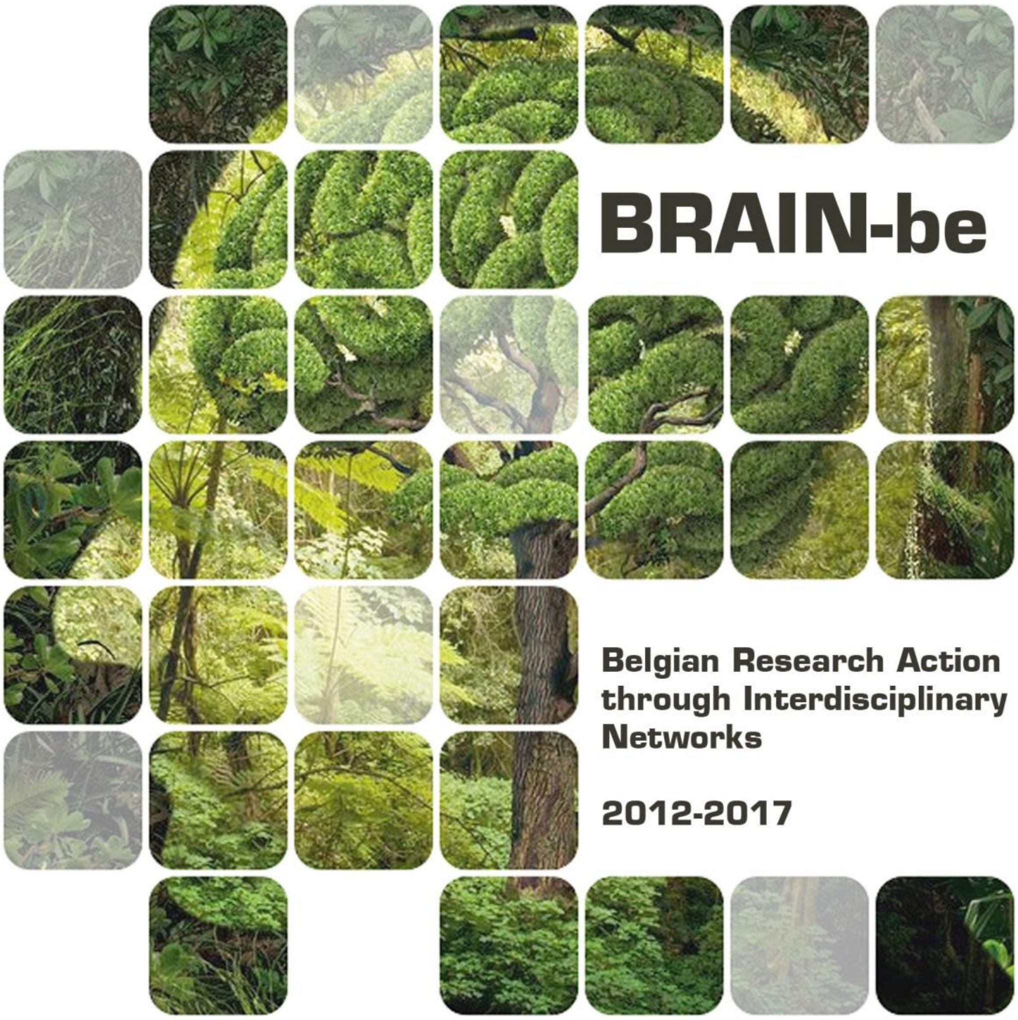

FENESTRA

800 Years of FENESTRAtion history.
Flat glass and windows in Federal Scientific Institutes

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Axis 3: Cultural, historical and scientific heritage

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NETWORK PROJECT

FENESTRA

800 Years of FENESTRAtion history.

Flat glass and windows in Federal Scientific Institutes

Contract - BR/175/A3/FENESTRA

FINAL REPORT

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TABLE OF CONTENTS

ABSTRACT

Context

Flat glass is one of the greatest and most versatile art forms. Across numerous disciplines, stained glass windows in monumental settings have been thoroughly studied over the last two centuries. However, an even greater quantity of material remained unappreciated and unstudied in Belgian storerooms. The Art and History museum of Brussels has unparalleled resources for the study of flat glass in its depots providing a unique collection of material dated from the 13th to 20th century. This collection was the subject of this project. The collection can be divided in several sub-collections based on parameters like for example the flat glass type (individual fragment, roundel, unipartite panel, lead light, stained glass panel or complete windows), production period, production workshop, production technique, material and stylistic properties and specifications regarding acquisition.

Objectives

(1) **The conservation of the collection.** To evaluate concrete conservation issues and to act for preventive conservation and long-term storage of the full collection.

(2) **The creation of inventory files.** To make a detailed inventory of all material and create open access databases which are accessible by the broad public.

(3) **Study of the collection.** This very broad objective formed the umbrella of a subset of research questions that were either linked to the research of the individual pieces of the collection or to the use of the collection as case study to answer state-of-the art research questions. By applying a transdisciplinary evaluation of the collection, the goal was to understand the extent, the state, the formation, and the historical value of the collection as a whole or of some well-selected individual pieces and to contribute to state-of-the-art research questions which are linked to potentially hidden evolutions in glass composition and technology (in the Low Countries).

(4) **Dissemination and outreach.** The publication of the research results in a wide range of peer reviewed journals; as well as a *Corpus Vitrearum* (CVMA) publication. To bridge the gap between interesting academic knowledge and the broad public, an exhibition was organized at the end of the project.

Conclusions

- The complete collection has been brought together in a new storage room obeying the optimal temperature and humidity conditions.
- Files have been created that describe the state of an individual piece, the preservation actions that have been taken and if applicable advises for future conservation.
- A first cleaning step has been applied to all pieces. For twenty pieces an urgent restoration treatment was carried out. Fourteen panels were restored.
- The inventory list was completed and for each panel a high-resolution picture was taken. This information was added to BALaT and Carmentis.
- The historic research gave us important insights into the life history of the collection.
- One of the main conclusions of the transdisciplinary research is the remarkable character of the stained-glass collection, by its importance, the diversity of the pieces and the artists represented through them, with some pieces that can be considered as leading works.

- The transdisciplinary research allowed us to have a better view on the authenticity of those pieces for which the dating was questioned and provided us information on the used materials and techniques.
- During the art-historic research the iconography of the windows in the collection have been further studied and updated.
- The art-historical research findings include multiple examples of leading artists that applied their art to stained glasses.
- With the outcome of the macroscopic research, we were able to classify the roundels in groups based on the number of fabrication traces that were observable by the naked eye. Further research unveiled no direct relation between the number of air bubbles and the quality of the painting layers. However, an inverse relationship is observed between the purity of the raw materials and the number of appearing air bubble inclusions.
- During this project, we demonstrated the feasibility of applying UV-VIS-NIR absorption spectroscopy as a non-destructive method to better discern the subgroups of HLLA glass and their respective dating.
- A generic method was worked out to quantify the iron and the cobalt concentrations from the recorded optical spectra. This approach has been described in a submitted journal article ('Using UV-Vis-NIR absorption spectroscopy as a tool for the detection of iron and cobalt in glass: a case-study on HLLA material from the Low Countries') so that other researcher can apply this method to study glasses of other collections.
- The project findings helped us to better understand the glass consumption in the Low Countries. In most cases, the glass analytical research confirmed the expected HLLA composition. We concluded that in a minority of cases, the glasses are potash glass.
- The project permitted the investigation of the interplay between glass technology (glass 'quality') and daylight transmission. A comparison was made between non-figurative windows and a selection of six roundels. For both groups we observed an evolution towards less pure materials in later periods. It was observed that more light was transmitted through the roundels compared with the non-figurative windows due to their lesser thickness. This can be seen as proof for their status as a luxury commodity. These findings are published in a *Scientific Reports* paper ('The interaction between daylight and 15th and 16th century glass windows from the Low Countries').
- By studying the spectral profiles of two sets of silver-stained samples with known fabrication conditions, we were able to define a flowchart that could help in unravelling the applied silver stain technology of unknown samples (applied silver salt, temperature, type of mixing agent).
- The project helped us to gain insights on the applied silver stain technology in the Low Countries.

Keywords

Glass – Stained windows – Roundels – Window glass – Plain glass – Unipartite panes - Glass conservation – Iconographic research – Stylistic research – Archaeometry – UV-VIS-NIR absorption spectroscopy – Portable XRF – Glass consumption – Glass composition – High-Lime-Low-Alkali – Potash glass – Silver stain technology – Daylight transmission – Low Countries – History of the A&H collection Brussels

1. INTRODUCTION

The Fenestra project focused on the little-explored flat glass collection of the Art & History Museum of Brussels (A&H) (former Royal Museums of Arts and History – RMAH). This collection includes many of European masterpieces unveiling the art of stained glass between the 12th and 19th century. In figure 1 the different sub-collections are illustrated.

a b c d

Figure 1: The A&H collection contains roundels and unipartite panes (a), stained glass windows (b) and panels and fragments from stained glass windows (c-d)

The material has been approached from different backgrounds incorporating humanities and social sciences, applied sciences and conservation. A detailed inventory of individual fragments; roundels, lead lights and stained-glass windows has been made; combining research of technology and morphology; stylistic details and evolutions and conservation. Preservation actions were taken for those pieces that required an urgent treatment. The historical study of the formation of the collections supplemented with the art-historical research enabled a better understanding of the chronological and spatial context and iconography. Furthermore, optical spectroscopic techniques were used as first-line non-destructive analysis techniques followed by well thought-out sampling for chemical research. For this material research, the network made use of the broad gamut of available equipment within the network; Ultraviolet-Visible-Near-Infrared (UV-VIS-NIR) absorption spectroscopy, portable X-Ray Fluorescence Spectroscopy (p-XRF) and Laser-Ablation Inductively Coupled Mass Spectrometry (LA-ICP-MS). This integrated approach gave us important grasps in the life-history of the collection and the use of flat glass in the Low Countries. It provided us information on the composition of the glasses and as such further contributed to defining the hinge point from potash to High-Lime-Low-Alkali (HLLA) glasses of material originating from the Low Countries. In addition, the research helped us in studying the silver staining technology via optical means.

The pieces of the collection have been added to the digitalization platforms BALaT (KIK/IRPA) and Carmentis (A&H) and can therefore be consulted by the wide audience. A considerable part of the collection will be published in the sixth volume of the "Checklist" series of the *Corpus Vitrearum* (*Médaillons, peintures sur verre et panneaux de vitraux de petites dimensions conservés dans les collections publiques à Bruxelles*). The analytical research results have been and will be further published in high-impact journal publications. Finally, an exhibition 'Medallions – Miniatures on Glass' has been worked out, allowing the public to rediscover a major part of Belgian cultural heritage. The exhibition has been included in the permanent collection of the A&H museum and opened in June 2021.

As a result, we hope that this forgotten collection ('unexplored heritage') will become an important reference collection.

2. STATE OF THE ART AND OBJECTIVES

The research topic of this proposal was presented under the theme of 'unexplored heritage' since it concerns an almost forgotten collection of fenestrations of the Low Countries and abroad. It comprises a collection of roundels and unipartite panes, stained glass windows, panels and fragments from stained glass windows. The A&H Museum has unparalleled resources for the study of flat glass providing information between the 13th and the 20th century. The flat glass collection of the A&H museum illustrates the technical and stylistic evolutions of stained-glass art and glaziers craft in the (Southern) Low Countries. Despite the unique character of this flat glass collection, it has been largely neglected for a long time resulting in an inappropriate storage of the precious pieces (Figure 2), a lack of knowledge on the content of the collection and a related incomplete inventory list, a lack of information on the state of the pieces and no availability of a reference database that can be consulted by the research community or by the wider public. The very interesting study collection remained unappreciated and unstudied in the storerooms of the Belgian Federal institute. This formed the rationale to initiate this project.

Figure 2: Storage of the collection before the start of the project

The four defined main objectives are introduced in the next paragraphs.

Objective 1 – The conservation of the collection. In 2016 the collection needed to be moved to a temporary storage room (temporary exhibition room) due to an inundation. Because it was not possible to perform the project research in this room, it was imperative to install a new storage room. It goes without saying that the goal was to have a room where all pieces are stored in a safe and user-friendly way. Instead of storing the smaller pieces in wooden boxes, the aim was to select the storage assemblies and cupboards in such a way that every piece could be easily assessed individually. All good practices regarding the control of the environment (temperature, humidity) must be applied. Apart from the storage of the pieces, there was also a need to investigate the state of the collection and to apply a first cleaning. Finally, for every investigated piece, suggestions needed to be made on the most optimal type of preservation. For those pieces that required an urgent treatment, preservation steps needed to be taken.

Objective 2 – The creation of inventory files. A first goal was to complete the existing inventory list ensuring the inclusion of all pieces of the collection and to make this list available to all project partners. A second sub-objective was to collect old research data. A third aspect related to the state of the collection where a report was written for each studied piece. This report must define the current state of the piece and should contain advices for further preservation and conservation actions. A final goal was to add the info gathered for every individual piece to two databases that can be consulted by internal and external users. The information added to these databases must be linked to a photographic database containing a high-resolution picture of every piece of the collection. The generation of this photographic database formed part of the project work.

Objective 3 – Study of the collection. This very broad objective formed the umbrella of a subset of research questions that were either linked to the research of the individual pieces of the collection or to the use of the collection as case study to answer state-of-the art research questions. By applying a transdisciplinary evaluation of the collection, the goal was to understand the extent, the state, the formation, and the historical value of the collection as a whole or of some well-selected individual pieces and to contribute to state-of-the-art research questions which are linked to potentially hidden evolutions in glass composition and technology.

The different involved research domains were the following:

History – The research on the ownership history, or provenance of the A&H flat glass collection must shed light on the historical, social and economic context in which the fenestration was created, dismantled and collected. All these factors should contribute to the understanding and interpretation of the sub-collections that were studied by the other disciplines. The goal was to collect provenience and contextual data that over time had become separated from the collections.

Art history – The research aspects investigated by the involved partner focused on the study of the iconography, the painting styles and the used materials. The outcome of the art-historic research forms the basis of the selection of the pieces that will be included in the related *Corpus Vitrearum* publication and should act as an important knowledge provider during the transdisciplinary interactions by giving feedback on dating, origin and authenticity information of the different pieces.

Archaeology (macroscopic research) – The main goal of the macroscopic research was to unveil information on the fabrication process of the glass windows and with this info contribute to the raised questions related to the origin, the dating and the authenticity of the researched pieces. Since Roman times, glassmakers were applying spinning techniques to produce window glass using either the crown (Figure 3 - left) or the cylinder glass (Figure 3 - right) technique. To obtain crown glass, a glass was blown as a bubble that was then opened and spun around to form a disk of glass. The cylinder glass technique consists of blowing a glass bubble that is elongated to form a cylinder, which is then cut open and flattened.

Figure 3: Glass fabrication with the crown (left) and the cylinder (right) techniques. Pictures are taken from (Dungworth, 2011)

Both techniques often resulted in the appearance of glass bubbles which allows the identification of the crown technique in case of circular-shaped bubbles and the cylinder technique in case of elongated bubbles. Until the last quarter of the 16th century, two production centres dominated the glass market: French (Normandy) crown- and the Lorraine (Rhine area) cylinder-production centres. In the 14th century, improvements in the cylinder technique, which probably first took place in Bohemia, resulted in an increased flatness of the window surface. This knowledge was taken to Lorraine. In the second half of the 17th century, migrations of glass workers took place due to economic and political reasons, resulting in the diffusion of crown- and cylinder glass-productions centres located in the Low Countries, England, Germany, France and so on (Davison, 2003).

Photonics (microscopic research) – The main objective of this discipline was to study the glass windows via non-destructive means. The analysis was performed in view of the three defined sub-objectives: (1) to improve the methodology of dating flat glass based on optical fingerprints; (2) to investigate the relation between composition (glass purity), fabrication technology and optical transparency; (3) to research the technology of silver-stained glasses by optical means. To reach these targets the data was analysed according to the following 'topics':

Topic 1: Research on the identification of the optical measures of interest for glass pieces with a post-medieval glass signature.

