

Preserving Identity

**11th Forum for the Conservation and
Technology of Historic Stained Glass
Girona – Barcelona, 7–9 July 2022**

**Organized by the Catalan Committee
of the Corpus Vitrearum
in Association with the
International Scientific Committee for the
Conservation of Stained Glass (ISCCSG)**

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Forum Programme

7 July 2022 – GIRONA

- 08:00 Plaça Catalunya 21, Barcelona. Registration and departure to Girona (by bus).
- 09:30-10:00 Colloquium and Forum. Welcome by the local officials.
- 10:00-10:45 Coffee break at the *Casa de Cultura de la Diputació de Girona*.
Visit: Fita Foundation, 2nd floor.
- 10:45-12:05 **Lecture session 1** (papers and discussion), Aula Magna de la Casa de Cultura de la Diputació de Girona: chaired by Ivo Rauch.
- 12:15-13:15 **Lecture session** about the "Glaziers' Tables" (papers and discussion), *Sala Josep Irla*: chaired by Sarah Brown.
Speakers: Stefan Trümpler (Colloquium) and Anna Santolària (Forum)
- 13:15-14:30 Lunch break.
- 14:30-17:30 **Tour / Visit:** the Cathedral and the Art Museum (white-washed tables of Girona); optional: *Sant Feliu Church*, *Casa Masó*.
- 17:30 Garden of Art Museum.
- 18:00 Return to Barcelona.
- 21:00 Official dinner for Colloquium and Forum attendees.

8 July 2022 – BARCELONA

Seminari Conciliar de Barcelona, Aula Magna (c/ Diputació 231)

- 09:00 Welcome.
- 09:20-11:00 **Lecture session 2** (lectures and discussion): chaired by Sarah Brown.
- 11:00-11:20 Poster session and coffee break.
- 11:20-13:00 **Lecture session 3** (lectures and discussion): chaired by Yvette Vanden Bemden
- 13:00-14:30 Lunch break.
- 14:30-15:50 **Lecture session 4** (lectures and discussion): chaired by Claudine Loisel.
- 15:50 Departure to Reial Monestir de Santa Maria de Pedralbes (by bus)
- 17:00- 18:30 **Visit:** Church and Chapter House of *Reial Monestir de Santa Maria de Pedralbes*.

9 July 2022 – BARCELONA

Seminari Conciliar de Barcelona (Aula Magna).

- 09:00-10:20 CSIV meeting.
- 10:20-10:50 Poster session and coffee break.
- 10:50-12:30 **Lecture session 5** (lectures and discussion): chaired by Ellen Shortell.
- 12:30-13:15 **Conclusions:** closing of the 11th Forum for the Conservation and Technology of Historic Stained Glass: chaired by Ivo Rauch and Sarah Brown.



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FOREWORD – PRÉFACE – VORWORT – PREFACI

The Corpus Vitrearum family was last able to meet face to face in Antwerp in the summer of 2018. Although only four years ago, the impact of a worldwide pandemic in the interim means that this feels like a lifetime ago, and another world entirely. The patience and commitment of the Catalan committee of the Corpus Vitrearum in bringing this international community together again is therefore all the more remarkable, and ensures the continuance of this international scholarly exchange despite interruption and delay. During our brief meeting in Antwerp, members of the secretariat of the International Scientific Committee for the Conservation of Stained Glass raised the possibility of reuniting the colloquium of the Corpus Vitrearum and the technical forum of the ISCCSG. Much to our delight, the Catalan committee was very willing to make this possible, recognition that the future of our fragile heritage of stained glass relies upon the close collaboration of art historians and conservators. It is entirely fitting that during this 2022 meeting, delegates from both disciplines and from all over the world will gather in Girona to marvel at the medieval glaziers' tables and the windows made from them. No better way to celebrate the reunion of our international stained-glass community could be found!

The International Scientific Committee for the Conservation of Stained Glass

The Corpus Vitrearum project (originally Corpus Vitrearum Medii Aevi) was born out of the International Committee on Art History in 1952 and was adopted in 1954 by the Union Académique Internationale (UAI).

The Barcelona Committee of the Corpus Vitrearum, under the auspices of the Institut d'Estudis Catalans (IEC), was created in 1957 and the following year presented its programme for Catalonia at the meeting of the UAI. The state political situation made it impossible to develop the programme until 1979, when the Catalan Corpus Vitrearum team was created, made up of specialists from different fields.

Since then, first under the direction of Dr. Joan Ainaud (✠), then of Dr. Manuel Ascani Mundó (✠) and finally of Dr. Xavier Barral i Altet, all the known Gothic stained-glass windows in our country have been studied, and the five volumes of our Corpus Vitrearum Medii Aevi have been published.

Once the five medieval volumes had been completed, and again with the support of the Institut d'Estudis Catalans and also of the Generalitat de Catalunya, a first inventory, which extends to the first third of the 20th century, of the civil and religious stained-glass windows of our country has been made. We have been doing research all over our country for ten years, which has resulted in the study and inventory of most of our stained-glass windows from that era. Digitization of all materials has also begun. Now that this phase is closed, we do not want to stop there: we must continue on this path of study and conservation of heritage and include in our inventory other works and research that can be carried out. The discovery made in the Cathedral of Girona, at the end of 2019, of a medieval stained-glass window behind an altarpiece confirms that the search never ends. And for this task we hope to have the help of the corresponding institutions.

The 13th Stained Glass Colloquium was held in Catalonia (7–11 October) in 1985. The two stained-glass tables in Girona, unique in the world at that time, had recently been identified. We must keep in mind the exceptional fact that the stained-glass windows made with the tables of Girona are still preserved in the cathedral of this city. For an incipient Catalan committee of the CV, the celebration of this congress was a real challenge that allowed us to join the great family of Corpus Vitrearum.

Thirty-five years after that meeting, we have taken up the challenge of organizing a new Corpus Vitrearum colloquium, and we have also added the organization of the Forum; thus, in a single week the two most important meetings of this international organization are united. We have responded to this new challenge thanks to international support and also that of local institutions. Initially scheduled for 2020, the global pandemic situation forced us to postpone the 30th Colloquium and the 11th Forum first to 2021 and then to 2022.

So, after more than two years of pandemic, we can finally hold these meetings. The forum sessions take place in Girona and Barcelona and are organized by the Catalan committee of the Corpus Vitrearum in association with the International Scientific Committee for the Conservation of Stained Glass (ISCCSG) in conjunction with the Institut d'Estudis Catalans. The UAI and various Catalan institutions and foundations support the organization of these meetings.

The theme of this Forum will focus on the preservation of the 'identity' of historic stained glass in the intervention process. The search for balance between the values embodied in these pieces is a matter of great importance for this fragile heritage to be conserved correctly. This Forum will offer the opportunity to reflect upon and bring new solutions to this complex subject. The fragmentary nature and fragility of stained glass is widely accepted. To a greater or lesser extent, historic stained-glass windows, exposed to physical attack and weathering conditions over time, have suffered damage that has altered their appearance. These deteriorations are in addition to changes introduced by restorations, reconstructions, and interventions of varying extent and degree. All of these factors impact on the stained-glass windows that we see today. With every intervention they make, those responsible for maintaining this heritage face a series of decisions that are of great importance for the future reading and understanding of these pieces.

The response to this theme is a key factor in the creation of conservation plans, which can ensure the correct transfer of the piece to future generations. How should we combine the conservation requirements of the window with respect for all of the historic materials in and around it? How far can we go without diminishing the integrity of the piece? How can we make alterations in the surface or structure of the work while also respecting its antiquity and originality? At what stage, or level of quality, does an intervention gain historic value?

We have gathered in this volume the texts presented at the 11th Forum which have been the basis of the established discussions and which we hope will shed light on these topics.

We must thank all those who have remained faithful to our meetings for their patience, and we must mourn the loss of those whose illness or death has prevented them from being with us today.

In two years there have been many changes in the way we see the world, but stained glass is still the focus of our professional and personal attention. Thus, despite the still uncertain international situation, people from many parts of the world participate in the meeting. We present here 23 articles of great interest for the conservation of stained glass, texts by authors from points far away from each other: from Europe, where most of the papers are from, to America and Australia.

You are all welcome.

Corpus Vitrearum Catalunya



PAPERS

1.1

Schutzverglasung: ein thermodynamischer Rückblick auf die letzten 30 Jahre, Erfolge, Misserfolge und Schlussfolgerungen für zukünftige Projekte**Hans-Jürgen Daams**

Hajuveda Heritage

Michael Robrecht

iXtronics GmbH, Germany

Protective Glazing: A Thermodynamic Review of the Past 30 Years: Successes, Failures and Conclusions for Future Projects – Abstract

For more than 30 years protective glazing has been used for the preventive conservation of old and historically valuable stained glass in the windows of our churches. Initially, the main objective was to avoid condensation, as this has been proven to have a negative influence on the durability of the glass painting. In the course of time, many influencing factors, such as thermal insulation capacity, coatings and absorption capacity of the protective glazing, gap spacing, size of the ventilation surfaces, heat dissipation into the walls and iron, flow behaviour of the air in the air gap, ventilation by outside and/or inside air, thermodynamic properties of the air in the church, outside and in the air gap and

many more have been optimised in such a way that the risk of condensation on the original glazing has been reduced more and more. At the same time, knowledge of the causes of corrosion and their interaction with thermodynamic conditions has also become increasingly better. However, these have not yet been explicitly converted into limit values for thermodynamic measurement series. In fact, even today it is often the case that extensive data series are presented to the user without communicating what their significance is. The investigations presented here serve to define thermodynamic limits for a permanent monitoring of the historically valuable glass paintings and to make statements about the analysis results, instead of just a large amount of numbers.

Schutzverglasung: ein thermodynamischer Rückblick auf die letzten 30 Jahre, Erfolge, Misserfolge und Schlussfolgerungen für zukünftige Projekte – Zusammenfassung

Seit mehr als 30 Jahren werden Schutzverglasungen zur präventiven Konservierung alter und historisch wertvoller Glasmalereien in den Fenstern unserer Kirchen eingesetzt. Das Hauptziel war zunächst die Vermeidung von Kondenswasserbildung, da diese nachweislich einen negativen Einfluss auf die Haltbarkeit der Glasmalerei hat. Im Laufe der Zeit wurden viele Einflussfaktoren, wie z.B. Wärmedämmfähigkeit, Beschichtungen und Absorptionsvermögen der Schutzverglasung, Spaltabstände, Größe der Lüftungsflächen, Wärmeabgabe in die Wände und Eisen, Strömungsverhalten der Luft im Luftspalt, Belüftung durch Außen- und/oder Innenluft, thermodynamische Eigenschaften der Luft in der Kirche,

außen und im Luftspalt und vieles mehr so optimiert, daß das Risiko von Kondensat an der Originalverglasung immer mehr reduziert wurde. Auf der anderen Seite sind aber auch die Erkenntnisse über Korrosionsursachen und ihre Wechselwirkung mit thermodynamischen Zuständen immer besser geworden. Diese sind aber noch nicht explizit in Grenzwerte für thermodynamische Messreihen umgestaltet worden. Vielmehr ist es auch heute oft noch so, daß umfangreiche Datenreihen dem Benutzer präsentiert werden ohne zu kommunizieren, was denn deren Bedeutung ist. Die hier vorgestellten Untersuchungen dienen dazu, thermodynamische Grenzen für eine Dauerüberwachung der historisch wertvollen Glasmalereien zu definieren und anstatt einer großen Menge an Zahlen Aussagen über die Analyseergebnisse zu machen.

Thermodynamische Einflußgrößen

Abb. 1 zeigt in einer Skizze, welche physikalischen Größen die thermodynamischen Zustände bei einer Schutzverglasung bestimmen:

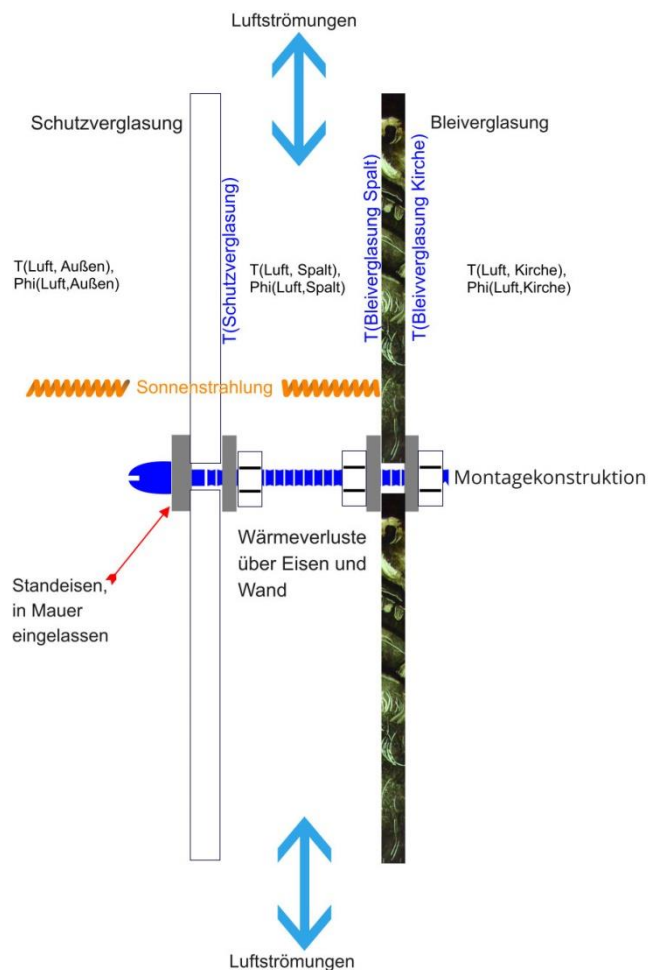


Abb. 1. Skizze der physikalischen Größen, die thermodynamische Zustände bei einer Schutzverglasung bestimmen.

Im Luftspalt stellt sich eine bestimmte Temperatur und relative Luftfeuchte ein, welche abhängt von:

- der Luft im Kircheninneren
- der Außenlufttemperatur
- der Aussenluftfeuchte
- der Sonneneinstrahlung
- der ein- und ausströmenden Luft über die Ein- und Auslassöffnungen
- den Wärmeverlusten über die Montageisen und die Wände

Die Oberflächentemperaturen von Blei und Schutzverglasung hängen von allen Lufttemperaturen der angrenzenden Luftschichten, der Strahlungsabsorption und der spezifischen Wärmekapazität der Gläser ab.

Glas- und Lufttemperaturen sind nicht gleich und daher kann es zu Tauwasserbildung kommen, wenn die Taupunkttemperatur der Luft an den Glasoberflächen unterschritten wird.

Ein kurzer historischer Abriss

Schutzverglasungen wurden bereits seit den 1950er Jahren z.B. im Berner Münster, in den Stadtkirchen St. Sebald und St. Lorenz in Nürnberg wie auch im Münster in York verbaut. 1985 wurden Untersuchungen zu Schutzverglasungen in Gouda (Holland) durchgeführt, um zu

analysieren, ob Schutzverglasungen bei holländischem Klima wirken können /JÜTTE 1985/. Im Laufe der Zeit wurde diese Art des Schutzes immer öfter mit unterschiedlichen Konstruktionstypen an unterschiedlichen Objekten erprobt. In den späten 80er und frühen 90er Jahren haben Fuchs und Leissner die Grundlagen für die objektive Darstellung der schützenden Wirkung von Schutzverglasungen gelegt /RÖMICH&FUCH 1993/, /LEISSNER 1993/.

Für die Überwachung des Schadens an den historischen Gläsern wurden spezielle Glassensoren vom Fraunhofer Institut für Silikat Forschung (ISC) entwickelt /FUCHS 1988/. Wichtige Beiträge zu diesem Thema kamen auch von Stefan Oidtmann /OIDTMANN 1993/ und /OIDTMANN 2000/. Auf Basis seiner Dissertation konnten wichtige Grundlagen zu diesem Thema gelegt werden. Weitere Forschungen wurden durch das BMFT (Bundesministerium für Forschung und Technologie) in den Jahren 1990 – 1995 im Projekt „Verbundprojekt zur Konservierung und Restaurierung historischer Glasmalerei“ durchgeführt. Hieraus entstanden in internationaler Zusammenarbeit zahlreiche Publikationen mit weiteren Grundlagen für die Erstellung von Schutzverglasungen /RÖMICH&FUCHS 1993/, /CAEN 1992/, /LAURIAT 1993/, /LEISSNER 1993/ /OIDTMANN 1993/. Intensive Untersuchungen zur Wirkungsweise von Schutzverglasungen wurden in der Nürnberger Sebalduskirche über Jahre dokumentiert /HÖR 2005/ und /HÖR in BÖTTCHER 2016/. Weitere Detailuntersuchungen zur Wirkungsweise eingebauter Schutzverglasungen fanden dann in den Jahren zwischen 2010 und heute statt /SCHUMACHER 2010/, /TORGE 2011/, SCHUBERT

2013/, /TORGE 2014/, /SELIGER 2017/. Diese Liste ist bei weitem nicht vollständig, stellt aber einen Erkenntnisstand dar, aus dem man Empfehlungen für die Konstruktion von Schutzverglasungen und deren Gelingen im realen Leben ableiten kann.

Definition der zu überwachenden thermodynamischen Größen

Für die Definition der zu überwachenden thermodynamischen Größen sind zunächst die Beanspruchungen zu klären, denen die Glasmalereien ausgesetzt sind. Hierzu gehören /Hör 2005/:

- Klimatische Beanspruchungen
- Luftverunreinigungen
- Mikrobielle Beanspruchungen

Aus thermodynamischer Sicht können die klimatischen Beanspruchungen sicherlich erfasst werden, allerdings können Luftverunreinigungen und mikrobielle Beanspruchungen nur indirekt referenziert werden, weil z. B. die Staubbelastung bei bestimmten mikrobiellen Beanspruchungen in Zusammenhang mit thermodynamischen Größen zu Schimmelbildung führen kann. Eine Überwachung der für die Schimmelbildung wesentlichen thermodynamischen Voraussetzungen ist durch Messung der Temperatur und der Luftfeuchtigkeit möglich. Die direkte Messung von Luftverunreinigungen und mikrobielle Beanspruchung wird in diesem Artikel aber nicht behandelt.

Martha Hör hat bereits 2006 festgestellt, daß thermodynamische Extremwerte, Häufigkeit des Auftretens von hoher Lufttemperatur und hoher relativer Luftfeuchte, Tauwasser, Reif- oder Eisbildung wichtige Einflussgrößen sind. Erstmals wurden hier nun Grenzwerte für einen Zielkorridor im Luftspalt gesetzt:

- Lufttemperatur: 12 °C bis 25 °C
- relative Luftfeuchtigkeit: 45 % bis 60 %
- Temperatur- und Luftfeuchtwechsel minimal
- Keine Tauwasserbildung an der Glasmalerei

Aufgrund von Messungen wurde später festgestellt, daß eine hohe relative Luftfeuchtigkeit von > 80 % r. F. an der Originalverglasung schon zu irreversiblen Veränderungen von korrodierten Oberflächen führen kann /GARREICH 2010/.

Oberhalb von 90 % r. F. in der objektnahen Luft kann es in Abhängigkeit von der Temperatur des Glases bereits zur Tauwasserbildung auf der Oberfläche kommen /TORGE 2011/.

Weitere thermodynamisch messbare Einflussgrößen sind /TORGE 2011/ die Gesamtschwankungsbreite von Temperatur und relativer Luftfeuchtigkeit und die Änderungsgeschwindigkeit dieser Größen, die bei Sonneneinstrahlung sehr hoch sein kann. Für beide liegen allerdings keine Grenzwerte vor. Hilfsweise kann aber auf die EN 15757:2010-12 zurückgegriffen werden. Diese ist zwar für organisch hygroskopische Materialien formuliert, gibt aber kurzzeitige Schwankungen von +/- 10% pro 24 Stunden in der relativen Feuchte und +/- 5 Grad Celsius pro 24 Stunden bei der Temperatur vor.

Bei vielen chemischen Reaktionen führt eine Erhöhung der Temperatur um 10 K schon zu einer Verdoppelung der Reaktionsgeschwindigkeit und die Dauer des gleichzeitigen Auftretens hoher Temperaturen und hoher relativer Luftfeuchte tragen wesentlich zur Korrosion bei /TORGE 2014/. Es gibt aber leider keine Grenzwerte hierfür.

Das Mikroklima im Bereich der Glasmalereien bestimmt die Bedingungen für das Wachstum von Schimmelpilzen oder Bakterien /Hör 2005/ und dies hat korrodierende Wirkung auf das Glas /DREWELLO 2004/. Thermodynamisch zu überwachende Grenzwerte hierfür wurden in Form von Isoplethen von /SEDLBAUER 2001/ erarbeitet.

2016 wurde der Grenzwert von 80% relativer Feuchte erneut bestätigt /HÖR in BÖTTCHER 2016/. Zusätzlich wurde festgestellt, daß häufige Wechsel um die 80% relativer Feuchte drum herum ein Schadenrisiko darstellen. Einige der Regeln aus 2006 konnten verschärft und in Zahlen dargestellt werden:

- | | |
|--|--------------|
| • Kondensat an der Schutzverglasung: | Null |
| • Frost auf der Schutzverglasung: | Null |
| • Temperaturkorridors der Oberflächentemperatur am Originalglas: | 0°C bis 40°C |
| • Luftfeuchtekorrridor im Luftspalt: | 40% bis 75% |

Zusammenfassend können nun folgende thermodynamisch zu überwachende Grenzwerte formuliert werden:

Definition von Grenzwerten für eine Dauerüberwachung

• Luftfeuchtekorridor im Luftspalt:	40% bis 75% (oder 80%)
• Eisbildung auf Schutzverglasung:	Null
• Oberflächentemperatur des Originalglases:	0°C bis 40°C
• Überwachung der Isoplethen für Schimmelbildung:	außerhalb der Isoplethen
• Tauwasser auf Originalglas:	Null
• Tauwasser auf Schutzverglasung:	Null
• Änderungsgeschwindigkeit der Temperatur:	+/- 5°C pro 24 Stunden
• Änderungsgeschwindigkeit der rel. Luftfeuchte:	+/- 10% pro 24 Stunden

Definition von thermodynamischen Größen, die zu ermitteln sind, für die aber noch keine Grenzwerte definiert wurden:

- Häufigkeit des Übergangswechsels bei einem Grenzwert von 80% rel. Luftfeuchte,
- Schwankungsbreite von Temperatur und relativer Feuchte im Luftspalt
- Das gleichzeitige Vorliegen hoher Temperatur und hoher relativer Feuchte im Luftspalt

Überwachungskriterien für die Messtechnik und an den Kunden zu übermittelnde Warnmeldungen:

- Rel. Feuchte im Luftspalt kleiner als 40% in % der Gesamtzeit
- Rel. Feuchte im Luftspalt größer 80% in % der Gesamtzeit
- Eis auf Schutzverglasung in % der Gesamtzeit
- Oberflächentemperatur des Originalglases kleiner als 0 Grad in % der Gesamtzeit
- Oberflächentemperatur des Originalglases größer als 40 Grad in % der Gesamtzeit
- Luftfeuchte über 75% und Lufttemperatur zwischen 20 und 40 Grad in % der Gesamtzeit
- Luftfeuchte über 85% und Lufttemperatur zwischen 10 und 40 Grad in % der Gesamtzeit
- Luftfeuchte über 75% und gleichzeitig Lufttemperatur zwischen 40 und 60 Grad in % der Gesamtzeit
- Luftfeuchte über 85% und gleichzeitig Lufttemperatur zwischen 40 und 60 Grad in % der Gesamtzeit
- Kondensat am Schutzglas oder rel. Feuchte der Luft im Nahfeld bei mehr als 90% in % der Gesamtzeit
- Kondensat am Originalglas oder rel. Feuchte der Luft im Nahfeld bei mehr als 90% in % der Gesamtzeit
- Tmax-Tmin im Luftspalt
- Phimax-Phimin im Luftspalt
- Delta T/Zeiteinheit im Luftspalt
- Delta Phi/Zeiteinheit im Luftspalt

Ergebnisse aus Praxistests

Um zu untersuchen, wieviele der erarbeiteten Grenzwerte in realen Objekten überschritten werden, wurde auf eine hervorragende Datenbasis von Manfred Torge zurückgegriffen /TORGE 2011 und 2014/. Die Ergebnisse dieser Untersuchung sind in folgendem Bild (Abb. 2) gezeigt.

Rot bedeutet, daß ein oben definierter Grenzwert überschritten wurde, grün bedeutet, daß das Klima sich innerhalb der Grenzwerte bewegt und gelb bedeutet, daß keine Daten ermittelt werden konnten oder dass es keinen Grenzwert gibt.

Das „bunte“ Bild zeigt, daß viele der gewünschten Grenzwerte nicht eingehalten werden. Es kam zwar an keinem der Objekte zu Tauwasser an der Originalverglasung, sehr wohl aber an der Schutzverglasung mit bis zu 221 Tagen im Jahr. In vielen Fällen gab es Frost an der Originalverglasung, in fast keinem Fall lag die Temperatur oberhalb von 40 Grad. Die relative Luftfeuchte in der Umgebung des Originalglases ist in fast allen Fällen größer als 80 %. In eher seltenen Fällen ist die Luft zu trocken. In fast allen Fällen ist die Luftfeuchte in der Nähe der Schutzverglasung größer als 80 % oder 90 %. Keine Messdaten gibt es zur Häufigkeit des Übergangs bei 80 % rel. Luftfeuchte und es gibt keine Auswertung, für das gleichzeitige Auftreten hoher Luftfeuchten und Temperaturen in % der Gesamtmesszeit, was für die Bewertung von Schimmel ganz besonders wichtig wäre.

Oberfläche temperatur des Originalglas kleiner als 0 Grad 1% der Gesamtzeit	Oberfläche temperatur des Originalglas größer als 40 Grad in % der Gesamtzeit	rel. Feuchte im Kircheninn enraum an der Originalver glasung größer 80% in % der Gesamtzeit	rel. Feuchte im Luftspalt nahe Schutzver glasung kleiner als 40% in % der Gesamtzeit	Feuchte im Luftspalt nahe Schutzver glasung größer 80% in % der Gesamtzeit	Feuchte im Luftspalt nahe Schutzver glasung größer 90% in % der Gesamtzeit	Eis auf Schutzver glasung in % der Gesamtzeit	Häufigkeit des Übergangs wechsels von 80% rel. Luftfeuchte im Spalt	Luftfeuchte über 75% und Lufttemper atur zwischen 20 und 40 Grad in % der Gesamtzeit	Luftfeuchte über 85% und Lufttemper atur zwischen 10 und 40 Grad in % der Gesamtzeit	Tage Kondensat am Schutzglas	Tage Kondensat am Originalglas	Tmax - Tmin im Luftspalt in Grad Celsius (höchster Wert im Jahr)	Phimax- Phimin im Luftspalt (Höchstes Wert im Jahr) in % r.F.	Delta T/H5 Minuten im Luftspalt	Phi/H5 Minuten im Luftspalt	über 75% und gleichzeitig Lufttemper atur zwischen 40 und 60 Grad in % der Gesamtzeit	über 85% und gleichzeitig Lufttemper atur zwischen 40 und 60 Grad in % der Gesamtzeit
3	0	23	0	55	20	20				81	0	41,8	55,6			"± 4%/min"	
12	0	11	0	32	33	2				6	0	44,5	53,2			"± 4%/min"	
10	0,1	28	4	37	0,1	10				30	0	52,9	78,9	4K/min		"± 4%/min"	
0	4	36	4	63	50	4				221	0	55,2	80,9	4K/min		"± 4%/min"	
0	0	0	4	43	14,5	2				58	0	53,6	84,7	2K/min		"± 4%/min"	
10	0	35	5	31	26					33	0	37,1	73,6				
		24		24	18					18	0	20	55				
15	0	5	0	25	14						0	20	43				
15	0	20	0	0,1	0,1						0	40	80				

Abb. 2. Darstellung der Überschreitung von Grenzwerten in realen Objekten auf Basis der Messdaten von Torge 2011 und 2014.

Messgeräte zur Dauerüberwachung

Die vielen überschrittenen Grenzwerte zeugen davon, daß hohe Risiken bestehen, wenn man die thermodynamischen Zustände nicht kontinuierlich überwacht. Aus diesem Grunde wurde in einem von der DBU geförderten Projekt /SANDER 2017/ „Entwicklung und modellhafte Anwendung eines neuartigen Sensorsystems zur Überwachung der nachhaltigen Wirksamkeit von Schutzverglasungen für durch anthropogene Umwelteinflüsse gefährdete Glasmalereien am Beispiel der Wiesenkirche in Soest“ ein Messgerät entwickelt, welches man einfach in die Deckschienen einhängt, einschaltet und dann für die Überwachung relevante Messwerte ermittelt, speichert und über Mobilfunk in die Cloud sendet. Über Benutzername und Passwort lassen sich dann die Originaldaten in einem Webbrowser ansehen, um eine Beurteilung der Situation durchzuführen. Abbildung 3 zeigt das System fertig montiert:



Abb. 3. Custos Aeris für die Dauerüberwachung der thermodynamischen Zustände von Original- und Schutzverglasung.

Mit diesem System werden Lufttemperaturen und relative Feuchten im Luftspalt und im Nahfeld der Originalverglasung auf der kircheninneren Seite gemessen. Darüber hinaus findet eine berührungslose Oberflächentemperaturmessung der Originalverglasung auf der kircheninneren Seite und auf der Luftspaltseite statt, sowie auf der Luftspaltseite der Schutzverglasung. Damit sind alle relevanten Größen für die oben dargestellte Überwachung von Grenzwerten vorhanden. Für die Auswertung und Darstellung von Gefahren werden bisher schon die Angaben zur Tauwasserbildung auf Original- und Schutzverglasung in % der gesamten Messzeit gemacht (Abb. 4). Rot bedeutet, daß Kondensat vorlag und grün bedeutet, daß die Verglasung kondensatfrei war.

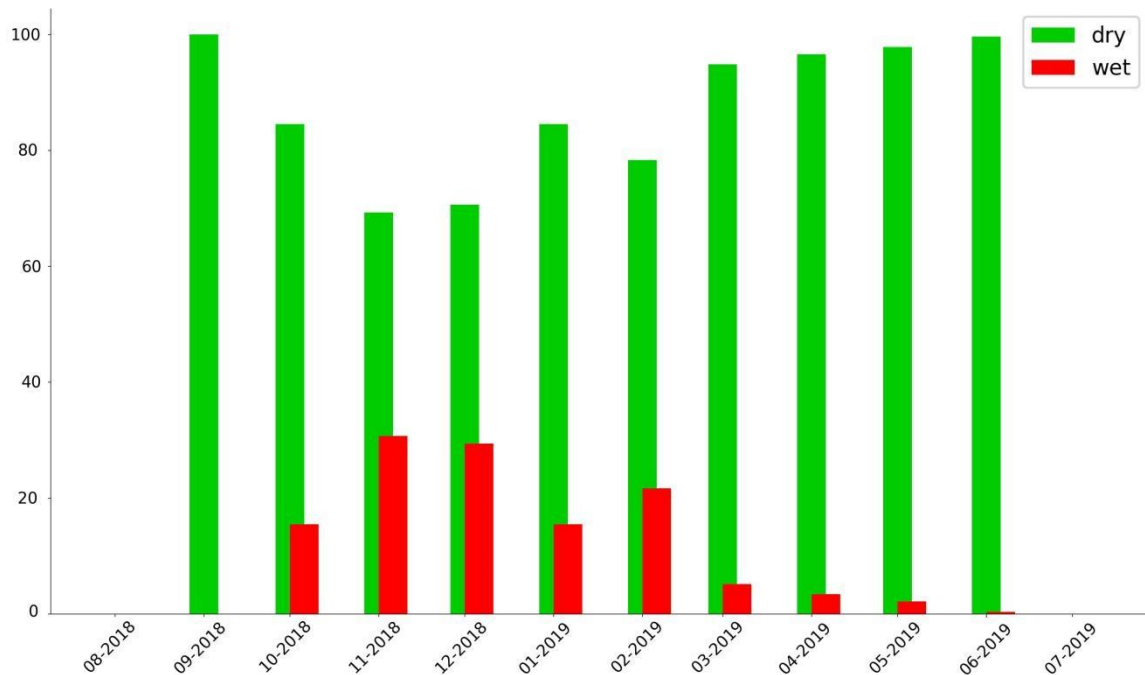


Abb. 4. Monatliche Darstellung des Kondensats in % der Gesamtzeit.

Risikoplots sind gut geeignet, um den thermodynamischen Gesamtzustand zu bewerten. Abbildung 5 zeigt einen solchen Risikoplot. Dargestellt sind die relative Luftfeuchte über der Temperatur. Die Farbskala gibt an, wie oft der entsprechende thermodynamische Zustand vorgekommen ist. Im grünen Bereich werden keine Risiken erwartet.

Da sich die thermodynamischen Zustände links in Abb. 5a aber stark im oberen Bereich bewegen, ist mit erheblichem Schimmelrisiko zu rechnen. Rechts ist dagegen eine Kirche gezeigt, in der voraussichtlich nicht mit Schimmel zu rechnen ist.

Custos Aeris wird nun so erweitert, daß alle anderen zu überwachenden Größen erfasst und die einzelnen Risiken dann dem Benutzer gemeldet werden.

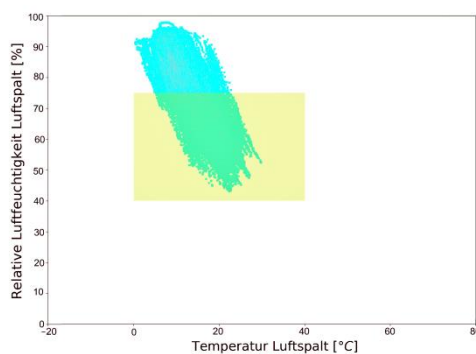


Abb. 5a. Risikoplot in einer Kirche mit hohem Schimmelrisiko.

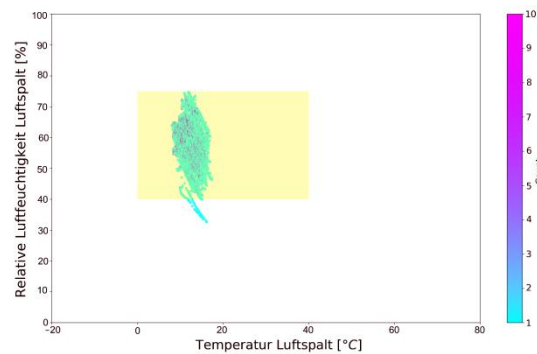


Abb. 5b. Risikoplot in einer Kirche mit geringem Risiko für Schimmelbildung.

Die Risiken in der Zukunft durch Klimaerwärmung

Durch die Klimaerwärmung wird sich voraussichtlich die Lufttemperatur um ca. 5 Grad bis Ende des Jahrhunderts besonders im Norden Europas erhöhen /LEISSNER 2018/. Der Mittelmeerraum wird wesentlich heißer und trockener /LEISSNER 2018/. Die Niederschlagsmengen im Norden Europas werden deutlich zunehmen. Die klimatischen Änderungen sind so gewaltig, daß es zu vermehrtem Aufkommen von Schimmel kommen wird. Für das frühe Erkennen von Risiken für die historisch wertvollen Schutzverglasungen ist es mehr als empfehlenswert, Dauerüberwachungssysteme zu installieren.

Forschungsbedarf

Bei der Durcharbeit vieler Literaturstellen für diese Publikation fiel auf, daß die Art der Sensoren und deren Anordnung bei unterschiedlichen Anwendungen unterschiedlich ausfällt. Eine Vergleichbarkeit der Messdaten und damit auch korrelierende Aussagen bei unterschiedlichen Objekten sind daher schwierig. Eine Normung von Messtechnik und Messpositionen wäre sehr hilfreich.

Für viele der vermutlich riskanten Parameter, die in der jetzigen Form nur mitgeschrieben werden, gibt es noch nicht hinreichend abgesicherte Grenzwerte. Hier liegt weiterer Forschungsbedarf vor, um die thermodynamischen Grenzparameter für die einzelnen Schadenmodelle zu erarbeiten.

Anhang: Kurzdarstellung für potentielle Verbesserungsmaßnahmen

Abstand zwischen Schutzverglasung und Bleiverglasung und Größe der Ein- und Austrittsöffnungen

In Simulationen (/Oidtmann 1993/) zeigt sich, daß ab einer Belüftungsöffnung von ca 30mm bis 50mm und bei 40mm und 70mm Spaltabstand kaum noch Einflüsse auf die niedrigste Schutzglas Temperatur vorliegen. Ein ähnliches Verhalten ergibt sich auch für die Originalglas Temperaturen, die Spaltluft-Temperaturen und die Luftgeschwindigkeit im Spalt, wobei diese mit kleinerem Spaltabstand zunimmt.

Art der Belüftung

Es gibt nicht-belüftete, innen-belüftete, außen belüftete und mischbelüftete Systeme.

In ersten Untersuchungen /RÖMICH&FUCH 1993/, zeigte sich, daß nicht belüftete System für den Schutz der Bleiverglasung ungeeignet sind und die Korrosionsbelastung erhöhen. Außenbelüftete Systeme haben nur geringe Schutzwirkung und zeigen eine negative Belastung der Originalverglasung durch Luftschadstoffe und Stäube. Je nach Spaltabstand und Lufteintritts- und -austrittsöffnungen zeigen innen-belüftete System die besseren Ergebnisse. Mischbelüftete Systeme sind schwierig zu überschauen und führen auf jeden Fall schadstoffbelastete Außenluft in den Spalt ein. Daher ist hier Vorsicht geboten. In seiner Dissertation /OIDTMANN 1993/ gibt der Autor eine sehr gute Einführung in Schutzverglasungskonzepte. Auch wenn die Außenbelüftung wegen geringerem Kondensationsrisiko bei der aufsteigenden Luft physikalisch besser ist, kann es immer passieren, dass die Bleiverglasung im unteren Bereich stark abgekühlt wird und das Risiko für Kondensation der warmen, feuchten Kirchenluft auf der Innenseite der Bleiverglasung besteht. Bei der Innenbelüfteten Schutzverglasung tritt die warme, feuchte Luft oben ein und kühlt sich beim Herabfallen aufgrund der kalten Außentemperaturen ab. Hier ist also a-priori ein höheres Tauwasserrisiko vorhanden, allerdings bildet sich das Tauwasser auf der Schutzverglasung und nicht auf der Bleiverglasung. Daher ist dieses Konzept zu bevorzugen.

Art des Glasaufbaus bei der Schutzverglasung

Verbundsicherheitsglas hat sicherlich sehr gute Wirkung gegen Vandalismus. Problematisch ist es jedoch, wenn diese in Bleiruten eingefasst werden, denn hierdurch besteht das Risiko des Wassereintritts an undichten Kanten. Die Bearbeitung von Verbundsicherheitsglas zu Rauten- oder Rechteckscheiben für Außenschutzverglasungen erfordert sehr große Erfahrung und eine präzise Vorgehensweise beim Zuschnitt des VSG. /TORGE 2011/.

Isolierglas

Bei einer Wärmeschutzverglasung mit innenbeschichteter Seite liegt die Glastemperatur des Schutzglases und die Lufttemperatur im Spalt höher als bei einfachem Floatglas. Dies führt dazu, daß Tauwasser am Floatglas bereits bei 4 Grad Außentemperatur einsetzt und bei ECOglas ab 2 Grad Außentemperatur /OIDTMANN 1994/. Insofern hat diese Art des Glases eine positive Wirkung. Aufgrund geringerer Temperaturunterschiede verlangsamt sich aber hier die Strömungsgeschwindigkeit. Vergleich-

chende Untersuchungen zum Thema Isolierglas wurden u.a. im Dom zu Xanten /SCHUBERT 2013/ durchgeführt. Um entsprechende Erkenntnisse in situ zu gewinnen, wurden vor je einem Fenster auf der Nord- und der Südseite des Domes verschiedene Varianten von außenliegenden Schutzverglasungen eingebaut und an diesen Modellfenstern zunächst über ein Jahr Luft- und Oberflächentemperaturen sowie relative Luftfeuchten gemessen. Auf der Grundlage der Messdaten wurde ein Vergleich der Verglasungen untereinander und mit einer als Referenz dienenden Einfachverglasung durchgeführt. Dabei konnte gezeigt werden, daß durch den Einbau der Isolierverglasung die Kondensatbildung auf der Glasmalerei fast vollständig verhindert wurde. Die Aufheizungs- und Abkühlungsprozesse auf der Glasmalerei verlaufen deutlich verlangsamt. Die Isolierverglasung mit Wärmeschutzbeschichtung hat optimale Ergebnisse geliefert /SCHUBERT 2013/. Die Lufttemperatur im Spalt wurde erhöht und die relative Feuchte verringert. Die Schwankungen von Lufttemperatur und relativer Feuchte wurden reduziert. Die Oberflächentemperaturen an der Schutzverglasung und an der Spaltseite der Glasmalerei wurden erhöht. Es verringert sich auch die Temperaturdifferenz der Oberflächen innerhalb des Domes.

Beheizte oder nicht beheizte Kirche

In Simulationen und Messwerten /OIDTMANN 1994/ kann gezeigt werden, daß bei beheizten Kirchen die Möglichkeit einer Tauwasserbildung geringer ist. Die direkte Beheizung des Luftspaltes hat eine positive Wirkung auf die Absenkung der relativen Feuchte /TORGE 2011/ und /HÖR in BÖTTCHER 2016/.

Staubdeposition

Die Untersuchungen zeigen, dass durch Staubdeposition auf Glasoberflächen mittelalterlicher Zusammensetzung unter Einfluss von Luftfeuchtigkeit und Temperatur Schäden entstehen können. Diese Schäden äußern sich in der Veränderung der Zusammensetzung der Glasoberfläche infolge von chemischen Reaktionen zwischen Staub, Luftfeuchtigkeit und Glas. Die aufgrund der relativen Luftfeuchtigkeit bedingte Anlagerung von Wasser an die Glasoberfläche führt bei sehr empfindlichen Gläsern bereits zu einer deutlich sichtbaren Auslaugung von Kalium und Calcium aus der Glasoberfläche /TORGE 2011/. Die für eine gut funktionierende Außenschutzverglasung notwendige Luftzirkulation im Spalt zwischen Original und Außenschutzverglasung ermöglicht den Transport von Staubpartikeln und Aerosolen /TORGE 2014/. Organische Verschmutzungen bilden in Kombination mit Feuchtigkeit, z. B. ablaufendem Kondensat, einen idealen Nährboden für die Ansiedlung und das Wachstum von Mikroorganismen wie Schimmelpilzen, Bakterien- und Hefekolonien. Diese können unter Umständen eine ernsthafte Gefährdung des Glasmaterials darstellen /SCHUMACHER 2010/.

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1.2

The Inherited Condition: The Complex Methodology Required to Conserve the West Choir Windows of Naumburg Cathedral, Germany

Sarah Jarron, Jana Hildebrandt, Mayre Maquiné, and Emily Yates

Der ererbte Zustand: die komplexe Methodik zur Erhaltung der Westchorfenster des Naumburger Doms, Deutschland – Zusammenfassung

Während seiner Entstehungszeit zwischen 1241 und 1250 wurde der Westchor des Naumburger Doms mit fünf figurativen Fenstern ausgestattet. Der Westchor mit seinen berühmten Stifterfiguren stellt ein Gesamtkunstwerk dar und war maßgeblich für die Verleihung des UNESCO Weltkulturerbe-Titels im Jahr 2018.

Im Laufe der Jahrhunderte wurden die Fenster des Chors vielen Eingriffen unterzogen. Drei der fünf Fenster weisen einen großen Anteil von Glasmalerei aus der Entstehungszeit auf, ergänzt durch Glas aus Restaurierungsphasen des 19. und 20. Jhs. Zwei verlorene Fenster wurden im 19. Jh rekonstruiert und der originalen Gestaltung angeglichen.

The Inherited Condition: The Complex Methodology Required to Conserve the West Choir Windows of Naumburg Cathedral, Germany – Abstract

Over the centuries, the windows in the West Choir of Naumburg Cathedral have been exposed to many alterations. These figurative windows were originally installed between 1241 and 1250, during the Choir's construction. The entire ensemble or Gesamtkunstwerk was a key factor in the Cathedral gaining World Heritage status, in 2018.

Today, three of the five windows retain considerable expanses of original glazing, as well as 19th- and 20th-century additions from previous restorations. Two windows were entirely remade in the 19th century with sympathetic designs.

Jede Restaurierung hat sich signifikant auf den Zustand der Glasmalereien ausgewirkt. Während allen Ergänzungen ein historischer Wert zugesprochen werden kann, verursachen viele der angewendeten Techniken und eingebrachten Materialien heute eine restauratorische Herausforderung. Das Glas aus dem 19. Jh zeigt extremen Malschichtverlust und Craquelé des blauen und gelben Glases. Die Vorarbeiten an den Glasmalereien des 13. Jhs zur Durchführung des Jacobiverfahrens führten zu starker Glaskorrosion, fragiler Malschicht und Acrylatrückständen.

Dieser Artikel befasst sich neben der Restaurierungsgeschichte mit dem überkommenen Zustand der Fenster und den durchgeführten Restaurierungsmaßnahmen. Des Weiteren wird beschrieben, wie der Gesamteindruck des Westchors visuell harmonisiert wurde.

Each restoration has significantly impacted upon the current condition of the stained glass. Whilst, over time, all introduced materials can attain historic value, it is clear that many of the techniques and materials applied to the West Choir windows have created substantial conservation challenges. The 19th-century glass exhibits extreme paint loss and craquelé of the blue and yellow glasses. The 13th-century glass exhibits severe corrosion, fragile paint and acrylate residues as a result of preparations for Jacobi-plating in the 1940s.

This paper will describe the restoration history and the balanced methodology required to unify these windows, whilst addressing the urgent interventions needed for their conservation.

Introduction

Naumburg Cathedral's West Choir has one of Germany's most extensive figurative window cycles from the High Middle Ages. These windows portray the victory of Christian faith over pagan traditions. Apostles and saints stand triumphant over their adversaries and personifications of virtues defeat vices. The medieval scheme also epitomises the *Zackenstil* or jagged style, which takes its name from the depiction of heavy folds in drapery, seen in the figure's heraldic clothing. This 13th-century aesthetic mixed French Gothic and Byzantine influences, with Naumburg at an intersection between these artistic movements. A narrow colour palette is combined with large figurative iconography on a monumental scale. Comparable in quality to the clerestory and transept windows of Chartres Cathedral, this glass undeniably has a strong identity and is instantly recognisable.

This scheme of five monumental windows remains a highly significant medieval work of art, despite now being a composite of interventions by the many generations of glass painters and conservators to work on them. Despite the 19th-century recreation of two windows, strong iconographic unity has been retained. However, the durability of these additions has created problems with the uniformity of tone and light across the Choir.

The last 150 years have witnessed three major restoration campaigns. Each successive team respected the quality of these windows and strove to ensure their interventions were ethical, harmonious and enduring. Unfortunately, each suffered a combination of poor execution, irreversible procedures, flawed

decisions and misfortune. Many of the materials and techniques utilised have culminated in the long-term degradation of the glass.

Between 2018 and 2020, a glass workshop was set up in the grounds of Naumburg Cathedral to address the urgent conservation required to stabilise and secure these windows for future generations.

The Impact of Past Decisions

Prior to the late 19th century, there are scant archival records about the condition and maintenance of the West Choir windows. The first record dates from 1584 and refers only to three medieval windows.¹

The loss of windows swII and wI is attributed to an undated extreme weather event. Archival images from the mid-19th century reveal they were replaced by rectangular quarry glazing.

Subsequently, there have been three major restoration campaigns. What follows is a synopsis of how these interventions have impacted the glazing. This combines archival research undertaken by Dr. Deiters and Dr. Aman,² together with our onsite and studio analyses (fig. 1).

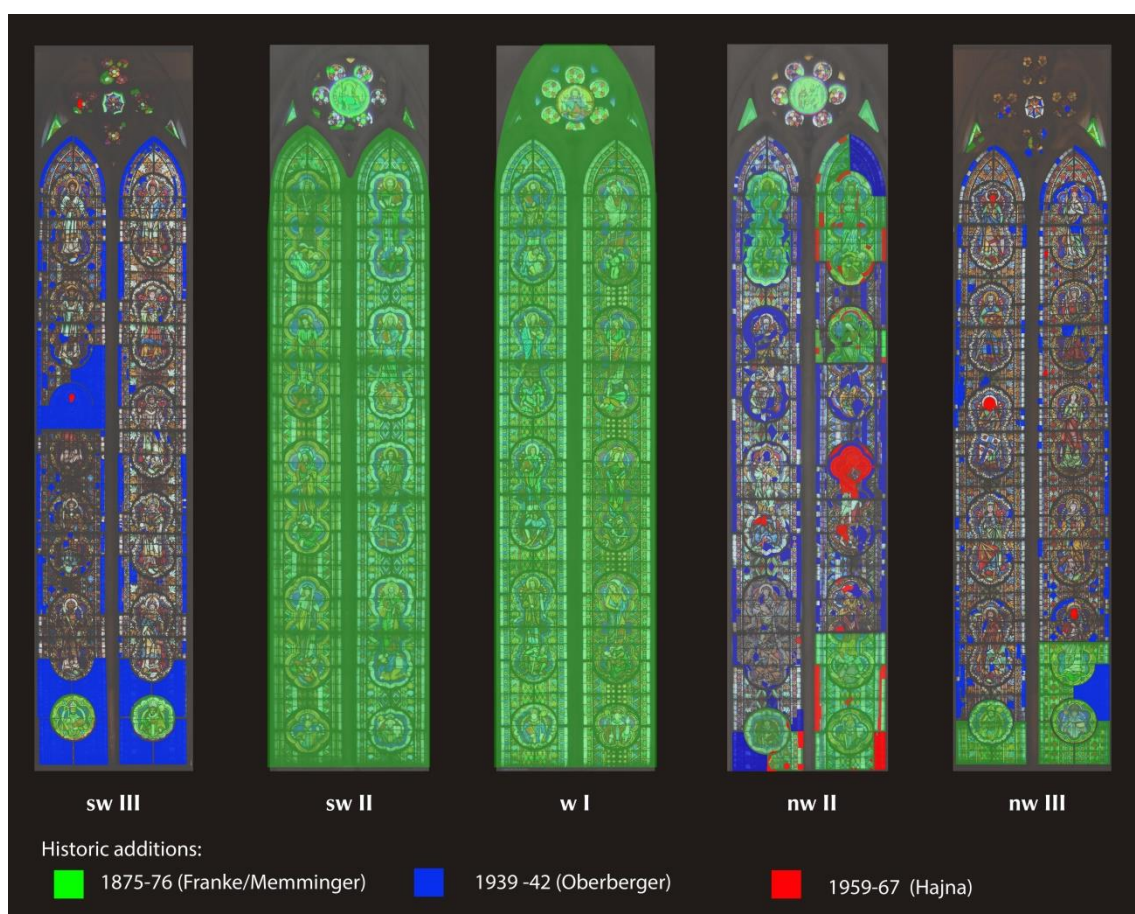


Fig. 1. Diagram of the restorations in the West Choir. © Vereinigte Domstifter.

Franke/Memminger 1875–1879

The first restoration was by Wilhelm Franke (Naumburg Master Glazier) and Karl Memminger (Architect). By the 19th century, the medieval windows (swIII, nwII and nwIII) were in disrepair, with gaps and missing panels. Memminger designed a scheme to unify all five windows, whilst remaining sympathetic to the original glass. The new glazing adhered to the same colour palettes for glass and

¹ Reinhard KÖPF and Ivo RAUCH, *Die Verglasungen des West- und des Ostchores des Naumburger Doms. Gutachterliche Stellungnahme zu Bestand und Zustand der Fenster und Empfehlungen für eine Sanierung bzw. Konservierung der Scheiben*, 2017, p. 8.