State-of-the-art research of VUB has demonstrated the use of UV-VIS-NIR absorption spectroscopy as a non-destructive tool to quantify the ionic iron concentrations in glass. This study was made for Late Antique glass fragments (Ceglia et al., 2016, 2015). Therefore, one of our objectives was to investigate if this tool is also of interest for glasses with a post-medieval signature. Another aim was to further explore the use of UV-VIS-NIR absorption spectroscopy for the study of cobalt. It was already proven that the position of the cobalt absorption bands can provide information on the matrix chemistry and as such can shed light on the authenticity of the window (Ceglia et al., 2012). Even though this knowledge was applied while studying the collection, another aim was to define a tool that allows the quantification of the cobalt levels based on the recorded spectra. The feasibility to fulfil this objective and the potential interest for the here studied collection was driven by the following three reasons. i) It has been reported in the literature that UV-VIS-NIR absorption spectroscopy allows the detection of very low levels of cobalt (Green and Alan Hart, 1987). ii) The collection contains material from a broad time span and as such most probably contains materials that are characterized by different cobalt impurity levels which formed the ideal case-study for our research. iii) The sampling of some of these pieces and the subsequent chemical analyses using Laser

Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS) allowed us to construct the calibration curve between the optical measure and the cobalt levels recorded with this high-end laboratory technique.

Topic 2: Unravelling the evolution in glass composition from potash to HLLA glass

The authentic glass windows studied in this project, were fabricated according to the wood/plant ash tradition. Wood/plant ash glass is typically subdivided into potash and high-lime-low-alkali (HLLA) glass based upon its K_2O/CaO ratio (Wedepohl and Simon, 2010). Researching the relation between glass type and chronology has shown that 15th-century material tends to be potash glass, whereas glass from 16th and 17th contexts often has an HLLA glass signature. However, an overlap exists between the uses of both glass groups for the early periods. According to the literature, the time transition point from potash towards HLLA glass strongly depends on the region. HLLA glass was identified by Wedepohl in German sites from 14th to 17th-century contexts (Wedepohl, 2000; Wedepohl and Simon, 2010). From the second half of the 15th century to the end of the 17th century, both potash glass and HLLA are present in Northern France (Barrera and Velde, 1989). Initially, potash glass was mainly appearing in the north-western region, and HLLA glasses were appearing in the north-eastern region close to the German borders. Afterwards, the diffusion of HLLA glasses from east to west was observed (Barrera and Velde, 1989). For England, the research of Dungworth demonstrated the occurrence of HLLA glasses from the second half of the 16th century onwards (Dungworth, 2011). References are scarce for the Low Countries. The existing literature suggests that most of the non-figurative 15th- to 17th-century material is HLLA (Schalm et al., 2007) and that the composition of the roundel glass of the Low Countries does not show significant difference from ordinary window glass, with HLLA glass being the dominant glass type (Caen, 2009). By researching the glass compositions of the glasses, the target was to evaluate if this statement holds.

Topic 3: To investigate the interplay between glass technology (glass 'quality') and daylight transmission

In post-medieval times glassmakers were confronted with less pure materials compared to modern materials. An important aspect that influenced the light transmission was the non-whitish tint of the glass originating from the applied raw materials. Naturally coloured glasses mainly owed their colour to iron impurities, which were present in the raw materials. In most silicate glasses, the two oxidation states Fe^{2+} and Fe^{3+} simultaneously occurred. The iron redox ratio (Fe^{2+}/Fe^{3+}) was influenced by the used raw materials (Bamford, 1977). Driven by the Reformation and Counter-Reformation they were at the same time challenged by the demand for increased daylight. Luckily, technological evolutions allowed the production of thinner windows and therefore the glass-forming technique could have also played an important role. Craftsmen could, for example, have tuned the glass thickness with the purity of the raw materials. Before the start of this project, it was an open question if glassmakers in the (Southern) Low Countries during the booming economic period from the 15th to 17th century made use of the interplay between material and fabrication properties to bring light into the darkness. Therefore, one of the aims of this project was to link the impact of glass purity and production technique to light transmission.

Topic 4: To study the technology of silver staining

Silver staining is applied to colour the glass and can impart a variety of hues from yellow to orange to red. The different involved processes of silver staining are well described in the literature. Silver staining consists of mixing a silver salt (Ag_2O, Ag_3PO_4, Ag_2SO_4, AgCl, $AgNO_3$) with a binding agent (ochre, clay, water, egg). This mixture is then applied to a bare glass surface and baked in an oven at a temperature which is preferentially close to the glass transition temperature. Upon firing, four successive steps occur. Ag+ ions penetrate in the glass via an exchange with the alkali ions and further diffuse in the glass. The silver ions further react with other elements present in the glass such as iron, non-bridging oxygen atoms etc. Finally, an aggregation of AgO into silver particles occurs. A clustering between these particles often takes place. The size of the silver nanoparticles, their distribution and their clustering depend on several parameters of which the silver salt type, the applied temperature and the compositions of the binding agents and the bare glass are the most important ones (Figure 4 - left). The silver particles lead to a characteristic absorption peak (Manikandan et al., 2003) (Figure 4 - right) for which it has been described in literature that the peak shifts in position and changes in shape based on the applied technology parameters (Jembrih-Simburger et al., 2002). Since information is lacking that links the spectral profile with the silver stain technology, we targeted an identification of the optical measures that would allow us to estimate the applied technology. This information will then in a second step be applied to the pieces of the collection to unravel their technology and as such obtain more information on the silver stain technology that was applied to the material originating from the Low Countries.

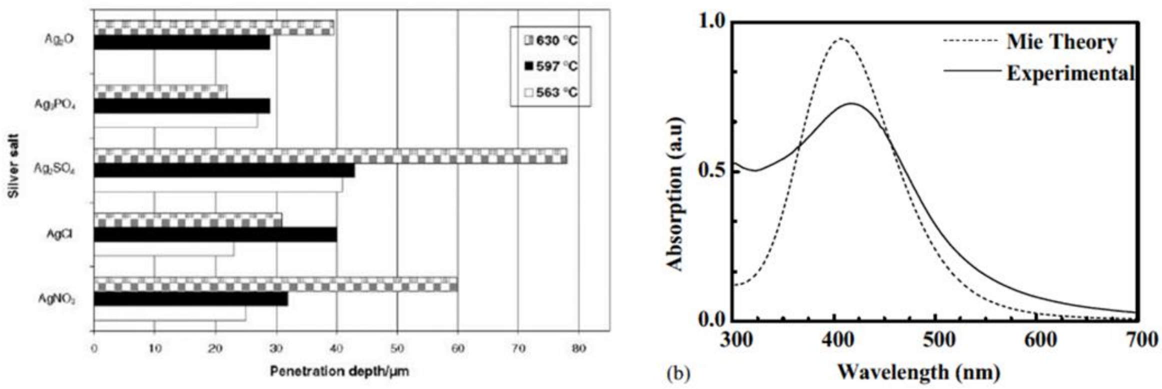


Figure 4: Penetration depth of the silver particles in soda glasses as a function of the applied silver salt and temperature (left). Picture is taken from (Jembrih-Simburger et al., 2002)*. The characteristic Surface Plasmon Resonance peak of the silver nanoparticles (right). Picture is taken from* (Manikandan et al., 2003)*.*

Objective 4 – Dissemination and outreach.

A diversity of different types of smaller and larger dissemination and outreach activities were defined. The main rationale was that each project partner had the responsibility over one main activity supplemented with several smaller activities. The main activities were the following:

Partner 1 – VUB – focused on the publication of the analytical research results in high-impact journal publications. These publications are in-line with the PhD dissertation thesis of Mrs. Mathilde Patin.

Partner 2 – KIK-IRPA – focused on the working-out of the sixth volume of the “Checklist” series of the *Corpus Vitrearum*. This volume considers medallions, ovals, rectangles, squares, and small panels preserved in public collections in Brussels and dating from before the 19th century. Five volumes have already been published in the series; this one will be the sixth: Isabelle Lecocq (dir.), Médaillons, peintures sur verre et panneaux de vitraux de petites dimensions conservés dans les collections publiques à Bruxelles (*Corpus Vitrearum Belgique-België*, « Checklist », 6), est. 2023.

Partner 3 – KMKH-RMAH (A&H museum) – focused on the working-out of an exhibition that opened at the end of the project and that shows some of the research results and unveils some precious pieces that were hidden in the storerooms for decades. The different disciplines are highlighted with four educational movies.

In addition, smaller actions were taken to communicate the project content and results to peers as well as to a broad public.

3. METHODOLOGY

Conservation

The methodology we followed to conserve the pieces consisted of three main steps which were carried out in a consecutive order: the installation of the storage room, the investigation of the state of the collection and the conservation of some well selected pieces.

At the start of the project, the collection was stored in a temporary storage room. Because it was not possible to perform the project research in this room, a first task that needed to be performed at the start of the project, was the installation of a new storage room. Before installation, a scouting was performed to investigate how similar collections are stored in other museums. Once the new storage room was operational (since July 2017), a first part of the collection was transferred to this location. At this stage, the monitoring of the environmental parameters (humidity and temperature) started with the goal to evaluate if further climate interventions were required. This monitoring occurred for a period of six months.

As soon as the first pieces arrived, the study of the state of the collection started. For each piece under test, the following focus points were considered during the investigation: the current state of the panel under test (does it allow a manipulation in its current state) including an overview of appearing alterations, its potential to be exposed in the exhibition and its position on the priority list of pieces that needed urgent future conservation tasks. Apart from this, suggestions were made concerning the type of preservation and a first cleaning (dry brush and vacuum cleaner with HEPA filter) was carried out.

As a last step, conservation actions were carried out for some pieces of the collection. Priority was given to those pieces that required an urgent preservation action.

To validate the photonics method, a benchmarking must be made with a destructive chemical analysis method (LA-ICP-MS). Therefore, a sample set needed to be taken. During the conservation of the collection, a selection was made of pieces that could be sampled (A&H museum) and that were interesting for the research (KIK-IRPA & VUB). The main criterium was to have a reliable sample set (diversity in time of production – KIK-IRPA and diversity in glass composition – VUB). For the sampling of the pieces, the consortium could count on the expertise and feedback of Chantal Fontaine (KIK-IRPA and member of the follow-up committee).

Inventory

As a first task, an in-depth screening of the A&H archives and of the existing literature was made to identify useful documents regarding the history of the collection (correspondence, reports of past restorations and documents about acquisition) (A&H). This information was supplemented with a scouting of the literature to research if chemical analyses data were present from past research actions on the collection (VUB). For this we closely collaborated with one of the members of the follow-up committee - Dr. Helena Wouters - who is an expert in chemical analyses techniques and who is affiliated to KIK-IRPA. At the same time, we revised the literature on post-medieval glass compositions (all partners).

A second block of tasks was related to update and complete the inventory lists. These tasks formed a close collaboration between KIK-IRPA and the A&H museum. After the storage room had been installed, the material was moved to the new location and the boxes were unpacked. An inventory was made of all pieces. The Excel table that was generated at this stage of the research, was distributed among the partners who used this as a reference file. In a next step, high resolution pictures were taken by a professional photographer of KIK-IRPA and the information was added to the digitalization platform BALaT (KIK/IRPA) and Carmentis (A&H museum). For this part, Emma Anquinet (KIK/IRPA) received a specific training on how to work with the Institute's database, Adlib XPlus 4.2. In this step, not only the pictures were added but also the remaining info was completed and updated if needed (KIK-IRPA). The introduction of the new colour photographs offered the additional added value that they could replace the old black and white photographs that were taken in the 1920s by the Belgian Documentation Service.

All photographs had to be processed by the photographers, numbered and indexed according to KIK-IRPA standards. Next, they were manually entered into IRPA's online image database, BALaT (for 'Belgian Art Links and Tools'). For each piece, a series of information was systematically filled in: identification, provenance, materials, technique, place of production and dating. The iconography required a significant effort of indexing, to structure the information in a way that would allow the most varied research possible on the various subjects depicted. Finally, the Fenestra project provided a unique opportunity to update the thesaurus of the terms related to the stained-glass technique, taking into account the current state of research.

Historic research

The study of the history of the stained-glass collection from the Art & History Museum was possible thanks to the availability of a variety of documents, i.e., publications related to the history of public and private collections in Belgium in the 19th and 20th centuries. Documents that were linked to the history of the Art and History Museum as well as to the history of stained-glass in our regions from the Middle Ages to the present time provided practically no information on the history of the museum's collection. Only one article published by Isabelle Lecocq gave some insights on the subject.

Therefore, in a first step, we went through the old publications of the museum and of the successive curators who were responsible for the management of this collection. This with the aim to understand the story of the collection. A few visitor's guides, formerly called 'catalogs', offered an overview of the growth of the collection since de beginning of the 19th century. They sometimes emphasized on certain remarkable pieces. The Museum bulletin, published from the early years of the 19th century onwards, includes here and there articles related to the collection (presentation, acquisitions…). Finally, in the 20th century, curator Jean Helbig published some studies, notably within the *Corpus Vitrearum*.

Moreover, some additional information could be collected from some more recent publications that are related to an object or a group of objects (reverse paintings, Flemish roundels, stained glass panel form the abbey of Parc…).

The museum archives offered the most important information on the history of its stained-glass collection. The archives contain accession books and old inventory files that identify the donors or sellers of the museum's stained-glass windows. They also include some catalogues of auctions from which the museum purchased items.

The series made of the acquisition files formed from the very end of the 19th century, offered unpublished documents on stained-glass windows that entered the collection but also on artworks that were refused, thus shedding light on the choices that were made by the museum's management. This series were supplemented by the scattered files that form part of the important series of the correspondence of the management of the museum. The starting date of collecting these files started coincides with the foundation date of the museum.

Finally, the archives of the stained-glass section itself, produced by its successive curators from the 1930's onwards (Helbig, Muller, Van Cauwelaert, Lefrancq, Montens), not only include acquisition files, but also correspondence and research notes from the curators as well as a very interesting series of restoration files.

To complete the information on donors and sellers, an in-depth biographical research was also carried out.

Art-historical research

A large part of the Art & History Museum's collection of stained glass was studied from an art historical point of view based on the methodology of the *Corpus Vitrearum*. The main aspects considered are technique and materials, iconography, style, and the relationship with contemporary artistic production. This art historical study was done in the perspective of the earlier mentioned sixth volume of the "Checklist" series of the *Corpus Vitrearum*: Isabelle Lecocq (dir.), *Médaillons, peintures sur verre et panneaux de vitraux de petites dimensions conservés dans les collections publiques à Bruxelles* (*Corpus Vitrearum Belgique-België*, « Checklist », 6), est. 2023.

Nearly 340 items of the Art & History Museum will be included in this study: 202 roundels, ovals, rectangles, and squares; 53 small panels; 20 Swiss panels and 65 fragments. The pieces were examined individually between May 2019 and August 2021.

Archaeology (macroscopic research)

This part consisted of a detailed macroscopic examination which was performed with the naked eye or by using simple optical instruments. The focus of this part of the research was to identify clues on the production traces. Therefore, the main approach was to report on the absence/presence (and their shape and orientation) of air bubbles and blowing lines, glass inclusions and the flatness or degree of undulation.

Photonics (microscopic research)

To study the raw materials and the silver stain layers of the windows, two non-destructive spectroscopic methods were employed, i.e., UV-VIS-NIR absorption spectroscopy and portable X-ray Fluorescence spectroscopy (p-XRF). For both techniques, some minor and major actions needed to be taken before we could apply them to the collection.

* The spectroscopic measurement set-ups had to be adapted in such a way that the panels of this collection could be measured. This task included the implementation of special museum foams in the set-up on which the panel was (softly) carried during the measurement process.

* A new approach must be applied of measuring the thickness of the glass in the centre of the panel. Some parts of the optical research required the normalization of the recorded spectrum to the thickness. The so far applied method employing a Vernier caliper could not be used in this case. Moreover, this type of device might damage the panel. The selection of the method that was finally used in this project, was made based on the feedback we received from Dr. Claudine Loisel (glass specialist at the Historical Monuments Research Laboratory in Champs-Sur-Marne, France and member of the follow-up committee). The decision was made to purchase an ultrasonic test gauge. Tests were performed to define the correct measurement procedure.

* The good measurement conditions for the p-XRF device must be defined and worked out. After the first tests, it turned out that the standard deviations were unacceptably high. With the feedback of Prof. Ian Freestone (the external international partner) it was decided to design and fabricate a nose which is connected to the p-XRF device and which should ensure a constant distance between the window and the measurement head and as such minimises the analysed variability in the recorded signals. The measurements confirmed the reduction of the standard deviation values. Since it was the first time that the VUB researchers applied the use of p-XRF to study glass materials, the necessary calibration curves were missing. Therefore, actions needed to be taken to calibrate the device. Calibration lines were defined for 10 major elements (K, Ca, Mn, Fe, Co, Cu, Rb, Sr, Zr, Ag) based on the recordings of five reference standards (Corning A and D, NIST 610, 612, 614).

* A feasibility study had to be made to define the type of window features that could be researched with UV-VIS-NIR absorption spectroscopy. Because the measurements of the first project year showed that characterizing the sanguine and grisaille layers with optical spectroscopy is difficult (due to the high absorption), it was decided to focus on the bare glass, the framework glass and the yellow stained parts.

* The analysis of the measurements made on the silver-stained parts showed that for darker stains the silver band could not be reconstructed. Therefore, we had to replace the optical spectrum analyser used in the original set-up (portable – array-based device - Avantes) with a more sensitive one (transportable – scanning-based – Instrument Systems). The 'transportable' character of this device (instead of being 'portable') made that measurement sessions needed to be well planned and this in consultation with the other people working in the workshop. Despite the higher sensitivity of the new set-up, the measurement times drastically increased (~10-15 minutes/measurement instead of ~ 1 minute). Therefore, it was decided to proceed with the original set-up (Avantes spectrum analyser) to study the bare glass parts and to use the set-up with the advanced optical spectrum analyser for the silver stain studies (Instrument Systems equipment).

* Evaluation of the potential interest of applying the optical measures that are linked to the iron ion concentrations for glasses with a post-medieval signature, required the combination of different research outcomes that were generated during the project. These were:

- The optical measures (intrinsic colour, UV Absorption Edge Value and the absorption at 1100 nm) that were calculated from the recorded UV-VIS-NIR absorption spectra.
- The dating (and origin) assignments that arrived from the art-historic research.
- The iron concentrations that were obtained from the LA-ICP-MS analysis of the sampled pieces.

* Already very early in the project it was confirmed that the fingerprinting cobalt absorption bands could be observed in the recorded spectra of the non-figurative naturally coloured and decoloured plain glasses and first observations showed qualitative differences in absorption strength. Therefore, there was a need to develop a non-destructive method to quantify the cobalt levels. By benchmarking the LA-ICP-MS cobalt concentrations with the characteristics of the cobalt absorption bands observed in the recorded spectra, we were able to construct a calibration line that allowed us in a next step to estimate the cobalt concentrations immediately from the recorded spectra.

* To study the link between the applied silver staining technology and the resulting spectral shape of the silver nanoparticles, we needed samples that were fabricated under known conditions. Therefore, a survey had to be made of existing custom-made samples. Two people kindly offered us their materials for study within this project. These are:

- Dr. Kristel de Vis (University of Antwerp - UA) – a collection of ~85 samples (published in (Jembrih-Simburger et al., 2002)). Soda-rich samples were stained with different silver salt (concentrations) at different temperatures. For all samples, the binding agent was yellow ochre.

- Mr. Kenneth Leap (USA artist) – a collection of ~200 samples containing samples with different silver salt types or silver-copper mixtures. All samples were prepared at the same temperature with a gradient of concentration. For these samples, the composition was again rich in soda and in all cases a red ochre binding agent was used.

We are very grateful to both people for grating us permission to study their material.

With the above-mentioned set-ups, we started the optical measurements on the roundels and the rectangular panels. The consortium (with the received feedback from the follow-up committee after the first project year) decided to focus on the roundel collection. For each panel, potential interesting points were selected. Two examples are given in Figure 5. After the measurements, a first step of the analysis process was to group the recorded spectra according to their spectral shape. In a next step the spectral patterns were studied. At the beginning of the project, the panels were measured without applying a specific selection criterium. However, during the project, a more focused selection of the roundels of interest could be made.

Figure 5: Illustration of the positions of the different measurement points

Finally, driven by the outcome of the art-historical and macroscopic research, where the difference between sanguine and grisaille was questioned, measurement sessions were performed to give a conclusive answer on the type of applied painting based on recordings with the p-XRF device.

4. SCIENTIFIC RESULTS AND RECOMMENDATIONS

Conservation

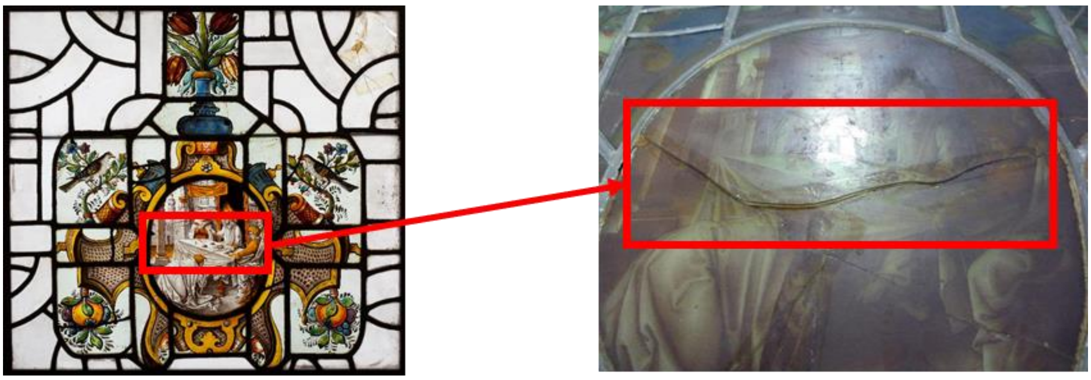
The new storage room was installed in the museum one floor below ground level. In the course of 2018, the installation of the storage room has been established and soon after, all pieces of the collection had been moved to this room. The evaluation of the humidity and temperature results led to the installation of a humidifier to stabilise the relative humidity to a level of 45 %.

After the installation of the new storage room, an inventory of the stained-glass collection was carried out to compare the existing files to the reality. A new location has been given to each item. This inventory made it possible to determine the items that needed to be photographed and to establish a list of items that needed to receive a new inventory number.

Over the course of the project, coordinating and organizing the workflow in the new storage room allowed each partner to conduct their own research on each piece in the collection. To do this, we kept track which work of art was studied and by whom in order to know the progress of each researcher and to be able to anticipate future work. The aim was also to reduce the number of manipulations and to guarantee the safety of the entire collection.

During the research on the state of the collection, the findings were described in well-defined documents including the related schemes. For each panel, a unique file was generated. For each piece suggestions were made concerning the type of preservation and a first cleaning was carried out.

For twenty pieces an urgent restoration treatment was carried out (removing the frame and /or removing the double glazing). Figures 6-8 show some illustrations of the situation before and after treatment.



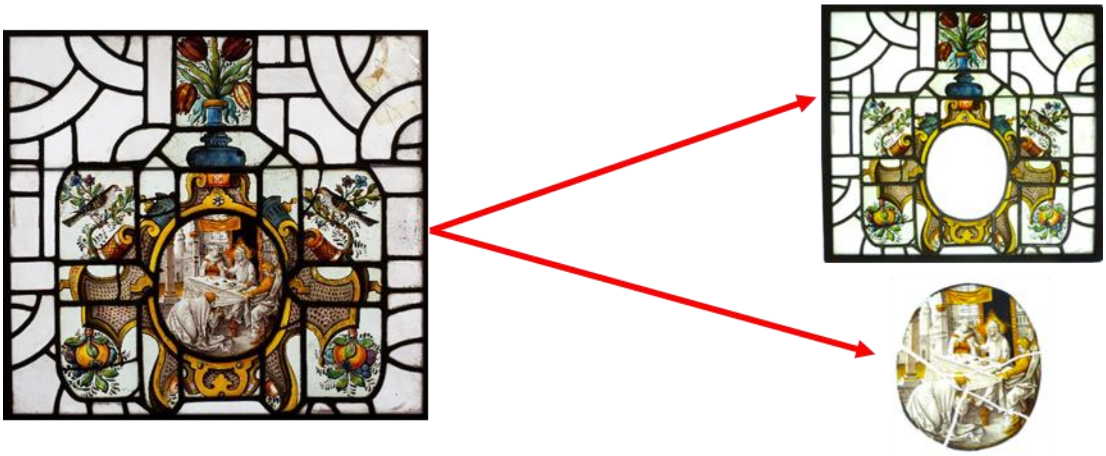


Figure 6: Illustration of the removing of roundel I.A. 4033 with the aim to stabilize the piece physically (Top picture – before, Bottom picture – after)

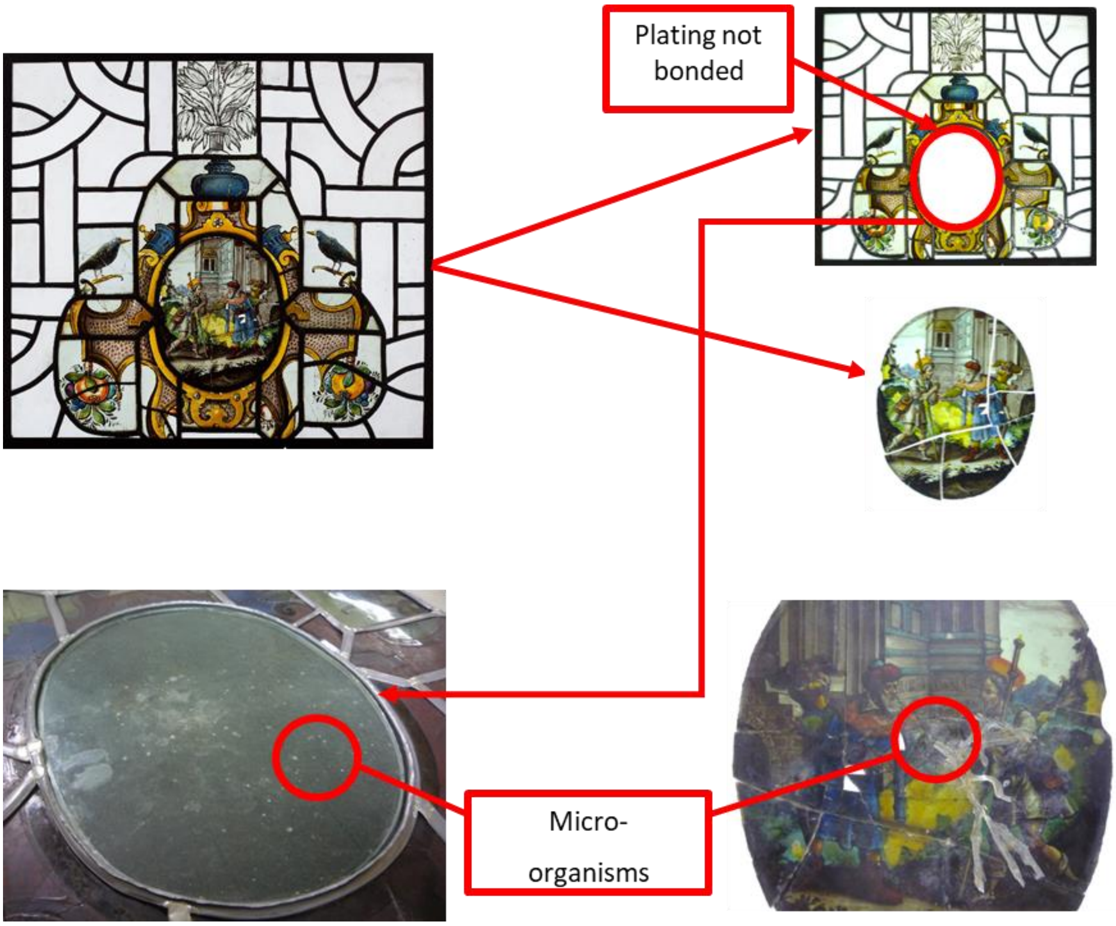


Figure 7: Illustration of the removing of roundel I.A. 4030 as a result of the presence of micro-organisms

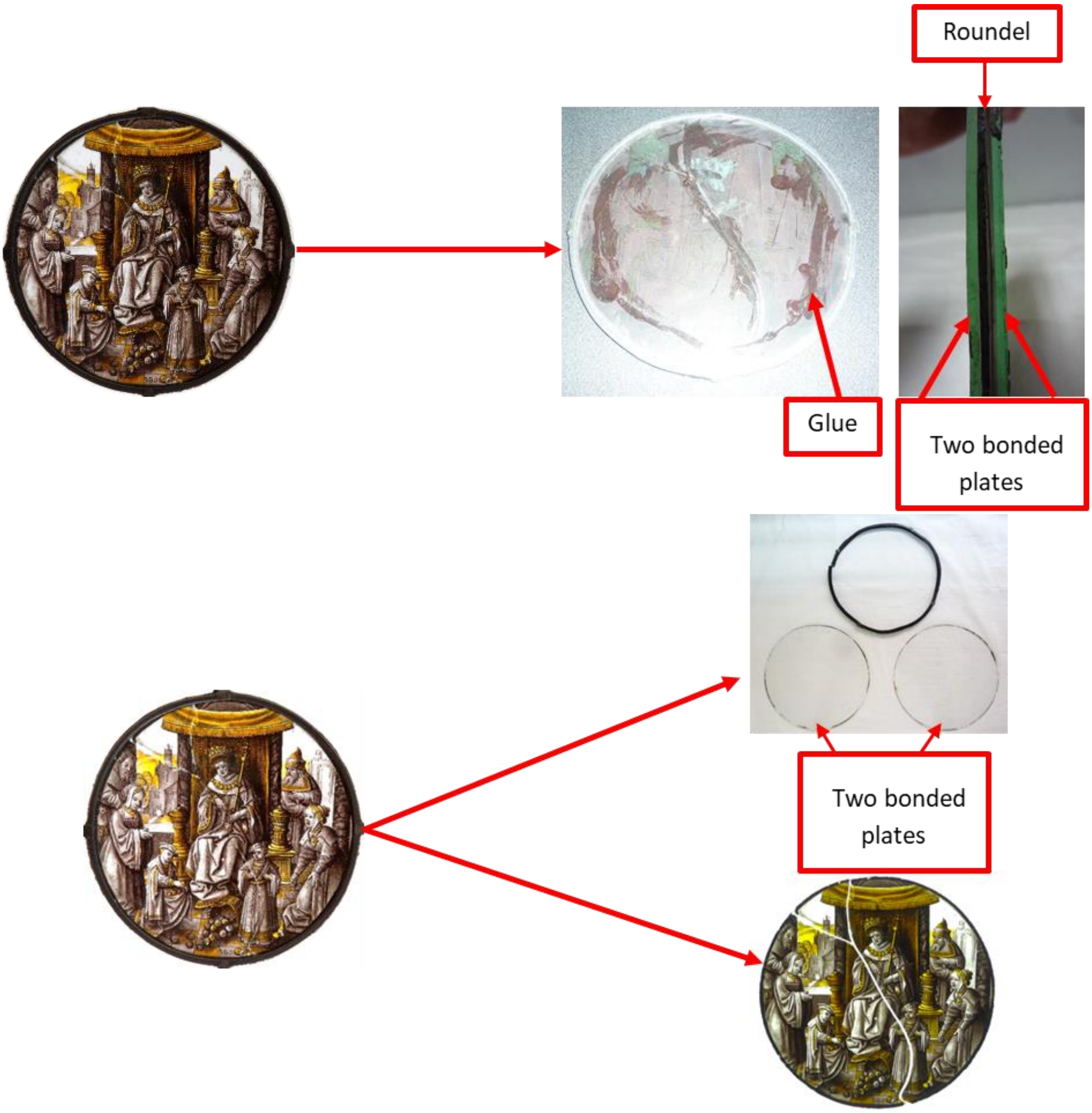


Figure 8: Illustration of the removing of roundel I.A. 980 which was performed to avoid mechanical stresses (Top picture – before, Bottom picture – after)

Fourteen panels (among which 7 are exhibited in the exhibition held in the museum from June 2021 « Medaillons ») were restored. The goal of the restoration process was to give back a visual unity to the object. Therefore, the fragments were glued together. The fragments were glued with a 2-component epoxy resin (Epotek® 301-2). For each item, a restoration report including all the details of the treatment, is made available. Figures 9 and 10 show the roundels I.A. 4016 and I.A. 6340 before (a), during (b) and after (c) their restoration, respectively.

a b c

Figure 9: Illustration of the restoration of roundel I.A. 4016, before (a), during (b) and after (c) restoration

a b c

Figure 10: Illustration of the restoration of roundel I.A. 6340, before (a), during (b) and after (c) restoration

Inventory

Collecting old research results

With the help of Dr. Helena Wouters (KIK-IRPA), we were able to expand our database on the existing literature on past archaeometry research actions on material from other Belgian sites. The outcome of this part of the research resulted in two main conclusions. This literature scouting confirmed our earlier findings (see also objectives) that only limited information is available on glass consumption in the Low Countries and that up to now no chemical analyses were made on pieces of the A&H collection.