² Cornelia AMAN, Maria DEITERS, and Martina VOIGT, *Vorabgutachten zur Restaurierungsgeschichte der Westchor- und Ostchorverglasung des Naumburger Domes*, 2016.

paint and used traditional painting techniques mimicking the three-tone medieval iconography. They used an early mouth-blown glass, leaded with fine came suggestive of the medieval lead. As this glass was largely available only in light tones,³ the design relied upon the use of multiple layers of paint.

In addition to remaking two windows, the three medieval windows were cleaned. Some of this work was conducted *in situ*, as Franke recorded, using a brush and soapy water from ladders and scaffolding.⁴ Corroded brush marks are now evident across the interior surface of the 13th-century glass. The traceries were also treated *in situ*. New glass infills were added by splicing the medieval lead from the interior side and resealing it with ample putty. Where panels were removed, they were reinstalled with cement.

Franke added cold paint to enhance missing grisaille. To make the windows appear less patchy, he applied a darkening layer to medieval pieces thinned by corrosion and a separate protective coating to the better preserved glass. One of these layers was later identified as an iron varnish or 'eisenlack'.⁵

Despite their best efforts, the final result was inharmonious. As with many 19th-century studios, paint-loss was a major problem. Franke was recalled to effect repairs that included the addition of cold paint to his own windows. However, this new glazing remained much brighter than the medieval glass. By the 1930's, substantial paint-loss was evident in all but the West Window, whilst the iron varnish had become black/brown and opaque. In addition, the blue and yellow glasses were unstable and began to show signs of craquelé. In 1937, Prussian state conservator Robert Hiecke lamented the Choir's "divided effect" and the next conservation team was commissioned.⁶

Oberberger 1939–42

In 1937, Josef Oberberger of Munich was commissioned to redesign and restore unity to the West Choir windows. He worked closely with the Dörner Institute and was keen to use their new scientific methods. Prior to conservation, large sheets of paper were stuck to the windows with protein glue.⁷ The paper's subsequent dry removal resulted in significant shaling of the glass surface; particularly, that of the 19th-century glass.

In 1939, as Oberberger planned to remake all Franke's glazing, only the lancets of the medieval windows nwII, nwIII and swIII were deinstalled for safety, due to WW2. This glass was stored in the basement of the north-west tower, from where it was taken piecemeal for conservation. Records reveal these windows were in poor condition, with swIII particularly fragile. Oberberger described the medieval lead as weak and unsalvageable, which was opportune as he was keen to test the new plating technique designed by Jacobi at the Dörner Institute.⁸

Jacobi's aim was to protect fragile glass and paint from water damage through a process of lamination. Plates were applied to both sides and the interspace filled with a liquid thermoplastic. Oberberger trialled this method using a mixture of PMA with diisobutyl phthalate plasticisers.⁹ This glass 'sandwich' was then shipped to the SIGLA (*Sicherheitsglas* or laminated glass) factory in Kunzendorf, where it was heat sealed at 130°C, rendering it waterproof.¹⁰

In 1940, two trial panels (swIII 11b and nwIII 17a) were selected for lamination.¹¹ In spite of unsuccessful results (due to excess weight and highly reflective surfaces), Oberberger plated at least 400 glass pieces, although PMA remnants have been found across most of the medieval glass. In order to accommodate these laminated pieces, the glass required reglazing. By 1941, all the medieval lead had been discarded.¹²

³ KOPF & RAUCH 2017, p. 8.

⁴ AMAN et al. 2016, p. 8.

⁵ *Ibid.*, p. 9.

⁶ KOPF & RAUCH 2017, p. 12.

⁷ AMAN et al. 2016.

⁸ AMAN et al. 2016, p. 12.

⁹ Elisavet KANAKI and Joseph BRANDT, *Erforschung historischer Konservierungsmethoden für Glasfenster. Ein Bericht zu Erhaltung mittelalterlicher Glasmalerei einschließlich der Ergänzungen aus dem 19. Jahrhundert im Naumburger Dom*, 2019, p. 13.

¹⁰ AMAN et al. 2016, p. 11.

¹¹ AMAN et al. 2016, p. 21, 23.

¹² *Ibid.*, p. 12.

Prior to lamination, Oberberger's team thoroughly cleaned the glass, using hydrofluoric acid to remove all dirt and traces of 19th-century iron varnish, coatings and cold paints.¹³ Two glaziers, Zörn and Bauer, were particularly skilled at judging how long to leave the glass in the acid without losing the glass paint.¹⁴ However, they did remove the corrosion products. Glass breaks were edge-bonded, and the paint consolidated using the PMA formulation.¹⁵

The Oberberger team began systematically replacing the Franke glass with mouth-blown real antique glass, in the same colours as the medieval windows. They achieved their aim of an artistically satisfying approach that did not falsify the iconography. Ornamental details were reproduced but glass pieces within the figures were remade using a stippled design. Infills were signed with the year and/or an 'x', and signatures were included within remade panels. These panels are extremely dark in comparison with the rest of the scheme.

Franke's team had replaced eight missing medieval heads, but these had either lost their paint or were badly executed. Oberberger created new heads for many panels but made a 'cloud head' for St Matthew in nwl. We cannot know whether this approach was planned for all eight panels, as the restoration was abruptly suspended in 1942. The two glaziers were conscripted and neither man returned. The medieval glass spent the next decade in the north-west tower basement, where it was badly affected by the damp, humid conditions.

Hajna 1959–1967

By the time Hajna was commissioned, the medieval glass pieces had stuck to the layout paper, fungus was growing on the acrylate, and the laminated panels exhibited broken plates, water ingress and acrylate discolouration.¹⁶ Franke's glass remained *in situ* and Hajna inherited the task of reunifying the choir.

The immediate priority was to reglaze the medieval glass. Hajna reversed most of the laminated plates by gently heating them, cutting the PMA with a long flat blade, and cleaning the surfaces with acetone.¹⁷ He did very little additional cleaning, retaining historic dirt and lacquer. Broken pieces were glued with 4-5 coats of PMMA or PBMA (Piaflex) applied to the exterior side.¹⁸ These products were applied liberally and cover up to 5mm of the surface on either side of the break. Piaflex was also used to consolidate paint and large deposits remain on the glass.

Whilst Hajna retained the majority of Oberberger's infills, he replaced remaining Franke additions with antique glass coated with fired and unfired paint, the latter proving undurable. He also dated some pieces and added seven further 'cloud heads', as well as 'cloud hands'. These cloudy pieces have remained contentious ever since.

Finally, Hajna placed all five windows, except the traceries, in protective glazing. To accommodate this, the medieval ferramenta was moved 10cm into the church and new bars were installed. This external glazing comprised rectangular quarries of different hues to tone down the 19th-century glass. It was not mortared into the stone and was sealed with putty to the condensation trays. Therefore, whilst affording the windows some protection, it did not shield the glass from the effects of humidity or air pollution.

Inherited Problems

Despite the best intentions of past conservators, the extant collection remained disunited and problematic. The 13th-century glass exhibited considerable active, powdered corrosion; likely exacerbated by the coatings, acid cleaning and damp storage conditions. Comparison between Hajna's photos from the sixties and the glass today, clearly demonstrate the increase in corrosion products. Where the corrosion had pierced the surface, the surrounding paint was flaking and extremely vulnerable.

¹³ *Ibid.*, p. 18.

¹⁴ *Ibid.*, p. 18.

¹⁵ *Ibid.*, p. 8.

¹⁶ AMAN et al. 2016, No: 61.

¹⁷ *Ibid.*, No: 78; No: 69.

¹⁸ KANAKI & BRANDT 2019, p. 12.

The glass also exhibited extensive PMA/DiBP residues. The acrylate held absorbed water against the glass surface during cycles of wetting and drying. Water ingress had contaminated the PMA, producing various shades from pale yellow to dark amber and darkening the appearance of the medieval glass. This PMA formulation has a low glass transition temperature (10°C) and the windows' thermal variation resulted in dust and dirt adhering to the sticky surface on the south facing windows.

Hajna's acrylates were more durable. However, many bonds had failed and small flies (thrips) had burrowed underneath the glue. Many of his infills were very bright, due to the failure of the cold paint. The Franke glass displayed substantial paint loss and the historic cold paint repairs had either failed or accumulated thick dirt layers. The glass surface exhibited large areas of shaling due to dry removal of paper and protein glue, which had become brown. Many pieces exhibited stages of craquelé. In spite of darkening attempts, these panels remained very bright. By contrast, the thirteen Oberberger panels appeared extremely dark.

All the panels were filthy, with dust and thick black particulate deposits comprising soot, gypsum, putty, and mortar, as well as silicon and aluminium particles.¹⁹ The dirt adhered to the paint and cold-paint, as well as traces of PMA.

Chemical analysis revealed these windows had been exposed to high levels of air pollution. In addition to gypsum and sodium sulfate, zinc oxalate and zinc ammonium oxalate were found on both sides of the panels.²⁰ The area surrounding Naumburg is rich in lignite deposits (brown coal), which contain high levels of carbon, nitrogen and sulfur, and heavy metals, including lead and zinc, that are released during incineration. During the GDR, many households were fuelled with lignite. The Geisel valley, 20km to the north east, was the location of vast opencast mines between 1698 and 1994. This mining gave rise to many chemical plants e.g. the BASF ammonia plant at Merseburg.²¹

Naumburg sits in the Saale river valley, where high humidity is common in the summer months. Since 2016, the relative humidity (RH) and temperature around the West Choir windows have been monitored, most recently with the Custos Aeris system.²² Between 2016 and 2017, the glass was exposed to extremes of temperature (from -5 to 46°C) and changes in humidity (between 10-99% RH).²³

Our Conservation Methodology

Primarily, the entire project was guided by preventative conservation. In order to address the rapid increase in glass corrosion, paint fragility and craquelé, environmental control was essential. As most stained glass corrosion and pest infestation are caused or exacerbated by moisture, the replacement of the protective glazing was imperative.

We also inherited the longstanding aim to try and unify this scheme of windows, whilst addressing the damage phenomena described. Enhanced iconographic legibility was also desirable. The project was overseen by an international Scientific Advisory Committee, comprising art historians, conservators and heritage officials. Their counsel was sought when defining the scope of any intervention.

Our approach was to preserve as much historic material as possible. In doing so, the strategy mixed preventative and interventive techniques. Over time, all materials introduced to an object attain value. However, historic value alone cannot be the defining factor in a conservation strategy, where damage can be related to specific materials.

It was thought that historic arguments for creating the cloudy heads and hands, no longer aligned with current views on aesthetic value and the balance required to ensure liturgical function, cultural and community value.²⁴ In consultation with the expert committee, it was decided to improve legibility by

¹⁹ Katrin RAHFOTH, Nicole STERZING and Ines TRAPPIEL, *Erforschung historischer Konservierungsmethoden für Glasfenster. Ein Beitrag zu Erhaltung mittelalterlicher Glasmalerei einschließlich der Ergänzungen aus dem 19. Jahrhundert im Naumburger Dom, Bericht zur Materialprobenentnahme für die wissenschaftlichen Untersuchungen an den originalen Glasmalereischeiben*, 2019, p. 39.

²⁰ *Ibid.*, p. 41.

²¹ D. BACHMANN, *Geisel Valley*, 2020.

²² For further information visit <https://custos-aeris.ixtronics.com/en/>.

²³ Data collected from the interspace between the stained glass and Hajna protective glazing on window swIII.

²⁴ HISTORIC ENGLAND, *Conservation Principles, Policies and Guidance*, 2008, p. 27-35.

reconstructing lost text, faces and hands. This was achieved through a combination of painted plates and infills (please refer to the article *Finding Faces* within this volume).

Unifying the Choir

The new environmental protective glazing is weathertight and internally ventilated. Lamberts mouth-blown Restauro UV glass was used, which filters wavelengths between 280nm and 400nm and has no risk of delamination. By removing the influence of weather, UV radiation and air pollution, we have ensured that the organic conservation materials will not deteriorate further.

As a first step towards unifying the light distribution in the Choir, a faint wash of paint was applied to the protective glazing, using the optical brightness of the medieval glass as a reference point. Reflecting their aspect and degree of paint loss, the glazing behind the 19th-century windows was darkened further. Tests ensured the UV protection would not be lost by firing the glass to 620°C. These results were corroborated by the BAM UV glass study.²⁵

As a further complication, the three medieval windows contained 19th-century panels with extreme paint loss. To address the light discrepancy, large painted plates were installed between the stained

glass and the protective glazing (fig. 2). Each bespoke plate addressed the light balance for a specific panel, using stippled paint which followed the iconography.

Cleaning

Varied levels of cleaning can be used to unify light transmission across a scheme of windows. However, due to the extent of glass degradation, our priority was surface stabilisation. As windows swll and wl were uniformly darkened by the external glazing, a straightforward approach was adopted, using wet and dry methods. However, on the Franke panels of the medieval windows, a balance was sought between how much dirt to remove and how bright the panel would become.

The medieval panels required careful intervention. Dirt, dust and active powdered and flaking corrosion products were removed using brushes and vacuum cleaners. Hard corrosion layers were thinned, but not removed entirely. The biggest challenge was safe removal of the PMA/DiBP. Where it had become hard and brittle on the north windows, it could be removed with the gentle application of a scalpel or brush.



Fig. 2. Naumburg Cathedral: Before and after installation of the darkening plate for panel nwll 1a1.

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However, on swlll it was well-adhered. Timed trials were made using acetone; ethyl acetate poultices; and a DMSO and Klucel G gel.

The DMSO gel was most effective at removing thick PMA residues. The gel prevented DMSO run-off and lowered the possibility of glass infiltration. Where pieces had an uneven topography, from corrosion and/or paint, this technique was used with extreme caution. The DMSO was used to thin the PMA, which was then removed with a scalpel. As sulfur is unstable at the pH of corroding glass, the use of

²⁵ In collaboration with Dr. Manfred Torge, Bundesanstalt für Materialprüfung, Berlin.

DMSO was limited and all traces were thoroughly removed post-treatment with swabs of deionised water.

Whilst acetone was less effective, it allowed a more cautious approach when cleaning over paint. Where the PMA/DiBP had been used as a consolidant, it was thinned but left in place. Acetone was also used as a fumigant to soften the acrylate when opening the few remaining Jacobi plates.

Retaining Craquelé Glass

During the 19th century, glass manufacture was redeveloped and industrialised. Experimentation resulted in some unstable glass compositions. Within Franke's glazing, all variations of the blue and yellow, glasses are prone to craquelé. The worst damage was seen in swll; by contrast, in window wl there were only two small pieces in the tracery exhibiting advanced craquelé deterioration.

At Naumburg, the craquelé can be attributed to low lime glass degradation and the LLHA (low lime high alkali) composition of the glass. This weakness, combined with high pollution and a damp environment resulted in the degradation. Calcium content is recognised as an important factor in the durability of glass, as it appears to slow the leeching of alkalis via hydrolysis. The most resilient glasses contain over 10% calcium,²⁶ whereas a sample of blue craquelé contained 6.78% calcium (and 25.44% combined Na and K).²⁷ Similarly, EDX analysis found a sample of amber yellow contained 6.34% calcium (and 27.19% total alkali). Both results fit within the anticipated parameters for vulnerable glasses.



Fig.3. Craquelé consolidation technique and post treatment result in nwIII 2a
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The craquelé process witnessed in Naumburg corroborates other descriptions of this phenomenon. The leeching of alkalis resulted in an efflorescence of sodium sulfate salts.²⁸ The glass surface developed micro-cracks, allowing water to penetrate deeper, causing the bulk glass to fragment. As well as environmental control, we researched consolidation methods, including the work of Marie Stumpf at the Burrell, Merlyn Griffiths at YGT, and the DBU project at the Cologne Dombauhütte.

At Cologne, they attached glass fibre material to the surface using either Ormocer or Paraloid B72. Both were found to be similarly effective and durable.²⁹ Building on their results, we conducted trials using glass fibre webbing with HXTAL and silane, and Paraloid B72 in ethyl acetate. Paraloid provided the best results.

The webbing was treated with a 10% coating of B72, to provide rigidity for measuring and cutting. A solution of 25% B72 in was applied to the exterior side of the breaks. The webbing was then adhered to this surface, with the 25% solution (fig. 3). Gaps were filled with B72 (or Araldite 2020, if the hole was larger than a Euro coin) and retouched with acrylics. We ensured the webbing did not adhere to the

²⁶ M. GRIFFITHS, *St John the Evangelist, Howsham (Yorkshire): Further Research into 'Crizzling'*, Vidimus Issue 98, 2016.

²⁷ KANAKI & BRANDT 2019, p. 47.

²⁸ RAHFOTH et al. 2019, p. 17.

²⁹ Ulrike BRINKMANN and Katrin WITTSTADT, *Anwendungen innovativer Restaurierungsmaterialien und methoden zur Sicherung craquelierter Glasmalereien Modellhafte Anwendung an Glasfenstern des Kölner Domes*, 2013, p. 67.

lead, as the differing thermal expansion rates of these materials could potentially damage the B72 film. The results were aesthetically satisfying, with the webbing undetectable from the interior side, and robust enough to retain these pieces.

As Paraloid B72 is known to fail in high humidity, this technique can be used only with internally ventilated protective glazing. In 2017, this technique was trialled in the West Choir by Derix, Taunusstein. This test panel has been monitored regularly over the last 4 years. The repairs remain stable, with no loss of adhesion or blistering in the webbing's surface.

Conclusion

Since the loss of windows wl and swll, many generations of conservators have attempted to restore a sense of unity to the West Choir. Each employed the most current knowledge and methods of their time. Their combined legacy – and our inheritance – was a disparate assemblage, ranging from the spectacular 13th-century windows, to the bright Franke panels, and the very dark Oberberger additions. Each element has its own intrinsic value and contributes to the overarching narrative of the West Choir.

Our methodology prioritised the immediate conservation needs of the windows. We also returned legibility to the iconography and replaced missing details with plates and infills. We stabilised the medieval glass and retained the 19th-century craquelé. All five windows are now protected with UV-filtered weathertight protective glazing and the disparity of light has been softened by the careful application of paint (fig. 4).



Fig. 4. The West Choir Windows post conservation, in 2020. © Vereinigte Domstifter.

In isolation, elements of this approach may be considered highly interventive. However, within the context of the overall scheme, the integrity of these iconic windows is undiminished, and our methodology has helped to unify the West Choir of Naumburg Cathedral.

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1.3

Finding Faces: Reconstructing Liturgical Identity in the Medieval West Choir Windows at Naumburg Cathedral, Germany

Emily Yates, Sarah Jarron, Mayre Maquiné, Jana Hildebrandt

Die Entdeckung der Gesichter: Rekonstruktion der liturgischen Identität in den mittelalterlichen Westchorfenstern des Naumburger Doms – Zusammenfassung

Während der zwei Restaurierungsphasen in den 1940er und 1960er Jahren wurden acht eigenschaftslose "Wolkenköpfe" in die fünf monumentalen Figurenfenster des frühgotischen Westchors des Naumburger Doms in Sachsen-Anhalt eingeführt.

Da es keine genauen Hinweise auf die verlorenen mittelalterlichen Köpfe gab, sollten die Lücken in den Figuren sympathisch gefüllt werden, ohne Täuschung oder Vermutungen über das ursprüngliche Aussehen. Die widersprüchlichen Standpunkte, die diese

ikonographischen Lücken umgeben, veranlassten jedoch zu einer erneuten Untersuchung des ästhetischen, spirituellen und gemeinschaftlichen Wertes eines der bemerkenswertesten mittelalterlichen Verglasungsschemas Deutschlands. Im Rahmen der 2017 begonnenen Konservierung des Doms wurden die acht fehlenden Gesichter anhand der technischen und stilistischen Zeugnisse der Fenster rekonstruiert. In diesem Beitrag wird der Prozess als Fallstudie zur Erforschung von Identität und Integrität bei der Restaurierung von Glasmalereien vorgestellt, insbesondere wenn keine Originalzeichnungen oder Archivbelege vorhanden sind.

Finding Faces: Reconstructing Liturgical Identity in the Medieval West Choir Windows at Naumburg Cathedral, Germany – Abstract

During two restoration phases in the 1940s and 1960s, eight featureless "Cloud Heads" were installed in the five monumental stained-glass windows in the early Gothic west choir of Naumburg Cathedral in Saxony-Anhalt.

Since no precise evidence of the lost medieval heads was available, this approach was intended to fill gaps in the figures sympathetically, without deception or conjecture about the original appearance.

The contradictory viewpoints surrounding the subsequent iconographic voids, however, prompted a re-

examination of the aesthetic, spiritual and communal value of the windows.

As part of the conservation of the cathedral's stained glass, which began in 2017, the eight missing faces were reconstructed after extensive consideration and discussion by an international expert advisory committee, using the technical and stylistic evidence remaining in the medieval windows.

This paper presents the process as a case study for the exploration of identity and integrity in stained glass conservation, especially where no original cartoon or archival evidence exists.

Introduction

The conservation of stained-glass windows today often involves the treatment of past restorative interventions. In some cases, the decisions made and measures implemented during previous restorations no longer align with current thinking in terms of ethics and the assignment of cultural values.

In the early Gothic west choir of Naumburg Cathedral in Saxony-Anhalt, Germany, eight lost faces from the monumental figurative window scheme were replaced with featureless neutrally toned infills as a result of two conservation campaigns carried out in the 1940s and 1960s. By the time this approach was used in Naumburg, neutral infills had already been implemented by restorers across Europe for over a hundred years. The development of the technique is particularly associated with the pioneering English stained glass historian Charles Winston in the mid-19th century.¹

Where no evidence of an original cartoon exists, a neutrally toned insertion may provide a minimally interventive solution to a number of complex ethical and technical complications. Nonetheless, the application of the concept in Naumburg's west choir failed to satisfy all stakeholders in subsequent years. The iconographical voids created by the so called 'Cloud Heads' resulted in conflicting viewpoints and prompted a deeper examination of significance in one of Germany's most remarkable medieval glazing schemes.

¹ A.C. SEWTER, "The place of Charles Winston in the Victorian Revival of the art of stained glass", *Journal of the British Archaeological Society*, XXIV, 1961, p. 85.

Naumburg's West Choir

The building of Naumburg Cathedral began in 1028 after the relocation of the formerly catholic diocese of Naumburg-Zeitz.² Most of the current building dates from the mid-13th century and was awarded UNESCO World Heritage Status in July 2018 as a landmark of the German late Romanesque and early Gothic styles. The current cathedral has two choirs, east and west, each divided from the nave by a rood screen. The west rood screen is an extremely important work of early gothic sculpture by the workshop of the anonymous 'Naumburger Meister'. The twelve donor portrait statues of the cathedral founders standing life size around the west choir are also attributed to his workshop. The representation of lay people in such an important part of the church and the incredible character and realism portrayed in the founder statues makes them unique in European sculpture from the 13th century.³

The west choir is a synthesis of artworks that together form a single 'Gesamtkunstwerk' which is now recognised as one of the most significant early Gothic monuments in Germany. The five stained-glass windows in the choir were glazed as part of this complete artwork and retain much of the original painted glass. The two outer windows show full individual standing figures of saints which often mirror the Naumburger Meister's sculpted figures in position and gesture. The three central windows show virtues overcoming vices and apostles standing in triumph over the enemies of the church.

Restoration Phases and the 'Wolkenköpfe'

Naumburg's west choir windows have seen numerous interventions in their 750 year history. One of the most significant campaigns was carried out between 1875 and 1877 by the workshop of Wilhelm Franke under the artistic direction of architect Karl Memminger. The windows had already suffered considerable damage and loss in previous years to an extent which necessitated the installation of two entirely new windows in positions swll and wl. Alongside the new windows, the restoration involved the addition of many painted infills, including several heads, within the remaining medieval lancets. The exact number of 19th-century replacements is unknown due to two subsequent restorations in the mid-20th century where many of these additions were removed.

Unfortunately, Franke's infills suffered from extreme paint loss over a relatively short period of time, succumbing to the widespread phenomenon seen in contemporary painted glass across Europe. Several of the replacement heads had lost almost all of their detail by the time they were photographed in 1930 and the problem likely contributed to their eventual replacement.

The conservation work in the late 1930s and early 1940s was led by stained glass artist and teacher Josef Oberberger. As a precaution during the Second World War, the medieval windows were removed from the choir. Amongst numerous interventive measures, including extensive lead removal, cleaning with hydrofluoric acid and the complete re-creation of several damaged panels, it was discovered during our inspection that the first of the 'Wolkenköpfe' or 'Cloud Heads' was also made by Oberberger's team in 1941. The war eventually put a stop to the work and the unfinished windows remained in pieces in storage for the next 17 years until the workshop of Erfurt glass painter Heinz Hajna took over in 1959.

Between 1959 and 1967, seven more heads were replaced with neutral infills.

It is unclear if Oberberger's neutral head in the figure of St Matthew, signed and dated in 1941, was part of a test panel for a solution which may have later been abandoned or if he would have treated all of Memminger and Franke's additions in this way had the war not interrupted the work. Nonetheless, it is evident that concerns about integrity, honesty and falsification directed Heinz Hajna's approach, as seven more neutrally toned heads, along with numerous undetailed inserts in place of hands, drapery and other elements, were inserted across the medieval windows north west II and III, and south west III between 1959 and 1967 (fig.1). The effect this had on the iconographic readability and aesthetic appearance of the windows was devastating.

² Mattias LUDWIG, *Der Dom zu Naumburg*, Edition Logika, München, 2013, p. 9.

³ LUDWIG 2013, p. 48-67.



Fig. 1. Naumburg, Cathedral, nwll: 'Cloud Heads' in panels 7a, 8a, 7b and 8b, 1250/1941/1967. © Holger Kupfer.

Our Concept

The guidelines expressed in The Venice Charter of 1964 indicate that stopping restorative intervention at the point where conjecture begins was at the forefront of conservation thinking when Naumburg's cloud heads were installed.⁴ Maintaining integrity and authenticity continues to inform all aspects of stained glass conservation today.⁵ Correspondingly, in many circumstances, a neutrally toned infill can provide a sensitive and successful repair. However, no approach to infills is guaranteed, decisive or universal. Each infill requires individual treatment and the consideration of all of its values within its surrounding panel, window and wider scheme.

As the building has maintained its original function, the visual disturbances and voids in iconographical context caused by the neutral inserts in Naumburg's west choir have been problematic for the church, its parishioners and its visitors for over 50 years. The question of maintaining authenticity is today explored through addressing cultural values holistically and understanding the importance of identity and recognition as part of community interaction.⁶

The concept for the current project was formed through an open dialogue with the cathedral directors and an international expert advisory committee over several years in preparation for the work. The possibilities surrounding the reconstruction of aesthetic and iconographic uniformity were examined in depth before the final approach was established. The practicability of printed detail was explored and extensive experimentation with cold paints and plating was carried out. Unfortunately, the density of the matting on the neutral infills greatly affected the visibility and legibility of any new details added through these methods. Ultimately, despite the lack of archival evidence rendering an archaeological reconstruction impossible, the predicted public benefit outweighed any possible harm to the cathedral's

⁴ ICOMOS, *International Charter for the Conservation and Restoration of Monuments and Sites (The Venice Charter)*, Venice, 1964, Article 9.

⁵ Ivo RAUCH, "Handle with Care: Ethics, Approaches and Best Practice in Stained Glass Conservation Today", in M.B. SHEPHARD (dir.), *The Art of Collaboration: Stained Glass Conservation in the Twenty-First Century*, London, 2010, p. 47; ICOMOS, *The Nara Document on Authenticity*, Nara, 1994, §10.

⁶ Jukka JOKILEHTO, *What is Modern Conservation?*, 2013, <https://www.york.ac.uk/media/archaeology/documents/taughtpostgraduates/conservation/Modern%20Conservation%20Jokilehto%202013.pdf>.

current values, and the decision was made to replace the neutral infills, where necessary, with newly painted additions.⁷

In this special case, the aim was to introduce iconographically accurate and stylistically corresponding faces based directly on the remaining medieval material in the windows. Guided by the principles established by the Corpus Vitrearum in 2004, neutral hands were only replaced where essential for the clarity of the figure and all other neutral inserts within drapery or elsewhere were not replaced. All infills removed from previous restorations were retained in the cathedral's archive and can therefore be re-inserted at any time.⁸

Finding the Naumburg Style

The 'Zackenstil' or 'Jagged Style' of the figurative panels represents a transitional style between Romanesque and Gothic which reached its crossing point in central Germany. The original glazier is unknown although the obvious direction of the Naumburger Meister has resulted in a unique "Naumburg Jagged style" which can be seen across all of the surviving medieval figures.⁹ These recognisable characteristics made it possible to create infills according to a certain set of stylistic rules. Despite the lack of an original cartoon, authenticity could still be retained by discovering, understanding and adhering to the Naumburg style.

In order to replicate it, the patterns and similarities in the surviving faces were closely examined. It was discovered that the distances between the eyes, the length of the nose and width of the mouth all tended to fall within a certain range, roughly corresponding to a template. The eyes conformed to a certain shape and line style and the eyebrows were almost always the same width, thickness and line weight. This made it possible to re-imagine the lost faces according to a specific set of rules (fig. 2). The reconstructions cannot decisively predict the exact appearance or placement of lost features, but they can give an informed impression of how a head painted for the original Naumburg scheme may have looked. Furthermore, each new infill remains fully reversible.¹⁰



Fig. 2. Naumburg, Cathedral, nwIII: the 'Naumburg Style', St Elizabeth and St Demetrius, 2018. © Vereinigte Domstifter.

⁷ HISTORIC ENGLAND, *Conservation Principles, Policies and Guidance for the Sustainable Management of the Historic Environment*, English Heritage, London, 2008, p. 60.

⁸ CORPUS VITREARUM, *Corpus Vitrearum Guidelines for the Conservation and Restoration of Stained Glass*, 2nd Edition, Nuremberg, 2004, §4.4.1.

⁹ LUDWIG 2013, p. 74.

¹⁰ CV GUIDELINES 2004, §4.4.1.

Case Study: St Mauritius. Portraying Ethnicity

The sculpture of St Mauritius at Magdeburg Cathedral, around 100 miles north of Naumburg and dating from around the same time as the west choir, sensitively and accurately depicts the physical characteristics of the third century martyr according to his ethnic origin. Historical research conducted early in the project suggested that St Mauritius was born in Thebes in Egypt but was probably of Sudanese descent. Accordingly, he has been portrayed as such in art since the 12th century.

It was possible to conclude through the examination of the original material in window nwIII, that the ethnicity of St Mauritius was considered when glass for the figure was selected. The surviving hands show that the medieval painter was extremely sensitive to variations in skin tone, especially between the outside of the hand and the palm. These subtle tonal changes, as well as the differences between this figure and others of European descent, were reflected in the chosen glass. After establishing that St Mauritius was almost certainly depicted accurately according to his ethnic origin, the question of his features still remained.

A photograph from 1930 showed the head of the saint had not suffered from paint loss although it was also clear from the image that the execution did not correspond to Memminger's *vidimus* nor the painting style or quality of Franke's work. It is therefore likely that this was an undocumented infill by an unknown glazing workshop. A rather more successful head was in the panel when it was photographed again in 1960. This was possibly a trial piece painted during Josef Oberberger's restoration. It is not possible to know without specific documentation, if the painter had any evidence for his design which has since been lost, or if he used a similar approach of interpreting and replicating the characteristic elements seen elsewhere in the windows. Nonetheless, this head had been replaced with a neutral infill by 1967.

In order to stay in line with our concept and to maintain our aim of providing sensitive reconstructions in the 'Naumburg Style', the new head of St Mauritius was developed in accordance with our model. The glass colour for the figure was matched as accurately as possible to the surviving medieval material but no attempt was made to differentiate the facial characteristics from the stylistic rules we had already established (fig. 3).



Fig. 3. Naumburg, Cathedral, nwIII: St Mauritius (with new head) and St Catherine, 1250/2018. © P. Hildebrand.

Case Study: St Elizabeth. Adapting to Spatial Constraints

The head of the figure of St Elizabeth of Thuringia was the only one of the eight neutral infills to have any kind of intentionally painted detail. Relatively wide linear applications of cold paint had been added to define the head shape within a larger space. This suggested that more than the facial features were missing in this case. In Memminger's vidimus for nwIII, St Elizabeth appears wearing a nun's wimple and veil. As an important saint in the region, there was plenty of evidence to draw upon for how she may have been portrayed in 1250. Notably, a sculpture of St Elizabeth stands in a chapel dedicated to her in Naumburg Cathedral. Valuable information was also gained from the narrative window at St Elizabeth's Church in Marburg.

The photographs of nwIII from 1930 indicate that the head of St Elizabeth had also been replaced in an undocumented restoration prior to its removal by Heinz Hajna. The face of the figure at that time was poorly executed with exaggerated features and it was certainly not based on Memminger's vidimus as the head did not feature a wimple. The wide neck area was instead left open and hair was painted within the voids either side. This configuration did not fit well into the surrounding space and was therefore visually disturbing. The known details of St Elizabeth's life and the numerous contemporaneous depictions of her supported the theory that she was most likely wearing a wimple in the original Naumburg scheme. Importantly, this was the only arrangement that satisfactorily matched the shape of the void. Furthermore, capturing the folds and movement in the wimple provided another opportunity to explore the Naumburg Zackenstil and how it could be represented through the new additions.

After the research phase, and following the same process as the other infills, the flesh tint was matched, and test samples produced on single pieces of glass. It was quickly apparent, despite the addition of washes, that the glass colour was unsuitable for the wimple. The pink tone was not iconographically accurate nor was it aesthetically pleasing. Through further discussion with the advisory committee it was concluded that to maintain historical accuracy in technique and appearance, the wimple should be made from separate pieces of white glass. Accordingly, the infill was separated into three parts, divided by two lead comes. Each part was treated as an individual infill and appropriately signed and dated.

Case Study: St Vincent. A Balancing Act

The final case study posed some ethical and practical questions about the blending in of infills into heavily corroded or discoloured surroundings. The lengths we go to in modelling new infills to imitate age or corrosion can often divide opinion. Is it acceptable to add imitation corrosion and under what circumstances? In every case, points of view do not always correspond. Fundamentally, a balance must be achieved in order to avoid visual disturbances.¹¹

In Naumburg it was necessary to adjust the opacity of the new additions to maintain visual harmony. This was especially important when consideration is given to the overall aim of the intervention. Significantly though, the head of St Vincent required much more modelling than any of the others. This was due to a combination of factors which affected the south side of the choir much more than the north. As part of the development of the Jakobi plating process by Richard Jakobi at the Doerner Institute, extensive tests were carried out on the medieval glass from swIII. Much of the glass was heavily cleaned with hydrofluoric acid and consolidated with layers of acrylate. As high temperatures are often reached on the south side of the choir, the acrylate softened, attracted dirt and deteriorated. The accumulation of pollutants in the unventilated protective glazing system may have further exacerbated this damage and contributed to the dark and patchy appearance of the panels. This is especially evident in the surviving medieval faces in swIII.

In addition, the upper half of the figure of St Vincent was fully reconstructed by Josef Oberberger in 1941. The entire panel had been re-made once before by Wilhelm Franke but suffered advanced paint deterioration along with most of the 19th-century additions. Oberberger's panel exhibits artificial corrosion across both the interior and exterior surfaces. The effect has been achieved using glass paint in combination with a widespread application of opaque cold paint which has resulted in the panel appearing very dark. This situation reinforced the need for individual consideration and prompted a re-examination of the values we were attempting to preserve and re-introduce.

¹¹ HISTORIC ENGLAND 2008, *Conservation Principles*, p. 58.



Fig. 4. Naumburg, Cathedral, swIII: development of head for St Vincent, 2018.
© Vereinigte Domstifter.

In order to maintain the aesthetic value of swIII, to reinstitute liturgical context and to avoid the same visual disturbances caused by the neutral infill, additional modelling of the new head was necessary to achieve a level closer to its immediate surroundings (fig. 4). By adding shading layer by layer until a satisfactory level was reached, the intention was to balance the appearance of the new head within its surrounding panel, along with the rest of the figures in window swIII and the entirety of the wider scheme.

Conclusion

The case in Naumburg highlights the often complex issues related to the replacement of lost detail where no original cartoon or archival evidence exists. A total of eight new heads were created for the west choir according to the 'Naumburg Style' which was interpreted through the evidence remaining in the original fabric. The new faces are fully reversible and were introduced as part of a concept intended to reestablish iconographical and liturgical uniformity, aesthetic and communal value and stylistic integrity in Naumburg Cathedral's west choir. Each infill posed interesting and sometimes unique problems and

highlighted the need for discussion, flexibility and a continually open dialogue when trying to retrieve or re-create missing information from stained-glass windows.

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1.4

The White-Washed Table and the Medieval Windows of Girona Cathedral

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La table de verrier et les vitraux médiévaux de la cathédrale de Gérone – Résumé

Tout au long de cette étude, il a été remarqué une constante corrélation entre les décisions qui ont été prises lors de la construction et de la reconstruction de la cathédrale de Gérone, et les informations livrées par les vitraux. Les pièces des vitraux conservés, l'emplacement de chaque vitrail dans l'édifice et la documentation, sont des éléments essentiels pour comprendre l'évolution des travaux architecturaux. La récente découverte de vitraux

datant de l'ancienne cathédrale romane nous a montré que ces vitraux s'inscrivaient également dans le remplacement progressif de la première église, dans laquelle certains éléments architecturaux ont été intégrés dans la nouvelle. L'étude au cas par cas des vitraux, en lien avec la période où le bâtiment de la cathédrale était encore en construction, pourrait également nous aider à éclaircir la transition entre les deux cathédrales, une question sur laquelle de nombreuses interrogations subsistent.

The White-Washed Table and the Medieval Windows of Girona Cathedral – Abstract

Throughout this study, the constant correlation between the decisions made during the construction and reconstruction of Girona Cathedral and the information stored in its stained-glass windows is highlighted. The preserved stained glass pieces, their location inside the building, and the extant documentation are key to understanding the evolution of architectural work. The recent discovery of stained

glass from the old Romanesque cathedral has shown us that the stained glass also fits in with the well-known progressive replacement of the first church, in which some of the architectural elements were integrated into the new building. Studying the stained glass pieces linked to the period when the cathedral building was still being developed section by section, could also help us to illuminate the transition of the cathedral, about which there are still many questions.

The first stained-glass window

Although there is little evidence of early Christianity in Girona, the burial of the holy martyr, Sant Feliu in the Roman cemetery outside Girona's walls at the beginning of the fourth century, and the extent of his worship, seems to indicate that the diocese already existed around the year 400.¹

On the first supposed Martyrium dedicated to the saint, which was the first Christian temple in Girona, the church of Sant Feliu was erected.

The first firm reference to the existence of the Cathedral of Santa Maria is from the year 842, when it is mentioned as a co-cathedral along with a cathedral located outside of Girona's walls. The failure to detect any substantial archaeological evidence in the forum area until shortly before the start of construction of the new cathedral indicates that the worship of Saint Mary would have begun in a converted forum, which would have operated as a Christian temple for at least two centuries.²

Countess Ermesenda, sister of Bishop Pere Roger and wife of Count Ramon Borrell of Barcelona, was the main promoter of the construction of the new temple, and made generous donations for its construction. The work started around 1010 and by 1038 construction had reached a state that allowed them to proceed to the dedication ceremony of the new Cathedral of Santa Maria. The works, however, were not completely finished, and as later testaments and donations show, the roof of both the nave and the bell tower, the upper part of the west wall, and the sculptural decorations were still to be completed.³

Work at Girona Cathedral seems to have been an ongoing process. Although the essential construction work of the Romanesque cathedral and the canonical outbuildings took place during the first half of the 11th century, recent discoveries indicate that during the first half of the 13th century, new architectural details were still being incorporated into the building.

¹ NOLLA 2003, p. 99-114.

² SAGRERA & SUREDA 2003, p. 115-126.

³ SUREDA 2008, p. 511.

The new discovery of medieval stained glass in the last chapel on the south side of the current ambulatory has shown that in 1230, the Romanesque Cathedral of Girona was the beneficiary of some exceptional quality stained glass. Until 17 October 2019, there was no physical or documentary evidence of the existence of stained glass in the Romanesque cathedral. The discovery of six panels, re-used in the Gothic chancel's opening which was built between 1312 and 1347, shows that some of the chapels of the old Romanesque Cathedral had been decorated with figurative stained glass dedicated to the life of Christ and the Virgin Mary. These stained glass panels not only bear witness to the existence of high quality stained-glass windows in Catalan counties in the early 13th century, but they are a key element in understanding the transition between Romanesque and Gothic in the construction process of Girona Cathedral.

By the end of the 13th century, the old cathedral structure had become too small for Girona – a city whose population had increased tenfold in less than three hundred years. The cathedral was to serve an increasing number of canons and clergy whose benefaction ensured worship in various altars and chapels. The building, unable to accommodate such a large number of new altars, was reconstructed where nine altars were incorporated into the apse.⁴ The intention to renew and enlarge the Romanesque building dates back to 1292, when Guillem Gaufred left 10,000 silver coins (sous) in his Will, allocated to the construction of the new apse. Work began in 1312, led by Master Enric de Narbona and supervised by Bishop Bernat de Vilamarí and the Chapter, who soon delegated its management to Archdeacon Ramon de Vilarig, Canon Arnau de Montrodon and Priest Dalmau de Pujals.

The new, purely Gothic style apse incorporates the stained glass from its inception, and so the construction process and preserved documentation informs us of the fabrication of the stained glass and vice versa. Until recently, the oldest known stained-glass windows in Girona Cathedral were those dedicated to the life of Mary in the presbytery, linked to the famous Girona white-washed tables. Joan Ainaud and de Lasarte linked the eleven highest windows of the cathedral apse with the first mention of stained-glass windows in the Diocesan Archive, an account settlement dated 21 May 1348. This document states that some stained-glass windows were made within the previous four-year period.⁵

Thanks to this recent discovery of medieval glass behind the altarpieces of Santa Caterina (sV) and of Sant Martí and Sant Francesc (s-VI), we may suggest, albeit without documentation, that the first stained-glass windows to join the new apse could have been those inherited from the apses of the ancient Romanesque structure. Indeed, according to Marqués, the text of 1348 mentions stained-glass windows, "some of which had already been adapted before".⁶ It is interesting that, as pointed out by Sureda, the seven main altars of the old cathedral (the largest dedicated to the Virgin, then the saints Miquel, Anastasia, Andreu, Joan, Benedict and Sepulcher) are precisely the seven first altars documented in the new apse, despite the fact that, later on, some have changed their location.⁷ If the work which began in 1312 was originally intended only to improve the apse of the cathedral rather than to begin work on a whole new cathedral, as happened later, then we may think that the first altars were moved to the new ambulatory, including their stained glass and altarpieces, if they existed. It is clear that the existing stained-glass windows would not have been destroyed but stored and reinstalled in the new openings, certainly adjusted where necessary to accommodate the shape of the new openings and possibly altered for the iconography.

This was the case with the chapel of Sant Francesc and Sant Martí, which has two benefactions, in 1341 and 1344; the first instituted by the Canon Guillem de Cornellà⁸ and the second by the Canon and then Abbot of Sant Feliu, Vidal de Blanes.⁹ The timeline of the donations, however, does not match the exact date proposed for the saints' panels, which may suggest that the chapel did not have stained glass for at least four decades after its completion. The presence of notches in the wall suggests that shutters may have been used to seal the window openings temporarily.

⁴ SAGRERA & SUREDA 2003, p. 115-126.

⁵ AINAUD et al. 1987, p. 30-42.

⁶ MARQUÈS CASANOVAS 1981, p. 286.

⁷ SUREDA 2008, p. 360.

⁸ MARQUÈS I PLANAGUMÀ 2009, p. 86.

⁹ SUREDA 2008, p. 361.

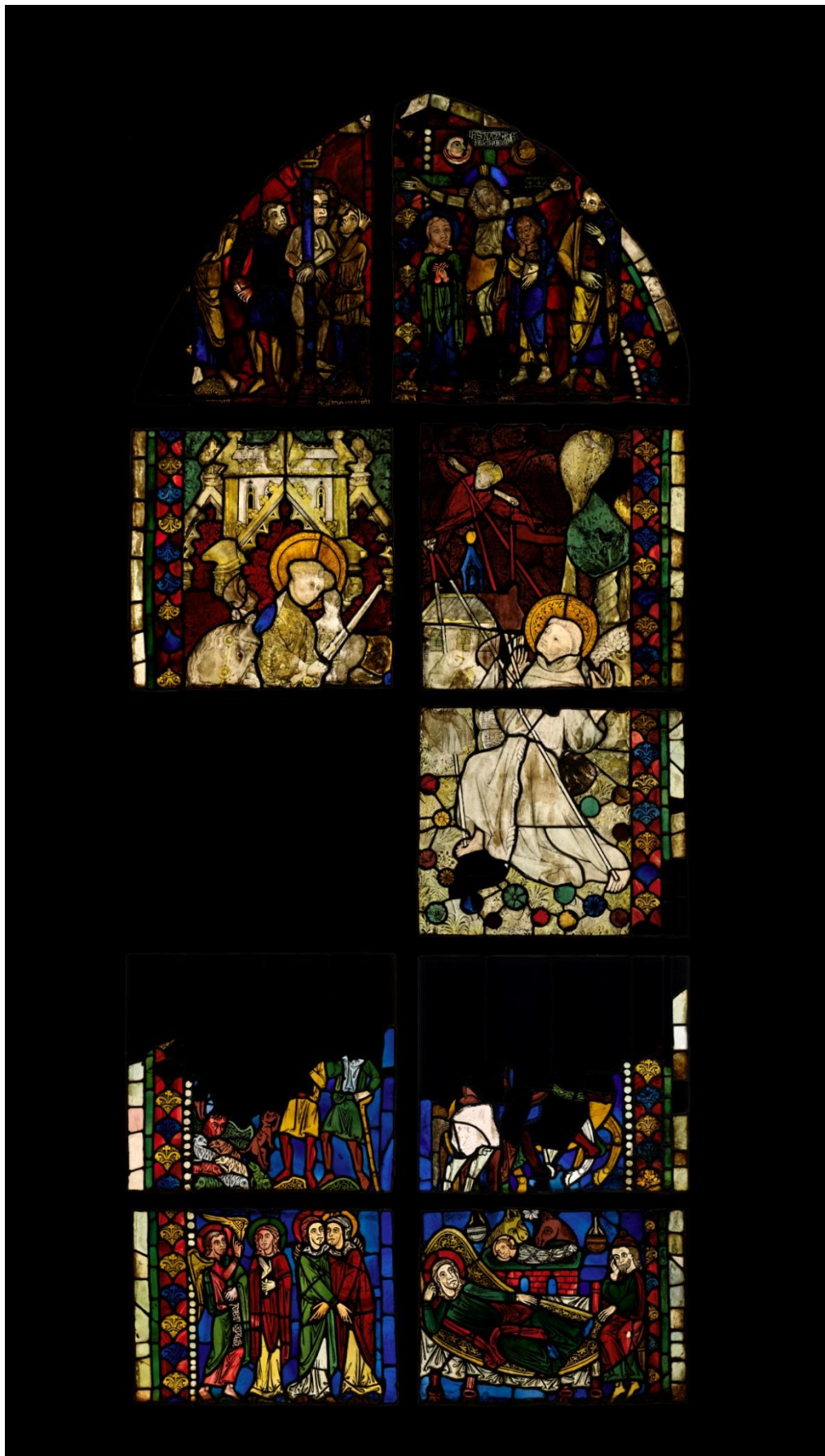


Fig. 1. Stained-glass window from the Chapel of Sant Marti and Sant Francesc.
© Capítol Catedral de Girona. Photo: Julià Guisado, 2021.

The stained-glass window recently discovered in a chapel was a composite window made up of ten panels, of which only four panels would have been made specifically for this location, representing the saints the chapel was dedicated to (fig. 1). Unfortunately, the panel with Sant Martí's feet has disappeared, and only fragments recovered from the window sill are preserved. The painting and composition of these panels is of an International Gothic style with excellent technical and artistic quality. The fine brushstrokes and the shading and highlights on the faces achieved by the Master Glazier shows us a full Gothic style with a solid Italian heritage. The Cathedral Archive has documentation of a Lluís Borrassà working in the cathedral in 1380, with his work identified and documented in the c.1380 restorations of the presbytery stained-glass windows. One of the heads in these windows has been suggested as a Borrassà restoration. The painting style of this head is the same as the Master Glazier's hand in the four panels of the composite window, possibly linking Borrassà to the role of Master Glazier.

The windows of the presbytery and the white-washed table

The dedication to Mary of the main apse of the old Romanesque building took on a very prominent role in the new Gothic chancel. This was the first large ensemble of Gothic stained glass commissioned by the cathedral, which would have needed to have been completed by the day of the new consecration, on 12 March 1347. Marian iconography surrounded the central altar from the highest openings in the new apse. The sequence filled the eleven large windows, providing a full clockwise reading. The Master Glazier hired for this eminent work is still anonymous and is known to everyone as the Master of the Presbytery.

The connection of this Marian cycle to the white-washed table has allowed us to understand the methods and techniques used in medieval glass workshops (fig 2). Combining this information with the work of Theophilus' *De Diversis Artibus*, we have deepened our understanding of a variety of processes taking place in stained glass workshops at the turn of the 12th century. During these monumental cathedral projects, the processes and organisation required would surely have been quite different to Theophilus' descriptions of traditional practices.



De Diversis Artibus describes processes that correspond with the evidence we see on the white-washed table in Girona. Theophilus recommends that you take a lead or tin spike and draw the perimeter measurements with rulers and compasses.¹⁰ This technical drawing for Girona Cathedral's apse windows is clearly visible on the plaster preserved on the table, although much of the perimeter and lead lines laid out with black pigment have been lost. Chapter 17 of the second volume of this treatise does not tell us about teamwork, which can be deduced from a detailed examination of the table. The creation of a set of eleven large windows was not a single man's job and the hired Master Glazier would be responsible for the organisation of the studio and work, and the management of a team of professionals.

Fig. 2. Details of the white-washed table and window H-I from the presbytery.

Table © CRBMC Centre de Restauració de Béns Mobles de Catalunya.

Photo: Carles Aymerich, 2013.

Window: © Arxiu de l'Institut d'Estudis Catalans. Fons CVMA. Photo: Ramon Roca i Junyent, 1985.

¹⁰ DODWELL 1961, p. 61.

The white-washed tables were portable, mounted on trestles and used at different times during the project. The first step, the design of the tables, would have been the direct responsibility of the Master Glazier, as shown in the 1351-2 glazing accounts of St Stephen's Chapel, Westminster.¹¹ But the degree of definition of these drawings was not included in the contracts, and on the table we can see other hands redefining the general outlines established by the master. These details are visible in the upper section of Table 1, where we find the canopy corresponding to panel b5 of the east stained-glass window. Between the master's strong black lines, we see faint, reddish lines, made to bring the design closer to the reality of the stained glass and to avoid excessively delicate pieces.

Another interesting feature omitted in Theophilus' text is the constant reuse of the white-washed tables. Once the glass had been cut along the lines drawn on the plaster, the glass was most likely painted on a surface that allowed light to pass through. Finally the glass returned to the white-washed table to be leaded and completed. The process would then begin again, reusing the table. To work in this way, at least three systems would have existed: two of which are visible on the table. The first and most obvious is the reuse of the designs drawn to make more than one panel of the same model. This system is evident in the lower section of Table 1, where the perimeter of a lancet head is scratched over the geometric design of the lower lancet panels. The second system, also visible at close quarters on the table, is the dissolution of the uppermost layer of plaster, probably with the help of a wet cloth using the same solvent that would have been used to apply the first layer. This system was detected by Joan Vila-Grau on the white-washed tables, who, when viewing darkened areas of the table took the first photographs in ultra-violet light.¹² The UV light revealed that underneath the geometric design laid out in the plaster on Table 1, the outline of the Virgin was retained in the plaster from the central scene of the Annunciation (window b4). Lastly, it is tempting to suggest that the total removal of the plaster could also have been a possible way of re-using the boards, but of course there is no evidence of this conserved on the white-washed tables.

Thanks to the collaboration of the Centre de Restauració de Béns Mobles de Catalunya (CRBMC) during the studies carried out on the tables in 2013, the plaster layer was analysed to acquire information about the materials used. The lack of binder described by Theophilus would not have created a work surface as stable as that preserved on the tables in Girona. Theophilus' description perfectly matches its use if the aim is to create a single stained glass panel. In cases like the windows in Girona or Westminster, the boards had to endure extensive use, and the use of a binder was essential. Documents from Saint Stephen's Chapel show that glaziers bought beer "for washing and whitening the tables",¹³ while the Girona workshop would have used a protein binder (egg or casein) to ensure the layer's strength.¹⁴

The two white-washed tables (made of walnut wood boards) kept in the city's Art Museum, would have originally been a single board of at least 2810 × 445mm and could have served the Master Glazier's team for up to twenty-two panels of the three central windows of the presbytery.¹⁵ The board retains information that will be useful during the next restoration of the presbytery windows, which are undoubtedly of unmatched historical value.

The Marian stained glass of the presbytery is also interesting in artistic terms. They are in a linear Gothic style with some Romanesque elements, and are a monumental example of 14th-century Italian-Byzantine style.¹⁶ The ensemble maintains stylistic links with stained glass from the church in the Monastery of Pedralbes and with the stained-glass window, the Virgins of Tarragona.¹⁷ The large figures are superimposed on the architectural background with canopies, apart from the Dormition of Mary window (S-VI) where the horizontality of the scene necessitates the depiction across three lights.

¹¹ SALZMAN 1926, p. 31-35.

¹² VILA-GRAU 1986, p. 33.

¹³ SALZMAN 1926, p. 32.

¹⁴ Ricardo SUÁREZ DE LA VEGA, *Resultats anàlisis: Vitrell*, CRBMC, September 2013. Unpublished source.

¹⁵ SANTOLARIA 2014, p. 80.

¹⁶ AINAUD et al. 1987, p. 11-27.

¹⁷ Rosa ALCOY, "Evolució estilística del vitrell medieval a Catalunya" in MUNDÓ et al. 2014, p. 95.

Master Guillem of Letumgard

Coming from the Diocese of Coutances (Normandy), Guillem of Letumgard is documented as working at Girona Cathedral in 1357 and 1358, shortly before moving to Tarragona, where he signs a contract to make the stained glass for the chapel of the tailors. In Girona, it is documented that he is responsible for the creation of stained glass for the chapel of Saint Margaret, Saint Peter and Paul, Saint Michael, as well as other stained glass for the ambulatory windows above the chapels. The stained-glass windows that are extant today, except some fragmentary remains from these aforementioned chapels, are these ambulatory windows located in this second level (fig. 3). In this significant space, Letumgard made a set of stained-glass windows dedicated to the Passion of Christ, with a very fine grisaille and silver stain. His style draws parallels with some of the stained-glass windows in Saint-Ouen in Rouen, with influences of Italian styles and with the miniatures by the Parisian Jean Pucelle.¹⁸



Fig. 3. Detail from window nIII (b6) by Master Letumgard.

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Currently only seven out of a likely ten windows are preserved in a fragmentary state, the northern panels being in the worst state of disrepair, as is the case with the presbytery stained glass. The most significant damage is due to the attacks from the mountain of Montjuïc during the Peninsular War (1808-14), although further destruction was done through iconoclastic attacks that could have been carried out from the outer terraces of the apse.¹⁹ The resulting restoration, which replaced heads and inscriptions, has hindered legibility.

As is the case with the presbytery, the composition of its stained-glass windows is a series of images, alone or in groups, located inside niches supported by columns and capitals. This structure does not detract from the scenes' horizontal thematic continuity, but unlike the stained glass of the presbytery, it frames each and every one of the scenes. The details used in Letumgard's architectural forms within the glass are incomparable to the decorations found in the previous set. The columns and arches are made of white glass, worked with glass paint and silver stain, and serve as a contrast with the blue or red backgrounds that surround the figures. The conserved faces indicate a great skill in the painting, and a technical, very personal style. Faces are shaped using long, thin lines of grisaille, creating a very characteristic effect that we also find in Tarragona Cathedral. Letumgard's style has been linked to that of some extant stained-glass windows dating to 1330 and 1350 at York Minster, and could be considered precedents of Master Letumgard.²⁰

The beginnings of the new nave

The plan of only building a new apse seems to have changed shortly after the first phase of work had begun. It was necessary to rebuild the cathedral to create more space for new chapels and altars. Although it is unknown exactly how the rebuilding took place (between 1350 and 1368, when the first architect's consultation was performed), it seems that the first section of the nave had been constructed with a different layout than its final approved formation.²¹ The construction of the Gothic nave would have been slow and intermittent, surrounding the Romanesque building while demolishing, as the Gothic process of rebuilding took place.

¹⁸ Joan AINAUD I DE LASARTE, "Introducció" in AINAUD et al. 1987, p. 20.

¹⁹ Joan VILA-GRAU, "Catàleg" in AINAUD et al. 1987, p. 122.

²⁰ Rosa ALCOY, "Evolució estilística del vitrall medieval a Catalunya" in MUNDÓ et al. 2014, p. 106.

²¹ Pere FREIXAS 2003, p. 129.

Once Letumgard had left Girona to south Catalonia, four new glaziers' names are documented as working at Girona Cathedral during this period when the construction of the single nave had begun. These are the architects and sculptors Pere Sacoma and Ramón de Gilabert (1375), the painter Lluís Borrassà (1380) and also the architect and sculptor Guillem Morey (1376-1386). We do not have a record of Sacoma's work but we know that he was hired to repair a three-lancet window in December 1375. Gilabert was a master from Mallorca who Pere el Ceremoniós would call "*familiarium et domesticorum nostrum*", and should therefore be considered as an artistic personality to take into account.²² Gilabert is documented as making stained glass for the chapel of Santa Magdalena and Sant Ivó but unfortunately only very few fragments remain. Documentation exists which shows that Lluís Borrassà would have been responsible for restoring some of the stained glass in the presbytery. As mentioned earlier, Master Borrassà may have been assigned to paint a head on the N-V stained-glass window, which has features very similar to the stained glass found in the chapel of Sant Martí and Sant Francesc.²³ Finally, there is Guillem Morey, of whom we only have evidence of the purchase of materials related to the repair of unidentified stained-glass windows.

After Morey, there is no documentation of a name linked to the stained-glass windows of Girona Cathedral for more than fifty years. During the construction work of the nave, there were many controversies regarding whether or not to construct a nave of unprecedented width, which would have slowed the works and stopped the creation of new window openings. There are two windows which connect the Gothic apse with the beginning of the great new nave. These windows have been studied little and could perhaps still reveal much about this difficult time in the history of the cathedral's construction. These are the two southern rose windows, on either side of the large eastern rose. These roses, which depict six red cherubs in the highest group and floral elements in the rest of the window, have been linked to the stained-glass window of the Apostles, which we will discuss below, but the paint lines of the few conserved cherubs have a delicacy far removed from the cherubs of the 15th century Apostles window. The painting style, however, could perhaps show more parallels with the cherub in the newly rediscovered stained glass (sVI) which casts rays that mark the stigmatisation of Saint Francis. The study and comparison of these three pieces, as well as the remains preserved in the chapel of St Ivó, could help us to unfold a moment in the history of the cathedral in which there are still so many questions.

The unique nave

In 1416, architects were consulted to decide on the construction system of the nave. Twenty-one years later, work on the stained-glass windows resumed. On 7 September 1437, a contract was signed with the Master Glazier Antoni Tomàs de Toulouse, for the completion of the Apostles stained-glass window, the first large window in the Gothic nave (fig. 4). Despite the origin of this stained glass master, Antoni Tomàs was very active in Catalonia in the years following the creation of this first large window in Girona Cathedral. In the stained-glass windows made by the Palau de la Generalitat de Catalunya (Barcelona, 1439), Antoni Tomàs based his work on the cartoons of the renowned painter Bernat Martorell.²⁴ In the case of Girona, it is unknown if Master Tomás made his own cartoons following the instructions of the detailed contract, or if, as in the case of Barcelona, he also collaborated with a painter to design them. In any case, the stained glass is spectacular due to its size and the predominance of red glass. The work, divided into three levels of four figures contained under canopies, has an archaic style that brings to mind the art of the first third of the 15th century. The architectural canopies within the window have no early Netherlandish elements which may have been present in stained glass designed by Martorell.

In the year of Bishop Bernat de Pau's death (1457), work was commissioned for the chapel of Sant Francesc and Santa Clara, carried out by the painter Ramón Solà.²⁵ The two saints' figures were painted and a stained-glass window was made, neither of which exist today. There is also evidence of

²² Rosa Alcoy "Evolució estilística del vitrall medieval a Catalunya" in MUNDÓ et al. 2014, p. 109.

²³ Rosa Alcoy "Evolució estilística del vitrall medieval a Catalunya" in MUNDÓ et al. 2014, p. 109.

²⁴ Joan AINAUD I DE LASARTE, "Introducció" in AINAUD et al. 1987, p. 21.

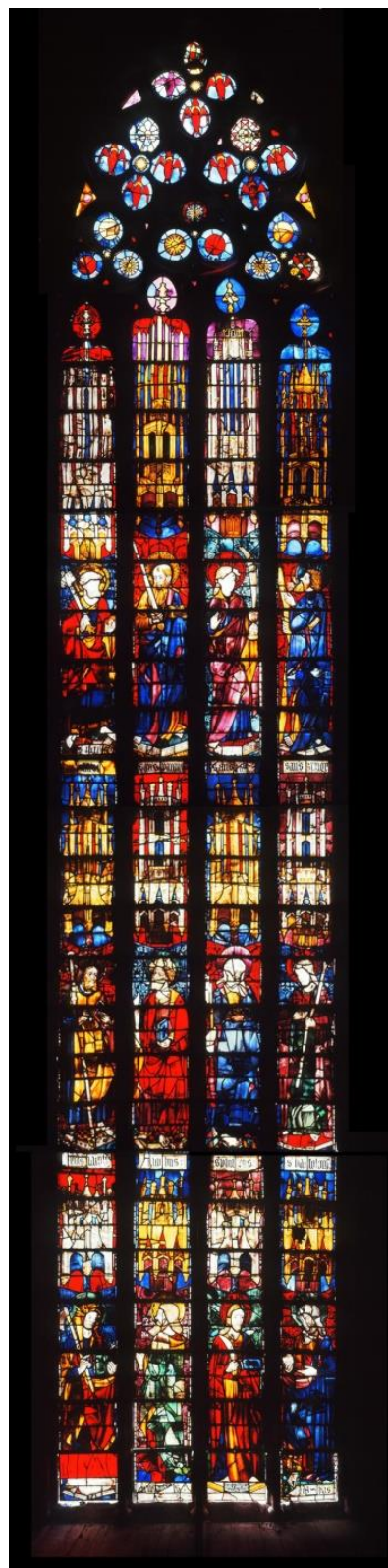
²⁵ PRATS 1994, p. 453-480.

restoration work carried out by Master Glazier Joan Gili on Girona Cathedral's south window in 1472 and 1478.²⁶ Although it was still a time of profound instability, the Catalan Civil War had ended.

After a long period of interrupted work, economic stability was achieved. The creation of a second monumental stained-glass window was contracted in 1520 – an artwork which has become an important example of Renaissance art in Catalonia. A few years earlier, Girona had become a key place in the introduction of Renaissance style in Catalonia, especially by the presence of artists such as the German Ayne Bru and the Alsatian Joan de Burgunya. The stained-glass window of the Sibyls is contracted to Jaume Fontanet, brother of Gil Fontanet, famed for the clean Gothic style in Barcelona Cathedral. Jaume had worked in Barcelona and Lleida as an altarpiece painter, but there is no evidence to show that he was knowledgeable about Renaissance art. For this reason, and because John of Burgundy endorsed the stained glass in his contract with the cathedral, Ainaud and de Lasarte always considered that the cartoons had been made by this renowned painter. The altarpiece in the church of Sant Feliu is also Burgunya's as is the altarpiece in the chapel of Santa Úrsula and the Eleven Thousand Virgins in the ambulatory of the cathedral. The latter altarpiece (1519-1521), may have replaced one of the first stained-glass windows, whose repair is documented in 1414.²⁷

In 1523 until 1538, Jaume Fontanet was hired to carry out the annual maintenance on the stained-glass windows in the temple.²⁸ During this time, the creation of new stained-glass windows diminished, especially in the lower-level chapels. Only new glass for the culmination of the union between the apse and the new Gothic nave is documented. In 1528, the secretary Pere Llobet notes that the major rose window has recently been "brought to perfection with a representation of the Universal Judgment" in the Chapter's book.²⁹ Of this great representation of the Last Judgment, there is no trace of the authorship, but it was badly damaged in June 1694 during the nine-year war and later replaced by the current stained-glass window of Sant Miquel, commissioned to the painter Francesc Salàdrigas in 1704. In Llobet's text, it is interesting to note that he mentions the temporary closing of the rose window with "stone tables from Banyoles". This material, unlike the waxed cloths we find documented to temporarily cover the chapel openings, could have been used to temporarily close the largest windows. This may be the reason why, in the contract for the Sibyls stained-glass window, the window must be opened at the expense of the glazier.³⁰

Fig. 4. Window of the Apostles.
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Photo: Ramon Roca i Junyent, 1985.



²⁶ Joan AINAUD I DE LASARTE, "Documentació" in AINAUD et al. 1987, p. 40.

²⁷ Joan AINAUD I DE LASARTE, "Documentació" in AINAUD et al. 1987, p. 37.

²⁸ MARQUÈS CASANOVAS 1981, p. 272.

²⁹ MARQUÈS CASANOVAS 1981, p. 272.

³⁰ The "stone of Banyoles" is a type of travertine that is much appreciated in the area, which appears in the quarries of Serinyà, Banyoles and Mata. It was used widely during the Middle Ages and is still used today in architectural decoration. Its geological features allow it to be cut in slabs (or, as in the case of the contract), so that it could perfectly fulfil the function of alabaster or the aforementioned wax cloths.

The modern era

Saládrigas is the only Master Glazier who worked on creating new stained-glass windows for Girona Cathedral when this job was not part of the cathedral's program of works. He would have been responsible for the Sant Miquel Rose window, and also for the finished rose on the western facade, in 1732.³¹ Between 1528 and 1704 the contracts speak only of restorations and major repairs, which the stained-glass windows would have required due to the effects of the wars and sieges that Girona suffered during this long period. After 1732, no new stained-glass windows were contracted until the explosion of the neo-Gothic style, during which new stained-glass windows by studios such as Amigó or Espinagosa were commissioned. During the Spanish Civil War (1936-1939), some of the side chapel's altarpieces in the cathedral were damaged and later decorated with new stained-glass windows, a highlight of this phase of work is the window in the axial chapel of the apse, commissioned to the versatile artist Domènec Fita from Girona. In 2011, Girona Cathedral took the last step in filling the final plain-glazed window (the large west window of the north façade) with a commission by the Irish artist Sean Scully.

Girona Cathedral's story is a large volume where the history of the stained glass is intertwined with the history of the city. Further in-depth study of its stained-glass windows will be crucial in delving into the great questions that are still being raised about the construction of the cathedral.

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³¹ CORTÉS PIZANO 2001, p. 59.

2.1

The Importance of Preferences and Taste in the Conservation of Works of Art

Fernando Cortés Pizano

Die Bedeutung von persönlichen Präferenzen und Geschmack in der Konservierung von Kunstgegenständen – Zusammenfassung

Die Art, wie wir ein Objekt behandeln und präsentieren, beeinflusst unweigerlich seine Erscheinung, Integrität und Werte, und damit die Art, wie der Betrachter es wahrnimmt. Während der Konservierung von Kunstgegenständen werden wir mit einer Fülle von Möglichkeiten und Optionen konfrontiert, ein Problem zu lösen und das Endergebnis zu präsentieren. Es muss eine Reihe von Entscheidungen getroffen werden, welche fraglos sowohl einen Einfluss auf das technische und ästhetische Resultat, als auch auf die Bedeutung und die Werte des Objektes haben.

Der gleiche Kulturgegenstand, potenziell von verschiedenen Restauratoren behandelt, würde auf unterschiedliche Art bearbeitet, ergänzt und präsentiert werden und jede Version könnte akzeptabel und korrekt sein. In der Tat gibt es wahrscheinlich kein richtig und falsch, wenn es um ästhetische Entscheidungen geht. Glücklicherweise arbeiten wir im allgemeinen nicht alleine und diese Entscheidungen werden idealerweise zusammen mit Kollegen, Experten und sonstigen Beteiligten verglichen, besprochen und vereinbart. Das gilt besonders für die technischen Aspekte unserer Tätigkeit. Wenn es jedoch um Entscheidungen ästhetischer Natur geht, so sind wir oft weniger geneigt, eine Zweitmeinung einzuholen,

da wir alle unsere eigenen Präferenzen und Vorstellungen von Geschmack haben, welche, wie wir wissen, oft schwieriger konkret auszudrücken sind. Auf dieser Vorstellung von Geschmack gründen fraglos viele Entscheidungen, die wir im Laufe unserer Tätigkeit treffen, ob wir das nun gern zugeben oder nicht. Präferenzen und Geschmack sind unbestreitbar subjektiv und können daher weder gemessen noch wissenschaftlicher Analyse unterzogen werden. Sie basieren auf unseren persönlichen und beruflichen Erfahrungen und sie werden sich für die meisten von uns im Laufe der Jahre verändern.

Aus all diesen Gründen wurde die Frage, welche Rolle Präferenzen und Geschmack in unserer Tätigkeit spielen, in den klassischen wissenschaftlichen Theorien und Konservierungsprinzipien des 20. Jahrhunderts traditionell vermieden, abgewiesen und unterdrückt. Trotzdem haben neuere Theorien und Ansätze in unserem Beruf jetzt begonnen, die subjektive Natur unserer Arbeit und die Bedeutung des persönlichen Geschmacks der Restauratorin/des Restaurators zu akzeptieren und einzubeziehen. Es ist das Ziel dieser Präsentation aufzuzeigen, auf welche Weise Präferenzen und Geschmack bei der Entscheidungsfindung im Feld der Konservierung und Restaurierung von Kunstgegenständen gegenwärtig sind, und es immer schon waren. Ein Besonderer Schwerpunkt wurde dabei auf den Bereich der Buntglasfenster gelegt.

The Importance of Preferences and Taste in the Conservation of Works of Art – Abstract

The way we treat and present any object will inevitably affect its appearance, integrity and values, and therefore the way the public will perceive it. During the process of conserving works of art we are generally confronted with a wide array of possibilities and options, with different ways to resolve a problem or present the finished work. A series of decisions have to be made, and these will unquestionably affect the result, both on a technical and aesthetic level, as well as the object's significance and values.

It is often the case that, the same artefact, treated by different conservators, would potentially be tackled, completed and presented in different ways, and they can each be acceptable and right. In fact, there is probably no right or wrong when it comes to choices of an aesthetic nature. Fortunately we do not generally work alone and these decisions are ideally contrasted, discussed and agreed with other colleagues, experts and stakeholders, especially those regarding the technical aspects of our work. However, we are not always so inclined to go through the same process of asking for second opinions on decisions affecting the aesthetics of

our work, because we all have our own preferences and our notion of taste, which as we know, can be harder to argue in concrete terms. This notion is unquestionably at the bottom of many of the decisions we make during our work, whether we like to admit it or not. Preferences and taste are undeniably subjective and therefore cannot be measured or be subject to scientific analysis. It is based on our own past and present personal and professional experiences and, for most of us, it will keep changing through the years.

It is precisely for all those reasons that the role of preference and taste in our work has traditionally been avoided, rejected or banned in the classical scientific theories and principles of conservation, originating during the 20th century. Despite this, more recent theories and approaches in our profession have come to accept and embrace the subjective nature of our work and the importance of the personal taste of the conservator during her or his work. It is the aim of this presentation to show how preferences and taste are, and have always been, present in the decision-making process in the field of conservation and in the restoration of works of art, with special emphasis in the field of stained glass.

Introduction

“Beauty is no quality in things themselves: It exists merely in the mind which contemplates them; and each mind perceives a different beauty. One person may even perceive deformity, where another is sensible beauty; and every individual ought to acquiesce in his own sentiment, without pretending to regulate those of others”.¹

This paper wouldn't have been possible without the considerable influence and input that the writings of Salvador MUÑOZ VIÑAS have had on me over the years. It was only after I first read his seminal, ground breaking *‘Teoría Contemporánea de la Restauración’* (2003),² that I began to understand what my profession was really about. With this book, and many other articles by the same author, I was confronted with new, challenging and eye-opening concepts that made me rethink how I perceived the field of conservation-restoration. This article is not intended to be a review of Muñoz Viñas' texts. However, some of his ideas and concepts, mainly those related to the subjectivity of our decisions and the substantial weight that taste and preferences play in some of our actions in the conservation of cultural heritage, will be used as a starting point and a catalyst for debate. This article aims to be an attempt to explain and understand the impact and implications of these concepts on the field of stained glass conservation.

The need to learn to communicate and share information

There is no doubt that during the past decades, the field of stained glass conservation has greatly evolved and grown into a discipline in its own right. The amount of research and literature that has been produced, and the number of meetings, seminars and courses held, is something to celebrate. The very existence of this Corpus Vitrearum 11th Forum held in Barcelona in 2022 is a good example.

Many topics within our field have been studied and analysed over the recent years, most of them by art historians, glaziers, conservators and scientists. We have been lucky to have a large number of experts from all these fields contributing to our knowledge of stained glass and its conservation from many different angles.

This sharing of knowledge and joined efforts have turned the field of stained glass conservation into a grown up discipline. We've come a long way but we must not rest on our laurels. We still need to do more to allow our profession to gain the same recognition and respect as other conservation disciplines. We need to continue broadening our knowledge, encouraging new people into the field while supporting the existing ones, and promoting research, meetings, dissemination and publications. At the same time, we also need to learn to communicate better what we do, both between ourselves and to wider audiences. Sometimes, I feel that we don't share enough of our findings, our advances or our mistakes, to allow us all to learn and benefit from them. And finally, we need to encourage more across-field's exchange of information and debate with our colleagues from other conservation areas.

It was actually by reading papers outside the stained glass field that I came to realize how little thought or debate we have actually carried out on what could be called the philosophical aspects of our profession. By this, I'm not suggesting that the field of stained glass conservation should have a different set of rules or ethics than other disciplines. However, each field, each material, each object, has its own characteristics and problems, and inevitably the solutions applied during their conservation-restoration will sometimes be different. And perhaps, also, our approach to the ethics behind it.

The list of philosophical topics in conservation which has been discussed and debated over the past decades is long and interesting -it can also be controversial. For the purpose of this paper I would like to focus and elaborate only one of these issues and some its possible ramifications: the importance that personal preferences, inclinations, opinions and taste play in many of the decisions we make as conservators. One simple example to get us started is the fact that we have chosen stained glass as a medium, as a profession, over others. We have grown feelings for this particular medium and feel passionate about it. This, without a doubt, is an act of taste that shows our preferences, at least for most of us.

Conservation: a profession in constant evolution

In the same way that the concept and definition of cultural heritage has undergone multiple changes over time, so have our profession, our goals, our methods and our principles. Cultural heritage embraces a vast array of concepts such as customs, practices, places, objects, artistic expressions, values, etc. Furthermore, all of these concepts within the scope of conservation have often been subdivided into other categories: fine arts;

¹ HUME, 1757 (<https://home.csulb.edu/~jvancamp/361r15.html>) [accessed December 2021].

² Translated into English as *Contemporary Theory of Conservation* and published in 2005 (MUÑOZ VIÑAS 2005).

applied, industrial, popular or folk arts; portable or non-portable, made to last or ephemeral, monumental or small format, tangible or intangible, etc.

Thus, conservation-restoration is a field undergoing constant transformation. If we want to adapt to these changes and stay in tune with the developments in our profession, we must embrace this diversity and learn to think outside the box. What we learned a few years or decades ago might not apply today, and therefore the way we care for any given object in the past would, quite possibly, also be different. That is why it is so important that we keep learning and maintaining a high level of knowledge about our profession through continuing professional development.

The ideas or principles used in conservation can also be different depending on which part of the world, country or school of thought someone lives or has been trained in. Similarly, the solutions and approaches applied in one field of conservation might not always follow the same principles applied in others. In this light, it is interesting to highlight how architectural conservation, just to mention one field which is probably easily relatable to most of us, may sometimes seem to follow its own rules.

In the same way, some of the solutions we often apply to stained glass, especially when it comes to reconstructing missing areas, recovering legibility or the aesthetics of protective glazing, sometimes seem to come across as rather daring, striking or even shocking to the eyes of other conservators, as if we were deviating from the norms or taking liberties which would not be allowed to them.

We can all agree that each conservator would probably have a different opinion or approach on what may be the best way to conserve any particular object, especially if we add the restrictions of a given budget and time frame to the equation. Furthermore, the same conservator would probably do things in a different way under different circumstances and in different moments in time. This lack of fixed instructions, this flexibility of criteria that defeats scientific objectivity, reveals the human factor of our profession, and it is this that makes it so interesting and fascinating.

We all know that our profession doesn't really abide by 'one-size-fits-all' solutions. So perhaps we just need to be more open minded and flexible and give up on the notion of fixed rules, embracing the fact that different objects may demand different approaches, or that the same object can be dealt in different ways. Each conservator is different to the next and we may adopt different solutions to the same problem. Clearly, we must take our individual roles seriously, but not so seriously that we forget that, *Conservation should not be regretted, suffered or merely 'tolerated' by the affected people, but instead admired, enjoyed and respected by as many people as possible. Conservation should not be imposed, but agreed upon.*³

Are codes of ethics truly guiding our work?

Many professions, like Medicine, Law or Journalism, just to mention those which are the most well-known, are bound to a code of ethics or conduct, designed to provide positive support to those seeking to act ethically. These codes offer guidance for ethical conduct, but deviation from them may result in legal consequences. Conservation is no exception since various codes of ethics have been drafted in different charters over the years. These charts, however, haven't turned out to be as effective in helping and guiding us in our work as it would have been expected. *Some associations dealing with conservation have drafted codes of ethics, but in fact they don't have the power of enforcement or prosecution for the actions of their members. They are not subject to legal liability, understood as the potential responsibility for payment of damages or other court-enforcement in a lawsuit.*⁴

The reality is that these charters are not mandatory, and decision makers are not legally bound to them. Indeed, in most countries, anyone can carry out restorations since the profession is not legally recognised. In other words, a conservator would hardly be accountable for an alleged act of malpractice, since this concept is clearly subjective and open to interpretation.

It is interesting to note that we all seem to know the basic rules of our profession, or at least we like to believe that we follow, or are guided by, some ethical principles. But is it really so? Is there actually such thing as a code of ethics guiding us all, in the same way, during our work? The existence of occasional, or not so occasional, controversies or disputes between peers shows that our principles and ethics, or the way we interpret them, might not necessarily be the same as those of our colleagues. We can be very critical and

³ MUÑOZ VIÑAS 2005, p. 194.

⁴ CORTES PIZANO 2013, pp. 5-20.

judgemental about the work of others. Quite often, if we think about it, it's all just a matter of taste and preferences, or of us not liking the end result because we would have done it differently. But, if we are honest with ourselves, these behaviours may sometimes be rooted in professional jealousy, fear or insecurity on our part.

The words of Bernard Berenson sum up all of this in a very clear way: *Few problems are more controversial than the problem of how to restore a painting. I have never encountered a practitioner of the craft who approved of the work of another.*⁵ Though this may come across as a pessimistic view of our profession, I'm actually of the opinion that these differences are positive, and that we need to learn to embrace the human factor behind the decision-making and accept that each of us would do things differently.

Value judgments, cognitive biases and common sense

We have touched on the decision-making processes in conservation, but how does this work from a psychological point of view? The reality is that we are constantly making value judgments; we form opinions or make statements about how good or bad some things are. These judgments are often based on our principles and beliefs and not on facts which can be checked or proved. Similarly, we are often led by cognitive or psychological biases, which are systematic errors in thinking. These biases will influence our decisions and judgments and may lead to perceptual distortion, inaccurate judgment and illogical interpretation. In this sense a cognitive bias would be the opposite of common sense and clear, measured judgment.

Is it therefore possible to say that the decision-making processes in conservation are subject to or guided by 'common sense', understood as *the ability to think about things in a practical way and make sensible decisions*⁶ or as *the ability to use good judgment in making decisions and to live in a reasonable and safe way*?⁷ Since 'sensible decisions' and 'good judgment' can be arbitrary and subjective notions, I would be inclined to say that each conservator would probably have her or his own notion of common sense in each particular situation. However, there are many situations where, for the safety of the conservator and the object we are dealing with, it would be advisable to have the same notion of common sense, like for instance when we are removing a window, transporting, handling or cleaning stained glass panels, etc.

It is in that sense that I believe common sense should have a place in our profession, and we should try and listen to this inner judgment and allow it to guide us through some of our decisions. I guess this might be in line with the *revolution of common sense* that Muñoz Viñas calls for: *...no theory, no book, no catechism can substitute good old common sense. Contemporary theory of conservation, in any form, is perhaps nothing less than a revolution of common sense.*⁸

Classical versus contemporary theories of conservation

Classical theories of conservation, whether scientific or aestheticist, which developed during the late 19th century and throughout the 20th century, have often been challenged and refuted. Consequently, some of the concepts traditionally regarded as almost unchallengeable and immutable in conservation, like *minimal intervention, reversibility, discernibility, objectivity, authenticity, 'original' state, truth*, etc., have also been called into question by a number of authors. As a result, these concepts can no longer be taken for granted as guiding principles in our work. We cannot shelter behind them anymore, or at least not without keeping a critical attitude and acknowledging their flaws.

The inconsistencies of these theories have been exposed by Muñoz Viñas: *...scientific conservation, as it is commonly understood, is based on strong assumptions which are taken for granted: it is assumed that Truth must prevail, and that Truth must be determined by scientific methods...[...].for classical thinkers, conservation is a Truth-based operation. In classical theories, the value and quality of an act of conservation is defined by its adherence to Truth: it is reprehensible if it hides the Truth or lies, and deserves praise if the Truth is preserved or revealed. It is the restorer's duty to preserve or reveal authenticity.*⁹

In the same way that contemporary theories of conservation have challenged the concept of 'truth', the same can be said about the concept of 'authenticity'. *Basically, when we speak about an 'authentic' object, or*

⁵ Cit. in BECK & DALEY 1993, p. 152.

⁶ Oxford Learners Dictionary online (<https://www.oxfordlearnersdictionaries.com/definition/english/commonsense?q=common+sense>) [accessed December 2021].

⁷ Cambridge Dictionary online (<https://dictionary.cambridge.org/dictionary/english/common-sense>) [accessed December 2021].

⁸ Salvador MUÑOZ VIÑAS 2005, p. 199.

⁹ Salvador MUÑOZ VIÑAS 2002, pp. 26-27.

*about the 'authentic' state of an object, we are actually referring to an expected or preferred state of the object. Conservators often alter or delete the authentic imprints of history for the sake of 'authenticity'; the problem with those imprints (a marred surface, a missing fragment, a darkened varnish, you name it) is not that they are not authentic, but that we do not like them. We prefer the object to exist in a different state. Conservators thus modify reality (which is undoubtedly authentic) to suit our expectations, needs or preferences. So authenticity is useful because it helps us to believe that we are acting for some higher reasons (truth, science, objectivity, etc.) and not that we are simply implementing our own expectations or preferences.*¹⁰

It is clear therefore, that the contemporary theories of conservation have acknowledged the importance of personal, subjective views and embraced the role that taste, inclinations and preferences play in our work. Furthermore, even feelings need to be accounted for. *Feelings or sentiments are not easy to quantify furthermore, they can be easily faked. Perhaps for this reason, they are seldom recognized as a valid factor when making decisions about anything heritage-related. [...] Feelings are neither measurable nor communicable, and for that very reason, some people just tend to ignore them. And yet, reckoning with them as a reality might have an impact on how heritage is viewed.*¹¹

The non-neutral nature of conservation

*...Restoration is generally regarded as an activity in which people's tastes or other equally subjective criteria are undesirable and must remain absent from the decision-making process.*¹²

This perfectly sums up the idea that many people still hold onto, that *Conservation is a purely neutral activity, an activity that lies outside the history of the object. [...]...the non-neutral nature of heritage conservation needs to be acknowledged. And it should be acknowledged that conservation is not neutral for a good reason: it changes heritage for the better. It makes heritage objects more valuable, more engaging, longer-lasting, more efficient. Conservation alters because conservation improves.*¹³ Some authors like van de Vall take this statement even further, considering *...the conservator to be a manager of change, whose main responsible lies in deciding the amount and quality of change that is acceptable.*¹⁴

This idea of conservation being a neutral activity is generally so ingrained in us that it can be difficult sometimes to realise what an important role subjectivity, personal preferences and taste play in our profession. Decisions are made based upon our judgment, practical knowledge and skills. However, my experience will inevitably be different to someone else's experience and therefore my preferences, expectations and taste, will play a big role in the methods or solutions I will chose for each particular case.

Every decision we make involves a selection process of different options and possibilities, of which only one will be carried out and many other will be disregarded. One of the consequences of this selection is that some of the values and meanings of the object will be altered, maintained or highlighted, while some others may diminish, or even disappear. *This kind of dilemma (the choice about which meaning should prevail and which ones should be sacrificed) lies at the heart of nearly every conservation controversy.*¹⁵ And *quantifying the values that have been gained and lost, however is not simple. In fact, some may consider it simply impossible. This is so because many of the values that conservation increases or reduces are immeasurable.*¹⁶

Another interesting way of looking at this is seeing any intervention as a deal or a negotiation, where there will be both gains and losses. *A conservation treatment is akin to a transaction: there are costs and there are benefits. These cannot be objectively or precisely assessed, since very diverse types of factors (aesthetic, symbolic, emotional, political, economic, technical) need to be compared and evaluated.*¹⁷

Cosgrove takes this even further when he considers conservation to be a creative activity. *Any decision to deploy specific technical skills to restore an object to its 'original' state, to an intermediate state, or simply to keep it from further change is by definition arbitrary and should be recognized to be so. Conservation may thus*

¹⁰ MUÑOZ VIÑAS 2008, p. 22.

¹¹ MUÑOZ VIÑAS 2003, p. 50.

¹² MUÑOZ VIÑAS 2014(a), p. 75-88. Translation into English from the original Spanish text by Fernando CORTÉS PIZANO.

¹³ MUÑOZ VIÑAS 2018, p. 65.

¹⁴ MACEDO et al. 2012, p. 7.

¹⁵ MUÑOZ VIÑAS 2009, p. 54.

¹⁶ MUÑOZ VIÑAS 2018, p. 44.

¹⁷ MUÑOZ VIÑAS 2018, p. 63.

*be regarded as itself a creative intervention, subject to the same individual and social negotiations and struggles over meaning and representation as any other action.*¹⁸

González Tirado makes another interesting and thought-provoking analogy when she claims that restorers are some sort of ‘artists-interpreters’. She compares *the work of the restorer with that of certain types of artists called performers. [...]...defining the performing arts as those that present to the public the creations of other artists; therefore, we will include in this group the actors of theatre and cinema, the dancers, the musicians playing some instrument and the singers.*¹⁹

Fallibility, risks and compromises in conservation

When confronted with a new object, we can choose only one route for that particular object at that particular moment in time. The path we choose will surely affect the ways in which the public will view or perceive that object. Interestingly enough, even if different conservators would take the same route, the result would probably be also different. The resulting differences between each conservator can be due to either *the manual skill of each of them, their technical and scientific knowledge, their critical judgment, their interpretation of the deteriorated work or their idea of how it should look once restored.*²⁰

However, in our profession, we generally don’t act unilaterally, and therefore we might not always have the final saying on how to best conserve any given object. Also, the available options may not always be the ones we would have chosen ourselves; the ones we might consider the best for that particular situation. But, nonetheless, we may find ourselves in charge of a project and will have to make the final decisions, and no matter which path we chose, how much thought we put into it, how many people we consult, or how neutral we try to be, the final result will never please everyone. There will always be advocates and detractors. We must be prepared to take criticism on board, whether this might be based on scientific facts or on someone’s personal taste. As we must also be able to put ourselves in someone else’s place, making an effort to know all the facts, before we judge. In the words of the British Philosopher David Hume: *“We are apt to call barbarous whatever departs widely from our own taste and apprehension: But soon find the epithet of reproach retorted on us.”*²¹

Sometimes mistakes and errors do happen. Of course they do! And, on the occasion that the perceived errors are not due to personal preference and taste, all we can do is but accept our fallibility and humbly learn from the experience. Marincola and Maisey very wisely state that *Mistakes and errors, whilst unfortunate, are almost universally recognised to be invaluable tools for learning and development. Indeed, successful practice in many professions, including conservation, benefits greatly from the lessons learned through the attempted – and failed – approaches in the past. In recent decades, conservation has achieved a far greater degree of specialisation and recognition than ever before. Paradoxically, the culture of infallibility and risk aversion that has developed out of this directly hampers our collective acknowledgement and sharing of mistakes.*²²

Thankfully, in most cases, there is no doubt that the decisions we make in conservation are taken in good faith and with the best intentions. This doesn’t mean that there are no risks involved. There will always be risks and consequences to our actions and we can only try to contain and minimise them. These risks are part of the nature of our profession and they should not scare us or leave us paralysed and afraid of making decisions. Otherwise we might end up falling into what Ashley-Smith has very cleverly called *the ethics of doing nothing.*²³ According to Muñoz Viñas *...taking risks is a core trait of our profession. Sure, we take as little risk as possible, but we do take risks. As is the case for many other professions, conservators are rarely 100% sure that a given treatment will be absolutely safe. In this regard, we compromise.*²⁴

This brings us to the need to acknowledge that, in our profession, we do not always carry out the best treatment for the object. Allow me to explain. The fact is that the best treatment can be a debatable and subjective notion. The reality is that we often have to make a sensible compromise for a greater good, and negotiate an acceptable or ‘best possible’ result. To better understand the extension of this statement, I will quote Muñoz Viñas once more: *In fact, we often know that our treatment of choice is not the best possible*

¹⁸ COSGROVE 1994, p. 263.

¹⁹ GONZÁLEZ TIRADO 2010, p. 7.

²⁰ GONZÁLEZ TIRADO 2010, p. 8.

²¹ HUME 1757.

²² MARINCOLA & MAISEY 2011, p. 1.

²³ ASHLEY-SMITH 2018.

²⁴ MUÑOZ VIÑAS 2014 (b), p. 5.

*treatment. In most conservation treatments, things could have been done in a better way. Not because the conservator did anything wrong, but rather because he or she consciously chose a given course of action, fully aware that better technical options existed: a more comprehensive set of analysis, a slower and more gentle cleaning technique, a better and costlier reinforcing material, etc. However, I would argue that, in a vast majority of cases, conservators make sensible and perfectly correct decisions when opting for the less-than-ideal option.*²⁵

In the light of this, it seems an impossible task to try and pin down what defines a good or bad conservation-restoration, or how we measure the success of any intervention. Personally I would say that a good conservation is probably the one that will reach, please and benefit the largest amount of users for the longest period of time. However, I would also agree with Muñoz Viñas when he says that *If the conservation treatment is considered successful, it is not because the object has been preserved as it was before the treatment, but because the gains are greater than the losses, so its value is now greater than it was.*²⁶ And also that [...] *the degree of success of a conservation treatment can only be checked as time passes.*²⁷

There is no accounting for taste

*Conservation is about bringing the object to a preferred state. We adapt objects to our preferences and that's it.*²⁸

When we speak about preferences and taste we have to consider, first of all, our personal taste as conservators, since we are the ones who perform or implement the actions that will affect any work of art. But we also have to take into consideration the preferences and taste of all other stakeholders and people involved in the conservation process, as well as the prevailing taste or fashion of our time, both within our profession, school of thought or milieu, and also within our society, country or culture. The combination of all these factors, to a greater or lesser extent, and whether we are aware of it or not, will have an impact on the final result of our intervention.

Before we go any further, and since this presentation revolves mainly around the concepts of preferences and taste, let's see what we generally understand by them. By and large, 'preference' is what you prefer and 'taste' is what you like or dislike. By 'taste' we generally understand either *what a person likes or prefers*, or *a person's ability to choose things that people recognize as being of good quality or appropriate.*²⁹ Similarly, 'preference', is *the fact that you like something or someone more than another thing or person*³⁰ or *a greater liking for one alternative over another or others.*³¹

We are all very familiar with these terms and there is probably nothing new here, except perhaps for the fact that we might not always realise the important role they play in the decision-making processes in conservation. Painting conservator Mark Leonard has a very interesting take on this when he claims that *... a lot of conservation in the past was done in the name of scientific objectivity, when in fact, what we were really doing was absolving ourselves of any responsibility.*³²

All in all, since preferences and taste are an intrinsic part of our human nature, and conservation is carried out by people, then we cannot expect these biases not to show in our profession. After all, *Science has little to do with decisions regarding tastes, beliefs, preferences and expectations, except for the authority it may exert upon offended users, making it easier for them to accept the 'offense' as being scientifically based.*³³

Another way of looking at this is realizing that we all grow strong attachments to a great variety of objects and actions, from the tools we use to the way we just prefer to carry certain actions or just do many things in our job. And these preferences and attachments condition our judgments and perceptions of how to best do things, and can easily lead to considering there is a "best" way, a "proper" way of doing them. There is plenty of scientific evidence that we tend to attach positive and negative associations to just about everything there is. And in this respect, an interesting example is the concept of "perfection" which only exists in our minds.

²⁵ MUÑOZ VIÑAS 2014 (b), p. 5.

²⁶ MUÑOZ VIÑAS 2018, p.59.

²⁷ MUÑOZ VIÑAS 2018, p.50.

²⁸ MUÑOZ VIÑAS 2008, p. 23.

²⁹ Oxford Learner's Dictionary online (https://www.oxfordlearnersdictionaries.com/definition/american_english/taste_1) [accessed December 2021].

³⁰ Cambridge Dictionary online (<https://dictionary.cambridge.org/dictionary/english/preference>) [accessed December 2021].

³¹ Lexico Dictionary online (<https://www.lexico.com/definition/preference>) [accessed December 2021].

³² CONSIDINE 2000, p. 156.

³³ MUÑOZ VIÑAS 2005, p. 184.

Perfection is an illusion which depends on our perception, cannot be measured and can therefore be considered as a subjective notion.

Some examples of the presence of preferences and taste in stained glass conservation

*Every treatment represents an attempt to bring an object to a specific previous state, but the choice of that state is not a foregoing conclusion. Ergo, any treatment is an interpretation.*³⁴

Over the centuries, many works of art were destroyed, removed, relocated or drastically altered due to new preferences and changes in the taste of the time. Buildings are a perfect example of this, and with them all their movable and immovable works, like stained glass, altar pieces, painting, metal and wood works, floors, etc. Buildings are alive and in permanent change. Elements have often been removed or transformed and new ones added. Stained glass windows, for several reasons, have traditionally been easy targets, and have been frequently removed, replaced or altered to conform to the preferences of the new times. Similarly, new stained glass windows have always coexisted next to the older ones, often showing considerable differences in style.

During the second half of the 19th century, a new sensibility was developed, and with it the concept of scientific conservation that was going to prevail for the most part of the 20th century. However, as we have seen, most of these ideas have proven to be obsolete and out of touch with the present demands of

conservation, leading to embracing subjectivity and taste back into our profession. The way taste works in conservation has been clearly summarised by Muñoz Viñas as follows: *Taste has an influence on the conservation criteria used in each treatment in three different ways: In prioritizing the conservation of some objects; In making a 'true condition' of the object prevail over other possible ones; In re-creating that condition in a given way.*³⁵

In the field of stained glass conservation, the examples of operations or decisions where taste and preferences are involved are numerous and varied. The most obvious ones are probably those related to the insertion of new glass infills and the aesthetics of protective glazing. These two areas can easily trigger criticism and heated debate among us, let alone among conservators from other disciplines. So, let's look into them with more detail.

As for the new infills, whether they are just one small piece of glass, a big section of a panel or half a window, the choices ahead of us can be many, and so can the possibilities for judgment and criticism. From the selection of the type of glass or paints used, the painting style and technique, the degree of imitation or recreation of the original pieces, etc., the variants can be almost endless, to the point where no two painters would be able to have the same result, no matter how hard they might try.

With regard to protective glazing, once we have agreed on the technicalities of its construction (external or internal ventilation, types of metals and other materials used, etc.), then the remaining decisions will be of an aesthetic nature, mainly concerned with how to minimise its impact on the

legibility of the building and of the window itself. The fact that different countries clearly seem to prefer one method over another, based on aesthetic grounds, shows once again how much these decisions and choices can be based on preferences and taste. Although, to be totally fair, let's not forget that some of the decisions we sometimes have to make can be influenced by budgetary restrictions too (fig. 1).

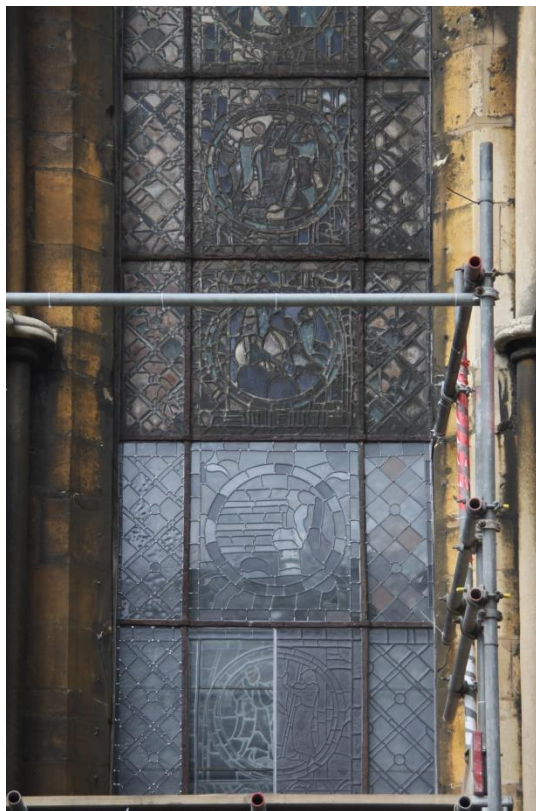


Fig. 1. 13th-century stained glass window in Lincoln Cathedral (UK), where seven different types of protective glazing were temporarily installed to test their aesthetic impact.
© Fernando Cortés Pizano.

³⁴ Barbara APPELBAUM 2010, p. 6.

³⁵ MUÑOZ VIÑAS 2005, p. 108.



Fig. 2. Reuse of 16th-century fragments of glass in one the windows in San Marcos Church, León (Spain). © Stained glass firm 'Grisallas'®, León (Spain).



Fig. 3. Stained glass window from 1992-1998 by Johannes Schreiter in Marktkirche, Goslar (Germany), incorporating a 12th-century panel. © Fernando Cortés Pizano.

These two examples are easily recognisable by all of us, but there are many other actions or decisions clearly based on taste. Among these we could surely mention the removal (or keeping) of previous infills, stop gaps, mending leads, strap leads, etc.; patination or darkening of leads, solder, perimeter lead bands or panel frames; dying or blackening of cement or putty; the level of retouching with cold paints; even the degree of acceptable cleaning of a panel can be different from one conservator to another, or between different studios (fig. 2).

Other interesting examples of this situation are the rearranging or relocating of glass within one or different panels; the rearranging or relocating of panels within the same window or within a building; selecting panels for musealization and/or exhibition.

Sometimes, as previously pointed out, we might be in the situation where we need to decide, due to budgetary or time restrictions for instance, which windows (or panels) are to be conserved and which ones are not, or which are a higher priority. We might have to make judgements based on which ones we consider more important, valuable or even beautiful. These difficult decisions can be based, to a certain extent, on the age, prestige or values of the object, but they may also be based on our preferences and taste.

In this sense, we could also say that many of the stained glass windows that have made it to the present day are the result of a succession of decisions and choices made by different people over the years. To illustrate this, during the Second World War, many windows from different buildings across Europe were removed and stored for safeguarding until the end of the conflict. Thanks to these decisions, based primarily on the extended belief that the oldest ones were more important, many stained glass windows were saved.

Many other examples could be added to this list but there is one that I personally find very appealing and illustrative and I would like to share it. I am referring in particular to new stained glass windows made out of either a collection of old panels, fragments of old glass, or a combination of old and new glass in a clearly artistic fashion. This way of working is certainly not a new trend and it can be traced back over many centuries. In these particular type of windows, glaziers and conservators seem to enjoy a higher degree of creative freedom and artistic licence, and therefore their taste and preferences come to light more evidently. This I consider to be some sort of hallmark of the stained glass field, since I cannot think of similar examples of the 'creative', 'artistic' reuse of fragments of old works of art in other conservation disciplines at present (fig. 3).

Some final reflexions of legibility and likability

In case there is still any doubt, any attempt to improve legibility is per se subjective and therefore an act of taste. *When conservators decide to render an object 'legible', they are actually making a choice; they are deciding which legibility should prevail over the many possible ones. [...] It is the conservator who chooses which meaning (which legibility) should prevail, often at the expense of permanently excluding other possibilities.*³⁶

³⁶ MUÑOZ VIÑAS 2005, p. 100.

An interesting example to illustrate this flexible idea of legibility and likability is the Japanese method or art of the *Kintsugi*, also known as “golden joinery” or “golden repair”. The *Kintsugi* is a way of fixing broken fragments of pottery using tree-sap lacquer dusted with powdered gold, silver or platinum. “As a philosophy, it treats breakage and repair as part of the history of an object, rather than something to disguise”³⁷ and the result are a very noticeable fracture lines.

Similarly, whenever we are tempted to make any object more likeable or more pleasing, our decisions are being affected by both our taste and the taste we presume for the potential general public at the time. But can we objectively say that any object looks *better* or *worse* as a result of a restoration? Once again, using words like ‘better’ or ‘worse’ is a subjective judgment which clearly shows our preferences (fig. 4).

And what would happen if we personally don’t like the object we have to restore or conserve, if we think it is ‘ugly’, not very valuable or worthy of conservation? These are situations that do happen. Are we then, perhaps, unconsciously, more likely to lower our standards and make less of an effort to treat that object? Hopefully not, but as with many of the other questions that have been brought up here, we will probably never know the answer. Perhaps because there are many possible answers. Some more food for thought.

Conclusion

Many more examples and case studies could be added to this list, but the main point here is to be aware that many of these routine decisions that we take, whether conscious or unconscious, are subjective and based on our preferences and inclinations. We might like the final result of a given intervention or not, but that does not mean it is right or wrong. What is acceptable for some may be unacceptable for others. Therefore, it is very important to keep an open mind and a humble and constructive attitude, letting go of ego, vanity and prejudices. The truth is that there is nothing wrong with preferences and taste in conservation. They are an intrinsic part of our job and they are, after all, what make us human and what make our profession so interesting and challenging.

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Fig. 4. 16th-century stained glass window from Segovia Cathedral (Spain), reconstructed after significant damage caused by a big storm at the beginning of the 20th century.
© Fernando Cortés Pizano.

³⁷ <https://en.wikipedia.org/wiki/Kintsugi> [accessed December 2021].