Creation of the inventory lists

Next to the state reports that were created (see section on conservation), the research outcomes on the study of the inventory of the A&H collection, were saved in three different files. This approach was applied to maximize the accessibility of information by the different actors in the field. In a first step, an Excel table was created containing the entire inventory list. To complete this list, an initial document was downloaded from the search engine ‘Belgian Arts Links and Tools’ (BALaT). This Excel list was completed during the first project years and the information was added to BALaT. Once the Excel file was finished, it was shared with all project partners and the information was added to a second database ‘Carmentis’, which is the online museum catalogue of the A&H museum. In addition to the text information, BALaT and Carmentis contain high resolution pictures. These pictures were all recorded in the framework of this project.

One of the key actions of the FENESTRA project was the systematic photography of the stained-glass collection. The last photographs were taken very recently, in the last days of August 2021. This last mission allowed to rephotograph the pieces that benefited from a conservation-restoration treatment, resulting in an altered appearance. In total, more than 700 photographs were taken, which formed the basis for the work carried out by all the partners in the project. At the same time, the inventory of the stained-glass windows was updated.

The additional advantage of seeing, examining, and photographing everything was the detection of some pieces that were insignificant at first sight, but later on proved to be interesting, such as a glass cross (inv. no. 2021.3.46, ancient inv. SN 2014.11), made after the model of a workshop operating at the end of the 17th or beginning of the 18th century, probably in Limburg.

Historical research

History of the collection

The historical research made through literature and archives allowed us to identify different phases in the history of the development of the stained-glass collection of the Art & History museum. It also revealed the prominent role assumed in its constitution by the private collectors on the one hand, by the curators on the other hand, as well as the intervention of various art dealers. The research findings will be published as an introduction to the volume of the *Corpus Vitrearum* devoted to *Médaillons, peintures sur verre et panneaux de vitraux de petites dimensions conservés dans les institutions publiques à Bruxelles* (in preparation).

The collection was formed during three periods.

The stained-glass collection of the Royal Museums of Art and History includes nearly 400 objects dating from the Middle Ages to the 20th century. This remarkable ensemble was formed in the first years of the existence of the *Musée d’Armes anciennes, d’armures, d’objets d’art et de numismatique* that was created shortly after the independence of Belgium (1830).

. National Gallery (1835-89): constitution of the core of the collection

In search of legitimation, the Government set up several measures aimed at establishing the young Belgian nation on solid historical foundations, among which this *Musée d’Armes, d’Armures et d’objets d’art* whose collection was quickly enriched by the sending of items from local excavations, as well as by important acquisitions. In 1844, the sale of the cabinet de curiosités of Joseph Van Huerne de Schiervelde et de Puyenbeke enabled the museum to purchase an initial series of roundels (Figure 11), thanks to the intervention of art dealer Etienne Leroy. Five years later, a new ensemble was acquired from the same dealer.

Figure 11: Illustration of a roundel that originally belonged to the collection of Joseph Van Huerne

The archival research revealed how the Belgian state in the later periods also succeed to purchase parts of major private collections.

In 1851 a part of the collection of Joan D'Huyvetter entered the museum, including more than 20 stained glass windows dating from the 16th, 17th and 18th centuries.

In 1853, when Mrs Van Parys died, the museum bought items from the ensemble of paintings and artworks that were gathered by her husband who died in 1829. One hundred thirty-seven numbers correspond to painted glass. Some of these numbers group several items like roundels and unipartite panels. The museum purchased 19 items: 16 roundels dating from the 16th century, with the exception of a 17th c. Nativity, and 2 unipartite panels.

In 1861, the purchase of the cabinet de curiosités of the Brussels collector Gustave Hagemans enabled the stained-glass collection of the museum to include some 20 remarkable new pieces including the window shown in Figure 12.

Figure 12: Illustration of a panel that originally belonged to the collection of Gustave Hagemans

When one of the three most important collections of stained-glass in Leuven, assembled by Jean-Baptiste De Fré, was sold in a public sale in 1866, 23 pieces were selected for the museum's stained-glass collection.

In 1874 and 1878, the museum had the opportunity to acquire a series of stained-glass windows belonging to general Meyers. This series contained a collection of items that illustrate the art of stained glass in our regions during the 17th century, as well as various elements gathered in panels of a window.

During the decades 1860 et 1870, the stained-glass collection of the museum also increased thanks to a few donations and, above all, could integrate a very important assemblage of 16th and 17th century-stained glass windows from the hospital Sint-Elisabeth in Lier.

. Gallery of Decorative Arts (1890-1930)

In the meantime, a project started to provide Belgium with a museum of decorative and industrial arts, like the South Kensington museum in London, intended to train the craftsman and develop the 'good taste' of the public. In 1880, this led to the construction of the *Cinquantenaire*, according to plans made by the architect Gedeon Bordiau.

In the early 1880s, the North wing of the Palace housed the plaster collection of the 'Museum of Exchanges' created for this purpose. In 1889, it was decided to also transfer the collection of 'antiquities' from the Hal gate to form the Museum of Decorative and Industrial Arts.

In the perspective of a museum intended for education, offering to the public objects chosen for their beauty which could serve as models for artists and industrials, the museum also integrated artworks from abroad.

The accession files keep track of certain acquisitions in the field of stained glass from abroad. In 1884, for example, the museum purchased three Swiss panels at the sale of Albert de Papart in Cologne (Figure 13). In 1911, a dozen panels were added, dating from the middle of the 16th century until the beginning of 17th century, thanks to the bequest of Gustave Vermeersch.

Figure 13: Illustration of a panel that originally belonged to the collection of Albert de Papart

During this period, some important donations also occurred. The donation made by the archaeologist Louis Cavens gave to the collection seven beautiful heads from the stained-glass windows of one of the chapels of the cathedral Saint Michel and Gudule designed by the Brussel painter Bernard van Orley in the 16th century. The association of The Friends of the museum in addition offered a roundel signed by Dirk Vellert and dated 1517 (Figure 14).

Figure 14: Roundel signed by Dirk Vellert and donated by the association of The Friends of the museum

The archives also show how the direction of the museum found in the meantime means to respond to the proposal of the administration of the Civil hospices civils of Leuven made in 1907, which would complete the collection with an important assemblage of roundels and panels coming from various institutions in Leuven.

. *Scientific collection (from 1930)*

The end of the 1920s and the beginning of the following decade constituted a period of important changes for the museum that modified its name in *Musées royaux d'art et d'histoire*. It engaged itself in the global study of civilizations and programs excavations in Belgium and abroad. Under leadership of archaeologist Jean Capart, its primary vocation as a 'conservatory for endangered objects' was now coupled with a 'scientific research' mission.

This new direction is clearly observed in the preserved accession files of stained-glass windows as well as in the correspondence of the curators responsible for this collection. Under the leadership of curator Jean Helbig, acquisitions are from the end of the 1930s rather rare and more targeted. They mainly concerned types of pieces less present until then in the collection, i.e., monumental stained-glass panels such as that of the 'gilde des Arbalétiers' from the Church St Rombaut in Malines or two windows from the cloister of Park Abbey painted by Jan de Caumont in the 17th century (Figure 15). The priority is again given to national art.

Figure 15: Stained window that entered the collection under the leadership of curator Jean Helbig

If roundels and small painted panels were still purchased for the collection (like e.g., those from the Aubry collection), their acquisition had to be scientifically justified. For example, the small panel illustrating the Geometry, however in poor condition, was purchased because of its interesting iconography.

In addition, Jean Helbig, succeeded by Marleen Van Cauwelaert, tried to orient the collection towards contemporary art by purchasing artworks form living artists. However, this effort would not continue because of the preference given at that time to Art Nouveau and Art Deco productions which until then had little presence in the collection.

The collectors of stained-glass windows

The history of the museum's stained-glass collection inevitably leads to a focus to other important actors in the artistic field: the collectors. They have various profiles, as the following three examples demonstrate (Figure 16).


a

b

c

Figure 16: Pictures of three key collectors that are linked to the A&H collection, Joseph Van Huerne (a), Gustave Hagemans (b) and Gustave Vermeersch (c)

Example 1: Joseph Van Huerne

This notable who became a nobleman in 1822, had a great fortune constituted by numerous land holdings in Flanders. Benefactor of many religious institutions, he was also a patron of several painters of his time and gathered, in his residence located in Bruges and his property in Izegem, a library and a large collection of artworks. The catalogue of the sale of the collection Van Huerne (130 pages) shows its diversity. It consisted of artworks and archaeological objects (« artificalia »), ethnographic objects (« exotica ») and natural history items (« naturalia »). In addition to pieces in ivory, enamel, pottery, bronze or glass, the collector from Bruges owned various stained-glass windows: rectangular painted panels, fragments from religious windows and also roundels.

Example 2: Gustave Hagemans

Gustave Hagemans (1830-1908) was the grandson of a banker, founder of the *Société Générale de Belgique*, which he inherited at the age of 21. His considerable fortune allowed him to build up a major collection in a short period of time. He first lived in Liege, where he studied law and afterwards moved to Brussels in 1861. He was ruined in 1875. He was an important landlord in the region of Chimay and Beaumont and became a liberal deputy for Thuin from 1866 to 1878.

From 1854, the young amateur archaeologist began to write the catalogue of his collection. This included not only objects from the Middle Ages and the Renaissance, but also Egyptian, Greek, Etruscan and Roman artworks. If it is difficult to determine precisely where the Classical Antiquities of the Hagemans collection originate from. It is assumed that some of these pieces were purchased by the collector in Italy where he was between 1856-57 and 1860 and in the Orient where he travelled in 1862.

In March 1857, Gustave Hagemans made a first donation of 10 pieces and sold some other objects to the Museum situated in the Hal Gate. This choice of the Brussels museum is thought to be motivated by the close relationship he had with its curator Antoine Schayes, his 'friend and disciple'. After his return from Italy Gustave Hagemans sold a large part of his collection to the same museum.

The collector seemed to have particularly appreciated the art of stained glass, which he even would have practiced himself. Thanks to him, the museum's collection expanded with the remarkable artworks, including very old panels, a series of eight portraits of the Habsburg family and only two roundels. If we add these objects to those which had already been purchased in 1857 (three Swiss panels and a small unipartite panel), it comes to a total of 20 stained-glass panels.

Example 3: Gustave Vermeersch

Gustave Vermeersch (1841-1911) was the only son of Jacques Vermeersch, jurisconsult in Gent. Following his marriage to a young woman from the French nobility, he settled in Brussels. Rentier, Vermeersch had a passion for ancient objects. In 1880, he participated to the organisation of the first exhibition dedicated to ancient art in the brand new *Cinquantenaire* Palace. Eight years later, he became involved in the Exhibition 1888 as a member of the organizing committee. He wrote a visitor's guide and lent many pieces from his personal collection. In 1880 he joined the supervisory committee of the Museum of Decorative and Industrial Arts. In addition to expert missions, he negotiated the purchase of artworks from individual collectors or public sales. Moreover, he was personally involved in the project that was born after the Universal Exhibition of 1897, to build a new wing for the decorative arts collections. The collector, who had no descendants, was undoubtedly already working in the perspective of the legacy of his entire collection after his death in 1911.

The Vermeersch collection comprised around 3000 pieces of decorative arts, mainly from Europe, dating from the Middle Ages to the 18th century. It testifies of the various interests of Vermeersch: ceramics, 15th and 16th century sculpture, metal objects, weapons, furniture, etc. Regarding the stained-glass windows, the assemblage shows the collector's concern to gather artworks which are representatives or civil stained glass in the 16th and 17th centuries.

In the collector's archives there are a few invoices which mention the purchase of some stained-glass windows, but to not permit their precise identification. In any case, they testify of an interest in this subject throughout his 'carrier' as a collector.

The curators and their relationships with collectors and art dealers

Ensuring its management, the curators are key players in the history of the museum's stained-glass collection. The first curator, Antoine Schayes (1808-1859), was an historian from Leuven and a forerunner of the history of architecture in Belgium. Under his leadership the '*antiquités, objets historiques ou de haute curiosité*' are placed on the second floor of the Hal Gate. The first catalogue of the collections he wrote in 1854 listed 69 pieces placed in Three windows and two frames.

According to the archives, Schayes had a close relationship with art dealer Etienne Le Roy, through whom stained glass windows were purchased at the sales Van Huerne, D'Huyvetter and Van Parys. Concerning this last, Etienne Leroy was responsible for the two public sales of October, while Schayes himself wrote the catalog.

From 1859, the management of the museum's collections was given to the historian Théodore Juste, under supervision of a steering committee. More than ever concerned with the development of research devoted to the history of Belgium, the government wanted to create, within the museum, a gallery dedicated to the illustration and glorification of the national past. Minister of Interior Affairs, Charles Rogier, asked Théodore Juste to gather a collection entirely devoted to '*l'histoire parlante de la vie privée de nos aïeux*'.

Beside the Hagemans collection, Théodore Juste continued his search for artworks on a 'national' level. In 1861, a small panel depicting the Seraing coat of arms was purchased. The next year, a 17th century panel with the coat of arms of the Van de Werve family was purchased at the Ford sale. In

1868, two panels from the beguinage of Sainte-Catherine in Tongeren were bought at the sale of the Brussels collection of E.F. Slaes-Cockx . In the museum's archives, we also found the sales catalogue of the De Fré collection (1866) annotated by Juste who selected 23 items for the museum.

When Théodore Juste prepared in 1878 the fourth edition of the museum's catalogue, the stained-glass collection increased to 127 items, i.e., 40 more than in the first edition. This considerable increase of the collections necessitated new arrangements within the museum.

Archaeologist and deputy curator of the Hal Gate museum since 1886, Joseph Destrée (1853-1931) succeeded to Théodore Juste and moved the collections from the Hal Gate to the curved gallery of the North wing of the *Cinquantenaire* Palace.

In the museum's archives, a series of accession files provided a better understanding of how the new curator had to deal with the steering committee of the Decorative Arts and more particularly with one of its most influential members, the collector Gustave Vermeersch, in charge of negotiating many purchases for the museum.