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2.2

The Use of Particle Accelerator Analysis to Identify the Origin and Production Processes of 16th-Century Stained-Glass Windows at St Mary's Cathedral in Auch

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L'analyse par faisceau d'ions pour identifier l'origine et les procédés de fabrication des vitraux du XVI^e siècle de la cathédrale Sainte-Marie d'Auch – Résumé

Parmi les vitraux conservés dans la cathédrale d'Auch (Gers, Occitanie), dix-huit, situés dans le déambulatoire, ont été créés entre 1510 et 1513 et signés par le peintre verrier Arnaud de Moles. La restauration des vitraux de la cathédrale a commencé avec la chapelle Saint-Louis (2017-2019), et se poursuit dans les autres chapelles et les baies hautes du chœur. Ce projet de restauration et de conservation a été réalisé par une équipe interdisciplinaire.

Les trois baies de la chapelle Saint-Louis représentent des scènes bibliques. Les premières observations en atelier ont montré un très bon état de conservation. Le projet de restauration visait à nettoyer et réparer les casses des vitraux, ainsi qu'à les protéger par une verrière extérieure. Une restauration est toujours l'occasion d'étendre la connaissance de l'œuvre. Ce projet a bénéficié d'un temps de faisceau à l'Accélérateur Grand Louvre d'Analyse Élémentaire (AGLAE), un accélérateur de particules développé par le Centre de Recherche et de Restauration des Musées de France (C2RMF, Paris). Les spectroscopies

PIXE et PIGE ont été utilisées pour effectuer des analyses non invasives et non destructives sur trois panneaux afin d'identifier la composition chimique quantitative des verres.

Les résultats ont révélé une composition très homogène pour tous les verres à l'exception des verres pourpres. Des analyses ont été effectuées sur les deux faces et ont révélé des verres rouge, vert et bleu plaqués. La composition du verre a été comparée à celle d'autres sites en France, et une similitude a été trouvée avec la composition du vitrail réalisé dans les premières années du XVI^e siècle pour la cathédrale Saint-Étienne de Sens. Les archives du site de Sens notent que le verre a été acheté à un marchand se fournissant en Lorraine. On peut donc supposer que les feuilles de verre utilisées par Arnaud de Moles, soufflées en manchon suivant la méthode lorraine, provenaient du même fournisseur, situé à mille kilomètres d'Auch.

La qualité exceptionnelle du verre et la remarquable conservation des verrières nous ont permis d'approfondir les connaissances existantes sur les procédés de fabrication du verre coloré et sur les routes commerciales du XVI^e siècle en France.

The Use of Particle Accelerator Analysis to Identify the Origin and Production Processes of 16th-Century Stained-Glass Windows at St Mary's Cathedral in Auch – Abstract

Among the stained-glass windows conserved in Auch Cathedral (south of France, Occitanie), eighteen, located in the ambulatory, were created between 1510 and 1513 and signed by the glass-painter Arnaud de Moles. A recent restoration of the cathedral started with Saint Louis' Chapel (2017-2019), then moved on to the remaining chapels and the upper windows of the choir. This restoration and conservation project was carried out by an interdisciplinary team.

The windows of the three bays in Saint Louis' Chapel depict holy characters and biblical scenes. The first observations in the studio showed few lead repairs and a very good state of conservation. The restoration project aimed to clean the stained glass, mend any broken sections and protect the three windows with protective glazing.

A restoration is always an opportunity to extend the knowledge of the artwork in question. This project benefitted from a session at the Accélérateur Grand Louvre d'Analyse Élémentaire (AGLAE), a particle

accelerator developed by the Centre for Research and Restoration of Museums of France (C2RMF, Paris). PIXE and PIGE spectroscopies were used to carry out non-invasive and non-destructive analyses on three panels to identify the quantitative chemical composition of the different pieces of glass.

The results revealed a very homogeneous composition for all the glass samples except for those with a murrey colour. Analyses were carried out on both sides of the glass and revealed the use of flashing for the red, green and blue glass samples. The glass composition was then compared with those of other sites in France, and a similarity was found with the composition of the stained glass made in the first years of the 16th century for Saint-Etienne's Cathedral in Sens. Archives from Sens note that the glass was purchased from a glasshouse in the Lorraine region. We can therefore assume that the glass sheets used by Arnaud de Moles came from the same supplier, located a thousand kilometres from Auch. The exceptional quality of the glass and the remarkable preservation of the windows have enabled us to extend existing knowledge on the manufacturing processes of coloured glass and on the 16th century trade networks used for their commerce in France.

1. Introduction

A conservation-restoration project is always a unique opportunity to examine stained-glass windows in detail. Indeed, their removal from their original position provides an ideal occasion to observe them carefully at very close quarters and understand the production processes used by the glass-painter. The possibility to combine these observations with chemical analyses to determine the composition of both the glass and paints used and then compare the findings with those obtained in other sites and other periods in time is an exceptional opportunity to deepen our knowledge of a work of art. We seized this opportunity to study the stained glass of St Mary's Cathedral in Auch (south of France). The windows were made by the glass-painter Arnaud de Moles between 1510 and 1513. Their restoration began in 2017 and involved an interdisciplinary team made of curators, conservators, architects, historians and scientists. Three window panels were analysed with ion beam techniques to identify the chemical composition of the glass and improve our knowledge of 16th-century French stained glass. This data was compared with findings collected from other French sites from the same period, and the results are presented in this paper.

2. Historical background

The reconstruction of the cathedral choir began ca. 1493. Shortly afterwards, the chapter clergy funded the complete decoration of the choir, including the glazing of the ten chapels surrounding the ambulatory. A total of eighteen monumental stained-glass windows were installed in their triple or quadruple lancet bays, crowned by complex and flamboyant tracery lights. The completion date of June 1513 is inscribed on a window panel of the last southern bay beside the name of the glazier Arnaud de Moles, presumably the main actor of this ambitious project, which was carried out over just three or four years¹.

This spectacular series is striking in terms of the formal coherence of its iconographic program, an illustration of the concordance between the Old and New Testament that is organized into an innovative scenography. This comprises three subjects in three windows which resume the redemption (Original sin, Crucifixion and Resurrection), and in the fifteen remaining windows, forty-nine tall standing figures which are depicted on various decorative backgrounds. These patriarchs, prophets, sibyls and apostles compose typological groups placed in each of the fifteen remaining windows, above small-format « predellas » illustrating related scenes. In addition to the architectonic variety of the compositions, the disparate tracery lights are filled with innumerable motifs, angelic musicians, allegories, coats of arms and other details.

Despite a clear scholarly interest from the early 19th century to the current day,² little is known about the origin of templates and patterns which appeared through new approaches that closely resembled sketches by the Milanese contemporaries of Leonardo da Vinci, and were provided for those implementing the stained-glass window projects. From a technical standpoint, these designs were applied by highly skilled craftsmen who used grisaille to obtain different visual effects on a range of glass colours. The remarkable quality of the pieces of glass allowed large sections to be cut and the insertion of numerous « jewels » in the panels, as well as abrasion or etching on the surfaces of coloured flashed glass. This material was very resistant to alterations, and needed little restoration throughout the following centuries, as confirmed by documentary evidence and archaeological observation. The main restoration campaign was carried out in 1872-75 by the Parisian glass-painter Emile Hirsch, who introduced minimal modern additions to this well-preserved glazing.

3. Restoration project

The restoration project at St Mary's cathedral in Auch began with the chapel of Saint-Louis (2017-2019). This project was launched by the regional cultural affairs directorate (the main project manager) and was carried out by Stéphane Thouin, the chief architect and contractor. The restoration of the stained-glass windows was entrusted to Anne Pinto and Claire Babet, two qualified conservators who worked together on this project. A scientific committee was named to attend the restoration and participate in decision making. It was made up of a cross-section of the different restoration actors: architects, conservators and curators, inspectors from the Ministry of Culture; art historians from the

¹ GATOUILLAT 2020, p. 191.

² GATOUILLAT 2020, p. 195.

Centre André Chastel and conservation scientists from the *Laboratoire de Recherche des Monuments Historiques (LRMH)*. Saint-Louis' chapel has three bays (numbers 4, 6 and 8) with windows representing holy characters and biblical scenes (fig. 1). All the panels were removed and brought to the conservators' studios for restoration under the supervision of the scientific committee. The project manager then decided to protect the stained-glass windows with a protective glazing placed in the original frame rebates.

3.1. Conservation process

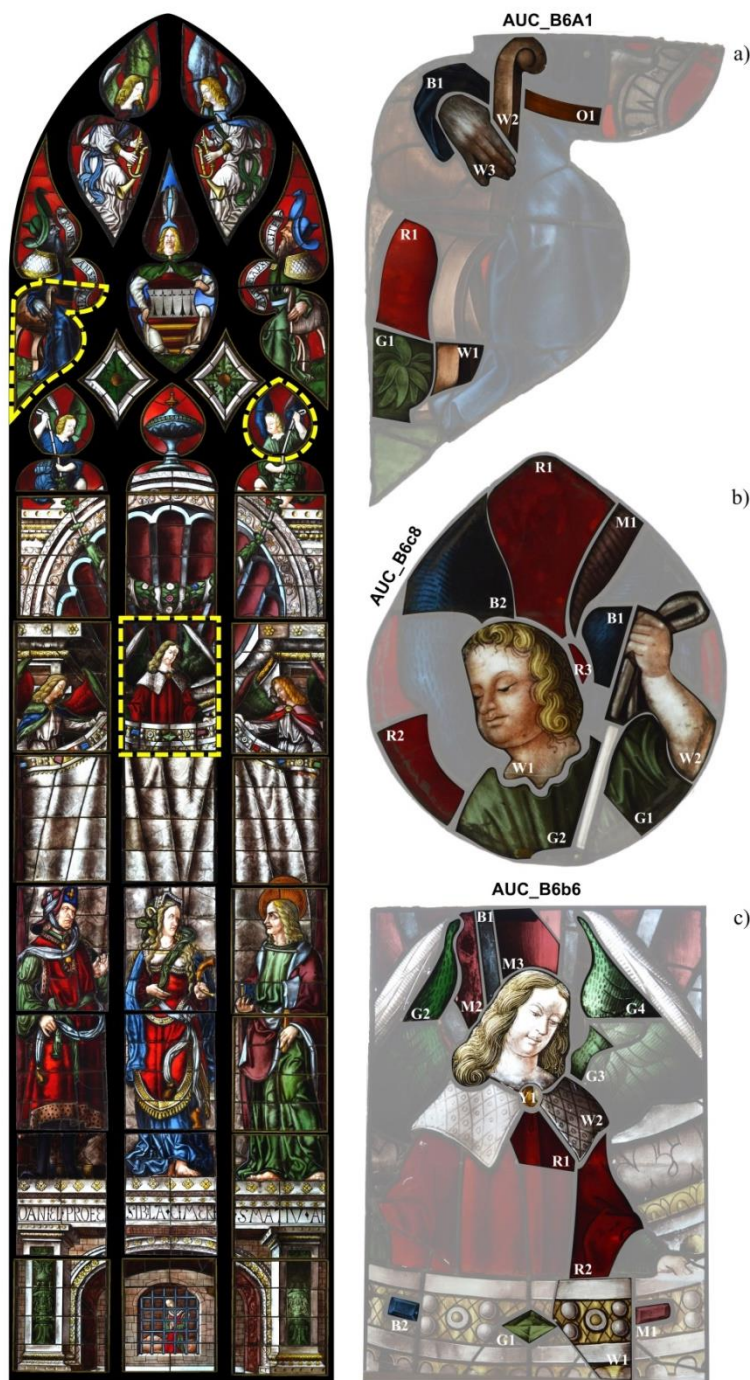


Fig. 1. Auch, St Mary's Cathedral, bay 6, internal face, transmitted light. Panels chosen for AGLAE analyses: a) Bay 6, panel A1; b) Bay 6, panel c8; c) Bay 6, panel b6. © C. Babet, 2018.

The first observations made on the panels showed a very good state of conservation of both the glass and the paint. Little mending lead was noted and the glass corrosion was very limited. The restoration was carried out in the conservators' studios and included the cleaning of the glass and the restoration of broken pieces of glass. Following the code of ethics, the mending lead was then replaced by silicone or epoxy edge-bonding when the two pieces of glass were contemporary or by copper foils when they were from different periods and restorations. Lead came was preserved as much as possible and only replaced when needed. The metalwork was treated as follows: when set into the masonry, lug-bars were stripped and treated with anti-corrosion products on site. Since the panels were placed in front of their original frame after restoration, the saddle bars were too short. New ones were made for the stained-glass windows and the original ones were preserved and placed on the protective glazing. A wide lead frame was fixed on all panels to fill the gap between the window and the masonry. Finally, new lug-bars were fixed to the old ones with clamps and steel-threaded rods in order to prepare the metalwork for the protective glazing. All original metals and new metallic objects added to this framework were treated to prevent corrosion, which is particularly common when different metals are used.

3.2. Protective glazing

The protective glazing prevents any further deterioration of the stained glass by stopping the formation of condensation on the internal face of the panels and protecting their external face from rain, wind and pollution. In order to be efficient several parameters must be respected, namely a distance of 3.5cm between the protective glazing and the stained-glass window, a natural air flow from inside the building and the installation of lead flashing at the base of the protective glazing to collect water from the condensation. The choice of window is purely based on the aesthetic considerations for each site, and in the case of Auch cathedral, the curator and the architect chose to use lead-glazed windows, placed in the original frame rebate.

4. Glass analysis research

Since 2006, a long-term research project by the LRMH and the *Centre de Recherche et de Restauration des Musées de France* (C2RMF) has concentrated on the use of the AGLAÉ particle accelerator (*Accélérateur Grand Louvre d'Analyses Élémentaires*) to analyse stained glass. Beam time access is granted twice a year and when stained-glass windows are under restoration, this provides a unique opportunity for researchers to study the chemical compositions of both glass and paints and thus extend current knowledge of French stained glass. AGLAÉ has high analytical performances and is non-invasive and non-destructive, as no samples are taken from the objects and the materials analysed are not modified in any way. In the case of stained glass, the panels can be placed directly in front of the beam. A mechanised system then obtains numerous measurements from their surface. This analytical technique is therefore well-fitted for inorganic compounds and precious works of art such as stained glass.

4.1. Experimental protocol

4.1.1. Instrumentation

AGLAÉ is the only particle accelerator that is solely dedicated to works of art, and has thus been located at the Louvre museum since 1988³. This instrument uses ion beam methods and is based on the interaction between light particles (protons, deuterons and alpha particles) and the atoms constituting the materials under study. Several detectors can be used to collect different emissions, including Particle Induced X-ray Emission (PIXE) and Particle Induced Gamma Emission (PIGE). The PIXE method is based on X-ray emission following the interaction between the inner electrons of an atom and the ion beam. This method allows the quantitative detection of chemical elements and particularly trace elements. It is coupled with the PIGE method, which is based on the emission of gamma-rays and can detect light elements such as sodium or magnesium.

4.1.2. Analytical parameters

Analyses are carried out on the surface of the panels (glass and paint) after prior selection of the least affected or unaffected areas. A proton beam set at a power of 3 MeV scans a surface of 500 x 500 µm. A detector is used to collect the gamma-ray from the PIGE emission, whilst the X-ray from the PIXE emission is collected by other detectors dedicated to low or high energies. All detectors are used simultaneously. A 40-mm helium flux is set up in front of the low energy detector to reduce the absorption of both the beam and the X-rays in the air. Aluminium filters with a thickness of 50 µm are placed in front of two high energy detectors (HE1 and HE3), and a 100 µm-thick aluminium filter is placed in front of the last high energy detector (HE4). This thick filter is used to enhance the detection of antimony and tin reflecting the amount of lead in the paintings. Three measurements are collected and averaged for each sample. National standards and reference materials (Brill standards and NIST 620) are used at the beginning and end of every day of analyses in order to calibrate PIGE data and monitor the accuracy of the quantitative data obtained from PIXE results. PIXE spectra are processed with GUPIX© software,⁴ using iron as the pivot element. Calibration is then carried out using the PIGE values collected for sodium.

³ PACHECO et al. 2016, p. 63-69.

⁴ PICHON et al. 2015, p. 48-54.

4.2. Samples

Three panels were chosen in the conservators' studios to obtain a representative sampling of all the colours and paints found across the three bays. These were B6A1, B6b6 and B6c8 (fig. 1). This choice was made after discussion with the art historians and conservators to ensure that panels with as many original glass pieces as possible were selected. Analyses were carried out on both sides of the panels when possible and were obtained for the glass (fig. 1) and the paint, namely grisaille, yellow stain and sanguine. Only the results for the glass samples are presented here. The list of all the glass samples is presented in Table 1.

4.3. Results and discussion

The quantitative analysis of the different pieces of glass was instrumental in determining the proportions of the different raw materials used by the glass-maker during the production process. The main raw materials today are the same as those used in the past, namely vitrifying agents (sand, quartz), fluxing agents (natron, plant ash) and stabilizers (alumina and alkaline earth oxides). Fining agents include manganese oxides (which are used as decolorizing agents), sulphates, chlorides and nitrates that are all already present as impurities in raw materials⁵.

Around 60 % of the composition of the glass at Auch cathedral is attributable to silicon dioxide (SiO_2), and the remaining 40 % is made up of high levels of calcium, potassium and/or sodium oxides (CaO , K_2O and Na_2O), with significant amounts of chlorine, as well as magnesium and phosphorus oxides (Cl , MgO , P_2O_5) depending on the type of ash used (forest or marine plants)⁶.

4.3.1. Quantitative composition of the glass samples

A similar composition was revealed for all the colours on all the glass pieces studied in this project, except for the murrey samples (Tables 2a and 2b). Indeed, the blue, red, green, white, yellow and orange glass was composed of approximatively 60 % of silicon dioxide (SiO_2), 20 % of calcium oxide (CaO), 5 % of potassium oxide (K_2O) and around 2.5 % of sodium oxide (Na_2O). They can be classified in the high-lime, low-alkali (HLLA) group⁷. The composition of these coloured sections also contains around 2.5 % of magnesium oxide (MgO), 0.5 % of chlorine (Cl) and nearly 3 % of phosphorus oxide (P_2O_5). The composition of the murrey glass sections is different, with 55 % of SiO_2 , 16 % of CaO , 15 % of K_2O and less than 1 % of Na_2O , whilst MgO , Cl and P_2O_5 concentrations are around 5 %, 0.1 % and around 1.5 %, respectively. Given that the hierarchical classification of stained-glass fragments is based on their major composition,⁸ the murrey glass samples cannot be placed in the HLLA group due to their potash content.

Table 1: List of samples

Colour	Sample	Face analysed	
		External Face (EF)	Internal Face (IF)
Blue	B6a1_B1	×	-
	B6b6_B1	×	-
	B6b6_B2	×	-
	B6c8_B1	×	×
	B6c8_B2	×	-
Green	B6a1_G1	×	×
	B6b6_G1	×	-
	B6b6_G2	×	×
	B6b6_G3	×	-
	B6b6_G4	×	-
	B6c8_G1	×	-
	B6c8_G2	×	×
Murrey	B6b6_M1	×	-
	B6b6_M2	×	-
	B6b6_M3	×	×
	B6c8_M1	×	-
Orange	B6a1_O1	×	-
Red	B6a1_R1	×	×
	B6b6_R1	×	-
	B6b6_R2	×	-
	B6c8_R1	×	×
	B6c8_R2	×	×
	B6c8_R3	×	-
White	B6a1_W1	×	×
	B6a1_W2	×	-
	B6a1_W3	×	-
	B6b6_W1	×	-
	B6b6_W2	×	-
	B6c8_W1	×	-
	B6c8_W2	×	×
Yellow	B6b6_Y1	×	-

⁵ MORETTI & HREGLICH, p. 23-47.

⁶ HENDERSON 2013, p. 83-126.

⁷ HARTMAN 1994, p.103-128 and SCHALM et al. 2007, p.663-668.

⁸ SCHALM et al. 2007, p.663-668.

4.3.2. Flashed glass

When considering the concentration of metallic oxides responsible for the coloration of glass, the surface on which the analysis has been made (i.e. internal or external face) appears to play an important role. Indeed, the literature reports that although the use of glass-flashing is necessary to ensure transparency when making red glass, this procedure is not necessary for the other colours⁹. However, the present study reveals that the glass-flashing process was used not only for the red samples but also for the blue and green sections. The concentration of cobalt and copper oxides (CoO, CuO) producing the blue colour in the blue glass sections ranges from 0.01 % to 0.09 % and from 0.02 % to 0.17 %, respectively. The lowest concentrations of CoO and CuO are found in the same sample (B6c8_B1). They are quite low for a blue glass,¹⁰ and are similar to the concentrations found in the white glass samples. The analysis of sample B6c8_B1 was only carried out on one face of the piece, and the use of flashed glass can therefore only be presumed. It is however clear that the flashed glass process was used for the green glass. Indeed, the analysis of one sample on both sides shows different concentrations of CuO, with 0.6 % on the internal face and 0.3 % on the external face. Another sample reveals equal concentrations on both faces, with just under 0.2 % CuO and less than 0.05 % of lead oxides (PbO) which seems quite low for green glass¹¹. The hypothesis of a double-flashed glass can then be made, the green glass core being covered by white glass layers on both sides. Finally, analysis of the red glass samples revealed an identical CuO concentration of 0.05 % on both sides of all three samples. This concentration is relatively low compared to the CuO concentrations found on stained-glass samples from other sites. For example, the CuO concentrations in the red glass on the rose of the Sainte Chapelle in Paris range from 0.03 % to 0.5 % on the same piece of glass, depending on the side that is analysed¹². The assumption can therefore be made that double-flashed glass was also used for the red glass pieces in Auch cathedral.

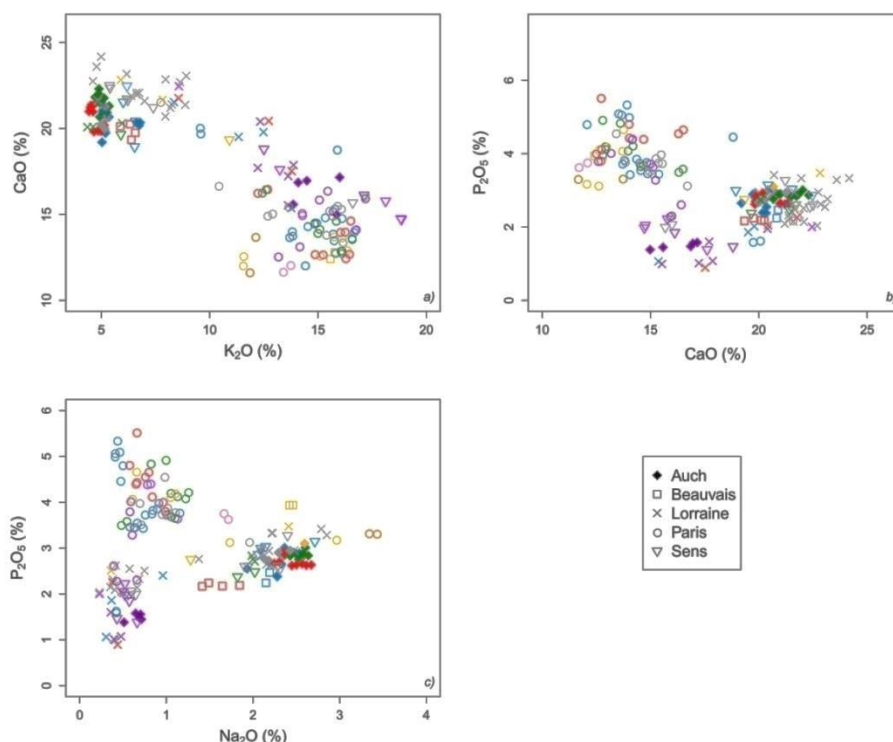


Fig. 2. The chemical compositions of 16th-century stained glass from different sites in France. The graphs show the ratio between two chemical elements:

a) CaO/K₂O

b) P₂O₅/CaO

c) P₂O₅/Na₂O

The colour of each symbol indicates the colour of the glass sample analysed, and uncoloured glass is shown in grey.

⁹ KUNICKI-GOLDFINGER et al. 2014, p. 89-105.

¹⁰ WEDEPOHL 1997, p. 883-891.

¹¹ WEDEPOHL 1997, p. 883-891.

¹² The analyses were carried out by the LRMH using an identical protocol for all samples, and the results have yet to be published.

Table 2a: Average concentration in % w/w (M) and standard deviation ($\pm\sigma$) of the glass samples from Auch Cathedral

Colour	Sample	Face	Na ₂ O		MgO		Al ₂ O ₃		SiO ₂		P ₂ O ₅		SO ₃		Cl		K ₂ O		CaO		TiO ₂		MnO		Fe ₂ O ₃		CoO	
			M	±σ	M	±σ	M	±σ	M	±σ	M	±σ	M	±σ	M	±σ	M	±σ	M	±σ	M	±σ	M	±σ	M	±σ	M	±σ
Blue	B6a1_B1	EF	2.37	0.03	2.59	0.05	3.54	0.03	59.79	0.02	2.99	0.02	0.15	0.01	0.40	0.01	5.35	0.01	20.67	0.06	0.15	0.00	0.66	0.00	0.84	0.00	0.09	0.00
	B6b6_B1	EF	2.53	0.09	2.62	0.05	3.72	0.03	60.77	0.06	2.89	0.08	0.36	0.02	0.55	0.01	5.19	0.01	19.73	0.04	0.17	0.00	0.55	0.01	0.58	0.01	0.01	0.00
	B6b6_B2	EF	2.33	0.06	2.47	0.04	3.72	0.04	61.54	0.10	2.65	0.01	0.29	0.00	0.45	0.01	5.03	0.03	19.20	0.06	0.16	0.01	0.53	0.01	1.18	0.00	0.09	0.00
	B6c8_B1	EF	2.27	0.05	2.76	0.03	3.76	0.01	58.58	0.03	2.39	0.05	0.17	0.02	0.33	0.01	6.74	0.04	20.18	0.04	0.14	0.01	0.81	0.00	1.16	0.01	0.08	0.00
	B6c8_B1	IF	1.93	0.04	2.54	0.05	3.90	0.08	58.26	0.52	2.55	0.08	0.27	0.03	0.43	0.01	6.62	0.10	20.35	0.37	0.14	0.01	0.84	0.02	1.30	0.15	0.09	0.00
	B6c8_B2	EF	2.28	0.02	2.80	0.01	3.71	0.03	58.49	0.13	2.38	0.03	0.09	0.04	0.28	0.01	6.79	0.08	20.34	0.11	0.13	0.00	0.82	0.01	1.16	0.01	0.08	0.00
	B6a1_G1	EF	2.60	0.09	2.58	0.07	3.62	0.03	58.50	0.12	3.01	0.09	0.32	0.01	0.45	0.02	4.87	0.07	22.03	0.06	0.15	0.01	0.63	0.00	0.59	0.02	0.01	0.00
	B6a1_G1	IF	2.49	0.05	2.49	0.04	3.63	0.05	59.11	0.13	2.88	0.05	0.29	0.02	0.49	0.01	4.71	0.02	21.81	0.10	0.15	0.01	0.63	0.00	0.58	0.00	0.01	0.00
Green	B6b6_G1	EF	2.45	0.04	2.75	0.07	3.68	0.08	57.87	0.20	2.90	0.03	0.38	0.05	0.42	0.01	5.36	0.04	21.30	0.04	0.16	0.00	0.65	0.01	0.67	0.03	0.02	0.00
	B6b6_G2	EF	2.45	0.06	2.54	0.03	3.50	0.02	59.39	0.03	2.90	0.04	0.27	0.01	0.52	0.01	5.26	0.06	20.91	0.04	0.16	0.02	0.63	0.02	0.65	0.01	0.04	0.00
	B6b6_G2	IF	2.53	0.01	2.30	0.14	3.78	0.21	59.61	0.55	2.76	0.12	0.32	0.02	0.49	0.01	4.92	0.07	20.67	0.46	0.16	0.01	0.61	0.01	0.58	0.01	0.02	0.00
	B6b6_G3	EF	2.47	0.08	2.01	0.04	3.75	0.05	58.63	0.17	2.90	0.11	0.72	0.04	0.50	0.01	5.08	0.01	21.00	0.00	0.17	0.01	0.67	0.01	0.66	0.01	0.01	0.00
	B6b6_G4	EF	2.43	0.05	2.74	0.04	3.49	0.02	58.64	0.18	2.83	0.02	0.33	0.07	0.54	0.08	4.98	0.04	21.50	0.07	0.16	0.01	0.67	0.00	0.69	0.01	0.04	0.00
	B6c8_G1	EF	2.56	0.03	2.90	0.02	3.46	0.01	58.44	0.04	2.87	0.03	0.25	0.02	0.40	0.01	4.89	0.03	22.30	0.06	0.16	0.01	0.64	0.02	0.57	0.01	0.01	0.00
	B6c8_G2	EF	2.58	0.09	2.74	0.04	3.52	0.05	58.79	0.17	2.88	0.07	0.28	0.01	0.41	0.01	5.13	0.04	21.76	0.08	0.15	0.01	0.64	0.01	0.58	0.01	0.01	0.00
	B6c8_G2	IF	2.64	0.04	2.60	0.08	3.58	0.03	59.11	0.12	2.84	0.02	0.26	0.03	0.46	0.01	4.85	0.02	21.73	0.06	0.16	0.01	0.63	0.01	0.57	0.01	0.01	0.00
Murrey	B6b6_M1	EF	0.51	0.03	3.72	0.06	3.46	0.05	57.29	0.14	1.38	0.01	0.40	0.06	0.11	0.01	15.86	0.02	14.98	0.13	0.17	0.02	1.15	0.02	0.38	0.02	0.00	0.00
	B6b6_M2	EF	0.65	0.04	4.40	0.02	3.25	0.03	53.64	0.18	1.58	0.01	0.28	0.02	0.08	0.00	16.00	0.06	17.16	0.07	0.16	0.01	1.64	0.05	0.42	0.01	0.01	0.00
	B6b6_M3	EF	0.70	0.02	4.62	0.03	3.67	0.03	54.56	0.33	1.56	0.04	0.38	0.04	0.07	0.01	14.48	0.06	16.96	0.10	0.18	0.03	1.60	0.01	0.50	0.02	0.01	0.00
	B6b6_M3	IF	0.69	0.02	4.55	0.06	3.61	0.09	55.23	0.20	1.47	0.02	0.28	0.02	0.08	0.01	14.09	0.11	16.86	0.18	0.19	0.02	1.66	0.03	0.47	0.00	0.01	0.00
	B6c8_M1	EF	0.71	0.01	3.83	0.03	3.68	0.03	56.99	0.19	1.45	0.03	0.32	0.04	0.11	0.01	13.86	0.12	15.58	0.03	0.16	0.02	1.89	0.05	0.46	0.01	0.01	0.00
	B6a1_O1	EF	2.58	0.06	2.69	0.03	3.56	0.06	60.21	0.09	2.82	0.01	0.11	0.02	0.52	0.01	5.20	0.02	20.74	0.04	0.16	0.01	0.59	0.01	0.53	0.01	0.00	0.00
	B6a1_R1	EF	2.36	0.05	2.51	0.03	3.54	0.02	60.85	0.08	2.93	0.05	0.31	0.02	0.43	0.01	5.13	0.02	20.18	0.08	0.17	0.01	0.67	0.01	0.57	0.01	0.00	0.00
	B6a1_R1	IF	2.45	0.03	2.22	0.02	3.82	0.06	61.90	0.10	2.62	0.02	0.36	0.09	0.48	0.01	4.66	0.01	19.82	0.08	0.17	0.00	0.65	0.01	0.52	0.01	0.00	0.00
Red	B6b6_R1	EF	2.30	0.04	2.37	0.06	3.64	0.04	61.60	0.12	2.70	0.08	0.46	0.07	0.53	0.00	5.01	0.04	19.84	0.09	0.16	0.00	0.50	0.01	0.59	0.01	0.01	0.00
	B6b6_R2	EF	2.37	0.07	2.36	0.05	3.66	0.03	61.51	0.02	2.86	0.02	0.39	0.06	0.48	0.02	4.84	0.04	19.86	0.04	0.16	0.01	0.52	0.01	0.63	0.02	0.01	0.00
	B6c8_R1	EF	2.67	0.05	2.64	0.05	3.50	0.00	60.21	0.01	2.63	0.04	0.21	0.02	0.45	0.01	4.65	0.01	21.37	0.04	0.16	0.01	0.60	0.00	0.57	0.01	0.01	0.00
	B6c8_R1	IF	2.62	0.04	2.64	0.05	3.49	0.06	60.63	0.16	2.63	0.06	0.17	0.01	0.51	0.02	4.49	0.02	21.20	0.04	0.16	0.01	0.58	0.00	0.55	0.01	0.01	0.00
	B6c8_R2	EF	2.50	0.19	2.61	0.02	3.48	0.03	60.90	0.13	2.64	0.04	0.27	0.01	0.43	0.00	4.62	0.00	20.97	0.07	0.16	0.00	0.57	0.01	0.55	0.01	0.00	0.00
	B6c8_R2	IF	2.57	0.05	2.63	0.03	3.48	0.00	60.95	0.07	2.65	0.02	0.24	0.03	0.50	0.01	4.44	0.02	20.99	0.02	0.16	0.00	0.56	0.01	0.53	0.01	0.00	0.00
	B6c8_R3	IF	2.25	0.01	2.59	0.09	3.60	0.05	60.68	0.08	2.67	0.06	0.18	0.02	0.51	0.00	4.53	0.03	21.35	0.05	0.18	0.01	0.58	0.02	0.56	0.01	0.00	0.00
	B6a1_W1	EF	2.09	0.06	2.36	0.07	3.10	0.01	62.20	0.15	2.94	0.09	0.28	0.02	0.45	0.02	5.18	0.01	19.83	0.12	0.14	0.03	0.57	0.01	0.51	0.02	0.00	0.00
White	B6a1_W1	IF	2.12	0.02	2.37	0.03	3.01	0.04	62.70	0.05	2.79	0.03	0.24	0.04	0.47	0.01	4.92	0.06	19.83	0.08	0.13	0.01	0.58	0.01	0.47	0.01	0.00	0.00
	B6a1_W2	EF	2.18	0.02	2.52	0.06	2.93	0.03	62.54	0.08	2.70	0.02	0.24	0.04	0.38	0.01	4.98	0.06	20.07	0.13	0.13	0.00	0.58	0.02	0.46	0.02	0.00	0.00
	B6a1_W3	EF	2.36	0.04	2.65	0.03	3.70	0.04	59.95	0.24	3.01	0.03	0.35	0.04	0.56	0.01	5.12	0.03	20.43	0.08	0.17	0.01	0.58	0.02	0.66	0.02	0.01	0.00
	B6b6_W1	EF	2.29	0.09	2.52	0.04	3.60	0.02	60.28	0.11	2.90	0.02	0.29	0.02	0.45	0.02	5.26	0.02	20.78	0.07	0.16	0.00	0.62	0.01	0.51	0.01	0.00	0.00
	B6b6_W2	EF	2.35	0.04	2.68	0.10	3.55	0.02	60.28	0.09	2.82	0.03	0.48	0.03	0.35	0.02	5.26	0.05	20.61	0.04	0.16	0.01	0.64	0.02	0.50	0.01	0.00	0.00
	B6c8_W1	EF	2.43	0.08	2.59	0.03	3.51	0.05	60.04	0.08	2.94	0.03	0.16	0.04	0.43	0.00	5.19	0.02	21.26	0.08	0.15	0.00	0.59	0.01	0.46	0.01	0.00	0.00
	B6c8_W2	EF	2.57	0.12	2.85	0.05	3.59	0.02	60.87	0.06	2.67	0.03	0.27	0.02	0.50	0.00	5.16	0.03	19.99	0.04	0.16	0.01	0.56	0.02	0.52	0.01	0.01	0.00
	B6c8_W2	IF	2.18	0.02	2.89	0.04	3.52	0.01	61.12	0.04	2.73	0.01	0.22	0.02	0.53	0.00	5.00	0.05	20.25	0.08	0.15	0.01	0.56	0.01	0.54	0.02	0.01	0.00
Yellow	B6b6_Y1	EF	2.60	0.03	2.64	0.05	3.55	0.06	59.80	0.41	3.10	0.24	0.37	0.01	0.60	0.03	5.01	0.03	20.67	0.14	0.15	0.00	0.59	0.01	0.55	0.01	0.00	0.00

Table 2b: Average concentration in % w/w (M) and standard deviation ($\pm\sigma$)
of the glass samples from Auch Cathedral

Colour	Sample	Face	NiO		CuO		ZnO		As ₂ O ₅		Rb ₂ O		SrO		ZrO ₂		MoO ₃		Ag ₂ O		SnO ₂		Sb ₂ O ₃		BaO		PbO	
			M	$\pm\sigma$	M	$\pm\sigma$	M	$\pm\sigma$	M	$\pm\sigma$	M	$\pm\sigma$	M	$\pm\sigma$	M	$\pm\sigma$	M	$\pm\sigma$	M	$\pm\sigma$	M	$\pm\sigma$	M	$\pm\sigma$	M	$\pm\sigma$	M	$\pm\sigma$
Blue	B6a1_B1	EF	0.04	0.00	0.06	0.00	0.04	0.00	0.00	0.00	0.01	0.00	0.06	0.00	0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.01	0.03	0.01
	B6b6_B1	EF	0.01	0.00	0.02	0.00	0.03	0.00	0.00	0.00	0.01	0.00	0.06	0.00	0.02	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.11	0.01	0.06	0.01
	B6b6_B2	EF	0.02	0.00	0.04	0.00	0.03	0.00	0.00	0.00	0.01	0.00	0.06	0.00	0.02	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.01	0.04	0.00
	B6c8_B1	EF	0.02	0.00	0.16	0.00	0.06	0.00	0.00	0.00	0.01	0.00	0.06	0.00	0.01	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.24	0.01	0.01	0.00
	B6c8_B1	IF	0.02	0.00	0.17	0.01	0.06	0.00	0.01	0.00	0.01	0.00	0.07	0.00	0.01	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.01	0.15	0.04
	B6c8_B2	EF	0.02	0.00	0.17	0.01	0.06	0.00	0.00	0.00	0.01	0.00	0.06	0.00	0.01	0.00	0.02	0.00	0.01	0.01	0.00	0.01	0.00	0.01	0.25	0.01	0.02	0.00
	B6a1_G1	EF	0.01	0.00	0.21	0.01	0.10	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.02	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.13	0.01	0.06	0.01
	B6a1_G1	IF	0.01	0.00	0.25	0.01	0.09	0.00	0.00	0.00	0.01	0.00	0.07	0.00	0.02	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.13	0.01	0.12	0.01
Green	B6b6_G1	EF	0.02	0.00	0.79	0.02	0.26	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.14	0.01	0.07	0.01
	B6b6_G2	EF	0.03	0.00	0.31	0.01	0.13	0.00	0.00	0.00	0.01	0.00	0.06	0.00	0.02	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.13	0.01	0.07	0.01
	B6b6_G2	IF	0.02	0.00	0.63	0.04	0.19	0.00	0.00	0.00	0.01	0.00	0.06	0.00	0.02	0.00	0.00	0.00	0.02	0.01	0.00	0.00	0.00	0.00	0.13	0.03	0.16	0.02
	B6b6_G3	EF	0.02	0.00	0.54	0.02	0.21	0.00	0.01	0.00	0.01	0.00	0.07	0.00	0.02	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.14	0.01	0.40	0.03
	B6b6_G4	EF	0.03	0.00	0.52	0.01	0.14	0.00	0.00	0.00	0.01	0.00	0.07	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.01	0.04	0.01
	B6c8_G1	EF	0.01	0.00	0.20	0.00	0.08	0.00	0.00	0.00	0.01	0.00	0.07	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.13	0.01	0.01	0.00
	B6c8_G2	EF	0.01	0.00	0.16	0.00	0.08	0.00	0.00	0.00	0.01	0.00	0.07	0.00	0.02	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.03	0.01
	B6c8_G2	IF	0.01	0.00	0.18	0.01	0.08	0.00	0.00	0.00	0.01	0.00	0.07	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.01	0.05	0.01
Murrey	B6b6_M1	EF	0.01	0.00	0.03	0.00	0.03	0.00	0.00	0.00	0.02	0.00	0.05	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.35	0.01	0.05	0.01
	B6b6_M2	EF	0.01	0.00	0.04	0.00	0.03	0.00	0.01	0.00	0.02	0.00	0.06	0.00	0.02	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.41	0.01	0.13	0.02
	B6b6_M3	EF	0.01	0.00	0.03	0.00	0.03	0.00	0.00	0.00	0.02	0.00	0.06	0.00	0.02	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.41	0.01	0.11	0.01
	B6b6_M3	IF	0.01	0.00	0.06	0.01	0.03	0.00	0.00	0.00	0.02	0.00	0.06	0.00	0.02	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.40	0.00	0.17	0.04
	B6c8_M1	EF	0.01	0.00	0.04	0.00	0.03	0.00	0.01	0.00	0.02	0.00	0.08	0.00	0.02	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.49	0.01	0.23	0.01
	B6a1_O1	EF	0.00	0.00	0.01	0.00	0.03	0.00	0.00	0.00	0.01	0.00	0.06	0.00	0.02	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.03	0.01
	B6a1_R1	EF	0.01	0.00	0.05	0.00	0.04	0.00	0.00	0.00	0.01	0.00	0.06	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.02	0.01
	B6a1_R1	IF	0.01	0.00	0.05	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.01	0.04	0.00
Red	B6b6_R1	EF	0.01	0.00	0.02	0.00	0.03	0.00	0.00	0.00	0.01	0.00	0.05	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.01	0.04	0.00
	B6b6_R2	EF	0.01	0.00	0.03	0.00	0.04	0.00	0.00	0.00	0.01	0.00	0.06	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.09	0.00
	B6c8_R1	EF	0.01	0.00	0.05	0.00	0.04	0.00	0.00	0.00	0.01	0.00	0.06	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.01	0.01	0.00
	B6c8_R1	IF	0.01	0.00	0.05	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.01	0.00
	B6c8_R2	EF	0.01	0.00	0.05	0.00	0.04	0.00	0.00	0.00	0.01	0.00	0.06	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.01	0.00
	B6c8_R2	IF	0.01	0.00	0.05	0.00	0.03	0.00	0.00	0.00	0.01	0.00	0.06	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.01	0.00	0.00
	B6c8_R3	IF	0.01	0.00	0.05	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.01	0.02	0.00
	B6a1_W1	EF	0.00	0.00	0.01	0.00	0.03	0.00	0.00	0.00	0.01	0.00	0.06	0.00	0.01	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.12	0.00	0.10	0.02
White	B6a1_W1	IF	0.00	0.00	0.01	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.01	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.12	0.01	0.11	0.02
	B6a1_W2	EF	0.00	0.00	0.01	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.01	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.12	0.01	0.03	0.01
	B6a1_W2	IF	0.00	0.00	0.01	0.00	0.03	0.00	0.00	0.00	0.01	0.00	0.06	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.01	0.03	0.01
	B6a1_W3	EF	0.01	0.00	0.03	0.00	0.03	0.00	0.00	0.00	0.01	0.00	0.07	0.00	0.02	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.12	0.02	0.15	0.01
	B6b6_W1	EF	0.00	0.00	0.01	0.00	0.03	0.00	0.00	0.00	0.01	0.00	0.06	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.01	0.07	0.02
	B6b6_W2	EF	0.00	0.00	0.01	0.00	0.03	0.00	0.00	0.00	0.01	0.00	0.06	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.01	0.03	0.01
	B6c8_W1	EF	0.00	0.00	0.01	0.00	0.03	0.00	0.00	0.00	0.01	0.00	0.06	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.01	0.01	0.01
	B6c8_W2	EF	0.00	0.00	0.01	0.00	0.03	0.00	0.00	0.00	0.01	0.00	0.07	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.01	0.01	0.00
	B6c8_W2	IF	0.00	0.00	0.02	0.00	0.03	0.00	0.00	0.00	0.01	0.00	0.07	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.01	0.03	0.01
Yellow	B6b6_Y1	EF	0.00	0.00	0.01	0.00	0.03	0.00	0.00	0.00	0.01	0.00	0.06	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.01	0.12	0.07

4.3.3. Comparison with other French sites

The results of this study were compared to the concentrations recorded for other contemporary French stained-glass samples from three different locations, namely the western rose of the Sainte Chapelle in Paris, the southern rose of Sens cathedral and the northern rose of Beauvais cathedral. The windows in Sens cathedral were made between 1500 and 1502 with glass produced in the Lorraine region¹³. The original source of the glass used for the Sainte Chapelle rose, built between 1483 and 1498, is not known¹⁴. This information is also lacking for the glass in panels at Beauvais cathedral, which are inscribed with the date 1537¹⁵. The samples from Beauvais cathedral are no longer on site in their original bay (323) as it was destroyed by bombing during the Second World War. A further set of archaeological samples from Lorraine (La Vôge) were considered in this data analysis. These fragments of glass were retrieved in 1981 during excavation on the site of a glass factory that was probably operational between 1448 and 1612¹⁶. The chemical compositions of the stained-glass samples from Paris and Beauvais were obtained with AGLAÉ between 2014 and 2019, whilst composition data for the stained glass from Sens and the archaeological samples from Lorraine were obtained with an electron microprobe¹⁷ between 2015 and 2016. The results show two to three distinct groups. Indeed, in figure 2.a two clusters can be observed. The first mainly concerns the samples from Sens, Lorraine and Auch, with a few exceptions for some (mostly murrey) coloured glass samples. The majority of the murrey samples are found in the second group, which is mainly made up of the Sainte-Chapelle samples. The glass samples from Beauvais are divided between the two groups. In terms of the CaO/K₂O ratio, the first group is described as wood ash lime glass (with a CaO/K₂O ratio of around 3.4) and the second as wood ash glass (CaO/K₂O ratio is around 1)¹⁸. However, figures 2.b and 2.c highlight that there are three groups as the murrey glass samples from Auch, Sens and Lorraine are not located within the Sainte-Chapelle cluster. However, with these chemical ratios, it is not clear which group the samples from Beauvais belong to.

The glass samples from bay 6 in Auch cathedral have a very homogeneous composition. They can be considered to form two groups: HLLA glass, and potash glass (i.e. the murrey samples). These two groups are defined by Schalm et al as *type A* and *type B*¹⁹. Type A glass is made using beechwood ash and lime as fluxing agents, while beechwood ash is the only fluxing agent used to make type B. The concentrations of P₂O₅ and MgO in the third group containing the Sainte-Chapelle samples are higher than those observed in the other groups, indicating that these pieces of glass may have been made with fern ash²⁰.

5. Conclusions

The conservation and restoration project of the Saint Louis chapel in Auch cathedral provided a unique opportunity to carry out a detailed study of the stained glass made by Arnaud de Moles. The observations and the analyses indicate that the glass came from the Lorraine area, and suggest that a different manufacturing process was used to produce the murrey glass. Future restoration projects for the other chapels will hopefully bring this interdisciplinary team together again and will provide further details to enrich our knowledge of stained glass. The AGLAÉ analyses will continue to allow the collection of multiple data and will provide the opportunity to use statistical treatments to pinpoint the differences between different types of glass and broaden our understanding of 16th-century stained glass in France. This restoration has also been a means to promote Auch Cathedral via the six-month exhibition run by the *Musée des Augustins* (a fine arts museum) in Toulouse presenting the panels to visitors after their restoration²¹.

¹³ MINOIS 2005, p. 111, 429.

¹⁴ HEROLD et al. 2016, p. 283-294.

¹⁵ GRODECKI et al. 1978, p. 177-181.

¹⁶ DELEMONTEY 2009, p. 461-465.

¹⁷ CAMPARIS, CNRS-UMR 7097, University of Jussieu (Paris).

¹⁸ WEDEPOHL & SIMON 2010, p. 89-97.

¹⁹ SCHALM et al. 2004, p. 1647-1656.

²⁰ WEDEPOHL & SIMON 2010, p. 89-97.

²¹ COHENDY 2018, p. 100-104.

Correlated with the results obtained for the chemical composition of the glass, the good state of conservation observed for these windows are a clear testimony to the well-preserved identity of the cathedral. The installation of protective glazing is therefore crucial for the long-term conservation of this monument.

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2.3

Konservierung historischer Spiegel. Konzept und Konservierung historischer Spiegel aus den Audienzgemächern Augusts des Starken im Dresdener Schloss

Markus Kleine, Simone Schmidt, Christoph Sander

Conservation des miroirs historiques. Conception et conservation des miroirs historiques des salles d'audience d'Auguste le Fort au château de Dresde – Résumé

Lors de la restauration des miroirs vénitiens ducaux du château de la Résidence de Dresde la tâche était de conserver l'existant mais aussi d'évaluer la manière de traiter les lacunes, les dommages modifiant les propriétés des matériaux et les anciennes

pièces de remplacement. La restauration des revêtements contenant du mercure sont soumises aux règles strictes de sécurité qui sont valable également pour leur stockage et leur présentation. D'un côté il était question de détecter la nécessité et le taux de la matière au mercure historique dégageant des émissions toxiques et de la supprimer et remplacer. De l'autre côté il fallait conserver l'existant.

Conservation of Historical Mirrors. Concept and Conservation of Historical Mirrors from the Audience Chambers of August the Strong in Dresden Castle – Abstract

During the conservation of the mirrors from the Dresden Royal Palace it was required to evaluate how to deal with missing parts, property-changing damages and previous partial additions.

The conservation of the mercurial coatings is subject of strict security rules. Those rules apply as well for their storage and presentation. The bilateral task was to spot the necessity and amount of toxic emitting historical coatings to be removed and replaced and the conservation of the historical matter.

Konservierung historischer Spiegel. Konzept und Konservierung historischer Spiegel aus den Audienzgemächern Augusts des Starken im Dresdener Schloss – Zusammenfassung

Bei der Restaurierung der herzoglichen Venezianerspiegel aus dem Dresdner Schloss stellte sich die Aufgabe, neben der Bestandserhaltung zu evaluieren, wie mit Fehlstellen, eigenschaftsverändernden Schäden

und früheren Teilergänzungen umzugehen ist. Die Restaurierung von quecksilberhaltigen Belägen unterliegt strengen Sicherheitsvorschriften, die im Weiteren auch für die Lagerung/Präsentation gelten. Hier galt es einerseits zu erkennen ob und wie viel historischer Bestand auf Grund zu erwartender giftiger Emission entfernt und ersetzt werden muss, andererseits den gewachsenen Zustand zu erhalten.

Vier Wochen lang wurde an der Elbe eine Hochzeit gefeiert, die ihres Gleichen in Europa suchte. Der sächsische Kurprinz Friedrich August, Sohn des Herrschers Augusts des Starken, vermählte sich mit der österreichischen Kaisertochter Josepha.

August präsentierte dem angereichten europäischen Adel eine Besonderheit sächsischen Reichtums.¹

„Rechnung über 2 kostbare Spiegel, die ich an den Hofhändler Stürzel verkauft und geliefert habe, damit sie nach Warschau an seine polnische Majestät geschickt werden, nach Festpreis ohne Rabatt in Wechselln bis zur nächsten Ostermesse in Leipzig. Zwei große und kostbare Kristallspiegel mit fein gearbeiteter königlicher Wappenkrone und Waffentrophäe, alles aus Kristallspiegelglas, die Spiegel haben eine Höhe von 81-82 Zoll und der Rahmen eine Höhe von 12-13 Fuß, Festpreis ohne Rabatt“.²

So lautet die Übersetzung aus dem Französischen, der Rechnung der königlichen Spiegelmanufaktur in Berlin vom 15. Februar 1715. Zwei weitere Spiegel wurden 1719 von der Berliner Manufaktur direkt in das Dresdener Schloss geliefert.

In Folge der Luftangriffe auf Dresden 226 Jahre später, brannte das Schloss gegen Ende des 2. Weltkrieges am 13. Februar 1945 bis auf die Grundmauern nieder. Teile der Spiegel konnten gesichert werden und lagen Jahrzehnte in Kisten deponiert. Anlässlich der Wiederherstellung des Schlosses zum 300. Jahrestag der Hochzeit wurden die Spiegel von schlosseigenen Restauratoren in Zusammenarbeit mit der Glasmalerei Krönke gesichtet, kartiert und zugeordnet. Ziel war es die Spiegel zum Jubiläum in den wiederhergestellten Räumen zu präsentieren.

¹ www.traumhochzeit1719.de [accessed December 2019].

² Rudolf VON ARPS-AUBERT, *Berliner Kristallspiegel der Spätbarockzeit*, Pantheon Heft 12 1942, p. 28-281.

Der zu bearbeitende Bestand umfasst zwei Spiegel mit Quecksilberamalgambelegung und einen Spiegel mit einer Silbernitratverspiegelung. Bei dem Silbernitratsspiegel handelt es sich um eine Rekonstruktion des 19. Jahrhunderts. Über die Jahre sind auch bei den Quecksilberamalgamspiegeln Teilergänzungen mit Silbernitrat und moderner Industrieverspiegelung hinzugekommen. Der Betrachter der Spiegel wird visuell mit mindestens drei Zeitabschnitten (18., 19. und 20. Jahrhundert) konfrontiert, die sich sowohl in Schliff als auch in der Spiegelfarbe deutlich unterscheiden. Daher sollten die konservatorischen und restauratorischen Maßnahmen neben der Bestandssicherung, dem Herstellen eines harmonischen Gesamteindrucks unter Wahrung des gewachsenen Bildes dienen.

Ein weiterer Aspekt sind die Schäden am Glas und der Spiegeloberfläche. Beide Spiegeltypen zeigen Schäden durch Materialveränderungen in Form von Ablösungen, Trübungen oder auch Fleckigkeit. Die Aufgabe des Spiegels wird visuell gestört, gibt ihm aber auch einen besonderen Charakter. Es galt jetzt zu evaluieren welche Möglichkeiten, aber auch welche Grenzen bei einer Spiegelrestaurierung in Betracht zu ziehen sind.

Geschichte der Spiegelherstellung

Die Geschichte der Spiegelherstellung geht Jahrtausende zurück. Zunächst wurden Metalle geschliffen und aufpoliert, bis sich bereits 1373 in Nürnberg die Glasmacherzunft gründete, die auch Spiegel herstellte. Die Verspiegelung der später als „Ochsenaugen“ bekannten Gläser erfolgte im glühenden Zustand der Glasblase in dem Blei und Antimon hineingegeben und geschwenkt wurde. Das Quecksilber-

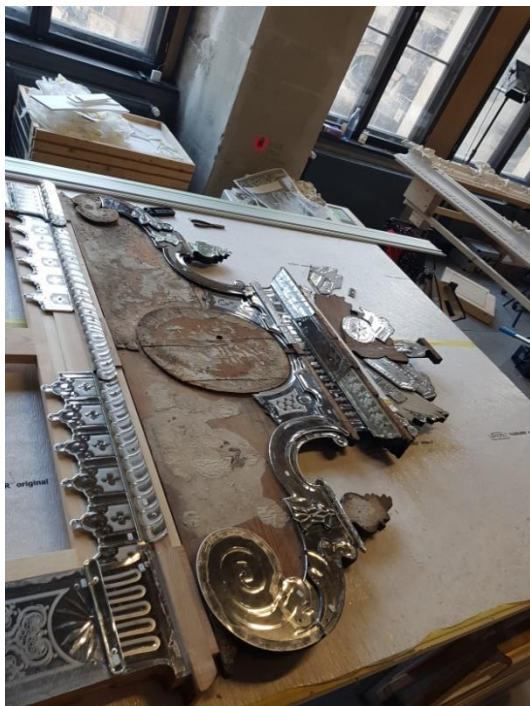


Abb. 1. Teilapplikation der restaurierten Spiegel.

amalgam als Spiegelbelag entwickelten die Brüder Dal'Gallo in Venedig. Es waren die ersten flachen Glasspiegel. Das hochwertige flache Kristallglas aus Murano wurde mit einer dünnen Zinnfolie belegt und mit einer starken Schicht aus Quecksilber über-gossen. Dieses Verfahren zur Spiegelherstellung fand bis in das 19. Jahrhundert Anwendung.³ 1886 wurde es dann verboten, was jedoch nicht den Besitz solcher Spiegel betraf.⁴

Aufbau der historischen Spiegel

Bei dem von der Glasmalerei Peters bearbeiteten Bestand handelte es sich um drei Amalgamspiegel aus dem Audienzgemach und einem Silbernitratsspiegel aus dem Vorzimmer des Dresdner Schlosses. Konservierungsgegenstand sind jedoch nicht die großen Hauptspiegelflächen, denn diese sind nicht mehr existent, bzw. maximal in nicht zuordbaren Fragmenten zu vermuten. Restaurierungsgegenstand sind die aus aufwendig geschliffenen Spiegelgläsern hergestellten Spiegelrahmungen und königlichen Waffentrophäen. Insgesamt besteht jeder Spiegelrahmen aus rund 130 Einzelteilen, die über Verschraubungen systematisch über fünf Ebenen über-lappend auf eine Holzunterkonstruktion aufgebracht wurde (Abb.1).⁵

Schadensbilder

Die Spiegel zeigen ein sehr differenziertes Schadensbild. Es gibt mechanische und chemische Schadensbilder am Glas wie auch an den Spiegelbelägen.

³ Ferdinand CREMER, *Die Fabrikation von Silber und Quecksilberspiegel*, Hartlebens chemisch technische Bibliothek, Wien 1904. p. 7.

⁴ www.chemie.de/news/138800/gift-aus-der-vergangenheit.html [accessed January 2020].

⁵ Die Unterkonstruktion wurde durch einen Holzrestaurator überarbeitet.

Glas

Es gibt zahlreiche oberflächliche mechanische Verletzungen der Gläser, wie Kratzer und leicht abgestoßene Ecken. Aber auch zahlreiche Brüche, meist ausgehend von den Bohrungen, die zur Befestigung der Gläser an der Unterkonstruktion vorgenommen wurden. Zu starker Druck an dieser Stelle, durch Montage oder Demontage führte zu Schäden. Besonders in diesen Bereichen gibt es immer wieder Fragmentverluste, aber auch der Totalverlust von Einzelscheiben ist zu verzeichnen. Neben den mechanischen Schäden treten craquelierte Gläser, sowie eine Oberflächenkorrosion des Glases in Bereichen geschädigter Amalgambelegungen auf.

Amalgambelag

Die durch Amalgam erzeugte rückseitige Spiegelfläche besitzt den Vorteil relativ unempfindlich zu sein. Deshalb ist dieser Spiegelbelag ohne Schutzbeschichtung in Nutzung gekommen. Der Belag ist weitestgehend griffstabil, jedoch für gröbere mechanische Angriffe empfänglich. So gehören Kratzer und kleine Löcher zu den Basisschadensbildern. Als mechanischer Schaden kann auch die provisorische Verklebung von Glasstücken mit Leinölkitt gewertet werden. So sind Kleinstspiegel ohne weitere Klammerbefestigung einfach auf größere Flächen geklebt worden. Durch die Alterung der Kitte und dem damit verbundenen Haftungsverlust an der glatten Glasoberfläche kam es zu Ablösungen der Kleinspiegel. Die Kitte zeigen sich jedoch auf der leicht strukturierten Amalgamoberfläche stabil, bzw. lösen durch alterungsbedingte Eigenspannung die Zinnamalgie rung von der Glasoberfläche, wodurch Löcher in der Spiegelfläche entstehen.

Die chemische Stabilität des zweiphasigen Belages ist nicht immer gegeben. Es existieren zwei Schadensmechanismen bei Zinnamalamspiegeln. Einerseits die Emission von Quecksilber

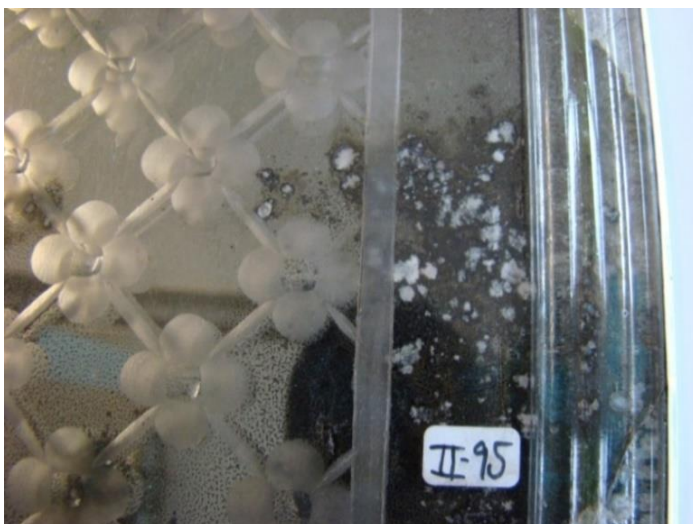


Abb. 2. Verfärbungen und Zinnester im Quecksilberspiegel.

und andererseits die Korrosion des Zinnamalgalms, die ineinander übergehen. Auf Grund des geringen Dampfdrucks verflüchtigt sich Quecksilber bereits bei Zimmertemperatur, so dass es zunächst aus der flüssigen Phase, später dann auch aus der festen Phase emittiert. Das Zinnamalgalms wandelt sich zu Zinn, Zinnoxid und metallischem Quecksilber (Abb. 2). Es kommt zu sichtbaren Schäden an den verspiegelten Flächen. Die Umwandlung endet in der kompletten Auflösung des zweiphasigen Systems in eine strukturlöse Zinnoxidschicht.⁶

Silbernitratbelag

Die durch eine Silbernitratlösung hergestellte Verspiegelung besitzt nicht dieselbe Stabilität wie die Amalgamschicht. Die sehr dünne Schicht wurde deshalb gegen mechanische Einwirkungen und Einflüsse der Luft mit einem Lacküberzug versehen.⁷ Auch hier sind mechanische Schäden zu verzeichnen, wie Kratzer, die die Lack- und Spiegelschicht beschädigt haben. Weiter ausgehend von den mechanischen Schäden an der Schutzschicht war es der so freigelegten Spiegelfläche möglich, an der Atmosphäre zu oxidieren. Dies führte zum Unterwandern der Lackschicht und weiteren Ablösungen. Zudem hat der partiell angebrachte Kitt einerseits ähnliche Effekte wie beim Amalgambelag, andererseits hat das Leinöl eine Reaktion in der Lackschicht ausgelöst, was wiederum zu chemischen Veränderungen und Ablösungen führte.

⁶ Manfred TORGE u.a., „Flüchtiges Quecksilber“, In *Restaura* 3/2012, p. 31.

⁷ Ferdinand CREMER, *Die Fabrikation von Silber und Quecksilberspiegeln*, In: Hartlebens chemisch technische Bibliothek, Wien, 1904, p. 103.

Die Silberspiegel weisen weiterhin braune Flecken auf, deren Ursprung bereits im Produktionsprozess zu finden ist. Dieses Phänomen ist bereits sehr früh in der Fachwelt als Problem erkannt und wissenschaftlich behandelt worden. Es handelt sich um Schwefelverbindungen auf dem Glas, die mit dem metallischen Silber des Spiegelbelags zu Schwefelsilber reagieren.⁸

Zum Umgang mit den Schäden und den Veränderungen

Für den Restaurator stehen meist die Ursachenfindung und die Behandlung des Schadens im Vordergrund. Der Fokus hier liegt jedoch auf dem Umgang mit dem Schaden/Veränderung und die Integrierung des Schadens/Veränderung in das Gesamtbild. Gerade in Städten wie Dresden, die stark von der Kriegszerstörung betroffen waren, ist der Wunsch der Wiederherstellung des „alten“ und „reinen“ Zustandes von großer Bedeutung. Doch Wiederherstellung bedeutet nicht „neu machen“, sondern das Finden einer Symbiose zwischen Ursprungsbestand, geschichtsbedingter Reparaturleistungen die Teil des heutigen Bestandes sind, befundeter Schadensbilder und dem was für die Ausstellung an notwendigen Maßnahmen ergriffen werden muss.

Glas

Bei den Gläsern handelte es sich um für diese Zeit hochweiße Spiegelgläser, also gegossene Gläser, die beidseitig auf großen Flächenschleifern plan poliert wurden. In der Oberfläche ist dieses Flächenschleifen deutlich ablesbar. Die Oberfläche ist durch Verkantungen beim Schleifen leicht bewegt. In diese ca. 1cm starken Gläser sind dann diverse Schliffe und Gravuren eingebracht worden. Einen besonderen Schliff hatten die seitlichen Rahmenelemente. Auf der gesamten Länge sind diese beidseitig mit einem gewellten Profil gesäumt worden, für die es zu dieser Zeit spezielle Schleifer mit einzig für das Projekt gefertigtem Spezialschleifwerkzeug gegeben hat. Schadensbild war der partielle oder totale Verlust von Gläsern. Wie sollte damit umgegangen werden? Insgesamt haben wir drei verschiedene Varianten an dem Objekt angewendet.

1. Kleinere bis mittelgroße Fehlstellen mit besonders kompliziertem Begleitsprungbild wurden in Bereichen, die durch andere Spiegelgläser gut mechanisch gesichert waren, mit Formausgüssen aus Epoxidharz ergänzt worden. Die Oberfläche ist mit Abformsilikonem am Original abgedrückt und dann als Gussform an das verklebte Originalstück angepasst worden. Anschließend konnte die Form dann ausgegossen werden. Die Oberfläche ist nachträglich aufpoliert, stellenweise mattgeschliffen und dann mit Quecksilberamalgame rückseitig verspiegelt worden.
2. Eine zweite Variante waren Neutralergänzungen. Einerseits als Ergänzung von einfachen Fehlbereichen, die partiell durch andere Spiegelflächen überdeckt wurden, im Weiteren als Ergänzung für vollständig verlorene Spiegelflächen. Zum Ansetzen an den Originalbestand wurden aus den umfangreichen Restbeständen an Quecksilberamalgame spiegeln farblich passende Reste ausgewählt und als Ersatzstück zugeschnitten. Diese Stücke sind nicht mit dem Original verklebt, sondern in Kupferfolientechnik miteinander verbunden. Aber auch als Komplettersatz wurden schlichte Spiegel eingesetzt. Einerseits aus dem Bestand geschnitten, andererseits als neues Glas, das mit Quecksilberamalgame belegt wurde. Dieser Vorgehensweise ist jedoch nur in Bereichen erlaubt gewesen, die teilweise oder vollständig verdeckt wurden.
3. Für Ergänzungsstücke im Sichtbereich haben wir drei Varianten aufgezeigt. Die Neutralergänzung mit Industriespiegeln, die kopistisch geschliffenen Scheiben mit farblich angepasster Verspatterung und die vom Bauherr gewählte Variante kopistische Totalergänzung mit Quecksilberamalgame. Anders als zur damaligen Zeit wurde jedoch kein Spiegelschliff, sondern ein entsprechend dickes Weissglas verwendet, in das die Profilierungen und Gravuren aufgebracht worden sind. Diese Form der Erneuerung war nicht Teil des Restaurierungskonzeptes und wurde in einem gesonderten Verfahren an entsprechende Glasschleifer vergeben.

Quecksilberamalgame

Neben der ästhetischen Wirkung, den diese Spiegel ausstrahlen, ist die wichtigste Eigenschaft des Spiegels zu glänzen und sein Gegenüber wiederzugeben. Die verschiedenen Schadensbilder betreffen diese Eigenschaft auf unterschiedlichste Weise. Ein Spiegelbelag aus Quecksilberamalgame lässt sich

⁸ Ferdinand CREMER, *Die Fabrikation von Silber und Quecksilberspiegel*, In: Hartlebens chemisch technische Bibliothek, Wien, 1904, p. 105.

glücklicherweise sehr gut „reparieren“. Es können gezielt partielle Schadstellen ausgebessert werden, die sich bei entsprechender Übung kaum vom originalen Spiegelbelag unterscheiden. Genau das ist jedoch auch die Herausforderung bei der Restaurierung. Mechanische Schäden sind leicht zu erkennen und als Schaden zu deklarieren. Weitaus komplexer wird es bei den chemischen Wandlungen. Der rückseitige Belag ist noch geschlossen und scheint intakt zu sein. In der Spiegelfläche erkennt man doch deutliche Trübungen, Schwärzungen und sich weiß absetzende Zinnester. Oberstes Ziel ist immer die Erhaltung von maximalem historischem Bestand. Für die Bewertung an welchen Stellen eine Handlung erfolgen muss, sind folgende Fragen ausschlaggebend:

- a. Ist die Ergänzung an dieser Stelle wichtig für den gesamten Spiegel, oder aber für das gesamte Raumbild?
- b. Ist von der Situation kurz- oder langfristig eine Verschlechterung des Zustandes unter Berücksichtigung der Raumsituation des Lagers/der Ausstellung zu erwarten?
- c. Geht von dem aktuellen Schadensbild ein mittelbares Gesundheitsrisiko für den Menschen aus?

Die ersten beiden Fragen sind Standardfragen der Restaurierung. Sie gelten für jedes zu restaurierende Objekt. Bei der dritten Frage sind wir schon in einer spezielleren Sparte, die nicht auf jedes Objekt zutrifft. Die Gesundheitsrisiken von Quecksilber sind seit dem 19. Jahrhundert bekannt, weshalb auch die Produktion von Quecksilberamalгамspiegel eingestellt wurde. Da existierende Spiegel jedoch nicht verboten worden sind, kommen sie überall in Museen, Schlössern und teilweise auch in Privathaushalten noch vor. Quecksilber in flüssiger Form ist zunächst unbedenklich, es fängt jedoch bereits bei Raumtemperatur an giftige Dämpfe zu bilden.⁹ Hier liegt das Hauptproblem der Spiegel. Das Zinnamalгам korrodiert oder löst sich vom Glas, was die ursprüngliche Verspiegelung zunächst erblinden lässt, sich Schwärzungen zeigen und Fehlstellen entstehen. Das dabei freigesetzte Quecksilber kann dabei über die Spiegelrückseite ungehindert emittieren und in die Umgebung freigesetzt werden.¹⁰ Es gilt also abzuwägen bei welchen Schadensbildern selbst bei optimierten Raumlagerungsverhältnissen ein Gesundheitsrisiko zu erwarten ist.

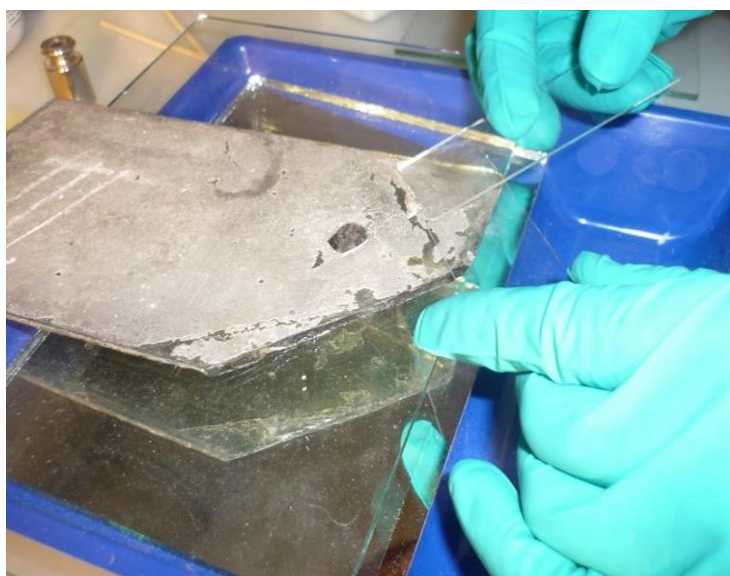


Abb. 3. Ausbessern von Fehlstellen in der Amalgamfläche.

Nach Auswahl der entsprechend „b und c“ klassifizierten Schadensbilder werden die Schadstellen vom Glas mittels Skalpell abgehoben und die Glasfläche mit Ethanol gereinigt. Da die restaurierte Spiegelrahmung aus bis zu fünf überlagernden Ebenen besteht erfolgt jetzt die Beurteilung der Fehlstelle nach Kriterium „a“. Wenn die partiell verlorene Spiegelfläche entweder von einem überliegenden Spiegel verdeckt, oder durch einen intakten unterliegenden Spiegel ergänzt wird, kann auf eine „Reparatur“ verzichtet werden. Die Grenzbereiche des noch intakten Beleges werden ganz

⁹ Manfred TORGE u.a. „Flüchtiges Quecksilber“, in *Restaura* 3/2012, p. 30.

¹⁰ Manfred TORGE u.a. „Flüchtiges Quecksilber“, in *Restaura* 3/2012, p. 30.

dünn mit Paraloid B72 versiegelt und von der Stelle weitere Unterwanderungen auszuschließen. Ist die Spiegelfläche für die Gesamtsituation notwendig, erfolgt der Ersatz. Dazu ist die freigelegte Glasfläche gründlich zu entfetten. Dann wird eine dünne Zinnfolie zugeschnitten. Auf einer separaten Glasplatte wird dieser dann etwas Quecksilber dazu gegeben. Zum Reinigen des Zinns wird die Folie zwischen zwei Glasscheiben gerieben, bis sich eine schwarze Schmutzschicht absetzt und eine spiegelblanke Fläche erscheint. Diese kann dann von der Trägerscheibe auf die Fehlstelle geschoben, leicht angedrückt und einen Tag beschwert werden (Abb. 3). Dann gilt es das Glas leicht schräg zu stellen um das nicht amalgamierte Quecksilber ablaufen zu lassen.

Silbernitrat

Silbernitratspiegel zeigen visuell ähnliche Schäden. Mechanisch beschädigte Oberflächen, aber auch Ablösungen der Silberschicht. Leider sind mit Silbernitrat verspiegelte und anschließend mit Lack versiegelte Oberflächen nicht in der Technik zu restaurieren in der sie hergestellt wurden. Vom Silbernitratspiegel geht keine Gesundheitsgefahr aus, Abwägungen zu vormals benannten Punkt „c“ sind somit nicht zu treffen. Auch muss nicht erneut abgewogen werden, ob verdeckte oder durch unterliegende Spiegel ergänzte Stücke bearbeitet werden müssen, dass ja bereits konzeptionell bei den Quecksilberspiegeln festgelegt wurde. Um notwendige Spiegelflächen zu schließen, wurden also diverse Ansätze getestet und ihre Tauglichkeit als Ersatzspiegelfläche abgewogen. Basis war wieder das Abtragen der geschädigten Beläge und Reinigen der Glasoberflächen mit Ethanol.

- a. Um die Spiegelfläche wieder herzustellen, wird eine Stanniolfolie aufpoliert und auf eine säurefreie Pappe gespannt. Um die Folie gegen verrutschen und Faltenbildung zu sichern wird diese mit Paraloid B72 an der Glaskante angeheftet. Karton und Glas werden in ein 0,5mm starkes gekantetes U-Blei gefasst.
- b. Um die Nachteile des Stanniols aufzuheben, wurde ein Test mit einer Spiegelfolie, die als IR-Folie an Verglasungen eingesetzt wird, vorgenommen. Der Vorteil dieser Folie ist eine Eigenstabilität, die ein Knittern ausschließt, eine stärkere Spiegelwirkung und die Möglichkeit zur individuellen Anpassung an die Spiegelfarbe durch eine breite Farbpalette auf dem Markt. Auch hier wurde zum Schutz der Folie wird das Stück vollflächig mit einem säurefreien Karton hinterlegt und in U-Blei gefasst.

Visuell überzeugte die Spiegelfolie in allen Punkten. Es stellte sich als schwierig heraus, die Zinnfolie besonders an größeren Fehlstellen vergleichbar dem Silbernitrat spiegeln zu lassen, zudem knitterte bereits bei leichten Bewegungen das Stanniol. Dennoch haben wir uns in intensiveren Gesprächen mit dem Bauherrnvertretern und Fachgutachtern gegen die IR Folie entschieden. Die fehlende Langzeiterfahrung mit diesen Folien in dieser Kombination war ein zu hohes Risiko, um es an einem historischen Objekt zu testen. Das Risiko Wechselwirkungen mit den Schutzlacken oder Oberflächenresten des Silbernitrats zu erzeugen war zu hoch. Die „Reparatur“ mit Stanniol wurde bereits früher an diesen Spiegeln eingesetzt, jedoch mit dem Fehler das Stanniol flächig zu verkleben. Der Klebstoff mattierte die Spiegelfläche und löste Spannungen mit den Schutzlacken aus. Die vollflächige, passgenaue Hinterlegung mit einer aufpolierten etwas dickeren Stanniolfolie und das aufspannen der Folie führte zu einer guten partiellen Ergänzung. Auf die Gesamtfläche war das Bild unmerklich geschlossen und im Detail wird die Ergänzung deutlich.

Insgesamt kann man von einer schlüssigen Restaurierung mit maximalem Erhalt historisch gewachsener Substanz sprechen (Abb. 4). Wenn auch mit gewissen konzeptionellen Abstrichen, die den Anforderungen der Eigentümer entsprachen. Diese Abstriche sind im Einzelfall sicherlich kritisch zu betrachten, in der Summe der Wiederherstellung aber dem Gesamtleitfaden geschuldet. Neben den konservatorischen Notwendigkeiten der Kategorie a-c, gibt es noch die Kategorie d. Unter diese Kategorie fällt einerseits der Ersatz fehlender Teile, die wie bereits beschrieben voll kopistisch in Schliff und Spiegeltechnik ausgeführt wurde. Hier hätten wir uns gewünscht wenn moderne Techniken oder Neutralergänzungen eingesetzt worden wären, da dies einerseits den für Denkmalwerte üblichen Regelwerken, wie der Charta von Venedig¹¹ oder aber auch den Restaurierungsregeln des CVMA¹² entsprechen würde, auf der anderen Seite zudem den hohen Wert des Bestandes unterstreicht.

¹¹ Charta von Venedig 1964, Internationaler Kongress der Architekten und Denkmalpfleger.

¹² Richtlinien für die Konservierung und Restaurierung von Glasgemälden, zweite Fassung Nürnberg 2004 CVMA.

Ebenfalls unter Punkt d fällt die symmetrische Angleichung der Spiegel. Die barocken Quecksilberspiegel waren teils durchsetzt mit Silbernitratspiegeln. Diese Spiegel setzen sich farblich und in der Tiefenwirkung vom Ursprungsbestand ab. Bei den Silbernitratergänzungen handelte es sich größtenteils um barocke Originalgläser, die zu einem späteren Zeitpunkt mit Silbernitratlösung neu verspiegelt wurden.¹³ Um eine farbliche Symmetrie zu erzeugen wurde dieser Spiegelbelag entfernt und durch einen Zinnamalgambelag ersetzt. Es wäre wünschenswert gewesen, dies als Bestand zu erhalten, da die neue Spiegelfläche vermutlich im 19. Jahrhundert aufgebracht wurde und (vermutlich durch das Quecksilberspiegelverbot eher ungewollt) eine moderne Auffassung von Rekonstruktion vertritt. Das stark historisierende Rekonstruieren, mit Schwerpunkt auf historische Arbeitstechniken, gehört jedoch zum Konzept der Wiederherstellung des Schlosses und ist als einheitliche Leitlinie zu vertreten.



Abb. 4. Teilaufbau
des fertigen
Spiegels im
Audienzzimmer.

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¹³ 1886 wurde die Herstellung von Quecksilberamalgamspiegeln verboten!

2.4

Narrative from Nonsense: Questions of Identity in the St Cuthbert Window, York Minster

Katharine Harrison

Récit d'un non-sens : questions d'identité dans la fenêtre de Saint Cuthbert, York Minster – Résumé

La structure narrative est un élément crucial de l'identité d'un vitrail narratif. Cet article prend comme exemple la baie de saint Cuthbert, datant du XV^{ème} siècle à la cathédrale de York, pour explorer comment la perte de la structure narrative originale

et l'introduction de nouvelles séquences au sein de celle-ci affectent l'identité de ce genre de vitraux monumentaux. Les questions éthiques, les défis et les opportunités que peuvent rencontrer les conservateurs qui souhaitent définir, communiquer et soutenir cette identité originelle sont explorés.

Narrative from Nonsense: Questions of Identity in the St Cuthbert Window, York Minster – Summary

Narrative structure is a crucial element of a narrative window's identity. This paper uses the 15th-century St Cuthbert Window, York Minster, to explore how the loss of original narrative structure, and the

introduction of new narrative sequences, affect the identities of monumental narrative windows. The ethical questions, challenges and opportunities faced by conservators who wish to define, sustain and communicate this identity are explored.

Introduction

Monumental narrative windows present complex challenges for conservators who aim to characterise and preserve their identity. As the transmission of a specific story or message is often the primary function of these windows, their legibility and structure are crucial components of their identity. Consequently, they are particularly vulnerable to the loss of narrative structure, as a result of disarrangement and damage, which can render a window's subject incomprehensible. Yet attempts to retrieve 'original' narrative structures present additional risks to both the historic fabric and structure of a window, and to material from later interventions. This paper draws upon insights gained during the author's recent doctoral research into the 15th-century St Cuthbert Window, York Minster, to explore the challenges and opportunities faced by conservators who wish to define, sustain and communicate the identity of monumental narrative windows.

The St Cuthbert Window, York Minster

The St Cuthbert Window (s7) was glazed in c.1440 and remains *in situ* in the eastern choir transept of York Minster.¹ The five lights of the window are divided by transoms into four equal sections (A-D), each containing twenty-five main panels (fig. 1). The lowest section (D) contains a large central figure of St Cuthbert, holding the head of St Oswald, flanked by two rows of members of the Lancastrian elite, all set within architectural canopies. The upper three sections (A-C) contain narrative scenes from St Cuthbert's life. The tracery that surmounts the main lights originally depicted figures of saints.

The author's recent doctoral research has established that there were originally seventy narrative panels, which were intended to be read from top to bottom, running left to right along each row (fig. 2).² However, interventions during the past five centuries have led to substantial disruption of the original design. The imagery of individual panels is affected by numerous mending leads, the disarrangement or loss of original glass and the introduction of alien insertions. The original tracery glass and six narrative panels had been lost by 1775, and the narrative had been entirely disarranged by 1877 (fig. 3).³ The current arrangement of the narrative panels reverses the original reading order, and is intended to be read from left to right, from the bottom to the top (fig. 4).⁴

¹ Sarah BROWN, 'Our Magnificent Fabrick', *York Minster: An Architectural History c.1220-1500*, English Heritage, Swindon, 2003, p. 232; Katharine HARRISON, "Illuminating Narrative: An Interdisciplinary Investigation of the Fifteenth-century St Cuthbert Window, York Minster", Unpublished PhD Thesis, University of York, 2019, p. 38, 165.

² HARRISON 2019, p. 39, 58.

³ James TORRE, "The Antiquities of York Minster Collected out of the Records of the Said Church and Some Other Authorities", York Minster Library and Archives, L1/7, c.1690-1, f.51r; Joseph Thomas FOWLER, "On the St. Cuthbert

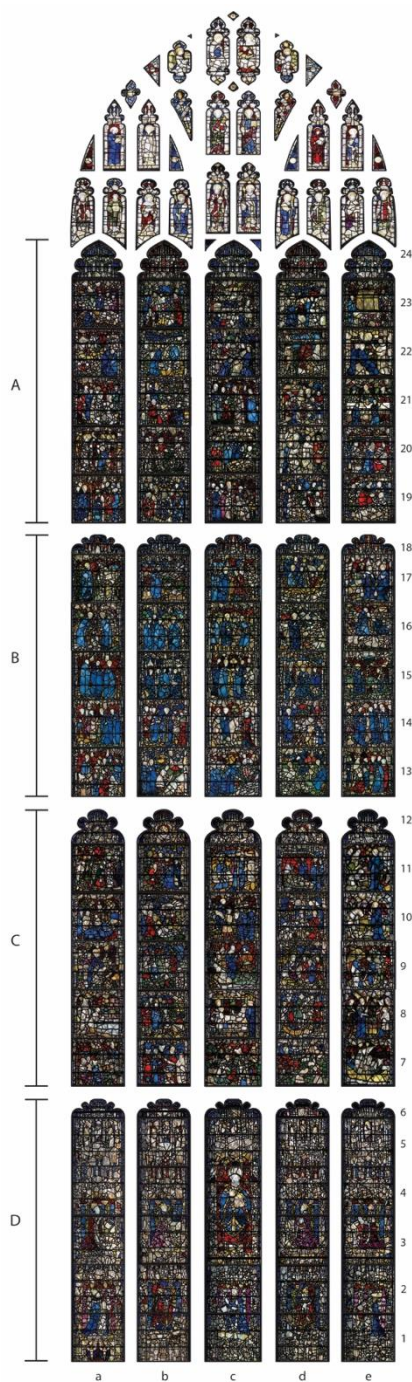


Fig. 1. Photo-composite diagram of the current arrangement of panels in the St Cuthbert Window, York Minster, c.1440, showing section (left), row (right) and light (bottom) labels. Image by author, using photographs by The York Glaziers Trust, reproduced courtesy of the Chapter of York.

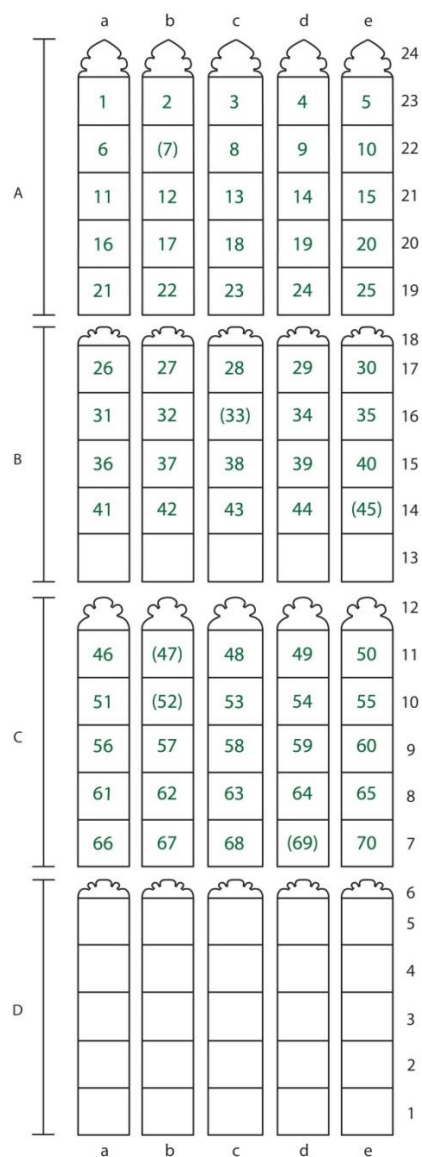


Fig. 2. Diagram of the St Cuthbert Window, York Minster, c.1440, showing the original arrangement of the narrative panels, numbered according to the reading order. Lost panels are shown in brackets. Image by author.

Window in York Minster", *Yorkshire Archaeological and Topographical Journal*, IV, 1877, p. 363, 373-375; HARRISON, 2019, p. 39, 1025.

⁴ HARRISON 2019, p. 70, 78.

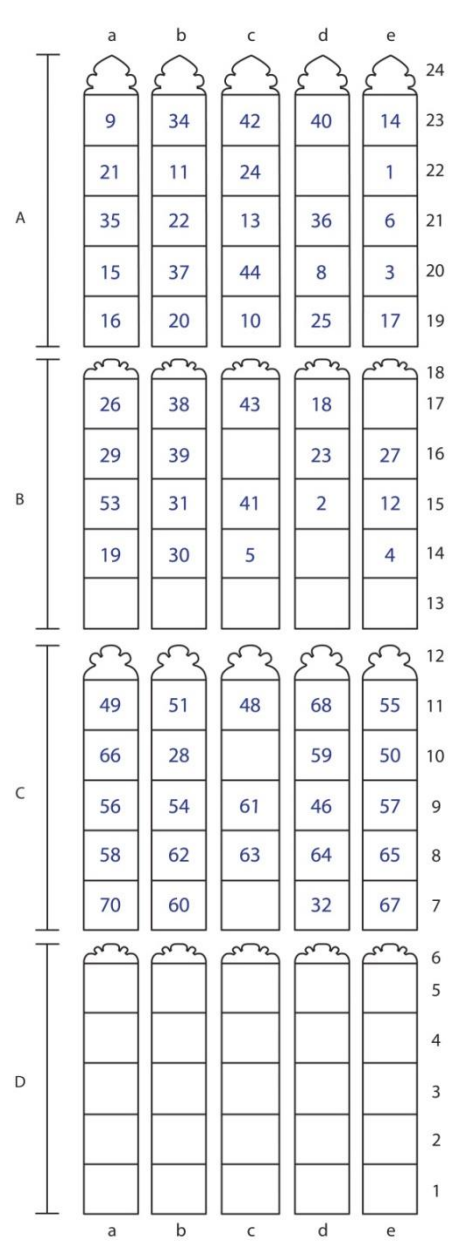


Fig. 3. Diagram of the St Cuthbert Window, York Minster, c.1440, showing the arrangement of the original narrative panels in 1877, numbered according to the original reading order. Image by author.

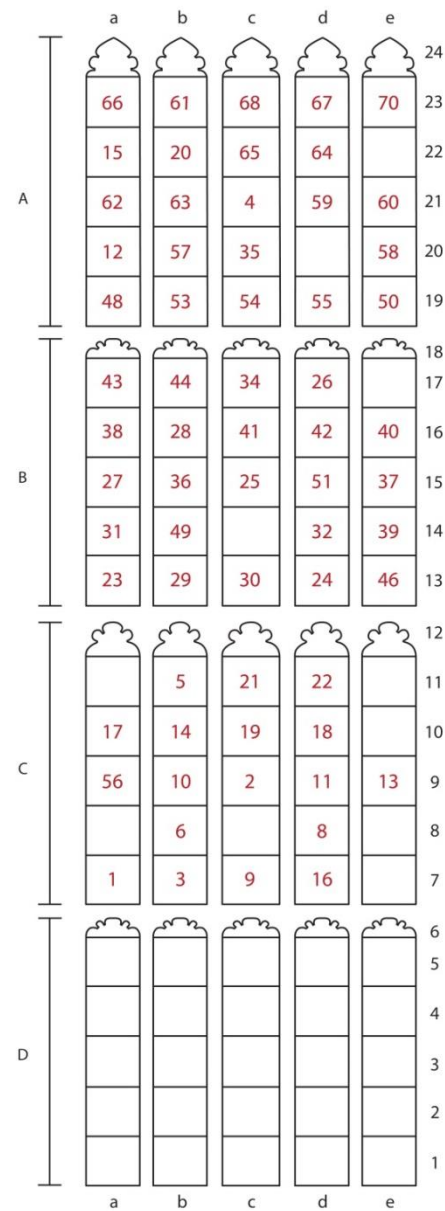


Fig. 4. Diagram of the St Cuthbert Window, York Minster, c.1440, showing the current arrangement of the original narrative panels, numbered according to the original reading order. Image by author.

The current arrangement was largely implemented by the York glazier John Ward Knowles in 1886-8, under the direction of Joseph Thomas Fowler, a canon of Durham.⁵ I will not undertake a detailed analysis of Fowler and Knowles' restoration here, but the impact of their intervention upon questions of the window's identity warrants a brief summary. It must be acknowledged that Fowler and Knowles' restoration was affected by the complete loss of narrative structure, and the constraints of the technology, knowledge and evidence available. Nevertheless, it is apparent that Fowler's analysis of the evidence was flawed. His misinterpretation of both individual panels and the overall reading order led to the introduction of a new narrative sequence, rather than the reinstatement of the "historical" narrative structure, as intended.⁶ The rearrangement of the panels led to the loss of original material, as slight differences between the heights of the rows across the window meant that many panels were cut down to fit their new locations. Fowler and Knowles also created eleven new narrative panels, six to replace the lost medieval panels and five to replace plain glazing which filled a row obscured by stonework.⁷ When considering the role narrative plays in the identity of the St Cuthbert Window, the extent to which the new scenes and narrative sequence introduced by Fowler and Knowles have affected the window's identity, and the challenges they present for future conservation, must be explored.

Defining Identity and Significance

First, it is necessary to establish how narrative structure contributes to the identity and significance of a window. Most obviously, narrative windows rely upon structure to convey meaning. While there is great diversity in the complexity and reading order of medieval narrative windows, all rely upon the arrangement of scenes in a particular sequence, which may emphasise certain elements of a story, or omit others. Often, the specific narrative depicted in a window was tailored to the interests of its patron and intended audience. The transmission of this narrative is therefore a primary original function of a window, and arguably an essential aspect of its identity.

The importance of narrative structure as a locus of identity and significance can be demonstrated by assessing a narrative window using modern conservation guidelines. These provide definitions and frameworks which enable the range of values that contribute to a work's cultural significance to be identified and considered during a conservation plan. This paper draws upon the guidance of the International Council on Monuments and Sites' (ICOMOS) 1964 *International Charter for the Conservation and Restoration of Monuments and Sites* (Venice Charter) and *The Burra Charter: The Australia ICOMOS Charter for Places of Cultural Significance 1999* (Burra Charter), which have both long been accepted as being applicable to stained glass conservation. Naturally, the author has also consulted the Corpus Vitrearum Medii Aevi's (CVMA) 2004 *Conservation Guidelines*, whose ethical principles follow the broader conservation principles outlined in a number of internationally recognised guidelines, including the Venice Charter, while providing guidance that is more specific to the medium.⁸ As the St Cuthbert Window is in the UK, guidance published by English Heritage (now Historic England) is also relevant and valuable when defining significance.⁹

The Burra Charter defines cultural significance as "aesthetic, historic, scientific, social or spiritual value for past, present or future generations" and recognises that cultural significance is embodied in a work's "fabric, setting, use, associations, meanings, records, related places and related objects".¹⁰ Likewise, the *Conservation Principles* promote comprehensive consideration of all of the values that contribute to significance, dividing these into four categories: evidential, historical, aesthetic and communal (including

⁵ HARRISON 2019, p. 39.

⁶ FOWLER 1891, p. 486; HARRISON, 2019, p. 39, 56-57.

⁷ Joseph Thomas FOWLER, "On the St. Cuthbert window in York Minster: Additional notes", *Yorkshire Archaeological and Topographical Journal*, XI, 1891, p. 486-487; Frederick HARRISON, *The Painted Glass of York: An Account of the Medieval Glass of the Minster and the Parish Churches*, S.P.C.K., London, 1927, p. 103, 110-111.

⁸ CORPUS VITREARUM MEDII AEVI (CVMA), *Guidelines for the Conservation and Restoration of Stained Glass*, 2nd edition, Nuremberg, 2004. Published online at www.cvma.ac.uk/conserv/guidelines.html [accessed 13 December 2019]: para. 1.3.

⁹ ENGLISH HERITAGE, *Conservation Principles Policies and Guidance for the Sustainable Management of the Historic Environment*, English Heritage, London, 2008, p. 27-32, 35-40.

¹⁰ AUSTRALIA INTERNATIONAL COUNCIL ON MONUMENTS AND SITES' (ICOMOS), *The Burra Charter: The Australia ICOMOS Charter for Places of Cultural Significance 1999*, Australia ICOMOS Incorporated, 2000, para. 1.2.

commemorative, symbolic, social and spiritual values).¹¹ Using the definitions provided by the conservation guidelines, we can identify the original narrative structure of a window as a locus of its significance, and identity, because it enables the meaning of a work to be understood, thereby contributing to the spiritual and social value of the window.¹² Additionally, the narrative structure of a window, chosen for a specific setting or audience, will have evidential and historical value.¹³ Assessments of aesthetic value can be subjective, but as aesthetic value can partly be derived from composition and “conscious design”, original narrative structures often contribute to the aesthetic value of an artwork.¹⁴

Narrative and Identity in the St Cuthbert Window

Turning back to the St Cuthbert Window, we can now consider how the disarrangement of the narrative affects the window’s identity and significance. While the window remains *in situ*, and the majority of the original narrative scenes survive, the window’s meaning, as originally conceived, is undoubtedly obscured by the loss of its original structure. Because the original sequence has been disrupted, numerous panels have, until recently, been misidentified and so are located in the wrong place within the narrative (fig. 4).¹⁵ This is particularly evident when scenes spanning more than one panel are considered. Of the seventeen groups of multi-panel scenes identified during the author’s research, only five now appear together within the window.¹⁶ As a result, both their meaning and that of the narrative as a whole remains unclear to the modern viewer. Additionally, the reversal of the narrative reading order means that the relationship between the narrative and the broader iconography of the window is no longer apparent. In particular, the author’s recent research has suggested that the original narrative structure was designed to fill Section C with panels showing Cuthbert’s election and life as a bishop.¹⁷ It is likely that these scenes were intentionally placed in close proximity to the commemorative section below, which contains figures of kings and prelates, including the window’s donor. The reversal of the reading order means that scenes from Cuthbert’s episcopate no longer appear directly above the commemorative section, preventing viewers from considering the didactic or symbolic messages created by the original arrangement.

It is, therefore, apparent that the loss of the original narrative structure not only affects the communal value of the window, but also the evidential and historical value. By obscuring the meaning and symbolism of individual panels, the wider narrative and the window as a whole, the disarrangement of the narrative has a negative impact upon the spiritual and symbolic value of the window. Additionally, as this structure also provided evidence of the interests and agendas of the window’s patron, the design approach of the medieval glaziers and the contemporary understanding of St Cuthbert’s cult, the historical and evidential value of the window is also affected.

Future Conservation: Questions of Identity

The author’s recent research has demonstrated that it would be possible to introduce a narrative order that is much closer to the original than the current arrangement, and which is based upon rigorous examination of the evidence.¹⁸ This intervention would prioritise the original material, and arguably its historic identity, by promoting the communal, historic and evidential values of the window that are negatively affected by the current arrangement. Such an intervention is permitted by the Venice Charter, provided that it is based upon “respect for original material and authentic documents”.¹⁹ Likewise, it would arguably comply with the CVMA *Guidelines*’ statement that rearrangements “should only be undertaken when fully justifiable based on thorough art-historical and technical research”.²⁰ However, although it could be argued that a rearrangement based upon a comprehensive review of the evidence would comply with this guidance, such an intervention would

¹¹ ENGLISH HERITAGE 2008, p. 27-32, 35-40.

¹² AUSTRALIA ICOMOS 2000, para. 1.2; ENGLISH HERITAGE, 2008, p. 31-32.

¹³ ICOMOS 1964, art. 3; AUSTRALIA ICOMOS, 2000, para. 2.3; ENGLISH HERITAGE, 2008, p. 28-29.

¹⁴ ENGLISH HERITAGE 2008, p. 30-31.

¹⁵ HARRISON 2019, p. 39, 56, 82.

¹⁶ HARRISON 2019, p. 82.

¹⁷ HARRISON 2019, p. 58, 220, 260.

¹⁸ HARRISON 2019, p. 88-89.

¹⁹ ICOMOS 1964, Art. 9.

²⁰ CVMA 2001, para. 4.4.1.

raise a number of ethical and practical issues, particularly regarding the treatment of the 19th-century arrangement and panels.

Even if we focus upon questions of identity and significance linked to narrative structure, it is evident that the original narrative order is not the sole locus of the window's identity. We must consider the significance of the current arrangement and how this would be affected by any potential rearrangement. With the exception of three panels, which were rearranged in the 1950s, the present arrangement follows that introduced by Fowler and Knowles during their intervention of 1886-8.²¹ Consequently, while the current narrative structure is demonstrably different from the original arrangement, it nevertheless has value as evidence of both the history of the window and 19th-century approaches to restoration.²²

In particular, as records created by Fowler and Knowles survive, comparison with the window's current condition can support analyses of their restoration approach.²³ For example, despite his flawed analysis of the evidence, it is evident that Fowler employed a methodology which is not dissimilar to modern conservation research, drawing upon the examination of historic records of the window and comparable cycles to guide his interpretation of the "historical" narrative order.²⁴ Similarly, Knowles' limited alteration of the glass within each panel, and the retention of previous insertions, demonstrates a degree of sensitivity and respect for the original material that was by no means universal in this period. The 19th-century panels support this interpretation, as they reveal Knowles' careful study and understanding of the original glass' design.²⁵ Both these panels, and the new narrative sequence they were designed to fit within, are not only evidence of the window's 19th-century history, but have now been part of the window for more than a century.

It can be argued that Fowler and Knowles' arrangement is now an integral part of the St Cuthbert Window's identity. The rearrangement of the narrative to an order closer to the original, as proposed above, would automatically result in the loss of the 19th-century arrangement. The eleven 19th-century panels could be retained to fill the gaps in the narrative created by the lost panels, and the previously plain-glazed row. Nevertheless, because they were designed to fit within the erroneous narrative sequence devised by Fowler, they would potentially be removed from the context for which they were designed. This would affect their evidential and historical value. However, to retain the current arrangement on these grounds would effectively prioritise the values derived from the 19th-century intervention over those derived from the original narrative sequence. This brings us back to the question of how we define the identity of the window. Are some aspects of its identity more significant than others? And how should conflicting loci of identity be treated in future conservation interventions?

The *Conservation Principles* recognise that, while conservation aims to retain all heritage values, "on occasion, what is necessary to sustain some values will conflict with what is necessary to sustain others".²⁶ This is particularly true of values derived from the original design or function, which "may be recoverable through repair or restoration, but perhaps at the expense of some evidential value".²⁷ They caution that, when deciding which values should be prioritised, the relative importance of these values should be comprehensively assessed.²⁸ Similarly, the *CVMA Guidelines* recognise that both rearrangements and later additions provide evidence of a window's history, and state that further "rearrangements, or replacements of later additions should only be undertaken when fully justifiable based on thorough art-historical and technical research".²⁹

In the case of the St Cuthbert Window, an argument can be made that the author's doctoral research provides sufficient evidence for the introduction of an arrangement which is closer to the original narrative sequence, and that this would have significant positive impacts upon the communal, historical

²¹ Eric MILNER-WHITE, "The Return of the Windows", *The Friends of York Minster Twenty-Ninth Annual Report*, H. Morley and Sons Ltd., York, 1957, 37; FOWLER, 1891, p. 487-501.

²² CVMA 2001, para. 4.4.1; ENGLISH HERITAGE, 2008, p. 28-29.

²³ HARRISON 2019, p. 40, 54-55.

²⁴ FOWLER 1891, p. 486; HARRISON, 2019, p. 44, 56.

²⁵ HARRISON 2019, p. 57.

²⁶ ENGLISH HERITAGE 2008, p. 38.

²⁷ ENGLISH HERITAGE 2008, p. 45.

²⁸ ENGLISH HERITAGE 2008, p. 45.

²⁹ CVMA 2001, para. 4.4.1.

and evidential value. Moreover, as any future conservation intervention would involve the installation of a protective glazing system, it would be possible to implement a support system which enabled future rearrangement of the panels to return them to their current arrangement, thereby adhering to CVMA principles of reversibility.³⁰ As noted above, the implementation of a narrative structure closer to the original would not necessitate the removal of the 19th-century panels, so some evidence of this part of the window's history and identity would be retained.

Nevertheless, the CVMA *Guidelines* state that any treatment of rearrangement or later additions “must be guided by the principles of minimal intervention”.³¹ Moreover, the Venice Charter cautions that interventions “must stop at the point where conjecture begins”.³² Although there is convincing evidence for most of the original narrative structure, the original arrangement cannot be identified with complete certainty. Consequently, a small proportion of a rearrangement approximating the original order, although based on evidence-led deductions, would be somewhat conjectural. A case can therefore also be made for retaining the window in its present arrangement. Furthermore, as the questions regarding the future treatment of the 19th-century arrangement demonstrate, we must recognise that any interventions we make will contribute to the identity of the window, and consider how this may affect future conservation decisions. Consequently, conservation decisions must balance the treatment of the various facets of the window's identity, and should be guided by their potential impacts upon the expression of identity within the window as a whole.