He also had close ties with the patron, Count Louis Cavens, who was also a member of the Brussels Archaeological Society.

After World War I, priority was given in the museum to the completion of the rooms dedicated to the collections of decorative arts. On the first floor of the Nerviers building a 'circuit' from the Gothic period to the 18th century presented furniture, tapestries, sculptures, silverware and some stained-glass windows probably selected by curator Marcel Laurent who succeeded Joseph Destrée in 1920.

Under the leadership of Marcel Laurent, a specialist in Mosan art, the section did not buy any stained-glass window. Marthe Crick-Kuntziger who succeed him, quickly entrusted the collection to Jean Helbig.

Chosen by Jean Capart himself in 1929, Jean Helbig had a university and artistic training. He officially joined the scientific staff of the museum in 1937 and was entrusted with the collection of stained-glass windows which he studied, classified, restored and installed in exhibition rooms.

The archives testify of the many contacts he maintained with art dealers both in Belgium and abroad and with restorers

After Helbig retired in 1960, the stained-glass collection was entrusted to Josy Muller, an historian from Namur and former librarian in the museum of Mariemont. If he devoted himself mainly to Mosan goldsmithing and medieval brass work, Muller also managed the collection of stained-glass windows, as well as that of precision instruments. A such, he set up a new presentation of these collections in the museum cloister at the end of the 1960s.

When Marlene Van Cauwelaert took in charge the stained-glass collection in the early 1980s, she orientated it towards contemporary art. She also undertook a campaign to restore panels and roundels in the storage rooms.

Art-historical research

The study of the whole collection led to questions, beyond their provenance, about the origin and authenticity of the pieces, their modifications, the subjects depicted, the materials and techniques and their place in the artistic production of their time. A choice of significant examples gives an account of the work done from an art historical point of view.

The origin, modifications, and authenticity of the pieces

One of the major difficulties is that - with a few exceptions - the origin of the pieces is unknown and essential elements are lost, elements which can contribute to ensure the authenticity of the pieces and provide dating elements. On the other hand, the provenance of the pieces is mostly known. Many of them come from private collections, where they were sometimes presented in montages. From the point of view of the authenticity of the pieces, some pieces are problematic. The issue was to distinguish the old pieces from those created later, in the style of the old pieces. In some cases, such as a roundel of the Beheading of St John the Baptist (inv. no. I.A.631) (Figure 17 – left), on the basis of a stylistic analysis, it was possible to establish that the roundel preserved in the Museum is ancient, unlike its counterpart in Enghien, which may have been made during the Second World War, during the restoration of the window by the Charlier workshop in Leuven (Figure 17 - right). In other cases, however, it is difficult to know. The roundel representing a Nativity (inv. no. I.A.1606) (Figure 18 – left) has its counterpart in the Leuven Museum (Figure 18 - right). The question is whether we are dealing with an original (or at least an old piece) and a copy or with two old pieces. The composition must have been very successful, given the numerous copies recorded.


Figure 17: MRAH, I.A.631. Beheading of St John the Baptist, c.1510-1525 (left). Enghien, castle, Beheading of St John the Baptist, in a monumental stained glass, 19th c. (right)


Figure 18: MRAH, I.A.1606. Nativity, Anc. coll. De Fré (Leuven), 1866 terminus ante quem (left). Leuven, Museum M, 16th c. (right)

The question of the authenticity arises in particular for pieces from Leuven, acquired in 1866 at the Defré sale and in 1906 by purchase from the Hospices Civils de Louvain. In some cases, it appears that a pastiche is very likely (e.g., inv. no. I.A.1614, I.A.4013, I.A.4018)- (Figure 19); in other cases, it is less clear. The pieces in question (e.g., inv. no. I.A.1612, I.A.1618) (Figure 20) are considered "doubtful" by Paul Victor Maes, a specialist of Leuven-stained glass, but they show coherent pictorial techniques compatible with ancient work and the appearance of the glass is that of ancient glass. In these cases, it was decided to propose a wide dating range.


a


b


c

Figure 19: Roundels from Leuven considered as not ancient. MRAH, I.A.1614. Beheading of St John the Baptist. Anc. coll. De Fré/Leuven, 1866 terminus ante quem (a). MRAH, I.A.4013. Marriage of the Virgin. Prov. Hospices civils of Leuven, 1907 terminus ante quem (b). MRAH, I.A.4018. Story of the Prodigal Son. Prov. Hospices civils of Leuven, 1907 terminus ante quem (c)

Figure 20: Roundels from Leuven (anc. coll. De Fré/ auction in 1866), suspected by P.V. Maes to be from the 19th Century. MRAH, I.A.1612. St Anna, Mary and Child, 1866 terminus ante quem (left) and MRAH, I.A.1618. Donors, Virgin and Child, 1866 terminus ante quem (right)

For the pieces that are considered to be of a more recent date or to be doubtful, the analyses done by the analytical research show a compatibility with 16th century glass having an HLLA composition. They are not repainted pieces, but the possibility of the use of an old glass is not excluded. To be on the safe side, all the pieces whose dating is not certain, were dated with a terminus ante quem, which is the year in which the piece entered the Museum collections.

A very interesting case is the series of portraits of members of the Habsburg family (inv. no. I.A.979) (Figure 21). They were bought by the Museum on the sale of the Hagemans collection in 1861 and are said to come from a castle in the area of Huy. It was only recently that they could be studied in detail, after the pieces were removed from the paper on which they were glued. The macroscopic and the microscopic research findings as well as the observations of the art-historical research have confirmed their age. These pieces, for which the art-historical research assigned a date back to the

16th century, clearly date from different periods and some of them show affinities with pieces painted in Liege in 1530.

Figure 21: MRAH, I.A. 979. Portraits of members of the House of Habsburg, 16th c. (1525-50)

Materials and techniques used

Apart from the silver stain, the colours applied to the glass are vitrifiable colours. Generally speaking, one can distinguish grisaille, sanguine and enamels. But it is much more complex. There is a great variety of paintings, of different colours, black, grey, brown or brownish, orange, red or reddish, and it is sometimes difficult to know whether, for example, one has a reddish-brown grisaille or a sanguine.

The colours of the stained glass are applied on both sides of the glass: on the obverse, the grisaille, enamels and sanguine; the silver yellow on the reverse, sometimes with grisaille and sanguine. All of these contribute to the creation of particular effects. Sometimes, the shading is reinforced on the reverse with grisaille. In the Low Countries, enamel was systematically applied to the obverse, whereas in Swiss stained glass, we noticed that it was systematically applied to the reverse.

The use of what may be a cold paint is worth mentioning. It can be seen particularly well on a panel from the hospital of Saint Elizabeth in Lierre (inv. no. I.A.679). The cold (?) green colour is used for the vegetation.

Particular techniques have been observed: insertion of masterpieces without the use of lead (I.A.2247d) (Figure 22)) and engravings, which is used in Swiss stained-glass windows in abundance and with great virtuosity (V.2761) (Figure 23).

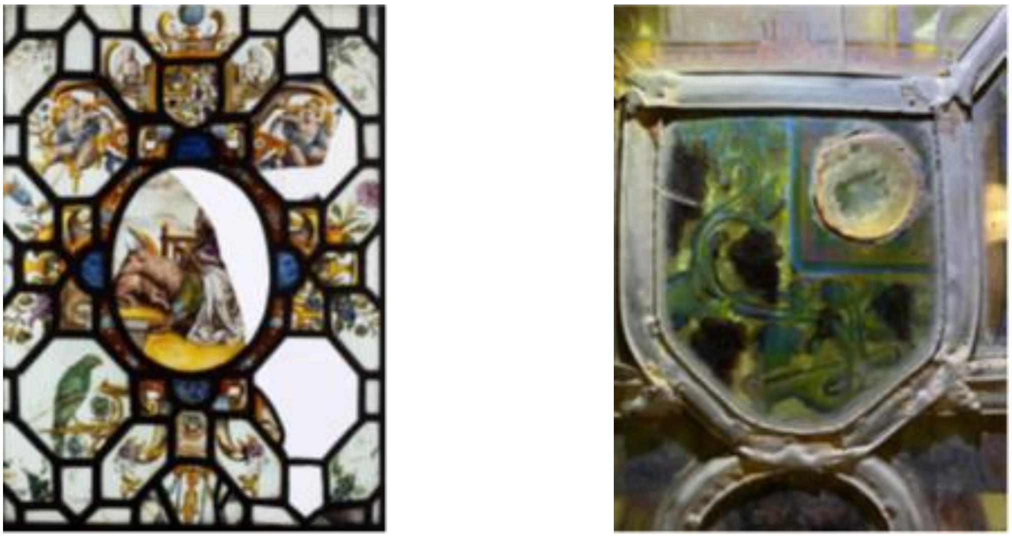


Figure 22: MRAH, I.A.2247d. Evangelist Saint Luke

Figure 23: MRAH, V.2761

The subjects depicted

The iconography of the windows in the collection were not the subject of specific studies, and the titles of the works are generally those given in the old sales catalogues or inventories. The project provided an opportunity to clarify certain subjects or themes. Four examples have been chosen to illustrate this.

<u>Illustration 1</u>

Four scenes from the Grisélidis story were identified (inv. no. I.A.569.B, I.A.571, I.A.569.A, I.A.681) (Figure 24). This story dates to the Middle Ages. Boccaccio and Petrarch gave it immense popularity all over Europe in the 14th century. Boccaccio tells the story of Grisélidis in the last novella of the Decameron and Petrarch made it the subject of a Latin story, which inspired Geoffrey Chaucer for one of his Canterbury tales. There are several indications that the text of Petrarch was used here rather than the one of Boccaccio.

inv. MRAH I.A.569.B

inv. MRAH I.A.571

inv. MRAH I.A.569.A

inv. MRAH I.A.681

Figure 24 – The story of Griselda

The story, which takes place in the 11th century, relates the trials that Griselda must overcome to prove her unfailing loyalty to her husband, the Marquis Gualtieri di Saluzzo. Four roundels, which are shown in the exhibition, illustrate the story precisely: (1) (inv. no. I.A.569.B) one of the richest lords of Piedmont, the Marquis Gualtieri di Saluzzo, forced by his subjects to marry, chooses Griselda, a poor shepherdess who was living with her father Janicole. (2) (inv. no. I.A.571) The Marquis dressed Griselda in fine clothes and jewels and took her to the castle. The Marquis Gualtieri di Saluzzo tests his wife's fidelity by submitting her to various tests that have been contrived, including the dissolution of the marriage and her repudiation so that he can take a new wife. The Marquis pushes the wickedness so far as to ask Griselda to prepare the wedding, and (3) (inv. I.A. no. I.A.569.A) Griselda is seen here happily welcoming the new wife. (4) (inv. no. I.A.681) On the wedding day, the Marquis Gualtieri di Saluzzo reveals to Griselda that what she has endured is a farce and that his remarriage is a fake. Griselda is re-established as his lawful wife and she 'dies of joy' at this announcement.

The story of Griselda must have been a success in stained glass, and the suite in the Museum is not the only one to illustrate the theme. The initial scene is also illustrated in a roundel in the Charlier collection and there are surviving drawings of the theme.

<u>Illustration 2</u>

The roundel identified as 'Temperance' (inv. no. I.A.43) (Figure 25), according to the inscription, actually depicts 'Prudence', with a coffin on her head, a mirror, a sieve in her hands, the emblems of the Passion on a parchment hanging from her shoulder, while a bag of coins is spread at her feet. These emblems were first associated with the virtue of Temperance in the early Middle Ages, in a fifth-century text, and were not illustrated until the mid-fifteenth century. The symbols can only be understood through the fifteenth century text, which states that Prudence requires thinking often of the death (thus the coffin), being aware that one's appearance is changing (thus the mirror), remembering the Passion of Christ (thus the Arma Christi or Passion symbols), separating the grain from the stalks in good time (thus the sieve), and guarding against the accumulation of wealth, which brings sorrow and disappointment (thus the bag of money she is treading on). This roundel thus clearly shows the relationship between stained glass, manuscript sources and illumination.

Figure 25: MRAH, I.A.43. "Temperencia", c.1500-1525

Illustration 3

This rectangle has so far been identified as a representation of Saint Barbara (inv. no. I.A.412) (Figure 26). Instead, we propose that it should be seen as St Susanna of Rome, based on the model that was obviously used for the roundel, a print after the Antwerp painter, draughtsman and engraver Theodore Van Thulden, a collaborator of Rubens. The silhouettes of the castle and the bridge of St. Angelo are clearly visible in the rectangle, faithfully transposed from the engraving, and remind us that St. Susanna was the niece of Pope St. Caius. At the saint's feet, the crown and a lictor beam remind us of her refusal to marry Maximian, the son of the emperor Diocletian.

Figure 26: Pieter de Bailliu (I) after a drawing by Theodoor van Thulden, 1623-1660 (left). MRAH, I.A. 412, c.1625-1675

Illustration 4

The fourth and last example is an illustration of the proverbial 'sitting between two chairs' (inv. no. I.A.978) (Figure 27). The representation of the stained-glass window can only be understood if we go back to the original proverb, which is 'Sitting between two chairs in the ashes', the meaning of which is 'Missing the opportunity'.

Figure 27: MRAH, I.A. 978. c. 1500-1525 (left). The Flemish Proverbs – 1559 (117 x 163 cm, Berlin, Staatliche Museum Berlin) (right)

The works and the art of their time

Stained glass windows are naturally part of the art of their time, from which they borrow a lot.

Borrowing is often done through engraving. We thus witness the transfer of motifs, compositions, forms and styles. Many artists are thus associated with stained glass: Dirk Bouts (inv. no. IA1603) (Figure 28), Hugo Van der Goes (in. no. I.A.567) (Figure 29), Albrecht Altdorfer (inv. no. I.A.678) (Figure 30); Albrecht Dürer (inv. no. I.A.419) (Figure 31), Martin van Heemskerck (inv. no. I.A.1771) (Figure 32), Martin de Vos (inv. no. I.A.691) (Figure 33), Theodore van Thulden (inv. no. I.A.412), Jacques Callot and Jansz Quast (inv. no. I.A.564) (Figure 34), among others.

Figure 28: St. Bernard, right panel of the painting ‘The Martyrdom of St. Erasmus’, by Dirk Bouts, c. 1460 (left). MRAH, I.A. 1603. Saint Bernard, c. 1480-1510 (right)

Figure 29: Circle of Hugo van der Goes, Tobias Drawing the Fish from the water, 1480-90 (left). Tobias at the river Tigris, c. 1500-1530 (right)

Figure 30: Albrecht Altdorfer, Transfiguration of Christ, Germany, c. 1513 (left). MRAH, I.A. 678. Transfiguration of Christ, c. 1525-1550 (right)

Figure 31: Albrecht Dürer, St. Philippus, 1525 (left). MRAH, I.A. 419. St. Philippus, c. 1600-1675 (right)

Figure 32: Jonah sitting under the miracle tree, Philips Galle, after Maarten van Heemskerck, 1566 (left). MRAH, I.A.1771. Jonah contemplating the city of Ninive, c. 1525-1550 (right)

Figure 33: Nativity, print by Antoine Wierix after Martin de Vos, published before 1619 (left). MRAH, I.A.691. Nativity, c. 1600-1650 (right)

Figure 34: After Pieter Quast, 1629-1652 (left). MRAH, I.A. 564, « Seigneur dans le costume de la première moitié du XVIIe siècle », c. 1630-1660 (right)

Leading artists applied their art to stained glass, such as the designer, engraver and glass painter Dirk Vellert, who brought the art of stained glass to a unique level of perfection, as can be seen in this roundel with the depiction of the Triumph of Time (inv. no. I.A.5956) (Figure 35), in the tradition of Renaissance triumphal representations. On the basis of comparisons of painting techniques and compositional principles with other works by the artist, the art-historical research performed within this project, proposed to attribute another roundel to Dirk Vellert or his immediate circle, illustrating a scene from the parable of the prodigal son (Figure 36).

Figure 35: MRAH, I.A.5956, The Triumph of Time, Dirk Vellert, 21 April 1517

Figure 36: MRAH, I.A.692. Dirk Vellert (attributed here), Parable of the Prodigal Son (c. 1530-1545) (left). Amsterdam, Rijksmuseum. Dirk Vellert,The Judgement of Cambyses (1542) (right)

Archaeology (macroscopic research)

During this project, a full macroscopic examination could be made for approximately 80 panels.

One of the main conclusions of this research, was the observation of the occurrence of a huge variety in the number of appearing air bubbles. Some examples of roundels that contained no or only a limited number of bubbles are ‘Griselda’s Tale’ (I.A.571), ‘Saint Nicholas’ (I.A. 677), ‘The Miracle of the Loaves and Fishes’ (I.A. 556B), ‘The Triumph of Love’ (I.A. 566) and ‘Woman, Cupid and Heron’ (I.A. 1797) (Figure 37).

a b c

d

e

Figure 37 – Examples of roundels that contain no or only a limited number of air bubble inclusions. I.A. 571 – Griselda's Tale (a), I.A. 677 – Saint Nicholas (b), I.A. 556B – The Miracle of the Loaves and Fishes (c), I.A. 566 – The Triumph of Love' (d) and I.A. 1797 – Woman, Cupid and Heron' (e)

Illustrations of roundels that contained a large concentration of air bubbles are 'Christ in the House of Martha and Mary' (I.A. 4039) and 'Parable of the Prodigal Son' (I.A. 692) (Figure 38).

Figure 38 – Examples of roundels that contain a large concentration of air bubble inclusions. I.A. 4039 – Christ in the House of Martha and Mary (left). I.A. 692 – Prodigal Son (right)

After the discussion of these findings with the follow-up committee, it was decided to further investigate if those panels that contained many fabrication traces were also characterized by a low-quality painting and less pure raw materials. Further research showed no direct relation between the number of air bubbles and the quality of the painting layers. One example refers to the 'Parable of the Prodigal Son' (I.A. 692) for which the stylistic research unveiled a high-quality painting, but the macroscopic research pointed to the presence of multiple air bubbles. Another illustration concerns the roundel 'The Triumph of Love' (I.A. 566) which has a high-quality painting and almost no fabrication traces, but for which the photonics research indicated the presence of iron impurities and as such the use of less pure materials. The latter is illustrated in figure 39 that relates the number of air bubble inclusions (on a scale from 1 to 5) and the optical measures that gives us an indication on the ion iron impurity levels; the farther away the recorded points are located from the origin of the graph, the more iron ions are present and the less pure the raw material is. An inverse relationship is observed between the purity of the raw materials and the number of appearing air bubble inclusions.

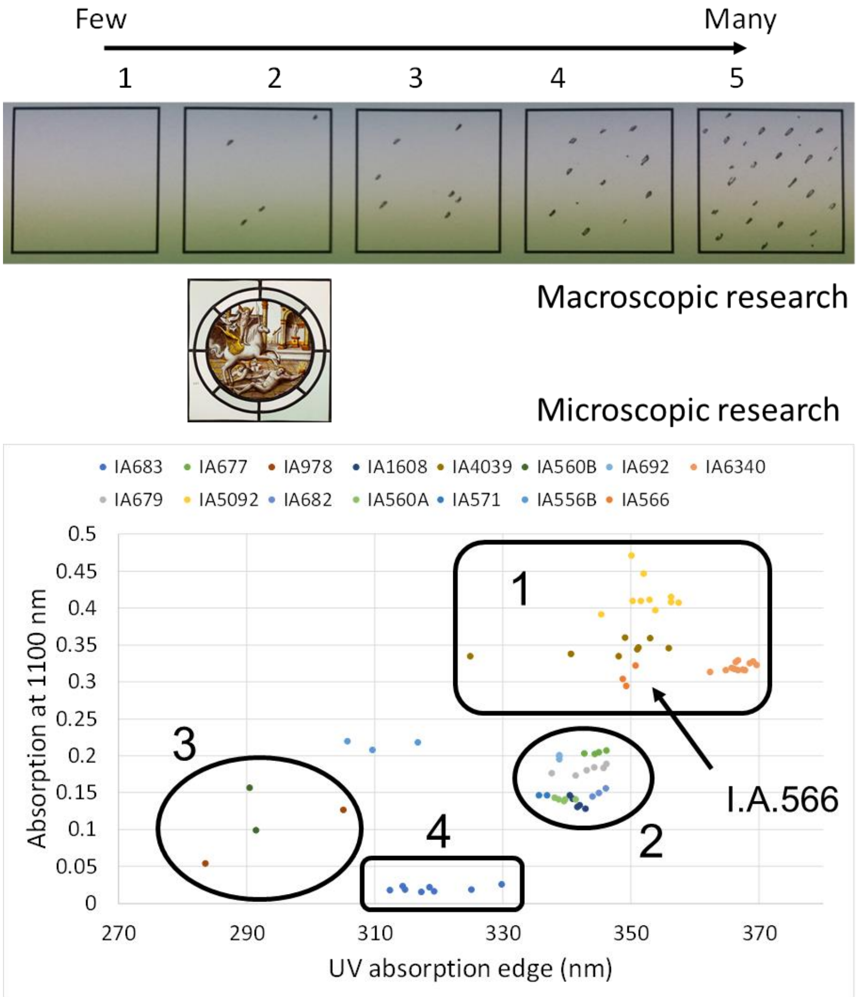


Figure 39: The roundel 'The Triumph of Love' (I.A. 566) has a high-quality painting and almost no fabrication traces (scale = 2). However, its high UV absorption edge and absorption at 1100 nm values indicate the presence of iron impurities and as such the use of less pure materials

In the previous parts of this report, it has already been described that the research findings obtained by the macroscopic research also contributed to answering authenticity questions. During the stylistic research of Dr. Isabelle Lecocq (or even prior to the project), the authenticity of some pieces was questioned. In those cases, a verification was made on the existing fabrication traces and the undulation of the surface. The presence of many inclusions and/or a strong surface undulation has been considered as a sign of authenticity. This information was in a subsequent step cross-checked with the findings of the photonics group giving clues on the purity of the raw materials and the composition of the glass. In case a soda-rich composition had been identified, it was concluded that the investigated parts were most probably non-authentic.

An illustration of a series for which the macroscopic research unveiled the presence of a severe number of fabrication traces (inclusions) and a rather undulated surface structure, are the set of Habsburg heads (Figure 21).

Photonics (microscopic research)

Topic 1: Research on the identification of the optical measures of interest for glasses with a post-medieval glass signature.

<u>Fine-tuning the set-ups</u>

The p-XRF and UV-VIS-NIR absorption spectra were recorded during multiple sessions. The applied workflow ensured that the three portable methods were carried out simultaneously. While the optical spectroscopy measurements needed to be performed in a dark room, the p-XRF measurements could be taken under daylight conditions. For safety reasons the operator of the p-XRF device should obey a certain distancing. Therefore, the device was operated remotely. The thicknesses at the different measurement locations were measured with the ultrasonic test gauge that we purchased at the beginning of the project. During the first project year we learned that to ensure the correct application of XRF spectroscopy when studying window panels, the distance between the XRF instrument and the window must be kept constant and must be standardized to obtain repetitive results. Therefore, we designed and fabricated in the second project year a so-called 'XRF nose'; a 3D-printed attachment that is mounted to the measuring head of the device ensuring the implementation of the correct distance. To safeguard the condition of the fragile window pieces, a set-up was worked out where the windows were positioned onto a polyethylene, acid-free foam. Figures 40-43 are some illustrative pictures of the different set-ups and employed devices.

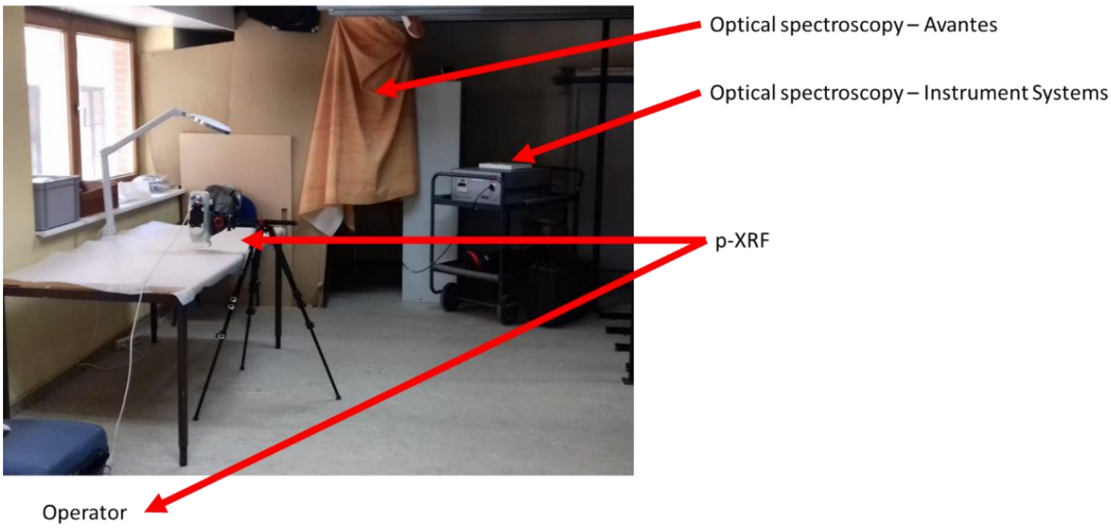


Figure 40: Illustration of the installation of the different devices in the storage room. The two optical spectrum analysers were installed in a dark room. The p-XRF device was remotely controlled by the operator for safety reasons

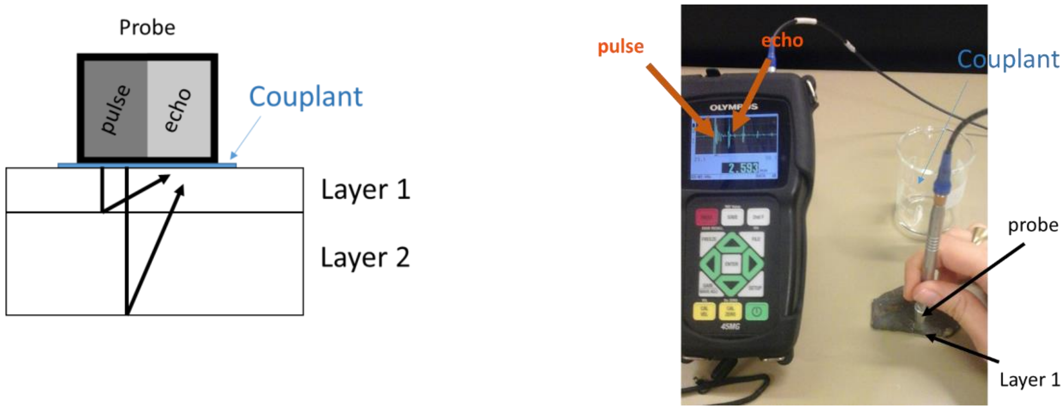
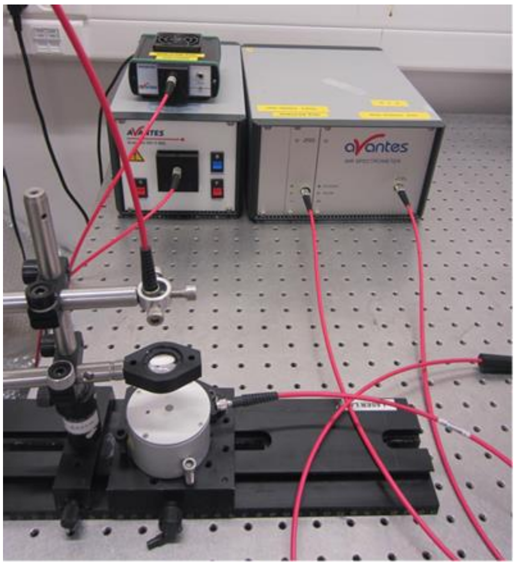


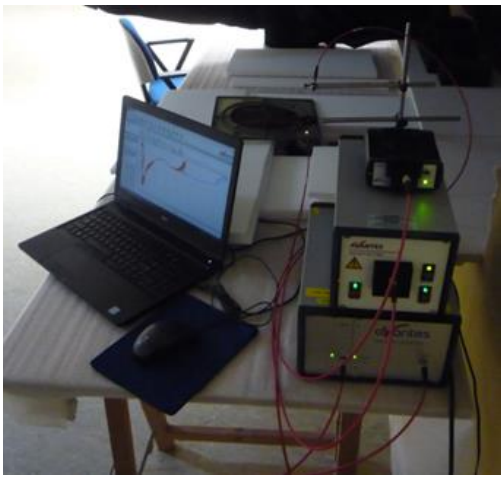
Figure 41: A rugged ultrasonic thickness gauge determines the sample thickness by measuring the amount of time it takes for sound to traverse from the transducer through the material to the back end of a part and back. The ultrasonic thickness gauge then calculates the data based on the speed of the sound through the tested sample

Figure 42: Illustration of the so-called 'XRF nose' which is a component that is mounted to the measuring head of the p-XRF device ensuring the implementation of a constant distance

In situ p-XRF analysis were performed to get insights on the chemical composition of objects that could not be sampled. The recorded data were calibrated with the calibration lines that were constructed during this project for ten major elements (K, Ca, Mn, Fe, Co, Cu, Rb, Sr, Zr, Ag) making use of two Corning (A and D) and three NIST (610, 612, 614) standards.



a



b

c

d

Figure 43: Illustration of the set-up that was used to record the UV-VIS-NIR absorption spectra. Light coming from a spectral broadband light source illuminated a small spot of the panel. The transmitted light was captured into an integration sphere and guided towards an optical spectrum analyser. For the study of the bare glasses, we used the device from the company Avantes (a-b), while the study of the silver stain layers required the use of the Instrument Systems device because of its higher sensitivity (c). During the measurements the panel was positioned onto a PE foam

<u>Benchmarking between the optical and the chemical method</u>

To benchmark the data outcome of the UV-VIS-NIR absorption and the p-XRF measurements, samples were taken throughout the project (cfr. methodology section). For each of the parts a well-defined corpus of material was selected. In the framework of the objective of unravelling the evolution in glass composition from potash to HLLA glass, the follow-up committee advised to narrow the time span. Therefore, we selected a corpus of material with a well-dated origin between the 16-18th century. We tried to work as much as possible with material from the A&H collection. However, in some cases the sample set needed to be supplemented with additional material. This to enlarge the sample set with well-dated pieces or to include pieces with high cobalt levels.

A total of 33 samples could be taken originating from 26 objects from the A&H collection. These objects were mainly roundels but also included a plain glass window, a Swiss panel and two stained glass window panels. Their dating covered the period from the first half of the 16th century to the last quarter of the 17th century. The samples were taken by Adeline Vanryckel and they were embedded in epoxy resin and polished at KIK-IRPA in collaboration with Dr. Leen Wouters. An illustration is given in Figure 44. This set was supplemented with 35 samples that were kindly provided by and form part of the private collection of Prof. Em. Joost Caen (UA- University of Antwerp). The consortium is very grateful to Prof. Caen for this kind support.

Originally, it was planned to determine the chemical composition of the sampled pieces with the Electron Probe Micro Analyzer (EPMA) instrumentation at the facilities of our international partner (UCL – Prof. Ian Freestone). Due to some technical problems supplemented with covid19 related issues, this was no longer possible. Fortunately, with the support of Prof. Freestone we were able to get the samples analyzed at the IRAMAT-Centre Ernest Babelon in Orléans. Since the applied technique was LA-ICP-MS it gave us the benefit of having the concentrations of both the major and minor (including cobalt) elements. We gratefully thank Prof. Bernard Gratuze for his help and support.