Digital Interpretation: New Ways of Looking at Identity?

It is apparent that either course of action would influence the identity of the window for future generations, and would necessarily prioritise some aspects of that identity over others. However, developments in technology provide the opportunities to communicate those values which are not evident within the window itself. A range of digital approaches to interpretation can now be used to facilitate public engagement with cultural heritage, particularly where that heritage is intangible or multi-layered.³³

For the St Cuthbert Window, interactive digital reconstructions, based upon detailed research and extant documentation, would enable the various historic narrative sequences to be explored, both on-site and remotely. These could range from simple 2D models, such as those created by the author to map the past arrangements of the window, to 3D models of the window, accessible in virtual or augmented reality, which would allow the viewer to move through different iterations of the St Cuthbert Window's narrative, examining the evidence and even rearranging the sequence themselves. As York Minster continues to function as a place of worship, fixed interpretation installations may not be suitable in the immediate vicinity of the St Cuthbert Window, which can only be viewed from the south choir aisle and the choir itself. However, the increasing use of portable devices means that interpretation materials can be provided via applications on these devices.

The creation of virtual versions of the St Cuthbert Window would enable the wider public to explore and question its identity in much greater depth than ever before. Yet, when considering their use as a way of managing or mitigating the potential negative impacts of conservation decisions, the relatively limited lifespan of digital formats must be recognised.³⁴

³⁰ CVMA 2001, para. 3.2.1., 4.4.1.

³¹ CVMA 2001, para. 4.4.1.

³² ICOMOS 1964, Art. 9.

³³ Jenny NEWELL, “Old Objects, New Media: Historical Collections, Digitization and Affect”, *Journal of Material Culture*, 17 (3), 2012, p. 293-4, 299-303; Mariëtte VERHOEVEN, “Revealing and Presenting the Past(s) for the Public Fethiye Mosque and Museum as a cultural heritage site in Istanbul”, in Linde EGBERTS and Maria D. ALVAREZ (eds), *Heritage and Tourism: Places, Imageries and the Digital Age*, Amsterdam University Press, Amsterdam, 2018, p.89-90.

³⁴ Stuart JEFFREY, “A new Digital Dark Age? Collaborative web tools, social media and long-term preservation”, *World Archaeology*, 44(4), 2012, p. 555-6.

Conclusion

Narrative lies at the heart of the St Cuthbert Window's identity. As a result, a case for implementing a narrative order closer to the original can be made. This would arguably prioritise the original material, and enhance its communal, evidential and historical value, by enabling viewers to engage with the window in a format which more clearly expresses its original identity. Nevertheless, the 19th-century arrangement is also part of the window's identity, and we must consider whether its loss would be worth the proposed gains. There is no straightforward conservation solution which can fully resolve these issues. Any new arrangement would not fully retrieve the original arrangement of the window, nor would it fully remove the 19th-century material. Might it therefore represent a balance of the competing loci of identity within the St Cuthbert Window? Or would it effectively create a new identity?

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3.1

Automatic Determination of Damage to Cultural Assets by Means of Artificial Intelligence

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Automatische Bestimmung von Schäden an Kulturgütern in Echtzeit mit Hilfe von künstlicher Intelligenz – Zusammenfassung

Im vorliegenden Beitrag wird ein neues Verfahren vorgestellt, welches Schäden an Kulturgütern automatisch erkennt und den Anwender darüber informiert. Das Verfahren basiert auf Methoden der künstlichen Intelligenz (KI). Zur Erkennung von Schäden werden verschiedene Sensortypen wie berührungslose Temperatur- und Luftfeuchtemessung mit einem Kamera-System kombiniert. Aus den Daten werden dann mit Hilfe von Convolutional Neural Networks

(CNN) automatisch die Zustände des zu beobachtenden Objektes ermittelt.

Die automatische Erkennung von Schäden an Kulturgütern ist besonders dann sinnvoll, wenn diese nicht direkt von einer Person überwacht werden können, bzw. wenn die permanente Schadensüberwachung durch Menschen zu aufwendig und kostspielig ist. Ein Beispiel dafür sind die Fenster von Kathedralen, die meist in großen Höhen eingebaut sind. Ein weiteres Beispiel sind Kirchenorgeln, wo die permanente Schimmelüberwachung auch innerhalb der Orgel einfach realisiert werden kann.

Automatic Determination of Damage to Cultural Assets by Means of Artificial Intelligence – Abstract

This paper presents a new procedure that automatically detects damage to cultural objects and informs the user about it. The procedure is based on artificial intelligence (AI) methods. To detect damage, various sensor types such as non-contact temperature and humidity measurement are combined with a camera system. Convolutional neural networks (CNN) are then used to automatically determine

the states of the object to be observed from the data.

The automatic detection of damage to cultural assets is particularly useful when they cannot be directly monitored by a person, or when permanent damage monitoring by humans is too time-consuming and costly. Examples of this are the windows of cathedrals, which are usually installed at great heights. Another example is church organs, where permanent mold monitoring can also be easily realized inside the organ.

Introduction

With a novel, innovative approach based on artificial intelligence (AI) algorithms, this article presents a procedure that automatically informs the user in real time about the development of damage to cultural property. For this purpose, a system platform was developed whose results can be understood without expert knowledge and which can be installed with minimal effort. This aspect of the simple applicability of a complex system has already led to very positive feedback from users in the Custos Aeris project (SANDER 2017).

The basis of the system platform (fig. 1.) is formed by microcontroller-based electronics, called real-time controller in the following, and a cloud server. The real-time controller, which is installed close to the object to be observed, combines a digital camera with illumination techniques in the visible light range. By evaluating the images with AI algorithms on the real-time controller, a system is created that enables automatic damage detection in situ and in real time. The system is supplemented with interfaces and sensors for recording temperature and relative humidity in the near field of the object to be monitored. In this way, the environmental conditions that led to the damage are also directly documented. The determined data is sent to the cloud server via LTE-connection. The cloud server takes over the data storage, the visualization of the data and informs the user in case of damage. The AI algorithms are also trained on the server.

The following objectives are to be achieved with the system:

- Autonomous detection and assessment of damage in the early stages of visibility – *in situ* and in real time
- Detection of different types of damage, e.g. damage due to condensation, cracking or mould
- Automatic generation of a warning message to the user
- Cloud-based data storage and data visualization
- Documentation of the history of the damage by recording the environmental conditions in the near field of the object to be observed.
- Detected sensor data and camera images can be used as the basis for a knowledge database to develop new algorithms for the early detection of damage.

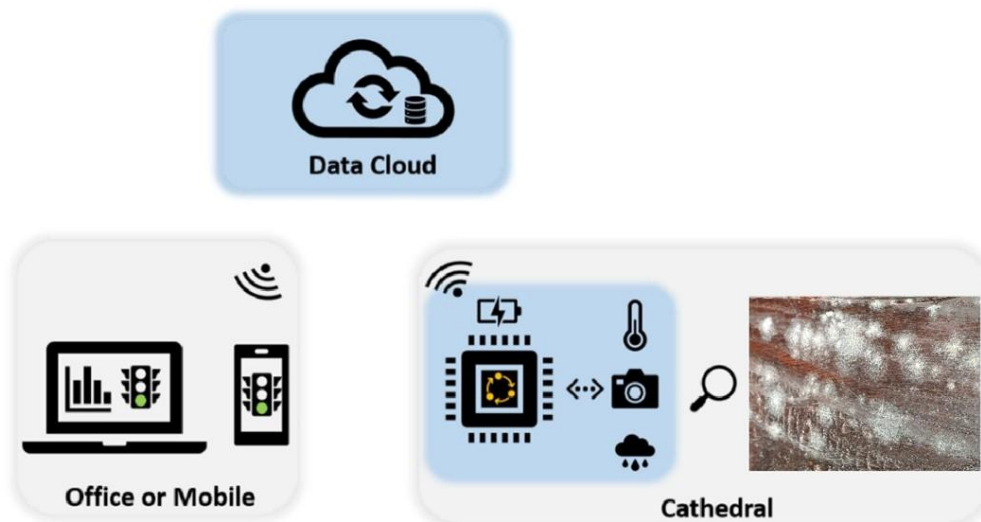


Fig. 1. System Architecture of the mold camera 2021 © iXtronics-Hajuveda.

As part of a DBU 35604 project funded by the Deutsche Bundesstiftung Umwelt (DBU), such a system platform for the automatic detection of damage to cultural assets was developed (DAAMS 2020). The aim of the DBU project is initially to detect the development of mold. However, the system platform is planned to be so general that it can also detect damage to historical windows, such as condensation or cracks. The necessary flexibility of the system platform results from the AI algorithms, which are trained to recognize a wide variety of damage through appropriate training with sufficient image material. In the case of cracks, the system platform can also be supplemented with acceleration sensors for vibration measurement via existing interfaces. In this way, the causes of crack formation can also be documented in this case.

State of the art

The use of digital systems for the protection and preservation of cultural heritage is becoming increasingly widespread, as evidenced, for example, by the EuroMed 2018 conference (IOANNIDES et al. 2018). The applications and methods described include numerical analyses using computer simulation models, 3D digitization and reconstruction, and virtual and augmented reality methods. Currently, artificial intelligence methods are also increasingly being used for the 3-D digitization of cultural assets. The starting point for these methods was the management of very large amounts of data during digitization, e.g. by laser scanners (BRUMANA et al. 2019, SANTOS 2017). To simplify data handling, artificial intelligence techniques such as Convolutional Neural Networks (CNNs) are used to automatically classify cultural objects (BELHI et al. 2018, LLAMAS 2017, PAOLANTI 2019). As a result, it is now possible to automatically catalogue extensive image databases and define more detailed criteria that lead to quick and reliable results for subsequent searches.

In recent publications (CHAIYASARN et al. 2018, KWON & YU 2019), CNNs are also used for damage detection in the cultural property sector. This is university research that uses CNNs for automatic damage detection of, for example, cracks in historical buildings, masonry or sculptures. The data is recorded by camera and subjected to subsequent analysis. However, according to current research, the

use of AI methods for preventive damage detection in situ and in real time is uncharted territory in the field of cultural heritage.

This is precisely the innovative character of the project. Based on CNN algorithms, a system is being developed that can detect damage to cultural objects in situ and in real time. By combining digital image recognition using CNN algorithms and sensors for recording the environmental conditions in the near field of the objects to be monitored, it will not only be possible to detect damage to cultural property, but also to directly document the environmental conditions that led to the damage. As an outlook, the data obtained in this way can be further developed into a knowledge database in follow-up projects.

Solution concept and realisation

The solution concept of the system platform is based on the components shown in fig. 1 and the cloud server. The cloud server forms the interface to the user by providing the data of the real-time controller via web server and informing the user about the status of the object to be monitored. The real-time controller collects all the necessary data on site in real time to assess whether there is damage or not and sends it to the cloud server via mobile radio.

Real-time controller functionality

The core component of the real-time controller is a microcontroller on which the peripheral components are managed. A sensor interface to non-contact temperature and humidity sensors is available for measuring the environmental conditions in the near field of the objects to be observed.

The camera interface makes it possible to couple a digital camera with the real-time controller. The camera is supplemented with a ring of LEDs in the visible range, which is controlled by the controller.

The real-time controller is equipped with an energy management system and a power supply based on primary cells in order to be able to work energy-autonomously and without interruption for at least 6

months. With the memory components flash memory and SD card, the data of the cameras and the sensors are temporarily stored. The function of the Real Time Clock is to wake up the microcontroller from the energy-saving mode at defined times and to provide the measurement data with a time stamp.

Since the system is intended to be energy-autonomous, the time intervals in which a measurement will be taken and the time intervals in which the data will be transmitted to the cloud server via LTE are synchronized. Due to intensive research on mold growth in churches, the time interval is set to once a day to once every 3 days at midnight.

Fig. 2 shows the front view of the mold camera including LED-bars for illumination and camera-objective. All electronic components are integrated in the housing. The temperature and relative humidity sensor is connected via a cable (hanging down in the picture).

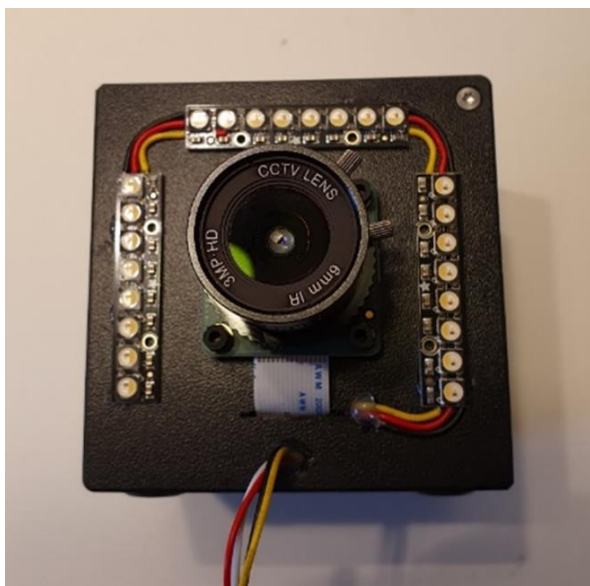


Fig. 2. Front view of mold camera 2021.
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Cloud server functionality

The cloud server forms the system interface to the user. By means of a web server and a user administration, the object data assigned to the user can be accessed and visualized on the system platform in an uncomplicated way by means of username and password via a web browser. The cloud server is also used to automatically notify the user of possible mold growth. The user can choose, for example, whether he wants to be informed by SMS or email.

The database of the cloud server contains the user data, the object data and additional image data for the AI training. The user data includes, for example, the user name and the assigned object data. The

object data stores information such as the object name, the object location and all data determined via real-time controller at the object.

The AI algorithms are also initially developed, trained and tested on the cloud server. Through a downstream automatic analysis of all data from the real-time controllers in the field, the cloud server decides during operation whether the AI algorithms need to be retrained.

AI algorithms

The AI algorithms belonging to the central solution concept can only be described here in principle due to their complexity. A detailed description of the topic can be found, for example, in (SCHWAIGER 2019 or CHOLLET 2018). The core of the planned AI algorithms is a special neural network, a so-called Convolutional Neural Network (CNN), which was developed for image processing.

The principle of a CNN, as with all neural networks, is to reproduce the brain of living beings and thus their pattern recognition abilities in the computer. Fig. 3a shows the structure of a CNN, which consists of a detection and an identification part. The identification part typically corresponds to a conventional neural network. The input image to be recognized is filtered in stages in the detection part and broken down into its features from simple to complex to extract the features to be recognized from the image at the end. The actual recognition of the features takes place in the identification part.

Just like the human brain, neural networks must also be trained. To do this, the network must be fed as much data as possible in the so-called training phase. In the case of optical pattern recognition, the neural network receives a correspondingly large number of images for learning. The definition of what a damage image looks like is determined by the user. In the learning phase, labels with the properties to be recognized are assigned to the image data in the database.

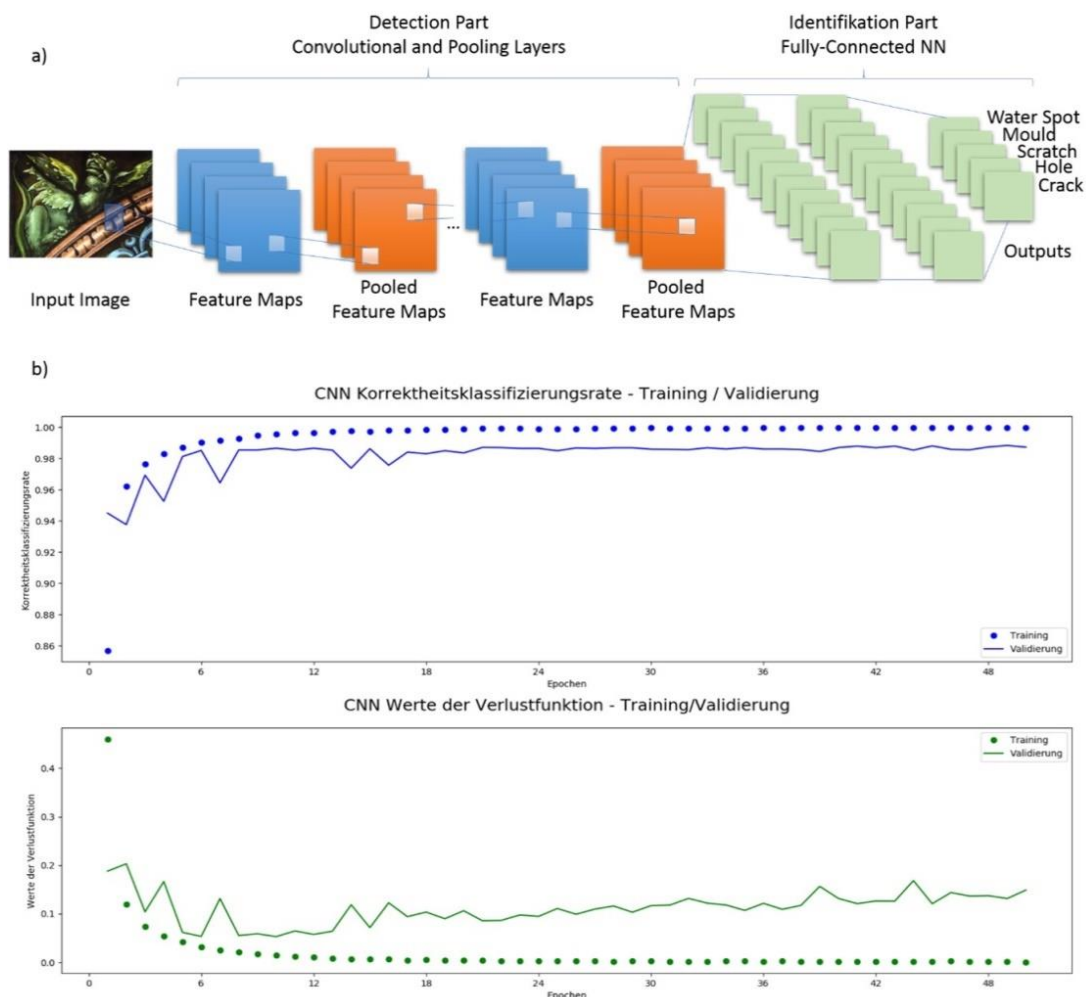
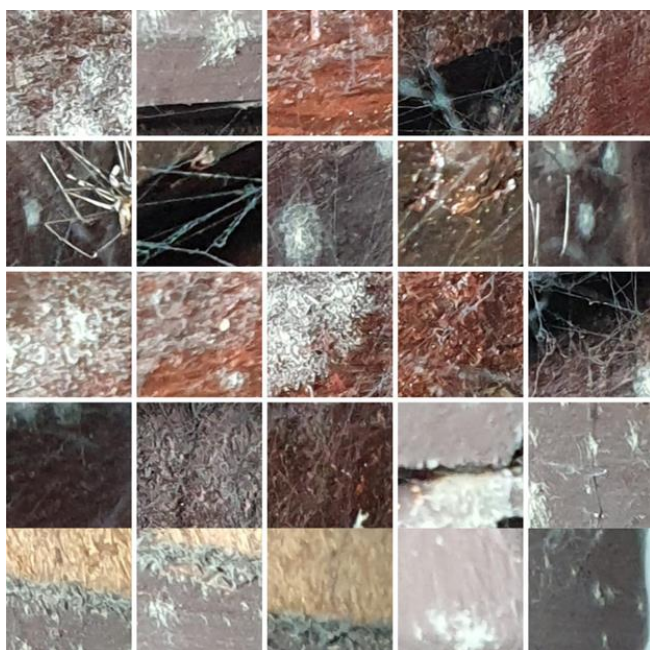


Fig. 3. Structure of a CNNs (a) and process of a Training (b) 2021. © iXtronics-Hajuveda.

Fig. 3 shows the development of the classification rate and the so-called loss function during a training phase for a CNN. The training is divided into so-called epochs. In each epoch, all training data, or training images, are fed into the CNN and optimization functions are used to change the parameters of the CNN in such a way that the recognition of the image information corresponds as closely as possible to the desired result. The optimum is a correctness classification rate of 1, which corresponds to a recognition rate of the images of 100 %. From the diagrams it can be seen that after several epochs the recognition rate for the test data approaches more and more the value 1. The recognition value for the validation data calculated simultaneously after each epoch also increases at first, but then stagnates at about 99 %. Theoretically, the CNN can be trained until a recognition rate of 100 % is reached for the training data. However, it quickly becomes apparent that the CNN achieves a lower recognition rate for new data, such as the validation data. This effect is also reflected in the loss function. For the training data, this numerical value drops towards zero over the epochs. For the validation data, it initially drops and then rises again. This is an indication that the CNN has been optimized too much for the training data and the flexibility to recognize unknown data sets is lost. In this case, the CNN is overtrained. To avoid this, there are various strategies for training a CNN that must be applied in the project.



Practical way for CNN-Training

To be able to train the CNN optimally, many images are initially required. All in all, the support of the project partners and users brought together more than 4000 fotos of mold in cultural objects. Images must be cut for two reasons: first it is necessary to see only one damage feature at a time and second the images should have maximum 250x250 pixels for the CNN to have acceptable computational time.

An example of cut images is shown in Fig. 4. Thanks to the very good support of the project altogether 350000 cut images were finally available for the training.

Fig. 4. Cut images from cultural objects, 2021.
© iXtronics-Hajuveda.

From this pool, the images for the training for the features mold, dust and "o.k." were then selected. Fig. 5 shows an example for mold:

Data augmentation is also used in the project as another way of obtaining the number of image data required. For this purpose, existing damage images from the database are zoomed, shifted, rotated and mirrored by algorithms in the computer. The training of the CNN is quite time consuming and requires computers with powerful graphic cards. The training was usually stopped after coming to 97% score rating, which means that 97% of the pictures shown were correctly classified to the right features.

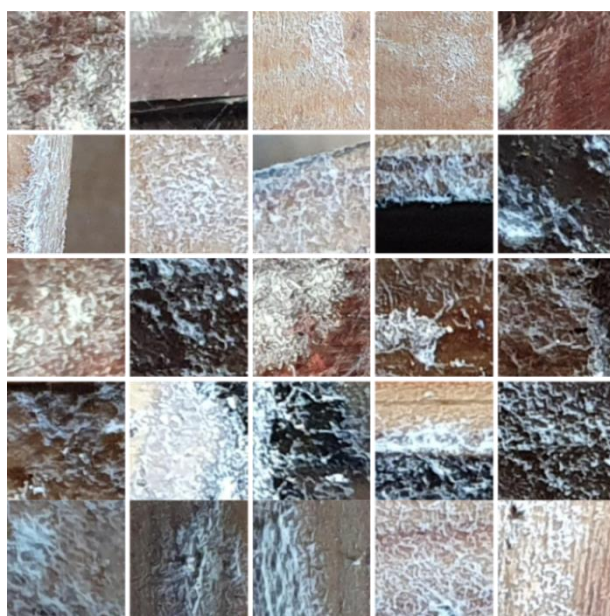


Fig. 5. Images cut of the feature "mold", 2021. © iXtronics-Hajuveda.

Testing of the technology in the Cathedral of St Victor in Xanten

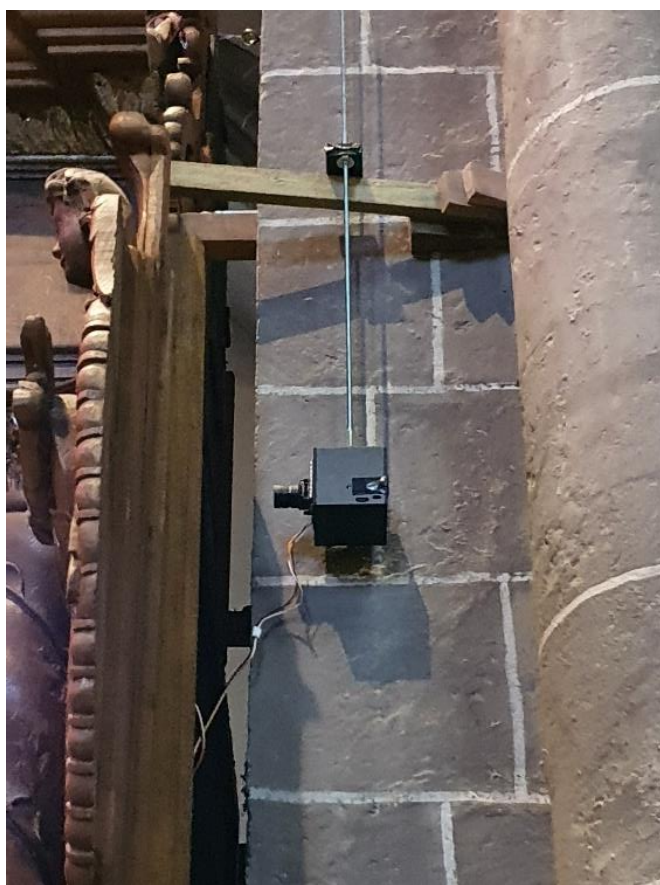


Fig. 6. The mold camera in a field test in the dome of Xanten, 2021.
© iXtronics-Hajuveda.

Many of the training images for the neural networks came from the Xanten Cathedral shortly before mold removal by a team of restorers. In order to detect renewed mold growth as early as possible, a "mold camera - Custos Mucoris" with the real-time controller described here was installed in Xanten Cathedral. Fig. 6. shows the camera looking at the back of an altar. It was suspended with threaded rods from a roof batten which was wedged into the column. The temperature and humidity sensor was stuck with an adhesive pad in the immediate vicinity of the back wall of the altar. The camera has an LTE stick that transmits the camera images and sensor data to the cloud.

Due to the slow growth of mold in churches, the cycle rate of the images was initially set to 1 photo per midnight and later to 1 photo every 3 days at midnight.

During the real-time monitoring of the camera over a period of 5 months, unfortunately no new mold appeared. Therefore, to check the functionality of the concept, 3 mold images were mounted into one camera image. Since the photos are always cropped to a size of approx. 250x250 pixels, the lower mold appears in a total of 4 pictures. Fig. 7. shows a section of the cut images in the back wall of the altar including the mold.

The mold was clearly detected by the neural networks. Based on this evaluation, the user is then informed by email about the occurrence of mold.

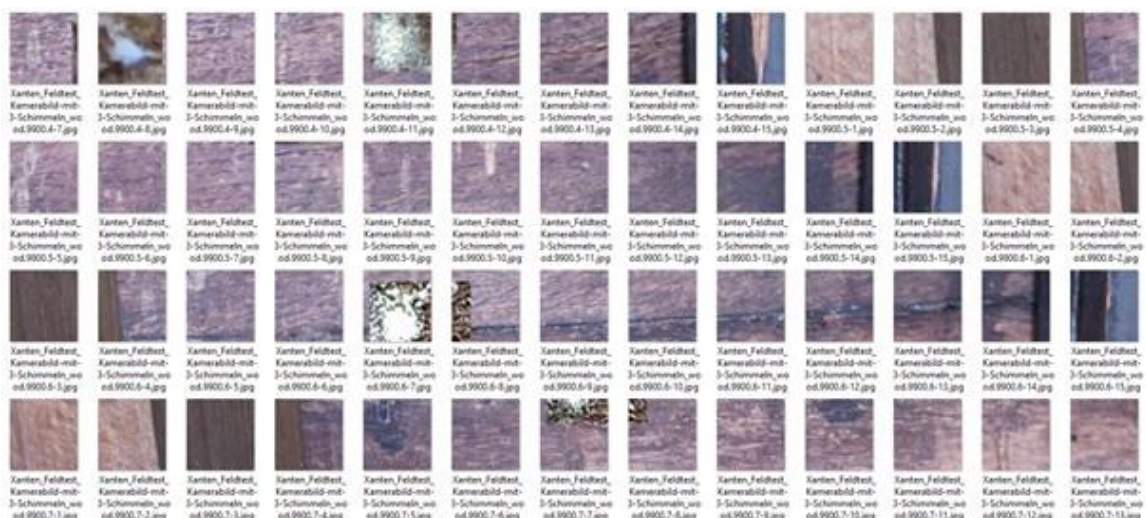


Fig. 7. Spitted image of the back of the altar including mold in Xanten, 2021. © iXtronics-Hajuveda.

Summary and outlook

In the article, the concepts, and the realization of a system platform for the automatic damage detection of cultural assets by means of artificial intelligence were presented using the example of mold. The central components of the system platform are the real-time controller with environmental sensors and the camera system, the cloud server with a database and web server function, and the development of AI algorithms for autonomous damage detection. In the course of development so far, the scripts for image evaluation have been created using CNNs and successfully tested.

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3.2

Ludwig Mittermaier und seine Glaswerkstatt – ein Multitalent des 19. Jahrhunderts

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Ludwig Mittermaier and his Glass Workshop – a Multitalent of the 19th Century –

Abstract

The glass workshop Mittermaier in Lauingen, Bavaria, existed from 1853-1910. Thanks to the Archive from the ancestors of the family Mittermaier, many workshop materials including letters, drawings and tools survived. They provided an exceptional insight into the workshop organization from the first contact with a customer to the final installation of the windows. This is illustrated by the example of the Reformation windows in Ravensburg, which were the center of a two-year research project. The seven windows were part of a new glazing scheme in the protestant church and were created from 1860-62. Little watercolour pictures of some of the windows were found in the Archives. They were probably used as a first draft as well as an advertisement to potential customers. These aquarelle drawings were used by the architect, who was in charge of the renovation at the time, to get sponsors for the windows. One condition for the assignment of

Mittermaier in Ravensburg was, that celebrity artists had to be used to create the cartoons for the windows. In the case of the Ravensburg project, two artists carried out the commission for the drawings of the Figures for the Reformation windows. In total, five of the original cartoons survived. One from Carl Christian Andreae of Dresden and four from Gustav König of Munich. A drawing, which shows the inside of the workshop of Mittermaier, gives us many clues regarding workshop practices. They can be confirmed through a diary of Ludwig Mittermaier, the founder of the workshop, as well as many of the writings of his ancestors.

The research of the archive material of the Mittermaier workshop in combination with the survey of the windows was necessary for the development of the conservation concept for Ravensburg. The results can also be used for further conservation projects on other Mittermaier windows and might even be comparable to other workshops of the same time.

Ludwig Mittermaier und seine Glaswerkstatt – ein Multitalent des 19. Jahrhunderts – Zusammenfassung

Der Erhaltung, Aufarbeitung und Auswertung von Werkstattnachlässen muss im Hinblick auf anstehende Restaurierungen ein großer Stellenwert beigemessen werden. Sie geben Einblicke in die Werkstattpraxis und -organisation und wertvolle Auskünfte zu Rezepturen für Glas-malfarben und -techniken. Die Auswertung des

erhaltenen Nachlasses der Werkstatt Mittermaier war, neben der Untersuchung an den Fenstern selbst, wesentlich für die Entwicklung eines restauratorischen Konzeptes für die Fenster in Ravensburg.

Außerdem können die Ergebnisse auch für weitere Restaurierungsarbeiten an Mittermaier Fenstern, wie aktuell in Biringen, angewendet werden und lassen sich evtl. auch auf andere Werkstätten der gleichen Zeit übertragen.

2016 begann die Sanierung der Evangelischen Stadtkirche in Ravensburg. Die Maßnahmen hatten zur Folge, dass man sich im Rahmen eines zweijährigen Forschungsprojektes intensiv mit dem vorhandenen Glasmalereibestand, entstanden 1860-62 in der Lauinger Werkstatt von Ludwig Mittermaier, beschäftigte. Im Fokus standen vor allem sieben große Fenster (sVII – sXIII), die namhafte Persönlichkeiten der Reformation darstellen und bis heute in situ erhalten sind. Dazu kommt ein umfangreicher Bestand an eingelagerten Glasmalereien.

Die Werkstatt wurde 1853 von Ludwig Mittermaier gegründet. Nach dem frühen Tod Ludwigs 1864 wurde die Werkstatt zunächst von seiner Witwe weitergeführt;¹ 1866-1885 stand sie unter der Leitung

¹ VOLK 2008/09, S. 237.

seines Vetters Bernhard Mittermaier.² Sein Bruder Max Mittermaier führte sie bis 1895 weiter bis schließlich Bernhards gleichnamiger Sohn Bernhard die Werkstatt bis zur Schließung 1910 übernahm.³

Bei den Nachfahren Mittermaiers hat sich ein umfangreicher Werkstattnachlass erhalten. Die Bestände geben einen guten Einblick in die Werkstattorganisation und -praxis. Für die Ravensburger Fenster konnte die Entstehung von Auftragsbeginn bis Einbau nachvollzogen werden. Gleichzeitig gaben die Aufzeichnung wichtige Hinweise und Ergänzungen für die Bestandsuntersuchungen an den Fenstern.

1. Kontaktaufnahme und Beauftragung Mittermaiers

Zur Zeit der Entstehung der Ravensburger Fenster befand sich die Werkstatt auf dem Höhepunkt ihres Schaffens: Mit bis zu sechs Angestellten bewerkstelligte sie in dem Zeitraum von 1854 bis 1864 über 100 Fenster im In- und Ausland.⁴ In der Nähe von Ravensburg schuf Mittermaier 1859 die Neuverglasung der Evangelischen Kirche in Leutkirch und 1860 die Chorfenster in Pfrungen.

Den Umbau der Evangelischen Stadtkirche in Ravensburg leitete der Architekt und Bauinspektor Gottlieb Pfeilsticker, der ein Jahr vorher auch die Umgestaltungen in Leutkirch vornahm.

Von ihm stammt vermutlich auch die erste Kontaktaufnahme zu Ludwig Mittermaier. Ein Briefentwurf an die Ravensburger Kirchengemeinde hat sich erhalten,⁵ der Leutkirch als Referenzobjekt benennt, sowie einige Aquarellskizzen, die den potenziellen Auftraggebern als farbige Entwürfe vorgelegt wurden (Abb. 1).



Abb. 1. Links: Aquarellentwürfe zum Lutherfenster, ca. 1860, Privatbesitz.

Mitte: Karton zu Lutherfenster von Gustav König, 1860.

Rechts: Ev. Stadtkirche Ravensburg, Lutherfenster, sIX.

© I. Geiger-Messner, LAD.

In seinem Brief vom 7. März 1860⁶ bestätigt Pfeilsticker die Beauftragung Mittermaiers für die Gesamtverglasung der Kirche in Ravensburg. Er bittet Ludwig Mittermaier darum, ihm die Kartons oder Skizzen erst mal zu überlassen, um seine „Bettelwanderung“ zu beginnen. Diese Beauftragung hatte allerdings die Bedingung, dass „die Cartons zu den Bildern nur von Maler Celebritäten gefertigt werden“. Zur weiteren Organisation wird der Rechner der Baukasse beauftragt „alles festzustecken“ und der Bauführer damit „die Fenster mit Maaswerk genauest in ganzer u. echter Größe zu zeichnen“. Auch die Themen der Fenster wurden nun vorgegeben.

Die sogenannte „Bettelwanderung“ von Pfeilsticker war offensichtlich erfolgreich, wie die Stiftunginschriften an den Fenstern bezeugen. Eines davon – das Lutherfenster (sIX) – wurde von

² SPRINGER 1990, S. 244.

³ SPRINGER 1990 II, S. 371.

⁴ BIZZARRO 1983, S. 224, Abschrift von handgeschriebenen Glasplatten von T. Steinle 1955.

⁵ Ludwig MITTERMAIER, Tagebuch 1856, Privatbesitz, Transkribierung Birgit Tuchen.

⁶ Brief von Bauinspektor Pfeilsticker an Ludwig Mittermaier vom 07.03.1860, Privatbesitz, Transkribierung Susann Seyfert und Birgit Tuchen.

Pfeilsticker selber finanziert. Neben Ravensburger Familien gewinnt Pfeilsticker auch die Königin Pauline von Württemberg als Stifterin für das Fenster von Herzog Christoph (sXI).

2. Entwurfszeichnungen

Für die Ausführung der Kartonzzeichnungen konnte Mittermaier die geforderten *Maler Celebritäten* gewinnen: neben seinem langjährigen Freund Carl Christian Andreae aus Dresden übernimmt Gustav König aus München den Entwurf für vier der sieben Reformatorenfenster: Johannes Brenz, Martin Luther, Philipp Melanchthon und Ulrich Zwingli. Die Vorlagen für die weltlichen Herrscher König Gustav II. Adolf von Schweden, Kurfürst Friedrich III. von Sachsen, genannt Friedrich der Weise, und Herzog Christoph von Württemberg sowie die Entwürfe für die Chorverglasung stammt dagegen von Andreae.

Von diesen Entwurfskartons sind insgesamt fünf Originale im Privatbesitz erhalten: Ein Karton für Friedrich den Weisen von Andreae und alle vier Entwürfe von König mit Signaturen der Künstler und den Jahreszahlen. Zusammen mit den Entwürfen sendete König auch Begleitbriefe, die weitere Anweisungen zur Ausführung der Fenster enthielten. Drei von diesen Briefen haben sich ebenfalls bis heute erhalten.

Der Vergleich zwischen Kartons und ausgeführten Fenstern macht deutlich, dass sich die Werkstatt sehr eng an die Vorgaben der Entwerfer gehalten hat (Abb. 1).

3. Umsetzung der Entwurfskartons: Bleirisszeichnung

Auf einer Zeichnung, die einen interessanten Einblick in die Glaswerkstatt Mittermaiers gibt, ist die Verwendung der Kartons während des Herstellungsprozess zu sehen (Abb. 2).



Abb. 2. Werkstattzeichnung, unbekannter Autor, Privatbesitz. © I. Geiger-Messner, LAD.

Erst wurde ein maßstabsgetreuer Papierentwurf entsprechend dem Aufmaß des Fensters gefertigt, der die figürliche Darstellung der Kartons übernimmt. Dieser sog. Bleiriss wurde entsprechend dem Gesamtkonzept der Fenstergestaltung mit Bordüren, Stiftungsfeldern im Sockelbereich und Hintergrundgestaltung weiter ausgestaltet. Für die Ornamentik standen der Werkstatt verschiedene Vorlagen zur Verfügung. So ist bekannt, dass Prof. Eisenlohr aus Karlsruhe Mittermaier 1850 eine Anzahl seiner bisher erschienenen Ornament-Zeichnungen zum Gebrauch zusendete.⁷

⁷ Brief vom Verleger an Ludwig Mittermaier am 25.02.1850, Privatbesitz, Transkribierung Birgit Tuchen 2018.

Der Bleiriss, der die verschiedenfarbigen Gläser trennt, wurde versteckt in Faltenwürfen und entlang der Figuren bzw. der Ornamente angelegt, was verhältnismäßig große Glaszuschnitte zur Folge hat.

Im Vordergrund des Werkstattbildes ist eine Person mit dem Zeichnen eines Bleirisses beschäftigt. Hierbei werden sorgfältig die Trennungen der einzelnen Felder von Quereisen und die Aussparungen der Bleiruten gezeichnet.

4. Glaswahl und Glaszuschnitt

Dieser Bleiriss diente anschließend dem Glaszuschnitt. Überwiegend arbeitete die Werkstatt Mittermaier mit Weißglas, d.h. ungefärbten Hüttenglas von 1-2mm Dicke. Die wenigen verwendeten Farbgläser wurden hauptsächlich in den Hintergründen und vereinzelt auch in den Gewändern der Figuren verwendet. Auch Überfanggläser oder doppeltes Überfangglas sind überliefert, die dann entsprechend im Gestaltungsprozess ausgeschliffen oder geätzt⁸ wurden.

Die Ausführung des Glaszuschnitt wird von Max Mittermaier 1871 folgendermaßen beschrieben: „Ist der Carton fertig u. eingetheilt, so wird er oder wenn er zu groß ist, ein Theil davon auf die Werkbank gelegt u. werden die verschiedenen Gläser über ihm ganz genau nach den Linien geschnitten. In der Regel geschieht dies mit dem Diamant, doch läßt es sich auch mit sog. Sprengkohle vornehmen.“⁹

Wie bei Pfrungen überliefert, übernimmt der Glasermeister Hans Sturm den Zuschnitt. Es heißt dort: „Der Glaser, Meister Hurin, genannt Sturmio macht aber eine gewaltige Faust wegen der sakrisch großen Glastafeln, die dem Diamanten abscheulich zusetzen...“¹⁰ Die Qualität des Zuschnitts der sehr dünnen Gläser konnte die Untersuchung der Ravensburger Fenster bestätigen, an einigen sehr tiefen Kurven sind Spuren von einem feinen Kröseleisen sichtbar.

5. Glasmalerei und -technik

Die Arbeitsteilung in der Werkstatt Mittermaier wird in einem Brief an Andrae deutlich: „Nach der Jahreszeit erhält der Ornamentiker wöchentlich 3-5 fl, Logis, Morgen- und Mittagkost, aber nicht Abendessen... Er wird bei mir kein Glasmaler, alles Technische ist meine Sache, die streng vom Atelier gesondert. Die Herren malen mit Farben, die mit Ölfarben sich auftragen, ganz gemächlich an der Staffelei.“¹¹

Bei einem Spaziergang 1861 erwähnt Ludwig Mittermaier gegenüber Andrae seine „vier Mälerchen“.¹² Darunter wird Paul Miller von Billenhausen gewesen sein, der seit 1854 bei Mittermaier angestellt ist und die künstlerische Gestaltung und Maltechnik übernimmt. Von ihm sagt Mittermaier „eine einfache klare Natur von scharfem Blick und großer Begabung der Ausführung der Figuren und in Ornamentik ein reiches Kompositionstalent.“¹³ Albert Böhner aus München wird als Meister im Malen von gotischen Ornamenten benannt.¹⁴ Des Weiteren werden seine Schwager Joseph und Bernhard Mittermaier von Thannhausen erwähnt, die seit 1858 in der Werkstatt mitarbeiteten.

Interessant ist, dass sich diese hauptsächlich mit der Malerei an der Staffelei befassen, während sich Ludwig Mittermaier selbst um das „Technische“ kümmert. Damit sind sowohl das Anmischen der Farben¹⁵ als auch sämtliche Brennvorgänge gemeint. Ludwig Mittermaier beschäftigte sich als gelernter Maler und Anstreicher längere Zeit mit dem Farbmischen, bevor er sich der eigentlichen Glasmalerei zuwandte. Mit Karl Samuel Scheinert (1791-1868), einem befreundeten Porzellanmaler aus Dresden, hielt er während der Zeit einen regen Briefaustausch und wurde von ihm schließlich ermutigt, die eigene zeitintensive Farbherstellung aufzugeben, um sich mehr der Malerei zuzuwenden.¹⁶

⁸ Ludwig MITTERMAIER, Tagebuch 1856, Privatbesitz, Transkribierung Birgit Tuchen.

⁹ Abschrift von Max MITTERMAIER, Bernhard MITTERMAIER, *Die Glasmalerei*, Lauingen 1871, Transkribierung Johann Mittermaier, Privatbesitz.

¹⁰ Brief von Ludwig Mittermaier zu Andrae, Anfang Februar 1860, VAASEN 1997, S. 154.

¹¹ VAASEN 1997, S. 152, nachdem 1859 seine Angestellten zu den Waffen gerufen werden (mit Ausnahme von Miller) bat er Andrae in Dresden für ihn zu inserieren.

¹² Ebenda.

¹³ BIZZARRO 1983, S. 224, Abschrift von handgeschriebenen Glasplatten von T. Steinle 1955.

¹⁴ SPRINGER 1990, S. 243.

¹⁵ BIZZARRO 1983, S. 207.

¹⁶ VAASEN 1990, S. 229, 232.

5.1. Technische Herstellung der Farben

Vereinzelte Farbrezepte und Abhandlung zur Farbherstellung sind aus Ludwigs Hand überliefert. Alte und neue Glasmalerei untersuchte er genau mit Lupe und Mikroskop mit der Feststellung, dass die Schmelzfarben gebunden und nicht gelöst sind, d.h. „*die trockenen gepulverten Metalloxide wurden nur mit dem Schmelzmittel aufgetragen*“, was „*mehr oder minder trübe Resultate*“¹⁷ erzielt. Daher entwickelte Ludwig Mittermaier eine ‚neue Technik‘ indem der Fluss wieder mit den verschiedenen Metalloxiden zusammengeschmolzen wird, statt diese trocken miteinander zu vermischen.

Max Mittermaier hält fest, dass die Werkstatt Mittermaier insgesamt vier verschiedene Flüsse für Farben herstellte, die sie dann je nach Anforderung mit den verschiedenen Metalloxiden zusammenmischte.¹⁸ Diese Flüsse bestehen aus Quarz oder Kiesel mit Mennige und/oder Borax und einen Silberzusatz bei Purpur-Flüssen. Statt Quarz wurde in der Mittermaier Werkstatt Kiesel verwendet, da reiner Sand in der Gegend um Lauingen nicht vorkam.¹⁹

Den erhaltenen Aufzeichnungen ist zu entnehmen, dass die Metalloxide von der chemischen Fabrik Geitner & Company in Schneeberg eingekauft und in der Werkstatt dann modifiziert und weiterverarbeitet wurden.²⁰ Auch Farben der Meißner Porzellanmanufaktur bei Dresden, die zur Porzellanmalerei dienten, waren vorhanden und wurden verwendet bzw. nachgemischt. Aus den Archivalien geht ebenfalls hervor, dass das Kobalt für die Herstellung von Blau und Schwarz aus Fossum in Norwegen bezogen wurde.²¹

Bei der Herstellung von den Glasmalfarben unterscheidet Max Mittermaier 16 verschiedene Farben, darunter auch vier Schwarztöne. Diese wurden unterschiedlich, je nach Metalloid, hergestellt und mit dem Fluss zusammengeschmolzen. Je nach Vorderseiten- oder Rückseiten-Bemalung kamen verschiedene Flüsse zur Anwendung.²²

5.2. Malvorgang

Die Aufzeichnungen über Glasmalerei von Ludwig, Max und Bernhard Mittermaier geben Aufschlüsse über die Glasmalereitechnik der Werkstatt.

Es wird zwischen zwei Bindemitteln der Glasmalfarben unterschieden: Wasser in Kombination mit Gummi Arabicum und Terpentinöl bzw. Dicköl aus Terpentin. Auch venezianisches Öl und Copaivbalsam werden erwähnt und in Mischung mit Terpentinöl als Dicköl angewendet. Die Wasserfarben fanden bei größerer Ornamentmalerei Verwendung, während die Ölfarben bei kleinerer Ornamentik und figürlicher Malerei zum Einsatz kamen.

Je nach Anforderung kamen manche Glasstücke, wie Hintergründe und farbige Gläser, mit nur einem Brand aus²³ während andere, wie Inkarnate und Köpfe, mehrmalige Brände benötigten.²⁴

Zunächst wurden die Umrisslinien vom Bleiriss auf das Glas übertragen. Dazu kam eine ganz fein geriebene dünne schwarze Wasserfarbe zum Einsatz, die später zu feinen Linien ausradiert wurden. Bei den eingelagerten Ravensburger Feldern konnte eine rückseitige Vorzeichnung nachgewiesen werden (Abb. 3).

¹⁷ STEINLE 1955 in Bizzarro 1983, S. 222.

¹⁸ Abschrift von Max Mittermaier, Bernhard MITTERMAIER, *Die Glasmalerei*, Lauingen 1871, Transkribierung Johann Mittermaier, Privatbesitz.

¹⁹ BIZZARRO 1983, S. 93 – Tagebuchabschrift Ludwig Mittermaier; hier Brief an Herrn Scheinert.

²⁰ Abschrift von Max Mittermaier: Bernhard Mittermaier: *Die Glasmalerei*, Lauingen 1870, Transkribierung Johann Mittermaier, Privatbesitz.

²¹ VAASSEN 1990, S. 232.

²² KIELMANN/ SEYFERT/ WÖLBERT (dir.) 2019, S. 155 ff.

²³ Bernhard Mittermaier, 1885, Ansichten über die Glasmalerei, Transkribierung Johann Mittermaier, Privatbesitz.

²⁴ „...besonders das häufige Schmelzen machte bei den großen Flächen die Arbeit höchst langwierig. Der Kopf voran 11 mal im Schmelzofen, bis sie entsprechen.“ Brief an einen Baron, dessen Schloßkapelle 3 Fenster von Ludwig Mittermaier erhielt, BIZZARRO 1983, S. 211.

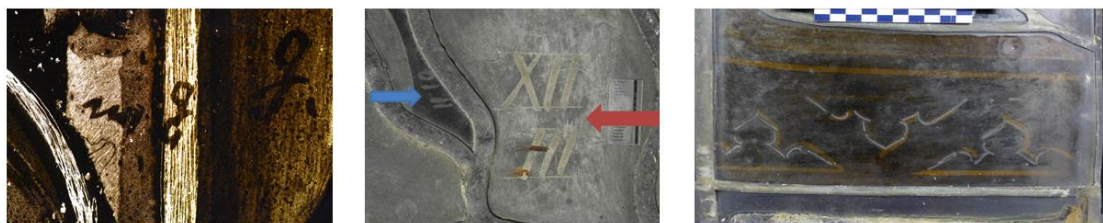


Abb. 3. Ev. Stadtkirche Ravensburg. Links: Ausschnitt aus sXII 3b, eingebrannte Malanweisungen; Mitte: Ausschnitt aus eingelagertem Feld K6 F21; blauer Pfeil: Felderkennzeichnung zur Zuordnung der einzelnen Glasstücke; roter Pfeil: Kaltmalerei mit Felderbezeichnung. Rechts: Ausschnitt aus eingelagertem Feld K13 F4, rückseitige Vorzeichnungen.
© K. Rahfoth, D. Kielmann, LAD.

Der Unterschied der beiden Malweisen besteht in dem nun folgenden ganzflächigen Überzug, der mal mit Wasser und mal mit Öl erfolgt. Bei den Inkarnaten wird ein Überzug mit einer Mischung von Eisenroth und etwas Schwarz erwähnt, während die Gewandteile mit Schwarz überzogen werden.

Bei beiden Techniken werden die Halbtöne als partieller Schattenauftrag in Öl ausgeführt. Nach dem Trocknen werden diese mittels Hölzer, stumpfen Pinseln oder Nadeln ausradiert, um Lichter zu erzielen.

Rückseitig wird Silbergelb bei den Nimben, Schmucksachen oder als Unterlage zu Rot, Grün oder Orange leicht aufgetragen und vertrieben. Auch einzelne Gewandfarben werden bei diesem ersten Mal-schritt angelegt. Außerdem gibt Max Mittermaier noch den Hinweis alle Inkarnate und Gewandteile, die beim ersten Mal nicht farbig gefasst wurden, mit einem weißen Mattüberzug zu versehen.

Jedes einzelne Glasstück wird entsprechend seiner Felderzugehörigkeit mit einer Buchstaben-Zahlen Kombination gekennzeichnet, um sie nach dem Brandvorgang wieder dem richtigen Feld zuordnen zu können. (Abb. 3).

Nur die Inkarnate und wenige Gewandteile werden einem zweiten oder mehreren Bränden unterzogen, da hier weitere Farbaufträge nötig sind.

Bei den Inkarnaten wird rückseitig ein flüssiges Rosenpurpur aufgetragen, während vorderseitig ein weiterer Farbüberzug aufgetragen wird. Zwischen heller und dunkler Haut wird unterschieden, indem man den Farbauftrag mal dicker bzw. dünner gestaltet.

Jene Gewandstücke, die beim ersten Malvorgang mit Silbergelb hinterlegt wurden, werden nun mit den entsprechenden Lokaltönen zu Grün oder Purpur ergänzt.