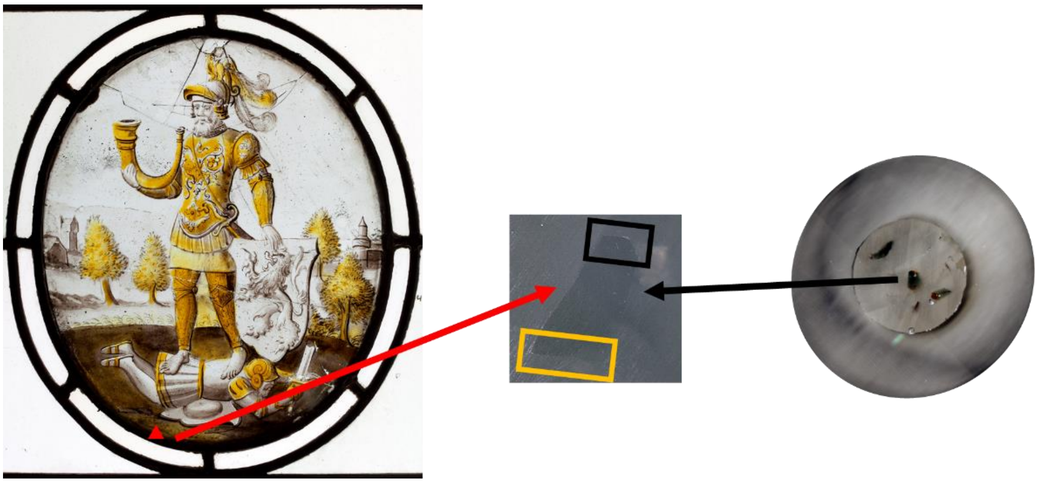


Figure 44: Illustration of one of the roundels (I.A. 4017) that was sampled

<u>Identification of the optical measures of interest for glasses with a post-medieval glass signature</u>

The findings of this research part are the content of a journal manuscript entitled 'Using UV-Vis-NIR absorption spectroscopy as a tool for the detection of iron and cobalt in glass: a case-study on HLLA material from the Low Countries'. The manuscript was submitted to the *Journal of Archaeological Science: Reports* (23/08/2021) and is currently under review (November 2021).

Authors:

Mathilde Patin (VUB), Karin Nys (VUB), Helena Wouters (KIK-IRPA), Hugo Thienpont (VUB), Wendy Meulebroeck (VUB)

The abstract of the submitted document is the following:

The early modern period is mainly characterized by High Lime-Low Alkali (HLLA) glass, a lime-rich glass made from plant or tree ashes, originating from 14th-century Germany and later used all over Europe. Attempts to link HLLA chemical subgroups to a particular point in time have failed so far. Driven by a request from the archaeological community, our research group has been exploring the feasibility of UV-Vis-NIR absorption spectroscopy as a non-destructive and in-situ applicable analysis technique for more than a decade. The main goal of this research is to provide a better understanding of the subgroups of HLLA glass and their respective dating via non-destructive means. A second topic relates to the role of cobalt as a potential indicator for either the type of applied ashes or for glass recycling.

In this paper, we present the UV-Vis-NIR and LA-ICP-MS results of a total of 45 HLLA colourless glass objects or fragments, supplemented with three blue glasses from the 15th to the 17th centuries. First, we observed the increasing amount of [FeO] as a function of time from the second half of the 16th century onwards. The technology change seems to be related to the type, or treatment, of ashes used as a fluxing agent. Besides, the presence of low amounts of cobalt in colourless glass, observed through the Co2+ absorption bands in the optical spectra (down to 18 ppm), is most likely related to the plant ashes. Then, we describe an approach to quantify iron and cobalt from the optical spectra and to date HLLA material by means of absorption spectroscopy, a valid, rapid, and non-destructive alternative for laboratory measurements. Finally, we show that the optical parameters (the Ultra-violet Absorption Edge (UVAE), the calculated Fe2+ and total iron contents, and the Co2+ absorption bands characteristics) allow discerning two glass groups: one dating to the end of the 15th-middle of the 16th centuries, and the other to the second half 16th-17th centuries These results gain valuable information to further resolve the study on the plant selection or treatment of the ashes used as a fluxing agent in HLLA glass.

Topic 2: Unravelling the evolution in glass composition from potash to HLLA glass

The research results of this part are driven by the glass study of 34 objects (roundels and unipartite panes). These are: D102 I.A.1603 I.A.1608 I.A.1622 I.A.2019.G1 I.A.3374 I.A.37 I.A.4019 I.A.4021 I.A.4023 I.A.4029 I.A.4039 I.A.43 I.A.552 I.A.556A I.A.556B I.A.560A I.A.560B I.A.569n1 I.A.571 I.A.6317 I.A.6340 I.A.677 I.A.679 I.A.682 I.A.683 I.A.691 I.A.692 I.A.8226A I.A.8226C I.A.978 SN2015.05 SN2013.23A V.2756 (see also Annex 1).

In a first step, we investigated the glass composition based on the p-XRF findings. We concluded that in a minority of cases, the glass is potash rich (I.A. 43, I.A. 37 and V. 2756) (Figure 45). The assigned crown glass method supplemented with the potash glass composition is an indication that roundel I.A.43 most probably originates from an earlier dating (compared to the other pieces of the collection).

a b c

Figure 45: Three panels for which the p-XRF measurements indicated the use of potash glass. I.A.37 (a). I.A.43 (b) and V. 2756 (c)

In most cases, the glass analytical research confirmed the expected HLLA composition. With the optical tool that we worked-out (see previous section – topic 1) we further grouped the panels based on the iron ion impurities present in the bare glass. One example relates to roundel I.A.2019.G1 from the St. Elisabeth hospital (Lier) for which the composition of the bare glasses indicates a late 16th century dating (Figure 46).

In a next part, we supplemented the previous data with the quantitative data on the cobalt concentrations. This analysis gave us better insights on the HLLA glass production. It was concluded that based on the iron ion and cobalt levels, distinct groups could be identified indicating the application of different recipes. An article is currently in preparation that will include more details on these results.

Figure 46: I.A.2019.G1 (St. Elisabeth hospital – Lier). Example of a roundel for which the composition of the bare glasses indicates a late 16th century dating

Topic 3: To investigate the interplay between glass technology (glass 'quality') and daylight transmission

The findings of this research part are the content of a journal manuscript entitled 'The interaction between daylight and 15th and 16th century glass windows from the Low Countries'. The manuscript was recently published (29 October 2021) in the journal *Scientific Reports* (11, Article number: 21338).

Authors:

Wendy Meulebroeck (VUB), Karin Nys (VUB), Mathilde Patin (VUB), Hugo Thienpont (VUB),

The abstract of the published document is the following:

The positive impact of daylight on various forms of life is well understood. The daylight conditions a person experiences inside a building strongly depend on the character of the glazing. Contemporary windows maximize the transmission of visible daylight. In post-medieval times glassmakers were confronted with less pure materials. Driven by the Reformation and Counter-Reformation they were at the same time challenged by the demand for increased daylight. Luckily, technological evolutions allowed the production of thinner windows. It is currently an open question if glassmakers in the (Southern) Low Countries during the booming economic period from the fifteenth to seventeenth century made use of the interplay between material and fabrication properties to bring light into the darkness. Therefore, this paper links the impact of glass purity and production technique to light transmission for a well-diagnosed group of excavated glass window pieces from the castle of Middelburg-in-Flanders and a set of roundels, all dating back to between the fifteenth and seventeenth centuries and explores what factors have influenced this technological improvement. A non-destructive approach making use of UV–vis–NIR absorption spectroscopy unveiled that the more recent material is less pure compared to the older dated material but that light transmission was maximized due to the applied production technique.

The conclusion of the published paper is the following:

This paper is the result of a close collaboration between art historians and optical engineers in the field of heritage research, and it offers new insights into the interplay between used raw materials and fabrication technology in the economic flourishing period from the fifteenth to the seventeenth century in the (Southern) Low Countries. Starting from two well-diagnosed groups of excavated non-figurative glass window pieces, we researched the combined influence of the purity of the raw materials and the glass thickness obtained with either the crown or the cylinder method on the amount of transmitted light transmission. Earlier-performed macroscopic research unveiled a difference in the obtained glass thickness between both glass fabrication methods. First of all, the analysis of the recorded optical transmittance spectra demonstrated that the earlier-dated lozenge shaped glass is purer compared with the more recent quadrangular material, mainly due to the lower iron-impurity levels. Nonetheless, the study of the light transmission properties has shown that despite its better glass purity, the lozenge glass is less transparent compared with the more greenish quadrangular glass. Linking the observations of the spectroscopic research with earlier reported chemical data on a subset of samples allows us to conclude that the glass was produced in (a) local workshop(s) employing different fabrication technologies regarding the use of raw materials. The fact that the more recent material is made from less pure materials but finally leads to increased window transparency demonstrates that changing socio-economic realities prompted the ancient glassmakers to innovate. In a second case study, we assessed these research findings and studied six roundels originating from glass ateliers located in the (Southern) Low Countries. For this glass material, we also observed an evolution towards less pure materials in later periods. Despite this, more light was transmitted through the roundels compared with the non-figurative windows due to their lesser thickness. This can be seen as proof for their status as a luxury commodity.

The above-described insights on glass technology and the related daylight transmission indicate that as is the case in today's world, societal and cultural needs strongly drove technological innovations, and glassworkers definitely succeeded in increasing daylight transmission as required by the Reformation and Counter-Reformation. This work can further contribute to historic research conducted in an attempt to unravel the relation between glazing choices and related social and economic encounters.

A similar research methodology can be applied in future research to validate the findings of this paper with materials from other sites, including the full range of existing glass pattern shapes.

Topic 4: To study the technology of silver staining

The starting point of this research was the spectral study of the silver stain samples that were fabricated with known conditions (K. De Vis and K. Leap sample sets). In this report we highlight some of the main conclusions that were drawn from this research. For the more detailed findings, we refer to a journal article that is in preparation.

A first conclusion relates to the observation of strong shape differences between samples that were fabricated with different temperatures. The recorded shapes are salt dependant. Figure 47 shows the recorded absorption spectra for a soda-rich sample stained with Ag_2O and yellow ochre (50/50) as a function of the temperature. Three temperatures were studied: 563°C, 597°C and 630°C. At low temperature, no particles are formed. At elevated temperatures particles are formed. The skewness of the curve is an optical estimate for the nanoparticle uniformity. At higher temperatures and for some salts a second peak could be observed. Combining the number of observed peaks and the calculated skewness could provide us a first clue on the applied silver salt.

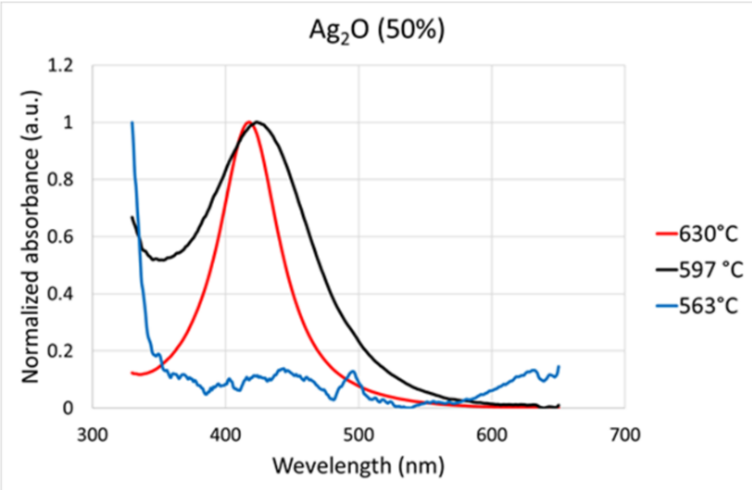


Figure 47: Strong shape differences are observed for samples that were fabricated with different temperatures

In the literature it is reported that the penetration depth depends on the silver salt and the applied temperature (Jembrih-Simburger et al., 2002). Our research has shown that the full-width-half-maximum (FWHM) value of the silver peak depends on the type of silver salt and the applied temperature. With this information we further studied the relation between the optical data and the penetration depths of the silver ions and concluded that the FWHM value is a good optical estimate for the penetration depth of the silver ions. This penetration depth seems to evolve towards a constant value from a certain threshold value onwards (for a fixed temperature).

During this research step we also investigated the influence of the fabrication parameters on the obtained colour values. For Ag_2O all applied temperatures resulted in a yellow-green colour while for Ag_2SO_4 all temperatures lead to a yellow-red colour. For the other studied salts (Ag_2SO_4, AgCl, $AgNO_3$), the higher temperatures had the tendency to colour the glass yellowish red; for lower temperatures the colour appeared to be yellowish green.

Another observation that was made relates to the influence of the mixing agent on the spectral shape. A clear difference in SPR peak position was recorded for samples prepared with yellow and red ochre respectively.

Finally, we also researched the influence of the presence of copper atoms in the binding agent. Only in very exceptional cases we observed the characteristic Cu SPR peak close to 560 nm. For the here studied soda-rich glasses we concluded that the observed Cu peak might originate from the application of a low temperature, or an additional surface treatment or a post-annealing step.

All this information was in a following step used to study the pieces of the A&H collection. We remark that since most of the glasses have an HLLA composition, we did expect to observe differences in spectral shape between the home-made modern samples and the historic window panels. This was confirmed by the measurements. For the historic glasses, we often observed saturated silver peaks. Several roundels of the collection include paler yellow colors as well as darker (more orange) colors. One example is shown in Figure 48. The observed SPR peak positions seems to indicate the use of different ochres. It must be further studied if a workshop indeed applied different ochres.

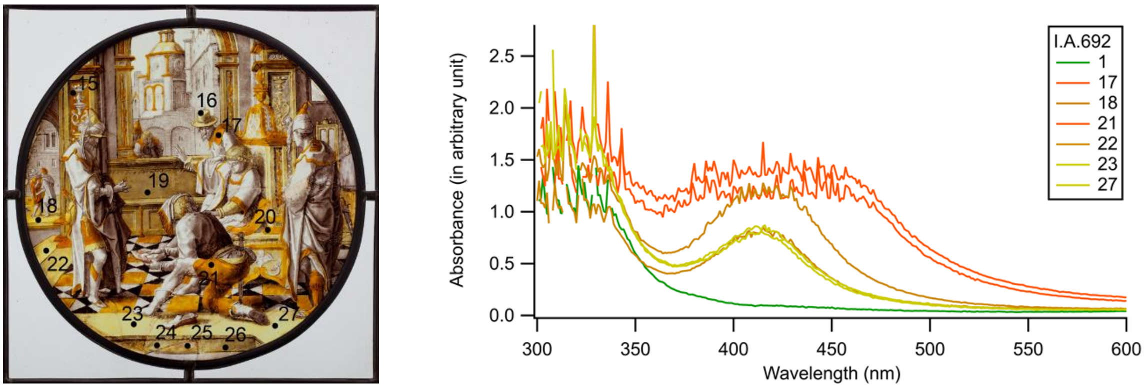


Figure 48: The different yellow-stain hues of panel I.A. 692 (left) results in different spectral shapes (right)

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5. DISSEMINATION AND VALORISATION

Exhibition

Exhibition 'Medallions – Miniatures on Glass'. The exhibition is included in the permanent collection of the A&H museum and opened in June 2021.

Databases

All pieces of the flat glass collection of the A&H museum are added to the BALaT and Carmentis databases and can be consulted via the corresponding urls: http://balat.kikirpa and http://www.carmentis.be.

Conferences

Lecocq, I., & Montens, V., 800 Years of FENESTRAtion History Flat Glass and Windows in Federal Scientific Institutes: Conservation, management and study of the RMAH collection, 29th international colloquium of the *Corpus Vitrearum*, « Stained glass in the 17th century. Continuity, Invention, Twilight », Antwerp, 2-6 July 2018, poster.

Lecocq, I., Boccaccio's heroine: the faithful and loving Griselda, 4th triennial conference of the American Boccaccio Association, (October 2019, Madison, USA), oral presentation.

Lecocq, I., 'L'authenticité du vitrail à l'épreuve de sa reproduction photographique' (Original or Copy: Virtual Reproductions and the Question of Authenticity, International Conference, Romont, 28 August 2021, oral presentation.

Montens, V. & Meulebroeck, W., FENESTRA: 800 Years of fenestration history. Flat glass and windows in Federal Scientific Institutes, The Glass and Ceramics Working Group of ICOM-CC (September 2019, London, UK), oral presentation.

Patin, M., Brightening Silver Particles. How to get technical issues about 16th century yellow stained glass roundels from optical spectroscopy?, 42nd International Symposium on Archaeometry (May 20-26 2018, Merida, Mexico), poster.

Patin, M., Optical fingerprints of flat glass from the Late Middle Ages to Modern Times in Low Countries and Belgium. The case study of the Royal Museum of Art and History of Brussels collection, 21st International Congress of the Association Internationale pour l'Histoire du Verre (September 3-7 2018, Istanbul, Turkey), oral presentation.

Patin, M., Ceglia, A., Nys, K. & Meulebroeck, W., From Silver to Gold. Retrieving the hidden meaning of stained glass by optical spectroscopy, VUB PhD cup contest (2019), poster.

Patin, M., Ceglia, A., Nys, K. & Meulebroeck, W., Technical evolution and dating of flat glass by chemical and optical fingerprints: from Late Middle Ages to Modern Era in the Low Countries, B-PHOT Team Building event (2019), poster.

Wouters, H., Patin, M. & Meulebroeck W., 800 Years of FENESTRAtion History Flat Glass and Windows in Federal Scientific Institutes: Archaeological and archaeometrical research for manufacturing techniques and dating issues, 29th international colloquium of the *Corpus Vitrearum*, « Stained glass in the 17th century. Continuity, Invention, Twilight », Antwerp, 2-6 July 2018, poster.

PhD, master theses and internships

PhD thesis

Mrs. Mathilde Patin was carrying out her PhD research in the framework of this project. She is currently in the final stage of her research and the expectation is that the defence will take place in the first half of 2022.

Master theses

Laith Adnan Ata Shamlawi, UV-Vis-NIR Spectroscopy for historical plain glass studies of material from the Low countries (2020-2021).

Aishwarya Shenai, UV-Vis-NIR Spectroscopy for historical plain glass and silver stain studies of material from the Low countries (2019-2020).

Internships

Julien Bouchat (Université de Namur, Belgium), The use of different non-destructive portable techniques to study historic glasses (summer 2021).

Joseph Le Cloarec (ENSICAEN, France), Portable X-ray fluorescence measurements on archaeological flat glass from the site of Bree in Belgium (November 2019).

Carlos Andres Diaz (Universidad EAFIT; Colombia), Data analysis of Lab-on-a-chip automatized measuring station (27 February 2019 – 25 May 2019).

Workshops & community meetings

Meulebroeck, W., Discover how light technology can contribute to the dating of ancient glass, MAS/Masterclass 1.0 (28/3/2019, Antwerpen, Belgium), oral presentation.

Montens, V. & Patin, M., De l'ombre à la lumière - Etude pluridisciplinaire de la collection de vitraux du Musée Art & Histoire (8/3/2020, Brussels, Belgium), oral presentation.

Montens, V., Vanryckel, A., Patin, M., FENESTRA: 800 Years of fenestration history, Art & History Museum / Science lunch (28/05/2019, Brussels, A & H Museum), oral presentation.

Patin, M., Optical spectroscopy applied to museum collections: glass windows and silver nanoparticles studies, Pizza Seminar VUB-B-PHOT (10/10/2018, Brussels, Vrije Universiteit Brussel), oral presentation.

Patin, M., p-XRF for Historical Flat Glass Study, AMGC seminars at VUB/AMGC (16/01/2020, Brussels, Vrije Universiteit Brussel), oral presentation.

Publications and outreach activities for the broad public

Meulebroeck, W., Historisch glas, vertel ons uit welke periode je was!, Dag van de wetenschap' (25/11/2018, Koksijde, Belgium), oral presentation;

Patin, M., The Science of Light and Our Cultural Heritage, VUB PhD cup contest (2/4/2019 & 27/5/2019), oral presentations.

Patin, M., The Science of Light and Our Cultural Heritage, Movie made in the framework of the PhD cup contest attended by Mathilde Patin. To be consulted at: https://www.sciencefiguredout.be/science-light-and-our-cultural-heritage

Patin, M., How photonics can help to answer questions in archaeology: Mathilde Patin for the CARLA consortium. To be consulted at YouTube: https://www.youtube.com/watch?v=vMr95xWgM60

6. PUBLICATIONS

Book

Lecocq, I. (dir.), *Médaillons, peintures sur verre et panneaux de vitraux de petites dimensions conservés dans les collections publiques à Bruxelles* (*Corpus Vitrearum Belgique-België*, *série « Checklist »*, vol. 6), est. 2023.

Scientific papers

All papers are peer-reviewed. Several publications are currently in preparation. These are not listed here.

Ceglia, A., Patin, M., Wouters, H., Anquinet, E., Vanryckel, A., Lecocq, I., Montens, V., Nys, K. & Meulebroeck, W., "FENESTRA: 800 Years of fenestration history. Flat glass and windows in Federal Scientific Institutes", in the proceedings Recent Advances in Glass and Ceramics Conservation 2019, pp. 33-42, the interim meeting of the The Glass and Ceramics Working Group of ICOM-CC, London, September 2019.

Lecocq, I. & Anquinet, E., "Jalons de l'histoire et enjeux de l'inventaire photographique des vitraux en Belgique", in Bulletin de l'Institut royal du Patrimoine artistique, 36, pp. 56-79, 2019-2020.

Lecocq, I., 'Une scène inédite de l'Histoire du fils prodigue de Dirk Vellert (v.1480/85 – v.1547)', Philostrato. Revista de Historia y Arte, n° 6 (2019), pp. 5-23.

Lecocq, I., 'Images de Griselda, la fameuse héroïne de Boccace' (publication to be confirmed in Colloquium proceedings, see below, "Participation/Organisation of Seminars", or in another scientific journal in 2021-2022?).

Meulebroeck, W., Anquinet, E., Ceglia, A., Freestone, F., Lecocq, I., Montens, V., Nys, K., Patin, M., Vanryckel, A., Wouters, H., "800 Years of FENESTRAtion history. Flat glass and windows in Federal Scientific Institutes", in Madeleine Manderyck, Isabelle Lecocq and Yvette Vanden Bemden (eds), « Stained glass in the 17th century. Continuity, Invention, Twilight. - 29th international colloquium of the *Corpus Vitrearum*, Anvers, 2-6 juillet 2018, Antwerpen/Brussels, 2018, pp. 169-172.

Meulebroeck, W., Nys, K., Patin, M. & Thienpont, H., 'The interaction between daylight and 15th and 16th century glass windows from the Low Countries', Article number: 21338, *Scientific Reports*, 11, 2021.

Patin, M., Nys., K., Wouter, H., Thienpont, H. & Meulebroeck, W., 'Using UV-Vis-NIR absorption spectroscopy as a tool for the detection of iron and cobalt in glass: a case-study on HLLA material from the Low Countries'. Submitted to the *Journal of Archaeological Science: Reports*, under review.

7. ACKNOWLEDGEMENTS

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Our special thanks go to Yvette, Claudine, Helena and Nicole; the follow-up committee members that were present at every single meeting and who helped us solving problems when they popped-up during the project. Yvette, thank you so much for your enthusiastic and open-minded attitude and all the constructive feedback we received during the meetings. Claudine, we really appreciate your annual travels from Paris to Brussels (this despite the challenging Covid19 circumstances) which allowed us to have in-depth face-to-face discussions on the applied analytical approaches and results. Helena, without your support we would not have been able to perform the project as originally planned. When we called you to help us out with the resin embedment of the sampled pieces, you were immediately prepared to support us. We much appreciate this together with all the other feedback you gave us during the yearly follow-up meetings or during meetings we additionally organized. Nicole, also you were always present during the follow-up meetings where you kindly offered your valuable expertise regarding the conservation and treatment of the fragile pieces. Thanks!

The general director of KIK-IRPA, Hilde De Clercq, as well as Christina Currie, head of Scientific Imagery, and Pierre-Yves Kairis, head of the unit Art History Research and Inventory, gave their full support to the project and facilitated the practical organization of the photographic documentation. Thanks to the former director of the A&H museum, Alexandra De Poorter, the impact of Covid19 on the project flow, could be decreased. She gave the non-museum partners the exceptional permission to proceed with the research once the situation allowed it. We are also grateful to the current director of the museum, Bruno Verbergt, for including the exhibition in the permanent collection of the museum. We thank them warmly. For the photography of the stained glass, we would like to thank in particular Hervé Pigeolet, photographer of the Scientific Imagery unit at KIK-IRPA, who deployed all his skills to produce numerous photographs, in conditions that were not always easy. Marie-Christine Claes gave expert advice for the introduction of the data to the BALaT platform; we thank her for this. For the sampling of the pieces, we gratefully thank Chantal Fontaine for the advises she has given.

The study of the collection from an art historical point of view benefited from the expertise of specialists in stained-glass art, Renaissance art, and artists who distinguished themselves in the art of stained glass at the time. Special thanks go to Yvette Vanden Bemden of the *Corpus Vitrearum Belgique-België* and professor emeritus of the University of Namur, a pioneer in the study of small glass paintings, Ellen Konowitz, of the State University of New York at New Paltz, who generously shared her knowledge of Dirk Vellert and the small glass paintings produced in the Low Countries and, Matt Kavaler, Director of the Centre for Renaissance and Reformation Studies at the University of Toronto, whose extensive knowledge of Renaissance art has been precious. We also thank Dr. Virginia Raguin for the discussions we had in the framework of this project.

Several other colleagues need to be acknowledged for the analytical research: Ian Freestone, Bernard Gratuze, Kristel De Vis, Kenneth Leap and Joost Caen. Ian, being our first international partner, your contributions to the project are numerous. We thank you for all the valuable feedback we received from you especially related to our p-XRF measurements. Thank you for travelling so many times between London and Brussels. Bernard, thank you for helping us out with the LA-ICP-MS measurements. Our special thanks go to Kristel and Kenneth for granting us permission to use their home-made silver-stained samples as reference material. And last, but not least, our sincere gratitude goes to Joost Caen. Joost, although the affiliated photonics researchers knew your name from scientific publications, it was only during this project that we met and that we could count on all the diverse support you offered us in kind. Thank you for the passionate tour you gave us in your atelier and workshop and for providing us the missing material for our sampling campaign. In addition, we would like to thank you for all the additional knowledge and expertise you shared with us during the project.

ANNEX

Annex 1 – Overview of the roundels that were researched with the analytical techniques.

Inv. No.	Sampled for LA-ICP-MS	Measured with pXRF (glass)	Measured with pXRF (paint layers)	Measured with Avantes (glass)	Measured with Avantes (silver stain)	Measured with Instrument Systems
D102		x	x	x	x	x
D104				x	x	
D106		x	x	x		
D107		x		x		
D108		x	x	x	x	
I.A.37		x	x	x	x	x
I.A.38				x		x
I.A.41				x		x
I.A.43		x	x	x	x	x
I.A.408		x	x	x		
I.A.552		x	x	x (+ borders)	x	x
I.A.553	x			x		
I.A.554				x (+ borders)	x	x
I.A.555				x (+ borders)	x	x
I.A.556A		x	x	x (+ borders)	x	x
I.A.556B		x	x	x (+ borders)	x	x
I.A.560A		x	x	x (+ borders)	x	x
I.A.560B		x	x	x (+ borders)	x	x
I.A.566				x (+ borders)	x	x
I.A.567				x (+ borders)	x	x
I.A.568				x (+ borders)	x	x
I.A.569.1		x	x	x	x	x
I.A.569.2				x	x	x
I.A.571				x	x	x
I.A.676				x	x	
I.A.677		x	x	x	x	x
I.A.678				x (+ borders)	x	
I.A.679		x	x	x (+ borders)	x	x
I.A.680				x (+ borders)	x	
I.A.681				x	x	x
I.A.682		x	x	x (+ borders)	x	x
I.A.683		x	x	x (+ borders)	x	x
I.A.684				x	x	
I.A.686				x		
I.A.689		x	x	x		x
I.A.691	x	x	x	x (+ additional	x	x

				plate)		
I.A.692		x	x	x (+ borders)	x	x
I.A.694		x	x	x		x
I.A.880				x		
I.A.978		x	x	x (+ borders)	x	x
I.A.979A		x		x		
I.A.979B		x		x		
I.A.979C		x		x		
I.A.979D		x		x		
I.A.979E		x		x		
I.A.979F		x		x		
I.A.979G		x		x		
I.A.979H		x		x		
I.A.980	x			x		
I.A.1600				x		x
I.A.1602		x	x	x		x
I.A.1603		x	x	x (+ borders)	x	x
I.A.1605				x (+ borders)	x	
I.A.1606				x		
I.A.1608		x	x	x (+ borders)	x	x
I.A.1611		x		x		
I.A.1614		x		x		
I.A.1618		x		x		
I.A.1621		x		x		
I.A.1622		x	x	x (+ borders)	x	x
I.A.1795	x			x		
I.A.2013.28				x	x	
I.A.2018.VI	x			x		
I.A.2016.Gter - SN2013.2		x	x			
I.A.2019.G1		x	x	x (+ borders)	x	x
I.A.2064		x	x	x		x
I.A.2066		x		x (+ borders)		
I.A.2239B	x			x		
I.A.2239F	x			x		
I.A.2246A	x	x		x		
I.A.2246B				x (+ borders)		
I.A.2246C	x	x		x		
I.A.2246D				x		
I.A.3079	x			x		
I.A.3095B		x				
I.A.3095C		x		x		
I.A.3095D		x				
I.A.3095E		x		x		
I.A.3095G		x				

I.A.3374		x	x	x (+ borders)	x	x
I.A.4013		x		x		
I.A.4016	x			x		x
I.A.4017	x			x		x
I.A.4018		x		x		
I.A.4019		x	x	x (+ borders)	x	x
I.A.4021	x	x	x	x (+ borders)	x	x
I.A.4022		x		x		
I.A.4023		x	x	x	x	x
I.A.4026	x			x		
I.A.4028	x	x		x		
I.A.4029 - SN2014.01	x	x	x	x	x	x
I.A.4030	x			x		x
I.A.4033	x			x		
I.A.4037		x	x			
I.A.4038	x	x		x		
I.A.4039	x	x	x	x	x	x
I.A.5092	x	x	x	x	x	
I.A.6317		x	x	x (+ borders)	x	x
I.A.6318				x (+ borders)	x	
I.A.6340	x	x	x	x	x	x
I.A.6360		x	x	x		x
I.A.6573	x	x		x (+ additional plate)		
I.A.7667		x		x		
I.A.7668		x		x		
I.A.8226A		x	x	x	x	x
I.A.8226B		x	x	x	x	x
I.A.8226C		x	x	x	x	
SN2013.03		x	x			
SN2013.15		x		x		
SN2013.17		x				
SN2013.18	x	x	x	x	x	
SN2013.19		x		x		
SN2013.22		x		x		
SN2013.23A		x	x	x	x	x
SN2013.23B		x	x	x		
SN2013.25		x		x		
SN2013.30		x		x		
SN2015.02	x	x	x	x		
SN2015.03		x	x	x	x	
SN2015.04				x	x	
SN2015.05		x	x	x	x	x
SN2015.08		x	x	x		
V.1943				x (+ borders)	x	

V.2752				x (+ borders)	x	
V.2755				x (+ borders)	x	
V.2756		x	x	x (+ borders)	x	x
V.2757				x		
V.2758				x		
Vi.86.1.1	x			x		x