Zur Malweise gibt Max Mittermaier noch den Hinweis, möglichst viele der Glasstücke auf der Staffelei zusammenzustellen. Im nächsten Schritt wird eine provisorische Verbleiung der Glasstücke vorgesehen, die nur an den Ecken verlötet werden, so dass sie beim Malvorgang zusammenhalten. Dazu wird ein schmaleres Blei verwendet als bei der Endverbleiung, um größtmögliche Glassichtigkeit zu erzielen.

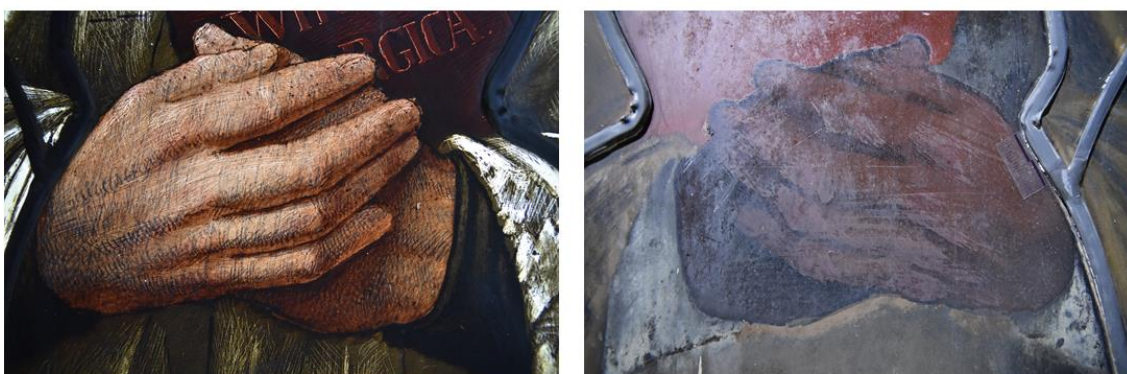


Abb. 4. Ev. Stadtkirche Ravensburg, Ausschnitt aus dem Brenz Fenster, sXII, 3b, Malereidetail.
Links: Vorderseite, Durchlicht; Rechts: Rückseite, Auflicht. © K. Rahfoth, D. Kielmann, LAD.

Bei diesem letzten Malschritt geht es um die Feinmodellierung der Schattenbereiche. Hierbei werden einzelne Bereiche mit unterschiedlichen Farben in Strichmanier modelliert oder teilweise als abermalige Überzüge aufgetragen, die abermals ausradiert werden. Dabei kommen bei den Hintergründen und

Gewandteilen eher schwarze Ölfarbe und Eisenrot zu Verwendung während bei den Inkarnaten mehrere Farben zum Einsatz kommen (Abb. 4).

6. Verbleiung

Nach dem letzten Brand werden die Glasstücke entsprechend dem Bleiriss zu einzelnen Feldern verbleit.

An einigen Fenstern Mittermaiers hat sich die Originalverbleiung erhalten. So auch bei den eingelagerten Feldern in Ravensburg sowie in der Kirche St. Kilian in Bieringen.

Demnach wurde für die Binnenzeichnung 6mm Blei verwendet und 11mm für die durchlaufenden waagerechte Bleie unter den Windstangen. Als Randblei fungiert ein 6mm gefaltetes Blei. Einige sehr schmale Sprungbleie gehören sehr wahrscheinlich ebenfalls zu dem Originalbestand. Die Kernhöhe sämtlicher Bleie ist 2mm hoch und passt sich damit dem sehr dünnen Glas von 1-2mm an. Die Bleihaften, die die Windstangen an den Glasfeldern befestigen, sind 4mm breit und zu Bleirosen gedreht. Die noch vorhandenen originalen Windstangen sind geschmiedete Eisen, die an den Enden spitz zulaufen. Sie haben einen Durchmesser von 9mm und entsprechen der Breite der jeweiligen Felder. Die Verbleiung ist sehr sorgsam verzinkt und mit flachen Lötstellen ausgeführt.

Die Fenster in Bieringen zeigen auf der Innenseite ein geschwärztes Bleinetz. Dazu findet sich folgende Aussage Mittermaiers: *„die Windeisen dürfen auf keinen Fall an die gegen das Innere der Kapelle gerichtete Seite der Fenster, wo die Bleie alle geschwärzt sind befestigt werden“*.²⁵

Trotz dieses Hinweises wurde in Ravensburg anders verfahren. Die Bleihaften befinden sich auf der Innenseite der Felder und auch bei der Schwärzung des Bleinetzes wurden die waagerechten Bleie, die durch die Windeisen verdeckt sind, ausgelassen.

7. Transport und Einbau

Bei Pfrungen ist aus den Quellennachweisen bekannt, dass Ludwig Mittermaier selber mit einem Gehilfen den Transport der Kisten sowie auch die Aufsicht beim Einbau übernahm. Er bittet die Gemeinde darum, dass er mit einem *„Fuhrwerk mit etwas Stroh u. einigen Stricken zum Festbinden der Kisten“*²⁶ am Bahnhof Aulendorf abgeholt wird.

Wie mehrere Quellen belegen wird der Einbau nicht von der Werkstatt Mittermaier ausgeführt. Er stellt allerdings eigenes Personal zu Verfügung, die vor Ort die Handwerker anleiten und einweisen. So auch in Ravensburg: *„Das Einsetzen der Fenster besorge ich nicht, mit dem ersten Figurenfenster werde ich jedoch ohne weitere Vergütung mit meinem Glaswerkführer kommen u. dadurch den Glasern in Ravensburg Gelegenheit geben, das Einsetzen zu sehen“*.²⁷

Für den Einbau der Fenster in Gersthofen sind die Anweisungen von Ludwig Mittermaier erhalten.²⁸ Demnach ist den Feldern eine genaue Papierzeichnung als Schablone für die Herstellung und Anbringung bzw. Positionierung der Quereisen beigelegt. Die Bezeichnungen auf den Feldern und Windeisen findet sich ebenfalls in der Zeichnung an entsprechender Position wieder, um den korrekten Einbau zu gewährleisten. Bei den eingelagerten Feldern in Ravensburg haben sich diese Felderbezeichnungen als weiße Kaltmalfarbe erhalten (Abb.3).

Entsprechend den Positionen sollen die Felder dann „einprobiert“ werden: *„Sind sie etwas zu groß, kann etwas wenig vom Blei abgeschnitten werden und wenn zu klein, ein Blei als neuer Rand noch hinzugeführt werden, doch sind dies äußerste Nothbehelfe, die nicht viel vorkommen sollen, wenn die Schienen gehörigen Spielraum haben“*.²⁹

Die Schrauben zur Befestigung sind gut zu ölen, während die Deckschienen einen Firnis als Rostschutz erhalten sollen. Zu guter Letzt gibt er noch den Hinweis, dass der Glaser die Schrauben nicht zu fest

²⁵ Brief an einen Baron, dessen Fenster seiner Schlosskapelle unterwegs sind, 1. September 1855, BIZZARRO 1983, S. 208ff.

²⁶ *„Der Fuhrmann wird uns leicht an den Kisten erkennen, die als unser Gepäck ausgeladen werden.“* Brief vom 25.09. 1868 von Ludwig Mittermaier an die Gemeinde in Pfrungen, Diözesanarchiv Rottenburg-Stuttgart, Pfrungen 1+2 DAR G 1.1 D 18.1, Transkribierung Birgit Tuchen.

²⁷ Ludwig Mittermaier, Tagebuch 1856, Privatbesitz, Transkribierung Birgit Tuchen.

²⁸ Wie Anm. 25.

²⁹ Ebenda.

anziehen soll, da Glasbruch zu befürchten wäre. „Daß mit den höchsten Feldern mit dem Einsetzen begonnen und mit den letzten, untern beschlossen werde, ist wohl nicht zu erinnern nöthig“.³⁰

8. Vergütung und Garantie

Laut dem Auftragsbuch von Ludwig Mittermaier von 1856 wird eine Vorschusszahlung bei Genehmigung der Entwürfe und danach gefertigten Kartons erwartet. Die übrige Summe wird mit der Fensterlieferung abgerechnet. Mitinbegriffen in den Preis sind die Glaser aus der Werkstatt Mittermaier, die den Einbau des Fensters leiten. Zusätzliche Kosten entstehen durch die Gehilfen beim Einbau vor Ort, Änderungen am Eisenwerk und Gerüst sowie Transportkosten.

Nur bei wenigen Fenstern hat sich auch eine Bepreisung der Fenster erhalten. Die Preise für die Fenster sind gestaffelt: ornamentale Fenster sind günstiger als figürliche. Wenn jedes einzelne Fenster individuell gestaltet werden soll, wird es teurer. Ebenso sind die Kosten abhängig von der Größe der Fenster und Entwurf durch einen Künstler.

Mittermaier verwendete, ebenso wie andere Werkstätten, Kartons durchaus mehrfach. Ungewöhnlich ist, dass er die Künstler der Kartons dann ein weiteres Mal bezahlte.³¹

Gelegentlich gab es auch Trinkgeld. Der Stiftungsrat der Gemeinde in Pfrungen war besonders angetan von dem Ergebnis der Glasmalereien und zahlte Mittermaier zusätzlich 7 Gulden.³²

Mit dem Vertrag für die Erstellung der Leutkircher Fenster gibt Ludwig Mittermaier eine Haltbarkeitsgarantie der Fenster von 10 Jahren, da die Sonne, Luft und Regen keinen Einfluss auf die aufgeschmolzenen Farben haben. Allerdings gilt dies nicht bei Naturereignissen oder „Frevel durch Menschenhand“.³³

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³⁰ Ebenda.

³¹ ANDREÄ 1864, S. 133.

³² Entschluss des Stiftungsrat der Gemeinde Pfrungen am 02.10. 1860, Diözesanarchiv Rottenburg Stuttgart, Pfrungen 1+2 DAR G 1.1 D 18.1, Transkribierung Birgit Tuchen.

³³ Ludwig MITTERMAIER, Tagebuch 1856, Privatbesitz, Transkribierung Birgit Tuchen.

3.3

Die Glasmalereien der Liebfrauenkirche aus Oberursel im Taunus. Eine Betrachtung der Fenster von Giselbert Hoke aus kunst- und restaurierungs technologischer Sicht

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Markus Kleine, Steffen Holtmann

The Stained-Glass Windows in the Liebfrauenkirche in Oberursel im Taunu: A Look at Giselbert Hoke's Windows from an Art and Restoration Technology Perspective – Abstract

The Austrian Giselbert Hoke (12.9.1927–18.4.2015) was a versatile artist and primarily concerned with frescos and oil paintings. Beyond that, he intensely engaged in glass paintings as of 1958, particularly for

churches in Austria and Germany. Through windows from the Liebfrauenkirche in Oberursel, his glass paintings are being presented, focusing specifically on the character of his painting as well as the use of airbrush-painting.

In addition to that, the work on the windows is being presented and discussed based on examples to demonstrate the conservation concept.

Die Glasmalereien der Liebfrauenkirche aus Oberursel im Taunus. Eine Betrachtung der Fenster von Giselbert Hoke aus kunst- und restaurierungs-technologischer Sicht – Zusammenfassung

Giselbert Hoke (12.09.1927-18.04.2015¹) war ein vielseitiger österreichischer Künstler, der sich über seine Kunst in der Wandmalerei und Ölmalerei seit 1958

auch intensiv mit der Glasmalerei beschäftigte. Anhand der Fenster aus der Liebfrauenkirche in Oberursel/Taunus wird seine Glasmalerei vorgestellt. Das Augenmerk liegt dabei auf seiner Malerei und der Anwendung der Airbrush-Technik.

Darüber hinaus wird die Restaurierung der Fenster anhand von Beispielen erläutert und diskutiert.

Le vitrail de la Liebfrauenkirche d'Oberursel-im-Taunus. Un regard sur les fenêtres de Giselbert Hoke du point de vue de la technologie de l'art et de la restauration – Résumé

L'artiste autrichien Giselbert Hoke (12.09.1927-18.04.2015) était un artiste polyvalent qui était aussi profondément impliqué dans le vitrail depuis 1958 en

plus de son activité dans la peinture murale et la peinture à l'huile. Ses vitraux sont présentés sur les fenêtres de la Liebfrauenkirche à Oberursel / Taunus; avec un accent sur sa peinture et l'application de la technologie aérographe. En outre, la restauration des fenêtres est expliquée et discutée à l'aide d'exemples pour mettre en évidence le concept de conservation.

Der vorliegende Aufsatz beschäftigt sich mit den Glasmalereien der Liebfrauenkirche in Oberursel /Taunus. Ausgehend von Einblicken in die ausgeführten Konservierungs- und Restaurierungsmaßnahmen wird auch die angewandte Glasmaltechnik Giselbert Hokes und er selbst als Künstler dargestellt.

Zum Kirchengebäude

Der Blick auf das denkmalgeschützte Kirchengebäude von außen verrät zunächst nur wenig über die Glasmalereien Hokes. Durch die Schutzverglasung aus einem Kathedralglas-Isolierverbund wird der Blick auf die Bleiverglasungen größtenteils verwehrt. Erst im Inneren erschließt sich der Grundriß des Gebäudes und mit ihm die Anordnung der 16 mit Glasmalereien geschmückten Fenster.

„Der Grundriss der Kirche stellt ein gleicharmiges Kreuz dar. Drei der Kreuzarme sind von der Gemeinde gefüllt. Der vierte Arm fasst die große Orgel und den Platz für den Chor. Der Altar steht in der Vierung, um drei Stufen erhöht. Die Konchen in den Kreuzungswinkeln ergänzen den Kreuzgrundriss zum Symbol der Rose und greifen so das Patrozinium der Kirche auf: Maria, die "rosa mystica", die geheimnisvolle Rose, die höchste Lobpreisung Gottes. Die drei Schiffe der Kirche schließen die Gemeinde zu einem großen, offenen Ring zusammen, der um den Altar steht. Sie bildet, wenn sie zusammentritt, den offenen Ring, die Urgestalt der Orante-Haltung, die der Priester heute noch einnimmt bei den Gebeten, die er spricht. Der Chorraum unterbricht diesen Ring, hier tritt das unendlich Offene in den Ring der Gemeinde.

Unverputzter Backstein und Sichtbeton bestimmen die Wandflächen der Kirche. Der Backstein hat ein schönes, mosaikartiges Farbenspiel und bestimmt mit seinem Rot den Farbton des Raumes. Die vier tragenden Mittelpfeiler sind, ebenso wie die Rippendecke, aus Beton. So entsteht eine Materialeinheit am Bau von Backsteinmauerwerk und Beton.“¹

¹ <http://www.kath-oberursel.de> [accessed January 2020].

Die Planung für diesen Kirchenneubau beginnt 1961. Im Einvernehmen mit der Bischöflichen Behörde und dem Kirchenvorstand von St. Ursula wird Prof. Dr. Ing. Rudolf Schwarz als Kirchenbaumeister gewonnen. Es soll eine „Marienkirche“ nach dem Vorbild der Trierer Liebfrauenkirche entstehen. Zur Architektur der Kirche schreibt Maria Schwarz, seine Gattin, die mit an den Arbeiten beteiligt war: *„Ein Kirchbau soll Abbild seines Schutzpatrones sein. Für mich war es eine besondere Freude, dass dieser große Auftrag eine Liebfrauenkirche werden sollte“.*

Die allererste Arbeit nämlich, die ich mit meinem Mann ausführte, war die Planung der Inneneinrichtung der im Kriege zerstörten Liebfrauenkirche in Trier gewesen. Bei dieser Arbeit hatte ich gelernt, dass ein Bau mehr ist als die Hülle für das Tun des Menschen, daß er Abbild sein kann einer Form des Lebens, einer Ordnung in der Welt, daß er sogar Abbild und Inkarnation des Menschen sein kann... Liebfrauen (Trier) ist in drei Zonen übereinander gebaut, in der untersten ist die Rose, die in zwölf Konchen erblüht aus dem Mittelgeviert, um das vier starke Bündelpfeiler stehen; dann wird es zum Kreuz, und oben ist es Kuppel. Rose, Kreuz und Kuppel sind aufeinandergestellt.“²

Maria Schwarz übernimmt nach dem Tod ihres Mannes im Herbst 1961 die Ausführung seiner Pläne:

„Die Kirche, die hier entstanden ist, hat die Liebfrauenkirche zu Trier zur Mutter, das kann man im Grundriss deutlich ablesen, aber sie wurde doch ein ganz eigener Bau, vielleicht eine bescheidene, einfache Tochter.“³

Viele Beschreibungen des Kirchenbaus sind in der Literatur zu finden. Darüber hinaus findet der Leser auch Informationen über die Innenausstattung, doch die 16 Fenster werden nur anreißend thematisiert und ihre Gestaltung nur vage angedeutet. So liest man beispielsweise:

„Die Fenster der Liebfrauenkirche des Kärntner Künstlers Giselbert Hoke passen sich der Grundstruktur und Symbolik der Kirche an, die aus der Natur genommen sind. Sie greifen das Lob Gottes aus der Schöpfung auf, wie es sich im alttestamentlichen Lobpreis der Jünglinge im Feuerofen (Dan 3) darstellt. Die Glasgemälde der Fenster verwenden volle Farben, die in lichtspendendes Weiß und in zarte gelbe, rote und blaue Farben ausstrahlen.“⁴

Giselbert Hoke – Eine kurze Biographie

Giselbert Hoke (12.09.1927* 18.04.2015†) war ein vielseitig schaffender, österreichischer Künstler, der 1973 von sich behauptet, bis zu diesem Zeitpunkt drei Leben gehabt zu haben.

Sein erstes Leben, war bestimmt von seiner Kindheit, der Schule und seiner Arbeit in einer Kunstschmiede. Das zweite Leben begann mit dem Verlust seines rechten Arms im zweiten Weltkrieg. Er beginnt 1946 mit dem Studium an der Akademie der Bildenden Künste bei Robin C. Andersen und an der Universität Wien. Zu seinen Kommilitonen zählen u.a. Schönwald und Hundertwasser.

„... An die Stelle der Schmiede (trat) das Atelier. An Stelle des Eisens die Farbe,“⁵ schreibt Hoke über sein neues Leben, in dem er sich fortan überwiegend mit Fresken und Wandmalereien beschäftigt, mit Ölbildern und Reisen nach Italien und Sizilien. Die Arbeiten an den Entwürfen für die Klagenfurter Bahnhofsfresken beginnen - sein erster Wettbewerb (1950). 1953 erhält er ein Paris-Stipendium. Berührt von der „Begegnung mit der großen französischen Malerei“ schreibt er: *„Hier wuchsen mir die ersten Flügel. Kunst, Liebe, Geist und Freiheit – Elend und Verwirrung brachten mich zu mir selbst. Es war, als wäre ich aus einer tiefen Ohnmacht erwacht. Als ich die Stadt verließ, war mir sehr elend zumute.“⁶*

1954 heiratete er die Malerin Margarethe Scholz aus Südtirol, mit der er vier Kinder haben wird. Ein herber Niederschlag in seiner künstlerischen Tätigkeit veranlasst ihn 1956 Klagenfurt zu verlassen. Nachdem er, inspiriert durch Picasso, sechs Jahre auf einer Gesamtfläche von fast 300 Quadratmetern die zwei Fresken (Wand der Kläger und Wand der Angeklagten) im Klagenfurter Bahnhof, malte, geriet er in die Kritik der Bevölkerung, der diese Bilder „viel zu modern“ waren.

Bereits seit 1958 beschäftigte sich Hoke auch mit Glasmalereien, Gouachen, Porträtmalereien und der Malerei mit Öl. Das erworbene Schloss Saager bei Grafenstein in Kärnten wurde erweitert, indem Werkstätten für Lithographie, Glas- und Emailarbeiten errichtet wurden. Von nun an beschäftigte er sich

² Ulrich KREBS, *Kirchen im Hochtaunuskreis*. Bad Homburg 2006, S. 56–57.

³ <http://www.kath-oberursel.de> [accessed January 2020].

⁴ <http://www.kath-oberursel.de> [accessed January 2020].

⁵ Margarethe ROSEL, *Giselbert Hoke, Gärten*, Wien 1973 (ohne Seitenzahlen).

⁶ Ebenda.

auch mit der Architektur. Hoke beschreibt dieses nun dritte Leben: „Im dritten Leben gab es nichts Wichtigeres als den Raum – die Freiheit tun zu lassen, ohne den Nachbarn zu stören oder durch den Nachbarn gestört zu werden (...). Ich erwarb Schloss Saager am Fluß inmitten der Berge und Wälder Kärntens. Ich lernte bauen und konnte mit Hilfe eigener Werkstätten der Architektur an vielen Orten das geben, was ihr fehlt: die lebendige Farbe.“⁷

Seit 1961 lebte und arbeitete Hoke dort und vergrößerte sukzessive die Werkstätten. Zuletzt 1998 entstand das „Werkhaus“, ein Projekt, um zu Lebzeiten des Künstlers, aber auch aktuell Interessierten die „Grundlagen der konstruktiven abstrakten Malerei erfahrbare zu machen und den Mut zum Experiment und zur persönlichen Weiterentwicklung zu stärken.“⁸

Die Mitarbeiter, mit denen er dieses Projekt aufbaute und die ihn begleiteten, kannte er aus seiner Lehrtätigkeit als Universitätsprofessor an der Technischen Universität Graz, Fakultät für Architektur, zu der er 1974 berufen wurde. Hier entwickelte und führte er das Institut für künstlerische Gestaltung während der nächsten 20 Jahre. Hinzu kam 1979 die Berufung als Lehrer an die Internationale Sommerakademie in Salzburg.

Seine Werke sind in zahlreichen Ausstellungen zu sehen, u.a. in der Albertina in Wien, Berlin, Tokio, MMKK Klagenfurt, Villa Manin und Privatgalerien in Österreich, Schweiz, Italien und Peru. Seine glasmalerischen Werke führte er u.a. für Kirchenbauten des bereits erwähnten Rudolf Schwarz aus, der als einer der führenden Architekten auf dem Gebiet des Kirchenbaus des 20. Jahrhunderts gilt. Hier zu nennen wären die Verglasungen für die Kirche St. Florian in Wien (1962) und die Glasmalereien der Liebfrauenkirche in Oberusel im Taunus (1967). Darüber hinaus entstanden Werke für das Krematorium in Wien (1976) und für die Grabeskirche St. Bartholomäus in Köln Bickendorf (1978).

Zur malerischen- und glastechnischen Gestaltung der Fenster

Die Fenster der Liebfrauenkirche wurden im Juni 2019 demontiert und befanden sich bis November 2019 in der Restaurierungswerkstatt der Glasmalerei Peters, Paderborn. Betreut wurden die Arbeiten durch das Büro Rauch.⁹

Im Folgenden werden die Informationen, die über die Glasmalereien während der Restaurierung gewonnen werden konnten, vorgestellt. Neben dem Versuch, den Glasmalereien genauer nachzuspüren, was nur durch den Blick ins Detail möglich ist, werden im Anschluss daran exemplarisch Problemstellungen, die während der Restaurierungsphase auftraten, dargestellt.

Acht Fensterpaare sind es, die Gieselbert Hoke in seiner Werkstatt im Schloss Saager bei Grafenstein in Kärnten entwarf und ausführte. In jedem der vier Kirchenarme befinden sich vier Fenster, als aufeinanderliegende Fensterpaare gegenübergestellt (Fig. 1).

Die erste, detaillierte Sichtung der Glasmalereien nach dem Ausbau erstaunte, nicht zuletzt aufgrund der malerischen Kombination aus Überzugstechnik und Airbrush-Technik sowie der

eindrucksvollen Farbschichtungen. Zudem zeichneten sich die konservatorischen Eingriffe vorangegangener Maßnahmen ab, die in der Ansicht im eingebauten Zustand optisch versteckt blieben. Vorhandene

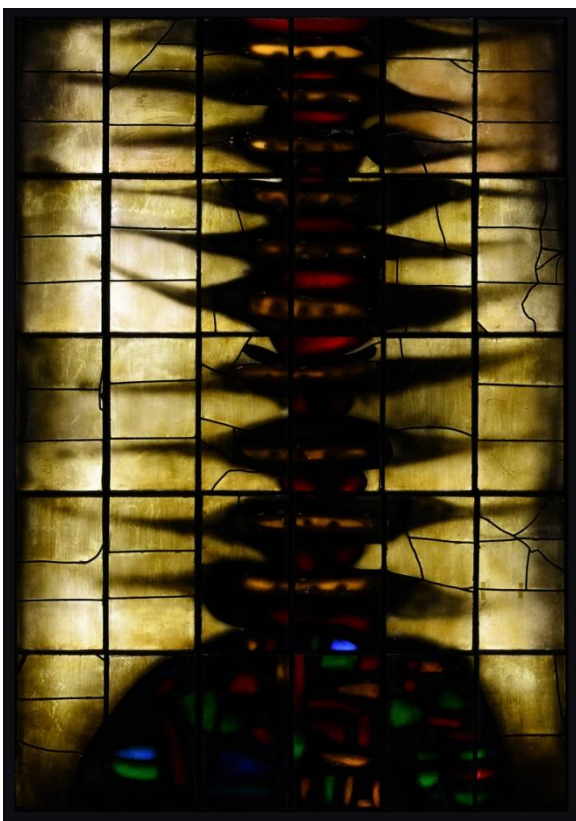


Fig.1 Oberusel / Taunus, Liebfrauenkirche,
Gesamtaufnahme Fenster sIV, G. Hoke, 1967.
© Glasmalerei Peters GmbH, Paderborn.

⁷ Ebenda.

⁸ www.hoke-werkhaus.at [accessed December 2019].

⁹ Dr. Ivo Rauch, Sachverständiger für Kunst und Denkmalpflege, Koblenz.

Ergänzungen hingegen, die bereits im eingebauten Zustand in Erscheinung traten, konnten nun aus der Nähe begutachtet werden. In der Gesamtansicht der Fenster ist festzustellen, dass Hoke zwei gestalterische Techniken der Glaskunst miteinander kombinierte: Das Farbmosaik und die Malerei auf weißem Glas.

In der Farbgebung intensiv, erscheinen die kleinteiligen Verdichtungen der Partien, in denen Hoke das Farbmosaik anwandte. Mit leuchtenden Antikgläsern schuf er kleine Inseln im großen Ganzen, die im klassischen Dreiklang rot, gelb und blau leuchten. Die Bemalung indessen ist zurückhaltend. Schwarzlot wird in Airbrush-Technik anlaufend schattierend aufgetragen, wodurch jedes dieser Glasstücke für sich das Durchlicht bricht. Dem Glaszuschnitt folgend verbinden 10mm breite Bleiruten die Farbstücke. Die schwarzen Umrisse der Bleie fügen sich ein, in das zum Rand der Glasstücke dichter werdende Schwarzlot. Dennoch verlieren die Antikglasstücke ihre charakteristische Eigenheit, im Sonnenlicht ihre Farbkraft zu entfalten, nicht. Jedoch scheinen diese Bereiche, speziell in zwei Fenstern (sIII und sIII¹⁰) Hoke Probleme bereitet zu haben. Es sind innenseitige Übermalungen vorhanden, die die gespritzte Konturfarbe mit Kaltmalfarbe überdecken. Hoke hat bereits nach der Verbleiung die korrigierende Übermalung ausgeführt, in dem er mit einem Pinsel diese schwarze Acrylfarbe auftrug. Auch auf den Bleistegen haftete die Kaltfarbe. Die Kaltfarbe überdeckt das Schwarzlot, in Bereichen jedoch, in denen sie sich inzwischen gelöst hat, ist der Zustand der Schwarzlotmalerei ersichtlich. Die Korrekturen findet man in Schwarzlotpartien, die während des Einbrennens aufgeköcht sind: Das Schwarzlot ist verkrustet und mit Blasen durchzogen. Im Durchlicht erscheint es löchrig, die gewünschte Deckkraft wurde nicht erreicht, was wiederum bedeutet, dass die anlaufende Schattierung der Gläser hier ausblieb. Mit der Kaltbemalung konnte Hoke das aufgeköchte Schwarzlot gezielt verdichten und die anlaufende Schattierung wiederherstellen. Mit derselben Kaltfarbe signierte Hoke seine Glasmalereien¹¹ (Fig. 2).

Die Signatur ist nur fragmentarisch vorhanden. Das Feld auf dem er signierte wurde ebenfalls neu verbleit und eines der Glasstücke ersetzt.¹² Hinzu kommt, dass die Kaltfarbe nicht mehr vollständig erhalten ist, einzelne Abschnitte der Schrift haben sich von der Glasoberfläche gelöst.¹³

Lesbar ist folgender Wortlaut: „*Schloss Saager. Grafenstein gemalt 1967 ... SII Po.*“

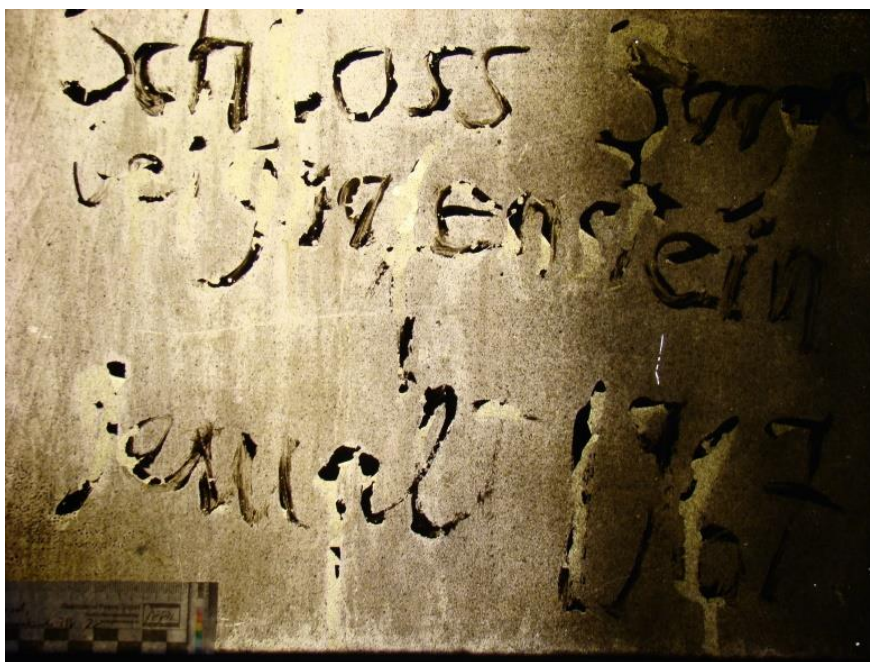


Fig. 2. Oberusel / Taunus,
Liebfrauenkirche,
Signatur des Künstlers,
G. Hoke, 1967.
© Glasmalerei Peters
GmbH, Paderborn.

¹⁰ Nach dem Nummerierungssystem des CVMA.

¹¹ Deshalb ist die Eventualität, die korrigierende Kaltmalfarbe sei nach Hoke aufgetragen worden, entkräftet.

¹² Die Signatur befindet sich auf dem Feld sIV 2c.

¹³ Die gelöste Kaltbemalung wurde durch das Acrylat Paraloid B72 gefestigt, gelöst in Ethylacetat 2%ig. Die Verunreinigungen, die auf der Farboberfläche und jene, die sich unter den hochstehenden Schollen befanden, wurden so gut wie möglich, entfernt. Unter Zuhilfenahme von beschichteter Hostphanfolie wurden zunächst die hochstehenden Schollen niedergelegt und anschließend das Festigungsmittel eingebracht. Die gefestigten Kaltbemalungsbereiche wurden abschließend noch einmal mit dem Heizspatel geglättet.

Im völligen gestalterischen Kontrast zu den Farbmosaiken stehen hingegen die Glasflächen, in denen das weiße Glas als Grundlage der Malerei dient. Hier dominieren nun unbunte, stille Töne die Fensterflächen. Hoke hat auch in seinen Ölbildern diese unbunten Farbwerte verwendet. Weiland Schmied schreibt über die Farben des Künstlers und berichtet, dass es „*vor allem Erdfarben und Grün in dunklen Variationen*“, seien, „*aber vor allem immer wieder das Braun ist, gegen dessen Kraft alle anderen Farben in Hokes Bilder ankämpfen.*“¹⁴

Nicht nur die Farbe, auch das Material Glas erfährt eine gänzlich andere Bedeutung, denn es wird zur Leinwand für Farbschichtungen, die in kombinierten Applikationstechniken aufgetragen werden.

Hierbei unterscheidet Hoke zwischen zwei Farbwerten für den Hintergrund, die er in den Fenstern eines Kirchenarms gegenüberstellt: Grün und Violett. Diese Farbwerte sind es, die die Fenster im Grundton dominieren und nicht weniger Einfluss auf die Präsenz haben, als die thematische Symbolik der Fenster. Sie wirken trotz ihrer Farben monochrom.

Als Basis dienen großteilige Zuschnitte von weißen Antikgläsern, die größten Glasstücke messen 30 × 45cm. Sie sind rückseitig weiß oder grau mattiert, nicht gleichmäßig, sondern mit breitem Pinselduktus. Durch den rechteckigen Zuschnitt entsteht eine Rasterung des Fensterrisses, wahrnehmbar durch den Bleiverlauf. Die Rasterung wird jedoch durch die überwiegend dichte Malweise zurückgedrängt und ist nur hintergründig erkennbar.

Die Malerei ist aufwendig und von experimentellem Charakter, kein Glasstück gleicht dem anderen. Es gibt Glasstücke die scheinbar nebeneinanderliegend großflächig bemalt wurden, erkennbar anhand der durchgehenden Pinselführung. Andere wiederum sind Einzelanfertigungen, die Malerei beschränkt sich nur auf die jeweiligen Einzelstücke, die verstreut in das Fenster eingebunden werden.

Betrachtet man das Grün im Detail, leuchten Farbkombinationen, die in Lasuren übereinandergelegt sind. Hoke beginnt mit Silbergelb, gleichmäßig aufgetragen erhält das weiße Glas hierdurch eine leuchtende, warme Lasur. Diesem wird durch die nächste Farbschicht in Form einer graugrünen, transparenten Schmelzfarbe ein kalter Ton entgegengesetzt. Diese Schichtung scheint Hoke als Grundkolorit gewählt zu haben, denn es begegnet dem Betrachter in den „grünen“ Fenstern durchgängig.

Die folgenden Farbschichten sind prägend für die Lichtstreuung. Mit oder durch den Auftrag deckender, unterschiedlich gefärbter Überzugsfarben in braun oder grün bilden sich nun unterschiedliche Transparenzgrade. Hierdurch wird das Durchlicht gezielt geführt, dem Grundkolorit Variationen zugefügt, es wird dynamischer. Diese Farbschichtungen brauchen jedoch intensives Sonnenlicht um aktiviert zu werden, nicht zuletzt aufgrund des beherrschenden Brauns, das für die darstellende Malerei verwendet wurde und sich wie dunkle Schatten im Fenster ausbreitet. Die Schatten sind bestimmend für jedes der 16 Fenster, ihre Silhouetten wandern mal schemenhaft mal konkret dargestellt über das Glas. Abermals verwendet der Künstler hier zur glasmalerischen Umsetzung die Spritztechnik. Bestimmend sind auch hier wieder die auslaufenden Schattierungen, durch die Hoke die gespritzten Farben gleichmäßig in den Hintergrund einfließen lässt. Hokes Art, gleichmäßig verlaufende Schattierungen durch die Anwendung der Spritztechnik auf Glas zu verwirklichen, ist eines der frühesten Beispiele dieser Art. Inwieweit Hoke diese Technik auch für seine früheren Arbeiten in Glas anwandte, wurde im Rahmen dieses Projekts nicht untersucht. Jedoch erahnt man bei der Betrachtung von Fotografien seiner Werke, dass dies der Fall ist. Ein Beispiel zum Vergleich: Für die authentische Umsetzung von Johannes Schreiers Brandcollagen in das Glas reichten die herkömmlichen Mittel wie Stupfen und Radieren nicht. Sie führten nicht zu den erwünschten Erfolgen. Hierfür wurde, laut Wilhelm Derix, 1967 erstmals die Airbrush-Technik in die Glasmalerei eingeführt.¹⁵ Es bleibt daher zu untersuchen, ob Gisbert Hoke hier eine Vorreiterrolle zugeschrieben werden darf, wobei die bisherigen Befunde darauf hindeuten.

Fast farbenfroh, auch farblich variierender, erscheinen dagegen die violetten Fenster.¹⁶ (Fig. 3). Der maltechnische Aufbau ist identisch. Auch hier sind die großflächigen Schatten mit brauner, deckender Farbe und die Malerei auf farbigem Antikglas mit schwarzer, deckender Farbe aufgespritzt worden. Nur

¹⁴ Weiland SCHMIED, *Hoke*, Academia Galerie, Salzburg, 1983 (ohne Seitenangabe).

¹⁵ Wilhelm DERIX, „150 Jahre und immer noch Lust auf Glas – wie kann man sich das erklären?“, in *Festschrift zum 150-jährigen Firmenjubiläum*, Taunusstein, 2016, S. 58-63.

¹⁶ Es kommen vereinzelt Ausnahmen vor, in denen Hoke innerhalb des Fensters die beiden Farbthemen miteinander vermischt.

die Färbung der großen, weißen Glasstücke erfolgte mit anderen Farben, nämlich in rosa, violett und blau. Der Auftrag der Schmelzfarben ist nie gleichmäßig. Immer verläuft er vom zarten bis zum intensiven Tonwert und steigert somit die Farbwirkung als solche, umspielt aber gleichzeitig die Schattenmalerei der Darstellung. Zur Intensivierung lilafarbener Bereiche wurde zusätzlich eine weitere Schicht lilafarbener Schmelzfarbe aufgespritzt.



Fig.3 Oberusel / Taunus, Liebfrauenkirche, Detail der Airbrush-Technik (nH 5c), G. Hoke, 1967.
© Glasmalerei Peters GmbH, Paderborn.

Zur Restaurierung

Die Glasmalereien befinden sich seit nun 53 Jahren in der Liebfrauenkirche und prägen ihre Innenarchitektur. Allerdings waren bereits zwei zurückliegende Überarbeitungen nötig um den Bestand zu erhalten. Mehrere Teile der Fenster wurden repariert, im Zuge eines Unwetters im November 1990 entstanden größere Schäden an der Schutzverglasung, die zum Originalbestand gehört. Daraufhin wurden in den folgenden Jahren (1992-1996) sämtliche Fenster in mehreren Etappen grundlegend saniert. Die Maßnahmen im nun dritten Eingriff konzentrierten sich auf die Restabilisierung des Bleigerüsts, die Klebung gesprungener Glasstücke und die Reinigung und Konservierung der Glas- und Bemalungsoberflächen, allesamt objektive Maßnahmen, die durch die Ausschreibungsunterlagen vorgegeben waren.

Weitaus diffiziler gestaltete sich aber der Umgang, in diesem Fall die Akzeptanz in seiner heutigen Form, im Hinblick auf die Veränderungen, die Fenster bisher erfahren haben. Konkret gemeint sind zunächst die Veränderungen der Malschichten, in Form von Verdunklung durch Ansammlung von Schmutzpartikeln und die Reduzierung der Malschichten durch Auswaschungen. Darüber hinaus ist das Erscheinungsbild geprägt von Ergänzungen, denn insbesondere großformatige Glasstücke wurden ausgetauscht. Zudem wurden zahlreiche Glassprünge durch Verklebungen mit schwarzem Silikon gesichert. Neben einzelnen, das Glasstück durchziehenden Linien sind vielfach schwarze Silikonnetze sichtbar.

Zwei Beispiele, die den Umgang mit den genannten Veränderungen aufzeigen, sollen einen Einblick in die durchgeführten Maßnahmen bieten.

Im ersten Beispiel geht es um Sicherung der Glasstücke durch schwarzes Silikon. Diese Maßnahme wurde mit der Absicht ausgeführt, möglichst unkompliziert und pragmatisch die gesprungenen Glass-

tücke zu sichern. Die Verklebungen erscheinen im Durchlicht ebenso schwarz wie die Bleistege. (Fig.4). Das Bleinetz spielt in den Fenstern gestalterisch betrachtet eine untergeordnete Rolle, primär übernehmen sie eine verbindende und konstruktive Funktion. Es wird nicht in die malerische Darstellung integriert, sondern zeichnet sich, mit Ausnahme der Verbleiung des Farbmosaiks, als gradliniges, schwarzes Raster im Durchlicht ab. Im Unterschied dazu schlängeln sich die schwarz überklebten Sprungnähte, in Abhängigkeit des Sprungverlaufs und der Anzahl der Sprünge, über die Innenseiten der Glasstücke. Dem Betrachter fällt dies zunächst nicht auf, da sowohl Bleie als auch Sprungnähte von ähnlicher Breite sind (ca. 10mm). Bei näherer Betrachtung jedoch ist der Unterschied zwischen gradlinigem Verlauf der Bleie und willkürlichem Verlauf der Sprungnähte offensichtlich. Festzustellen ist somit, dass der spätere Eingriff zwar primär nicht störend ist, aber (unbewusst) in den Entwurf des Künstlers eingreift. Die Überlegung, das Silikon zu entfernen, steht somit im Raum. „Die Restaurierung soll spätere Hinzufügungen als zur Geschichte des Kunstwerks gehörend respektieren“, heißt es in der Restaurierungsethik und den hier verankerten Maximen.¹⁷ Doch wie verhält es sich mit dem Respekt gegenüber der Arbeit des Künstlers und seinem Entwurf, der in Form der Glasmalerei umgesetzt wurde? Johann Thorn Prikker schreibt aus seiner Sicht über die Beziehung des Künstlers zum Kunstwerk: „...[es]wird im Geiste geboren, aus notwendigem, persönlichem Schaffensdrang.“¹⁸ Dieses geistige Abbild nicht zu verändern sollte also ebenfalls ein Anliegen der Restaurierung und Konservierung sein, oder sie sollte Veränderungen, wenn möglich, wieder rückgängig machen können.

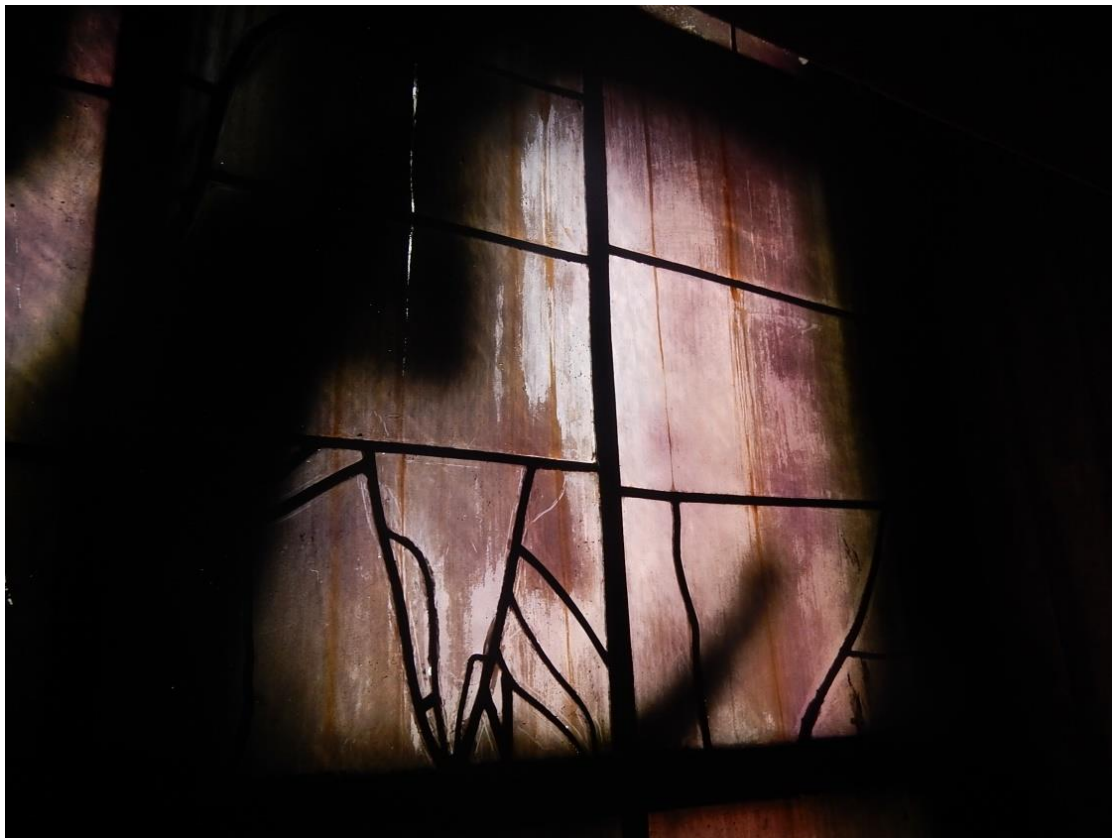


Fig. 4 Oberusel / Taunus, Liebfrauenkirche, Detail vorangegangene Sprungsicherung (SIII), G. Hoke 1967.
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Abgesehen von den restauratorisch-ethischen Argumenten ist die Möglichkeit, einen Eingriff rückgängig zu machen, gleichsam aus Sicht der Konservierungstechnologie und der Materialeigenschaften zu beurteilen. Silikon zu entfernen, stellt einer Herausforderung dar, insbesondere, wenn es auf empfindlichen Oberflächen haftet. Im vorliegenden Fall wurde das Silikon auf den Innenseiten der Glasstücke

¹⁷ Hergeleitet aus den Grundsatzpapieren wie der Charta von Venedig oder den E.C.C.O. Berufsrichtlinien 2004. Vgl. auch: Uta HACK, „Ästhetische Ansprüche an eine Restaurierung: Wunsch und Wirklichkeit“ in *Die Kunst der Restaurierung*, Hefte des Deutschen Nationalkomitees, München 2003, S. 216.

¹⁸ Myriam WIERSCHOWSKI (Hrsg.), „Gedächtnisrede für Johann Thorn Prikker“, in *...mit der Sonne selbst malen... Johan Thorn Prikker und der Aufbruch der Moderne in der Glasmalerei*, Linnich 2007, S. 118.

aufgetragen. Die Bruchkanten liegen direkt aneinander, stellenweise sind die Glasstücke aber verrutscht und liegen übereinander. Silikon ist nicht reversibel und ist sowohl mechanisch als auch nass-chemisch nur bedingt entfernbar. Rückstände verhindern dazu eine haltbare Neuverklebung des Glases, die dahingehend notwendig gewesen wäre, um die Sprünge zu kleben und somit zu sichern. Eine Abnahme in Gänze stellt eine Gefahr für die Bemalung dar, denn aufgrund einer vorangegangenen Untersuchung konnte festgestellt werden, dass insbesondere der zuletzt aufgetragene Überzug ungenügende Haftung zur darunter befindlichen Malschicht aufweist. „Die Restaurierung darf das Original nicht schädigen und soll dessen alterungsbedingte Veränderungen akzeptieren“. Diese Maxime berücksichtigend wurde das Silikon belassen. Auch wenn im Sinne des Kunstwerkes die Abnahme ein ästhetisch befriedigendes Ergebnis erbringen würden, würde sie dennoch einhergehen mit einer materiellen Schädigung und dem Verlust der originalen Substanz. Zudem wird diese Entscheidung untermauert durch die Tatsache, dass das Silikon eine gute Haftung aufweist, um die Gläser zu sichern. Die gesprungenen Glasstücke wurden diesbezüglich untersucht. Vereinzelt wurden Verklebungen im Bereich großer Glasstücke gefunden, die als unsicher eingestuft wurden. Hier erfolgte eine unterstützende Verklebung, indem das Acrylat Paraloid B72 punktuell von der Rückseite in den Sprungverlauf eingebracht wurde.¹⁹

Ein anderes Beispiel, mit dem die Restaurierung weiter vorgestellt werden soll, bezieht sich auf die Rückführung einer Restaurierungsmaßnahme, die im Feld SI 5c gefunden wurde. Es handelte sich hierbei um eines der zahlreichen Felder, die bereits neu verbleit worden waren. Zunächst waren in diesem Feld zwei großformatige Ergänzungen aufgefallen, deren Malerei (Struktur) und Farbigkeit (sowohl das Glas und die Glasmalfarbe betreffend) keinerlei Bezug zum glasmalerischen Umfeld nahm. Die Betrachtung des Feldes zeigte darüber hinaus, dass auch die von Hoke gemalten Formen einen unüblichen Verlauf angenommen hatten, was bedeuten musste, dass die Glasstücke bei der Neuverbleitung vertauscht worden waren. Nicht nur die Darstellung an sich, sondern auch der Farbverlauf der Überzüge und auch die Schadbilder ließen die ursprüngliche Zusammenstellung der Gläser erkennen. Besonders die im Auflicht zu erkennenden älteren Ablaufspuren und die Verläufe der Bemalungsauswaschungen waren ausschlaggebende Hinweise.

Im beschriebenen Fall geht es also nicht nur um die Ergänzungen der vorangegangenen Restaurierung, die für sich betrachtet, als *spätere Hinzufügung zur Geschichte des Kunstwerks gehörend respektiert werden sollen*. Es geht auch um die vorangegangene Maßnahme an sich, die nachweislich zum Fehler führte und daher die Kontinuität der Malerei und die Lesbarkeit in diesem Abschnitt verfälscht. Grundsätzlich betrachtet heißt dies: Diese Situation stört und die Grenze zwischen Erhaltungspflicht und Erlaubnis zur Veränderung wird hingehend zur Veränderung überschritten. Bestärkt wird dies durch die konkreten Hinweise bezüglich des ursprünglichen Zustandes und des Wissens um den maltechnischen Aufbau. Auf diesen Tatsachen basiert die Entscheidung, die jetzige Situation zurückzuführen. Das Feld wurde entbleit und die Glasstücke wurden in die richtige Anordnung gebracht. Die eingebrachten Ergänzungen waren somit „übrig“ und nicht mehr in den Kontext einzuordnen. Es fehlten nun zwei Glasstücke, die rekonstruiert wurden, um die neu entstandenen „Fehlstellen“ wieder zu schließen.

Für die Anfertigung einer Glasmalerei ist ihr Wesen zu berücksichtigen, denn sie wird von technologischen Eigenarten bestimmt, die alle anderen Kunstgattungen nicht kennen:

- Die Rolle des durchscheinenden Lichtes
- beidseitige Oberflächen und
- die Transparenz der Schmelzfarben.²⁰

Darüber hinaus sehen sich Restauratoren mit dem überlieferten Zustand konfrontiert, gemeint sind insbesondere die Veränderungen der Glasmalfarben durch die Einflüsse, die in der eingebauten Situation auf das Objekt über Jahre einwirkten.

Bei dieser Ergänzung sollte ein Glasstück rekonstruiert werden, welches sich optisch in den Bestand eingliedert in dem die Malweise Hokes möglichst genau kopiert wurde, jedoch der Zustand der Malerei mitberücksichtigt wird.

¹⁹ Paraloid B72 wurde viskos in Ethylacetat gelöst (10%ig), um das punktuelle, begrenzte Einbringen in den Sprungverlauf zu ermöglichen.

²⁰ Peter VAN TREECK, Elgin VASEN, „Aktuelle Entwicklungen bei der Präsentation fragmentarische überlieferter Glasmalereien und Mosaiken“, in *Die Kunst der Restaurierung*, Hefte des Deutschen Nationalkomitees, München 2003, S. 202.

Mehrere Farbproben auf weißem Glas wurden angefertigt, um den Malschichtaufbau der transparenten Schmelzfarben nachzustellen. Jedoch konnte auf diese Weise keine annähernde Farbwirkung erzielt werden. Alternativ dazu wurde auf grün gefärbtem Antikglas die auslaufende Blattspitze, die es zu rekonstruieren galt, im Airbrush-Verfahren analog des Bestandes mit brauner Konturfarbe auf das Antikglas aufgespritzt. Das hierzu ausgesuchte, grün gefärbte Glas kam in der Farbintensität des Malschichtaufbaus Hokes sehr nahe. Es erfolgte ein abschließender Überzug, der bewusst annähernd an den ausgewaschenen Zustand der Bemalung ungleichmäßig aufgetragen wurde. Dieser Überzug wurde mit einer grau-grünen Überzugsfarbe ausgeführt. Die Intensität war nach dem Brand zu schwach, daher wurde eine weitere Überzugsschicht aufgetragen. Die Ergänzungen fügen sich im eingebauten Zustand gut ein. Bei zu viel Auflicht aus dem Innenraum der Kirche, leuchten die Malereien Hokes im Vergleich intensiver, und die Ergänzungen sind somit wahrnehmbar. Die Farben der originalen Glasmalereien konnten also nicht im Durchlicht und gleichermaßen im Auflicht rekonstruiert werden. Licht- und Tonwerte konnten hier nicht in Einklang gebracht werden. In der Auflichtsituation wird nun sichtbar, was ergänzt wurde.

Schlussbemerkung

Viele Gemeinden stellen an die Restaurierung ihrer Felder den hohen Anspruch, einen Unterschied zwischen der „Vorher- und Nachhersituation“ erkennen zu wollen. Die Fenster sollen möglichst heller und leuchtender sein. Anspruch und Wirklichkeit ließen sich hier nicht gänzlich überein bringen. Der überlieferte Zustand, insbesondere die Veränderungen der Schmelzfarben, lassen sich nicht rückgängig machen. Indessen konnte der Gemeinde ein „konservierter Hoke“ übergeben werden. Das Wissen über den Künstler und über seine interessante Art, in der er die Glasmalereien für ihre Pfarrkirche ausgeführt hat, dürfte mit dem Wiedereinbau der Fenster nun als neue Wertschätzung des konservierten Bestandes dienen.

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3.4

A New Isothermal System that Avoids the Cold Bridge between the External and Internal Glazing (A Solution Specifically Designed for Extreme Weather Conditions)

Rob MacInnes
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Un nouveau système isotherme pour éviter le pont thermique entre les vitres externes et internes (solution conçue spécifiquement pour conditions climatiques extrêmes) – Résumé

60 degrés nord, à la même latitude que l'Alaska, au milieu de la Mer du Nord et de l'Océan Atlantique se trouvent les Îles Shetland, une des régions les plus humides et les plus venteuses de toute l'Europe. Les embruns constants d'eau de mer à 110 km/heure constituent un environnement hostile pour la flore et la faune, les êtres humains et... les vitraux.

À l'intérieur de l'hôtel de ville de Lerwick il se trouve une série unique et entière de beaux vitraux créés par Ballantine d'Édimbourg et Cox Buckley et Cie de Londres. Dans les hôtels de ville britanniques ces vitraux sont presque sans équivalents en ce qui concerne leur récit décoratif. Historic Scotland les a donc revalorisés à son plus haut niveau – classement « A ».

En 2012, Rob MacInnes et Linda Cannon ont été engagés par Shetland Islands Council pour remettre en état et pour protéger ces vitraux historiques.

Le vitrage secondaire existant en polycarbonate avec son butyl-mastic synthétique qui avait été installé à la fin des années 1990 avait subi une défaillance complète et il contribuait aux conditions extrêmes de tourbillons de vent entre les panneaux de verre

internes et externes. La flexion constante causée par ces tourbillons de vent provoquait des fissures partout dans le plomb et dans le verre. La maçonnerie autour, qui avait été remplacée à la même époque, souffrait beaucoup de la corrosion due au sel et à la pluie battante, ce qui se traduisait par un intérieur creux et alvéolé.

Les systèmes isothermes que nous avons étudiés étaient solides, mais ils ont été rejetés par l'architecte et par les organismes de financement à cause de leur système de pont thermique d'écrous et de boulons lourds et de leur structure solide. On nous a donc demandé de créer un système isotherme sur mesure pour les conditions climatiques extrêmes de Shetland, tout en respectant l'aspect esthétique du bâtiment à l'intérieur comme à l'extérieur. Le système a été conçu pour être ajusté afin de fournir une ventilation optimale pour chaque espace intermédiaire.

Après six ans de recherche et développement, en faisant appel à l'ingénierie de précision allemande et écossaise, et deux ans après l'installation, nous souhaitons présenter notre système breveté au Corpus Vitrearum.

Nous tenons à remercier le Professeur Joost Caen et Leonie Seliger pour leur aide dans la conception et les spécifications techniques.

A New Isothermal System that Avoids the Cold Bridge between the External and Internal Glazing (A Solution Specifically Designed for Extreme Weather Conditions) – Abstract

60 Degrees North, in the same latitude as Alaska, in the middle of the North Sea and the Atlantic Ocean, the Shetland Islands are one of the wettest and windiest parts of Europe. Constant driving salt-water sea spray, and 70 mph winds, provides a hostile environment for flora, fauna, people, and stained glass.

In Lerwick Town Hall there is a beautiful, unique, complete set of 19th-century stained-glass windows by Ballantine of Edinburgh, and Cox Buckley & Co of London. They visually tell the history of the Shetland Islands, and of its Hanseatic past. The windows are almost unparalleled in British Town Halls, as a decorative narrative, and have accordingly been upgraded by Historic Scotland to its highest "A" listing. In 2012, Rob MacInnes and Linda Cannon [Cannon-MacInnes] were instructed by Shetland Islands Council to restore and protect this historic glass. The existing secondary polycarbonate glazing, and synthetic butyl-mastic bedding compound, which had been installed in the late 1990's, had completely

failed, and was contributing to extreme wind-vortex conditions within the glazing interspace. Constant flexing, caused by the vortex, was causing lead-fatigue, and multiple cracks were appearing throughout the glass and the lead. The surrounding stonework, which had also been replaced at the same time, was suffering badly from salt corrosion and driving rain, resulting in a hollow, honeycomb interior.

Traditional isothermal systems which we studied are robust. However, their use of a cold-bridge system of heavy nuts and bolts and solid framework was rejected by both the architect and the funding bodies. We were required to design a bespoke isothermal system for Shetland's extreme weather, whilst being uncompromising in the aesthetic appearance of the building, both inside and out. The system is designed to be adjusted to provide optimum ventilation for each interspace.

After six years of research and development, using German and Scottish precision engineering, and two years since installation, we would like to present our patented system to the Corpus Vitrearum.

We would like to thank Professor Joost Caen and Leonie Seliger for their assistance with the design and technical specifications.

Isothermal Glazing in Shetland

The problem

Cannon-MacInnes Stained Glass [C-M] had annually monitored the unique stained-glass windows in Lerwick Town Hall for three years, from 2012 to 2015, after concerns about the stability of the windows throughout the building were raised. The clients, Shetland Islands Council [SIC], and their architects, Groves Raines Architects of Edinburgh [GRA], asked C-M to closely inspect each window for signs of failure and to remedially stabilise each problem until significant funding could be raised.

The complete glazing scheme of extraordinary Victorian windows [made by Cox Buckley & Co of London, and Ballantine & Co of Edinburgh, between 1883 – 1886] had been previously extensively restored and protected by another stained glass firm in 1997 using a Polycarbonate “glazing” system that had proved to be ineffective in the severe weather conditions. The polycarbonate actively contributed to several ongoing problems. In addition, instead of using traditional lime mortar, the windows had been reinstalled, at this time, using a butyl-mastic bedding compound which had been originally developed for the aircraft manufacturing industry. It produced an adhesive bed which was ‘springy’ and waterproof. Consequently, the windows ‘bounced’ on this adhesive and were therefore enduring constant movement. In high winds the leaded panels and the polycarbonate flexed as they were sucked inwards and outwards in a wind vortex created inbetween the polycarbonate and the stained glass. This constant flexing was disastrous for the lead, which was cracking and failing and deteriorating rapidly. The historic glass was noticeably cracking, year after year, as the lead weakened. To make matters worse, the soft sandstone which immediately surrounded each window had also been replaced in the 1990’s with a very porous stone from the Cotswolds in the South of England. It was unable to withstand the climactic conditions 700 miles further north and was contributing to the instability of the whole.

After three years of monitoring, it became clear to C-M, the clients, and the architect, that the ongoing deterioration of the windows, and the stonework surrounding them, had to be addressed with the utmost urgency.

Historic Environment Scotland [HES], who are major grant-funders in Scotland, had previously rejected the use of traditional isothermal systems. C-M were therefore commissioned by SIC and GRA to design a bespoke isothermal system, suitable for use in the Town Hall, which would satisfy the rigorous aesthetic and practical specifications which would be acceptable to all involved, and which would withstand frequent extreme weather conditions throughout the year, [Beaufort scale- 11/12]. Thus began a two-year program of research and development, in addition to Cannon-MacInnes’ private work elsewhere.

Previous knowledge of existing isothermal systems were well known to C-M; from seeing existing systems in place throughout the UK and Europe, attendance of previous BSMGP, CVMA Colloquia and other conferences since 1987, where the different types of isothermal systems had been discussed and dissected rigorously. C-M also supervised an HES Fellow, Joy Bunclark, in her dissertation of Isothermal Glazing Systems throughout Europe in 2006.

C-M’s analysis of the system required for Lerwick fell easily into two groupings: the aesthetic and technical requirements for the external protective windows, and that of the internally suspended leaded glasswork.

Externally there was a number of problems. The system had to be discreet, strong and easily repaired, if necessary. The external windows had to be able to withstand gales on the extreme end of the Beaufort scale, frequent driving rain, and the corrosive effects of seawater. The building was on the top of a small hill and faced vast open stretches of the North Sea and the Atlantic Ocean on three sides. On the fourth side, the windows faced the prevailing winds. All four elevations contained stained glass. Needless to say, the system had to be thoroughly waterproof in all conditions, a feat not achieved since the Town Hall was constructed in the 19th century. From their previous experience of extremely exposed, windy sites in Scotland, C-M realised that any air vent within the system would quickly cause driving rain to pour through and be driven up into the tiniest of gaps. This system had to be completely sealed from the external elements. In this instance, laminate sheet glass was chosen for the protective glazing rather than traditional leaded clear glass, to achieve a smooth completely waterproof surface. Laminate was preferred rather than toughened incase of failure above head-height in a public building.

Internally, the windows were at eye-level. Any system would be seen close up and could be touched. Most isothermal systems are not designed to be seen at quite such close quarters. It had to be elegant. Provision also had to be made for the additional inclusion of toughened protective glass on the inside.

Research & Development

Before C-M began the project, they consulted with colleagues: Professor Joost Caen in Antwerp, and Leonie Seliger, Director of the Cathedral Workshop in Canterbury. They very graciously allowed C-M to look closely at the various systems in use in Antwerp Cathedral, throughout Antwerp itself, and within Canterbury Cathedral. They allowed C-M to discuss with them, and their students and staff, the various strengths and weaknesses of different types of isothermal glazing systems.

During our analysis period, a major potential problem in the systems which we examined, was the inclusion of a metal 'cold bridge' for structural and support reasons. The structural connection between the metalwork in the external windows was to give the internal support metal strength and rigidity. Unfortunately, this also provided a potential 'cold bridge' between the external metal and the internal metal frameworks in the extreme conditions in Shetland. The bridge allowed a temperature difference in the metals touching the internal stained glass, allowing condensation to form and drip onto the leaded glass. The Hall itself was often full of people in the winter, with warm, high humidity inside, and freezing cold outside – the perfect conditions for condensation to occur. They could not allow the potential cold bridge to happen. It was felt that this would be a major weakness in the system given the climactic conditions involved.

They realised that by sealing up the exterior of the windows completely, a different micro-climate would be set up in the interspace in all the windows. They decided, therefore, to make the bespoke system flexible, and adjustable, to ensure that the most effective gap-width was achieved for each elevation.

It was important also, that a robust digital air exchange system was included in the structure of the Hall restoration program, to allow the building to breathe properly, and to restore a relative RH quickly and effectively when the Hall was in use. Cannon-MacInnes handed that particular problem over to the architect.

C-M started designing and developing ideas using a local blacksmith, but soon realised that the individual components had to be precision engineered. They identified an engineering manufacturer in the industrial outskirts of Glasgow who was skilled in producing computer lathe products for the oil industry. C-M produced drawings and scaled sizes for them. Several versions of the 'slide' unit were produced which would be used in our scheme. One was finally chosen and a prototype was produced.

All of the materials used were to be non-ferrous, using manganese bronze, phosphor bronze and brass sections; some off the shelf, some bespoke from the fabricator, some computer-cut and engineered, and some others hand-cut by ourselves on site. The choices between manganese or phosphor bronze were of cost and availability. Internal screws, nuts, washers and bolts were likewise a mix of off-the-shelf non-ferrous items, or precision engineered detailing. Finding or making the right item, and the correct number of items became an interesting question of logistics. Every part of the system was made with flat sections and nuts, screws and washers. Each piece could be individually taken apart without affecting the whole system.

A decision was reached to manufacture a barring system to hold each separate glass panel—in manganese bronze. This allowed C-M to use a material which was aesthetically pleasing and had strength and a discreet elegance suitable for the appearance of the building. It also meant the material could be easily drilled and then screw 'tapped' for comparative ease of production. Both GRA and HES preferred this appearance to the more traditional use of heavy iron bars.

Assembling the system, it quickly became apparent that a locking washer system was required for the slides and the locking nuts. MacInnes selected a locking washer manufactured by the Nordlock Company in Germany. Cannon suggested that C-M get in touch with this company to assess the technical parameters of these locking washers. When he talked to the engineers in Berlin, they asked him "how many thousands of revolutions per minute the locking washers would be subjected to?" When he said, "none", there was a distinct pause whilst the engineer in Berlin decided exactly what he wanted, and how little he knew of materials science. Each pair of interlocking washers had a laser cut, individual

number. In case of failure they would be extremely interested in having the parts back. Despite being used in the American space program in the stressful conditions of outer space, no failures had been reported to date. MacInnes brought back the findings, and it was agreed that C-M seemed satisfied that the lock washer system might hold.

After two years R&D, a final 'maquette' was produced for the client, the architect, the funding bodies, and Professor Caen, to allow for comments and improvements before finally going ahead.

*Using the system *in situ**

The butyl mastic was impossible to remove from the stone check as it simply stretched and snapped back into the stonework, forcing Cannon-MacInnes to have to cut the stonework itself to release the windows. The leaded glass had a number of problems to be addressed: broken glass, failure of previous epoxy resin joins, failure of plating, weak leads, solder-joint failure, broken ties, loose bars and so on. The glass itself, and the paint, were in good condition. The problems were purely structural, due to the use of inappropriate protective systems and an experimental waterproof bedding compound. The conservation of the stained glass will not be discussed here.

Replacement stone had to be dug by the main contractor's stone masons from a closed quarry in the North of Scotland. Much of the new stone proved to have extensive fault-lines and could not be used. Finding a good stone seam delayed the whole project by months after the removal of the windows. The unexpected extra time gave us more time to problem-solve on site.

Each panel was conserved and bound in shaped "U" channel made of manganese bronze. C-M are grateful to Leonie Seliger and her staff who patiently explained the specific workings of bending, shaping, and finishing the framing work, and to Keith Barley, who sold a job-specific "U" channel bender to enable the recreation of perfect curves and shapes.

By varying the internal width of each horizontal support bar, either a narrow secondary protective glass, or a double width stained glass plus protective toughened glass on the interior could be accommodated within the system. It proved to be extremely flexible in its use.

Finally, the new stones were cut and installed, and the stained glass conservation team worked directly behind the masons, working on each external window until the whole building was secure. The external windows were installed with traditional lime mortar and finished off with a burnt sand mastic and resin "skin" over the surface of the mortar, to keep it watertight. C-M had found, over the years of monitoring the building, that lime mortar pointing itself could not withstand the driving wind and rain in extreme conditions. Unlike the butyl mastic, the lime mortar and mastic skin is easily removed if required and is fully reversible. Importantly, its use, in this way, was also approved by GRA and HES. Each external window panel could now, if necessary, be removed if damaged, without having to remove the whole lancet.

Two different types of precision-cut, slide-bar units were designed and made for Cannon-MacInnes by the engineering firm: one type for the bottom cill (fig. 1), which could be used either vertically or horizontally next to the stonework; and one type for each panel separation going vertically up each lancet (fig. 2). The stone was carefully drilled, and the 'slide units' were attached to the stone ingoes, using high quality marine stainless-steel screws, embedded in a good German nylon/plastic fitting. The new stonework was often wet as the protective scaffold covering was constantly shredding and being blown across the North Sea to Norway. This alone made installation difficult. Care had to be taken with the drilling of holes into the new sandstone to avoid shaling.

The slide system, was incorporated into every part of the internal system, allowed each bar to be adjusted slightly, to achieve a perfect position, up, down, right left, in or out. The use a laser beam and a traditional spirit level, ensured accuracy and precision.

Each window panel varied in size, from approximately 0.2 m/sq to 1.2 m/sq. Although each individual panel was self-supporting, the lower panels also had to bear the additional weight of protective toughened glass up to head height.



Fig. 1. Lerwick Town Hall, Shetland, west elevation detail showing external glazing, mortar covered with burnt sand mastic "skin", bottom slide bar system placed vertically on stone cill, the leg extension to accommodate any overall height changes, and the lead condensate tray, 2017. © Cannon-MacInnes.



Fig. 2. Lerwick Town Hall, Shetland, west elevation detail showing external glazing, mortar covered with burnt sand mastic "skin", vertical slide bar system placed vertically on new stone mullion, the manganse bronze support bar, and a fully conserved "middle" panel in place, 2017. © Cannon-MacInnes.

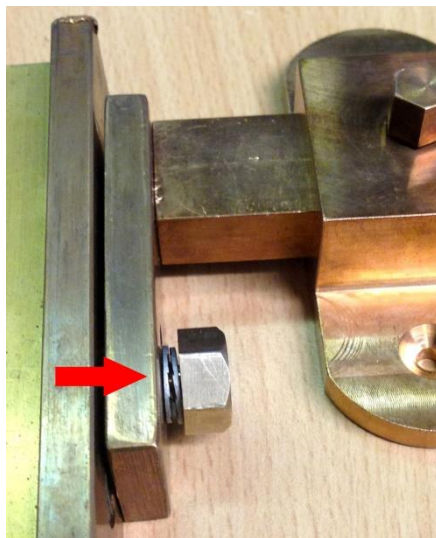


Fig. 3. Lerwick Town Hall, Shetland, detail showing "Nordlock" washers in place within the vertical slide bar system. One pair of washers on each side of the panel ensures the bar will not slip, 2017. © Cannon-MacInnes.



Fig. 4. Lerwick Town Hall, Shetland, south elevation detail showing the internal slide bar, which allows the whole system to be finely tuned to fit perfectly. Each panel can be adjusted on site, slightly up, down, in, out, right or left, 2017. © Cannon-MacInnes.

Each panel was installed in the same way, using one bar top and bottom, and two sliding units, each on either side. The Nordlock washers ensured there was absolutely no slippage once each panel was securely placed in situ (fig.3). Positioning one set of washers on either side of each panel guaranteed that if one washer ever slipped slightly, the opposite set would automatically tighten. Each bar was easily strong enough to bear an adult's weight on with no apparent effect. We had confidence in installing each panel either from the top down, or the bottom up.

On site, further additions were manufactured to the scheme as required; standard horizontal slot-plates which allowed slight lateral and height movement to visually match the external and internal barring (fig.4), and bespoke vertical slot-plates on the bottom unit, to match the depth of the curved cill. Each additional slot plate was secured using a standard ribbed bronze washer.

We suggested that the glazing system should be monitored for at least a year after installation. It is now three years since completion, and there has been no report of any problems with the glass or the glazing. Although water penetration through the stonework itself is of ongoing concern, this is for the clients and the stonemasons to fix and is not part of the glazing parameters. The mortar and mastic skin remain completely watertight around each window. Lead condensate trays placed on the sill in between the external and internal glass collect any condensate run-off during peak periods. The digital air control system within the room activates above a specific RH and the excess moisture is driven out of the building. This completely sealed glazing system would not function correctly, unless there is an air exchange within the building itself, allowing the building to breathe.

The building has been in use for many popular cultural events, and the circulation of humidity and control of the RH within the room appears to be working well, even on the most overused nights in winter.

Conclusion

The design and manufacture of this slide bar system does not, in any way, negate the successfully tried and tested isothermal systems in use throughout Europe for decades. It may not be ideal for every situation, but its design adds to the overall bank of knowledge on isothermal glazing systems.

This patented system is one solution, to solve a very specific problem; to address the specific requirements of grant-funding bodies, architectural aesthetics, and the extreme weather conditions in Scotland.

The inclusion of internal brass bars increases the overall height of each window exponentially. However, this problem is also one which occurs when using traditional isothermal systems which use heavy “cold-bridge” iron bolts. As with either system, this increase in height can be offset by shaving the top and bottom sections off the lead on each panel.

The slide bar system has been granted a patent: GB2516325.

<https://www.ipo.gov.uk/p-find-publication-getPDF.pdf?PatentNo=GB2516325&DocType=B&JournalNumber=6578>

As such, any use of this slide bar system should not be copied without the permission of Rab MacInnes.

Our thanks to Prof Joost Caen, Leonie Seliger ACR, Dr Jim Adams, Dr Stewart Stirling and Shetland Islands Council for assisting Cannon-MacInnes with this project.

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4.1

The Historical Requirement on the Identity of a Piece of Art

Paloma Somacarrera

Die historische Voraussetzung der Identität eines Kunstwerkes – Zusammenfassung

Jedliches Kunstwerk hat, wie jedes menschliche Erzeugnis, eine doppelte Beschaffenheit: einerseits die ästhetische, andererseits die historische.

Wir können wahrscheinlich darin übereinstimmen, dass die ästhetische Beschaffenheit auf der Kraft des Bildes beruht, unsere Aufmerksamkeit zu erregen und ein angenehmes Gefühl in unserem Gehirn hervorzurufen. Es ist jedoch anders, wenn wir vor einer Kopie stehen, wenn wir über eine konkrete Information über das Werk verfügen oder Ähnliches. Das Bild ist das gleiche, aber unser Erlebnis bei seiner Anschauung, ist wahrscheinlich anders. Dies beruht auf der historischen Beschaffenheit.

Wenn wir uns auf die Identität des Kunstwerkes konzentrieren, müssen wir alle Eigenschaften berücksichtigen, die dieses Objekt als einzigartig definieren. Wir müssen uns also bemühen, alle historischen Umstände und Bedingungen auszumachen, die es umgeben, und wir

müssen akzeptieren, dass diese sich mit der Zeit verändern können.

Im Oktober 2018 hatte ich die Ehre, an der Konservierung einer in der Dreifarbendruck-Technik realisierten Glasmalerei teilzunehmen. Das Werk, das sich in der Kapelle Inmaculada des Klosters Montserrat befindet, entstand 1910. Bis zu diesem Zeitpunkt hatte nur Gaudí diese Technik benutzt, und zwar in seinen Glasmalereien der Kathedrale von Mallorca.

Das Fehlen an Dokumentation über das Werk und der Konservierungsprozess selbst führten mich zu der Vermutung, mich vielleicht geirrt zu haben. Vielleicht waren einige der festgestellten „Fehler“ nichts anderes als die Essenz des Werkes, seiner Identität, nicht als Meisterwerk, sondern als Prozess, bei dem der Künstler seine Kunstfertigkeit in die Praxis umsetzte.

Ich würde Ihnen gerne von dieser Erfahrung berichten und Ihnen zeigen, wie sich meine Wahrnehmung des Werkes veränderte, und Ihnen somit eine andere mögliche Interpretation seiner Identität vorstellen.

The Historical Requirement on the Identity of a Piece of Art – Abstract

Every piece of art, as a human product, has a double requirement: on the one hand the aesthetic and, on the other hand, the historical. We can easily agree that the aesthetic requirement relies on the force of the image to catch our attention, producing a pleasing sensation in our brains. However, something doesn't work in the same way when we are in front of a copy, or when we have some specific information about the piece, etc. The image is the same but, our experience watching it will probably change. This is a matter of historical requirements. If we focus on the identity of a piece of art, we have to bear in mind all the characteristics or qualities that make this work only and different from the rest. Therefore, we have to make a special effort to research about the historical matters around the piece and to accept they could be one or another depending on the moment. I'm afraid that studying the piece from a current point of view can frequently be misleading, because what it is for us now is something different from what it used to be for the creator, for the customer and for its contemporary society in general. Time has gone by and our tastes and experiences have changed, too. Accordingly, in theory,

we can make a distinction between several historical determining, although in practice, we often mistake them – or, at least I must accept I have. In October 2018, I had the privilege of restoring a trichromia process stained glass. The piece is in the Immaculata Chapel of Montserrat Monastery and was made in 1910. So far, in Catalonia, only Gaudí used this technique for his stained glasses in Mallorca Cathedral. As I stood facing this important piece, it brought me about feelings of solemnity: the interest of the customer to have a rare modern technic piece, the glazier's challenge for design in three tinted images, the careful work with the fragile sheets of glass, the feel and pressure for the responsibility, etc. The lack of documentation and the restoration process led me to consider the possibility I could be wrong about that. Perhaps, some of the "mistakes" found, could actually be an evidence of its essence and its identity, not as a model of a modern art piece but, as a mere exercise, in which everyone tried to put into practice their skills. Humbly, I would like to introduce this experience, to share with you how my perception about it changed, unfolding another interpretation about the identity of this work.

In October 2018, I had the privilege of working on the conservation of a stained-glass window made by the trichromatic technique. The piece, in the Immaculata Chapel of Montserrat Monastery, was inaugurated in 1910.¹ So far, in Spain, only Gaudí used this technique for his stained-glass windows in the Cathedral of Santa Maria in Palma de Mallorca.

As I stood facing this important piece, its image caught me and several thoughts came to me: the customer's interest in having a rare modern piece made using this technique, the glazier's challenge to design by joining the three different colours within each image (red, blue and yellow), the careful work with fragile sheets of

¹ Arxiu de Montserrat, A-I e. 13, Josep DEÀS, *Restauración de la Iglesia de Montserrat*, p. 46-48.

glass, the feelings and pressure of the responsibility. I felt I was in front of a masterpiece; the place, the environment, the piece and most of all my emotions, all drove me to that feeling.

The quality that makes one piece of art different from another isn't always obvious or evident. On the identity of a work of art, several concepts matter. We can't be stopped in front of a stained-glass window looking at the colours, studying the design, analysing the materials, admiring the master's hand, etc and be sure after that, we have captured its identity. There are other reasons, not physical, that equally play in that question (perhaps something about its origin, or about the circumstances of its creation). We can agree that, every piece of art, as a human product, has a double requirement: on the one hand the aesthetic and, on the other hand, the historical.²

The aesthetic requirement relies on the ability of the image to catch our attention, producing a pleasing sensation in our brains. However, when we are in front of a copy, or when we have some specific information about the piece, something doesn't work in the same way. The image doesn't change but, our experience looking at it, probably does. This is a matter of historical requirements.

Accordingly, in theory, we can make a distinction between several historical moments in time because what it is for us now, is something different from what it used to be for the creator, for the customer and for its contemporary society in general.³ Nevertheless, despite accepting that time has gone by and our tastes, experiences and circumstances have changed too, studying the piece from a current point of view I'm afraid that we could mistake them.

Perhaps, because we aren't now speaking about only physical questions, it may be difficult to know when you aren't keeping in mind all the elements or at least the defining one; how do you avoid missing some information when you don't know about its reality, or its importance, when perhaps, you feel you have enough.

Montserrat Monastery is an ancient space with plenty of artistic works and its archives are famous for its large amount of documentation. However, not much information about the Immaculata Chapel or about the trichromatic stained glass exists to this day.

Before I started my work, I had read that Iu Pasqual had made this stained glass after working with Gaudí in Mallorca's Cathedral⁴ but, when I arrived at Montserrat, they gave me information about Darius Vilàs's role in the work and about the importance of the architect, Josep Maria Pericas, as the designer of the chapel.⁵

It's a pity we don't have much documentation about the trichromatic stained glass and the chapel. With the 19th century full of complex situations, including the expulsion of the monks from the monastery, the reconstruction works were necessary.⁶ We know about the economic difficulties, there is plenty of documentation about it, and how the works done were more decoration tasks than reconstruction actions where, in general, artistic details stood out above rich materials. The work started in the nave, hoping that the result encourages the devotees to pay for the continuation of the works; it continued to the main chapel, the roof of the church, the Virgin's chamber, etc. In the end only the lateral chapels were uncompleted.⁷

Due to the necessity to find a solution to finish the work the abbey accepted financial support from families who paid for rehabilitation work and the maintenance of the chapels, in exchange for the right to be buried inside and the celebration of several masses in their tribute.⁸

These families' patronage allowed the work to be completed while not following a strict program. Several chapels changed their saint images to the families' patron saint. However, the stained-glass windows of the chapels, follow the former program about the Virgin Mary's life,⁹ using an accurate technique and rich materials. The style of them, inside the traditional narrative current for the religious images, achieve the didactic objective thanks to the composition in a large sized image and the representation of iconic moments in Mary's life.

² BRANDI, 1996, p. 15.

³ BRANDI, 1996, p. 17.

⁴ VILA-GRAU and RODON, 1983, p. 91.

⁵ LAPLANA, 1998, p. 182-184, 187.

⁶ P. Josep Galobart, conversation on 3 December 2019.

⁷ ALTÉS 1992, p. 8.

⁸ P. Josep Galobart, conversation on 3 December 2019.

⁹ ALTÉS 1992, p. 218.

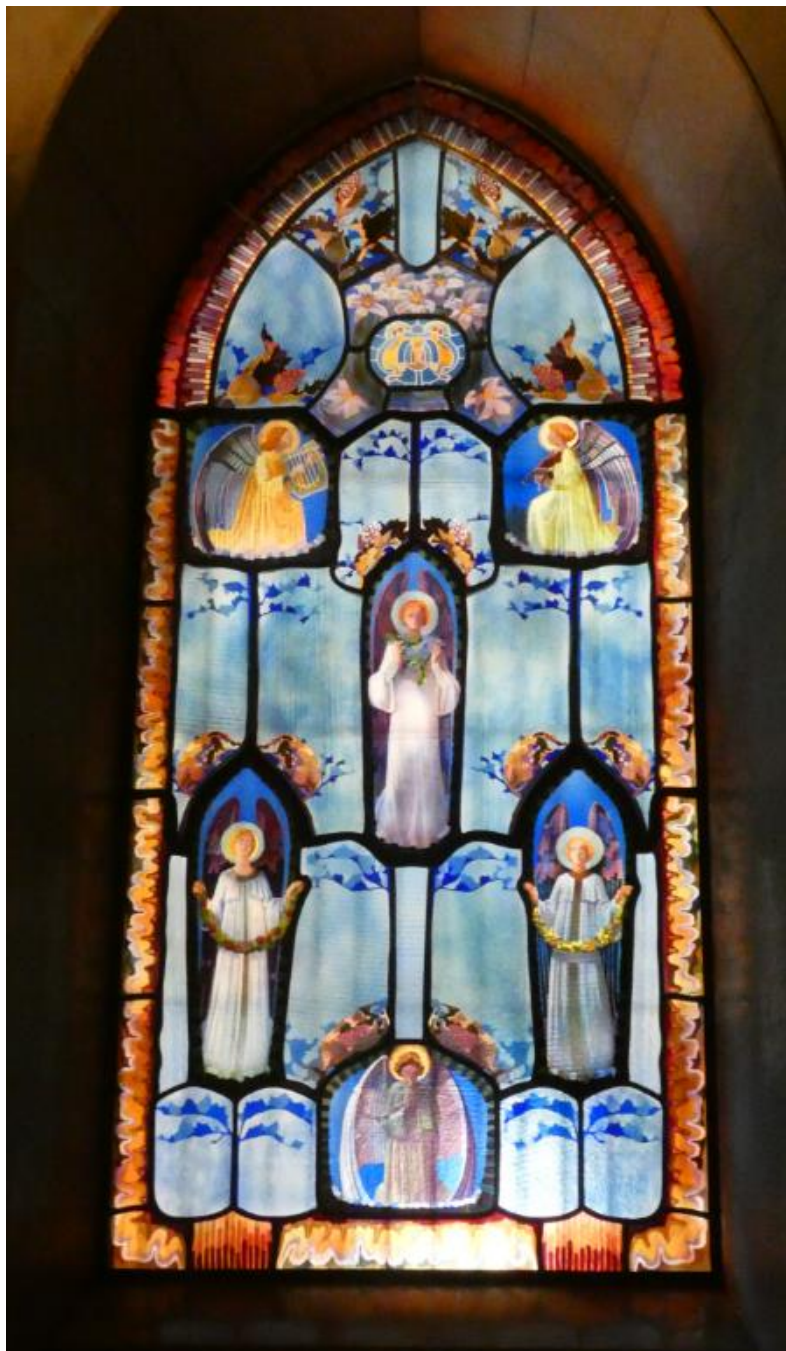


Fig. 1. Stained-glass window in the Immaculata Chapel of Montserrat Monastery (1910), Paloma Somacarrera, 2019.

Also there are **six angels** placed in the following order:

- In the bottom centre there is a forward facing, kneeling angel with its hands in a praying position.
- In the second row there are two angels, who are facing each other slightly, standing up and carrying flower garlands.
- In the middle row we find a forward facing angel standing up and offering grapes in its hands.

In general, the chapels were decorated by the addition of individual objects but, without a harmonic sense of the whole. In the Immaculata Chapel, it doesn't work in the same way. The architect thought about and probably drew the very last detail of most of the elements of the chapel and the stained glass too.¹⁰ In 1904 he incorporated a window in the chapel to let some natural light in because that was the only chapel that didn't have it.¹¹ As it wasn't possible to open a window in line with the others, it was done in the main wall connected to the atrium of the church. Gaudí's trichromatic stained-glass windows were installed in 1905¹² but, I suppose that his projects and previous researches were known by Pericas and Vilàs.

It's one of Pericas' early works, actually the first job he was commissioned as an architect,¹³ and despite his effort to get rid of decorative elements from the past and his attempts to break away from the current style at that time, it shows a modernist style with Gaudí's influence. In fact, he himself wrote that this Chapel was the result of "badly digested Gaudism".¹⁴

In my opinion, far from criticizing the work, the result was balanced, elegant and able to evoke a state of transcendence from the viewer.

The composition of this stained-glass window, plays with the alternation of **vegetable elements** in vertical (the lead, as shoots of a vine) and in horizontal (the blue grape leaves, as the ground beneath the angels and the brown and orange grapes and leaves above the figures).

¹⁰ Aleix CATASÚS I OLIA, 2016, p. 33-34.

¹¹ Arxiu de Montserrat, A-I e. 13, Josep DEÀS, *Restauración de la Iglesia de Montserrat*, p. 46-48.

¹² Joan SUREDA, 1998, p. 96.

¹³ Arxiu de Montserrat, A-I e. 13, Josep DEÀS, *Restauración de la Iglesia de Montserrat*, p. 46-48.

¹⁴ PLADEVALL 1980, p. 147-154.

- The top row has two angels facing each other, with one knee on the ground and playing a lyre (left angel) and a violin (right one).

In the top middle part of the stained glass there is the **letter “M”** surrounded by Madonna lilies, grape leaves and grapes.

Bordering the stained glass there is a powerful **orange graduated stripe** in contrast with the blue background, reinforced on the top with the addition of another stronger orange band.

Pericas had a global sense of art and believed in the mystical transcendental function of it; to serve that idea, he uses foreign artistic currents, like symbolism. Therefore, we are in front of an element dedicated to the Virgin's Immaculate Conception which has a symbolic language. The symbols are used as a resource to connect with the people, and are common in religious art. Here we find the use of them in a not so common way. The double finality of the religious representation in the church is to give and show dignity and grandeur to the space, as a parallelism of the dignity and glory of God or as in this case of the Virgin; at the same time waking up pious and devout feelings to the viewer, the language ought to be clear and direct. The symbolism must have a vocabulary capable of being captured and understood by most people.

Here, we find the following elements with meaning or possible sense:

- This stained glass is a tribute to the Virgin's Immaculate Conception and although she isn't shown, the capital letter M is.
- The blues are the dominant colours in a balanced contrast with the warm oranges of the borders and the grape leaves; both colours probably refer to the idea of purity and sacrifice.
- The presence of the shoots of the vine (probably designed to be more obvious than how they ultimately are), the leaves of the vine and the grape as a link between the figures and repeated again as offered fruit, in my opinion gives us an idea of the importance that it has. It could be because of the double meaning of the grape: as a fruit it could refer to the idea of fertility, and the wine could refer to sacrifice and the Eucharist.
- The borders, with its sinuous and orange graduated edging, could represent flames, repeating the reference to the ideas of pureness and sacrifice.
- The Madonna lilies around the letter M almost definitely represent purity and virtue.

That's all; there aren't any words that go with the images. If we agree the art of the church is aimed at most people and the more people the better, we can think perhaps this trichromatic stained glass, special by its technique and by its language looking for the transcendence of the art expression, only was totally understood by a specific group or at least not by the majority of the devotees. That was the language chosen by the architect and the patron to glorify the Immaculate Conception of the Virgin in this new stained glass; new because its opening didn't exist before, its theme wasn't in the general stained glass program, and because its technique was a complete novelty. I suppose, if they gambled on the use of this very expensive new technique in a non-traditional stained glass language, it must be because it was an important element for them and probably, they had a high expectation regarding the result. However in opposition of that idea, the trichromatic work had a low impact on the artistic environment.¹⁵

In the first decades of the twenty-century groups of young intellectuals were very active in taking positions in the cultural and artistic discourse for the arts: Art that served faith, the importance of the return to their own tradition, the necessity to be open to new foreign currents, etc. Several magazines picked up the differences and positions of every group and it is easy to find how each group judged and criticised the others.¹⁶

This situation allowed Pericas to find collaborating artists, from other specialities but who had shared ideas and were able to drive his project or designs in a close collaboration, to a harmonic work without a protagonist. Here, in the Immaculata Chapel, every element allows the viewer to gaze at each piece in a natural flow, from one to the next.

¹⁵ Joan Llimona “Un nou altar a Montserrat”, *Il·lustració catalana*, VIII, p. 506 / Lluís Rigalt “Los vitrales”, “Arts i Belles Oficis”, Barcelona 1927, in Vila-Grau and Rodon 1983, p. 191.

¹⁶ Marchi, 2011.

In the beginning of Pericas' professional career, Darius Vilàs was a close collaborator in paint and stained-glass technique elements. His main activity was as a painter, but he worked as a designer at stained glass workshops too, as well as at our colleague Bonet's workshop from when it was founded circa 1923.¹⁷

As a show of this close collaboration, we can observe in the design of this trichromatic stained glass, the possible presence of both of them:

- The letter M which can be found on the top of the stained glass, is almost identical to that which Pericas had designed for the daughter's of Maria's association flag, in 1905.¹⁸
- The way in which the vegetation grows upwards and open up at the top on both sides, may remind you of Pericas' solution for the double window decoration, from Casa Bayés in Vic in 1906.
- The treatment of most of the angels, the way they had been worked on, is a Darius Vilàs' characteristic.

We can probably accept that they worked together on the stained glass; that the person who designed it was Pericas, and the person making the images and the study for the work of the different flashed glass colour sheets, was Vilàs. However, I wonder about the person who suggested the use of the trichromatic technique. As well as that, there is no information about the glazier workshop which made the stained glass. In fact, until now, we don't have any documentation which mentions Vilàs as a collaborator in this chapel.

While we are waiting for an intensive and complete research of the documents about the works, we have to play with the current information and it shows us that the chapels' works were not done under the direction of the abbot Deàs (the person responsible for the monastery). We have lots of letters between the chief architect of the church, Villar Carmona, and the abbot discussing every new element or every change in the build but, until now, regarding the chapels we basically have nothing more than comments, about who made the altar, the sculptural elements and who paid for it. In reference to the stained glass, the abbot mentions the young architect Pericas as the person who designed and ran the project, with a new technique, at least new in Catalonia.¹⁹



Fig. 2. The glass pieces of the top panel, once the lead had been removed, at the workshop. We can observe the nice result of the good acid etching work. However, also we can see how the sinuous shape of the glass pieces don't always fit well with the shape of the glass piece beside. Stained-glass window in the Immaculata Chapel on Montserrat Monastery (1910). Paloma Somacarrera, 2018.

¹⁷ BONET 2016 and BONET 2011.

¹⁸ CATASÚS 2019, p. 170.

¹⁹ Arxiu de Montserrat, A-I e. 13, Josep DEÀS, "Restauración de la Iglesia de Montserrat" p. 46-48.

The decisions around the chapel's works, seem to fall on the patron and on the architect chosen. The sponsor of the Immaculata Conception Chapel was Ramón Soler i Vilabella.²⁰ He was Pericas' friend with whom he shared the religious sentiment and his interest in art and history. Focusing on the importance of the knowledge of our country they both took part in several excursions around Catalonia, to rediscover and analyse landscapes and old buildings. Ramon Soler was from a well off and industrious family;²¹ he wasn't an artist or an intellectual, but his views were totally in line with this new art, aimed at showing and expressing the religious sentiment and concepts in a deeper and more intimate way.

The stained glass has a total approximate size of 330 × 150cm and is installed in a pointed arch shaped iron frame which is divided into three panels by two zigzag lines, in horizontal sense, with a strong iron "T". Every panel has one strong support bar. The whole work is in trichromatic technique except the pieces without images (seven in the bottom panels and one in the top one) which don't have the red layer; but overall, every piece has four glass sheets: hammered white glass, blue flashed glass, red flashed glass and yellow flashed glass.

We realize the enormous technical difficulties that this new stained glass presented.²² On the one hand, it needs a very capable artist with a specific sense of colour, and a very precise acid etching. In addition, the adoption of this technique is supposed to quadruple the cost due to the extra glass and also the extra workmanship. Also, he needed to make a new kind of lead capable of holding the entire set of glass sheets. We don't have the bill but I'm sure that all these circumstances resulted in this stained glass being very expensive. As a result of this important effort, they produced a very delicate but heavy work which was probably difficult to manage, to be moved and to be installed in the opening.



*Fig. 3. The musician angels from the top row.
The figures show us different ways to work on them. Stained-glass window in the Immaculata
Chapel of Montserrat Monastery (1910). Paloma Somacarrera, 2018.*

²⁰ CATASÚS 2016, p. 33.

²¹ FATJÓ 2005, p. 23, 25, 27.

²² SUREDA 1998, p. 106.

On the other hand, with the application of this technique they created a very special atmosphere in the background by getting transparent colours minimizing the lead lines and avoiding future problems with coats of paint. Were these their own objectives? Did they think about Gaudí's Mallorca stained glass as a successful work and did they want to follow it? Why didn't anybody mention the Immaculata Chapel's stained glass? Is it because of its hidden location? Is it because the stained glass was considered a minor art? Was this piece considered a successful work for them?

The stained glass looked good, however, there were several problems such as a significant deformation on the bottom panel, several pieces of broken glass and the presence of layers of dirt. To resolve these problems, it was taken out and moved to the studio.

When I started the tasks at the workshop, several things surprised me:

- a) Taking out the lead, we discovered the presence of small pieces of wood (on the top and the bottom panels) or lead (in the central one) that were used to fill spaces between the glass and the lead because the pieces of glass were small. This looks like an improvised solution in which lead or wood was used without a clear reason.
- b) However, most of the pieces of glass didn't have a clean cut and had jagged edges. It seems that the glass was cut too big and then made smaller with a pliers. I suppose it was a difficult decision because of the thickness of this expensive glass. At what moment did they realize the size was excessive? Before or after the acid etched work?
- c) Also, the coloured glass layers of each set, weren't the same size, making the bigger glass weak and easier to break.
- d) The bottom panel had pieces with double lead.
- e) One of the blue pieces of the central panel, had a small part broken with the addition of a thinner fragment from other glass.
- f) The sinuous shape of the glass pieces didn't always fit well with the shape of the other pieces.
- g) The coloured layers had a general order but with exceptions in the inferior panel (two border pieces) and in the central one (a border piece and in the angel figure piece). It's true that for the trichromatic technique the order of the coloured sheets doesn't affect the result, but I think that the disorder is strange in a new piece of work where you need to pay all of your attention on avoiding mistakes.
- h) Spot presence of paint in specific areas to reinforce the colour tone (for example in the red piece's grape of the central angel) or correcting the acid etched work which had eliminated some elements (for instance, the eye of the music angel on right hand side).
- i) The presence of two yellow pieces without image, with the acid etched on the wrong side; it doesn't affect the result but again it shows a bit of disorder.
- j) Finally, looking at the angels, we could observe that perhaps several hands were involved in its creation. In my opinion there could be different ways to make the work. One with a confident hand and a structural use of the colour and, at least, another one which works on the image in a different way.

All of these facts made me think about the execution of the stained glass. In my opinion, it could look more like a group exercise than a professional workshop piece.

The Montserrat Monastery's documentation studied, gives us a little more information about other chapel elements' performance but concerning the trichromatic stained glass, only the abbot's reference, which was previously mentioned, can be found. The current monks say that the reason for the lack of information, is that the families who paid for the rehabilitation work, chose every element, so if anyone has the whole documentation it would probably be them.

On that point, and trying to get more information, I thought of contacting a descendant of Ramon Soler but, unfortunately, the descendants were no longer alive. The last known relative, gave the monastery all the documents related to their business between Montserrat and the family but, apparently, there was nothing about the Immaculata Chapel work.²³

²³ P. Josep GALOBART, conversation on 3 December 2019.

The abbot recognised the Immaculate Chapel as the one with the richest decoration compared to the others but rare by its modernist style.²⁴ Despite its uniqueness, it wasn't documented much. The monastery considered the rehabilitation and decoration of the chapel as a private religious act, so the work was done without advertising in a discreet way and, this discretion still now survives.



*Fig. 4. The two angels carrying flower garlands, in the second row.
We can observe different ways to work on each one and also, compare with the other figures.
Stained-glass window in the Immaculata Chapel on Montserrat Monastery (1910), Paloma Somacarrera, 2018.*

Summarizing:

If we focus on the identity of a piece of art, we have to bear in mind all the characteristics or qualities that make this work unique and different from the rest. Therefore, in my opinion, we have to make a special effort to research the historical matters surrounding the piece.

What this stained glass was for me, probably isn't the same as what this stained glass was for its creator or for its contemporary society. I won't throw in the towel and I will continue the research, hoping to find enough information to be able to close the circle around the only one sample of a trichromatic stained glass installed in Catalonia and, according to the date, the nearest follower of Gaudí's stained-glass windows of Mallorca, despite the fact it doesn't come from his direct collaborator group.

In the meantime, the most respectful attitude in our approach to stained glass is always necessary. However, when you have to intervene to preserve it, you must take some decisions and, inevitably, some changes are going to happen. Lastly, trying to satisfy your possible curiosity and without intending on being a model or guide for you, I'll briefly mention some of the actions we have taken:

- After documenting as much of the stained glass as I could, it was taken out, packed and moved to the workshop.
- In order to eliminate the dirt between the layers of glass and to glue the broken pieces of glass, the lead was removed by cutting it on the soldered points. The small pieces of wood or lead we had found, were documented and saved. The lead presented spot damages, but its condition wasn't very bad; at that point, we had to take the difficult decision whether to preserve it or to remove it. I didn't feel confident enough

²⁴ Arxiu de Montserrat, A-I e. 13: Josep DEÀS, "Restauración de la Iglesia de Montserrat", p. 46-48.

about how it was going to work after its manipulation, considering its return to an outside environment and knowing of the difficulties of further interventions. We debated it with the others people responsible and we agreed to change the lead network keeping samples of the old one.

- After cleaning and gluing the glass, in order to avoid new layers of dirt, we decided to introduce another important change: the sealing of the glass sets, with neutral transparent silicone put on the edges.
- We agreed the deformation of the bottom panel was caused by the small space it had. In order to fix it, we moved the zigzag “T” iron bars few millimetres up, looking at the free space there was on the top of it.
- The paint spots were conserved but we didn’t add what was missing.
- The elements which were in disorder and the ones that had the acid etching on the wrong side, were kept in their original position.

These are some of the main actions we carried out, in our intervention on the Immaculata stained glass of the Montserrat Monastery, trying to reach the difficult balance between the introduction of changes, aimed at improving its future condition, and the preservation of its original characteristics.

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4.2

Documentation and Reconstruction of the Depiction of the Virgin Mary in the 15th-Century Stained-Glass Window of the *Annunciation* from the Dominican Monastery in Kraków

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Dokumentation und Rekonstruktion der Darstellung der Jungfrau Maria im Glasfenster der Verkündigung aus dem 15. Jahrhundert aus dem Dominikanerkloster in Krakau – Zusammenfassung

In diesem Artikel werden die Ergebnisse der digitalen Dokumentation und Rekonstruktion der Mariendarstellung einer mittelalterlichen Glasmalerei vorgestellt. Das Glasfenster ist Teil der Verkündigung, die vermutlich um 1440 in der Werkstatt des dominikanischen Meisters für Marienleben angefertigt wurde. Aufgrund des schlechten Zustands der Glasmalerei (starke Korrosion des Glases, Farbschichtverluste, teilweiser Verlust der Lesbarkeit) war die Absicht, den aktuellen Erhaltungszustand zu dokumentieren und beschädigte Details der gemalten

Darstellung zu erkennen. Das wichtigste war die Verwendung von Techniken, die es ermöglichen, die Lesbarkeit der Komposition zu verbessern, ohne die historische Substanz des Buntglases zu beeinträchtigen. Aus diesen Gründen wurden Techniken wie die digitale Fotografie und Photogrammetrie, RTI/PTM und das digitale Mikroskop Hirox RH2000 angewendet. Die Ergebnisse ermöglichten die Ausarbeitung einer komplexen Dokumentation zum Erhaltungszustand der Glasmalerei: die Identifizierung von Maltechniken, das Erkennen von Spuren der gemalten Komposition und schließlich die Entwicklung einer Rekonstruktion der Mariendarstellung unter Verwendung digitaler Bildverarbeitungswerkzeuge.

Documentation and Reconstruction of the Depiction of the Virgin Mary in the 15th-Century Stained-Glass Window of the Annunciation from the Dominican Monastery in Kraków – Abstract

This paper presents the results of the digital documentation and reconstruction of the depiction of the Virgin Mary in a medieval stained-glass window. The panel is part of the scene of the Annunciation, presumably made around 1440 by the workshop of the Dominican Master of the Life of the Virgin. Due to the bad condition of the panel (severe corrosion of glass, losses of paint layer, partial loss of readability of the composition), a goal to document the current state of preservation and

recognize deteriorated details of the painted depiction was set. The most important was to use techniques which allowed the legibility of the painted composition to be improved, without interfering with the historical substance of the stained glass. For these reasons techniques such as digital photography and photogrammetry, RTI/PTM, and the Hirox RH2000 digital microscope were applied. The results obtained allowed for the complex documentation of the state of preservation of the panel, identification of painting techniques, recognition of deteriorated traces of painted composition, and finally, development of a reconstruction of the Virgin Mary depiction using digital image processing tools.

Introduction

In the Dominican Monastery in Kraków, many valuable works of sacred art can be found. Apart from unique works such as the Saint Hyacinth canonization banner from the 16th century and the figure of Crucified Christ with movable joints, the oldest Polish stained-glass windows are also preserved. It is worth mentioning that in Lesser Poland, only in Kraków are there three relatively substantial collections of indigenous medieval stained glass art. In the church of the Virgin Mary, 117 stained glass panels (1360-1400) and in the church of Corpus Christi 54 panels (from c. 1380 and 1420-30) are preserved.¹ The third collection of twenty-one stained-glass panels derives from the Dominican Monastery.² Unlike the other two, however, these works of art were taken out of the windows many years ago. Among them, the oldest examples of indigenous stained glass art from the 13th century are preserved.³ The collection also includes a group of seven panels made by the workshop of the Dominican Master of the

¹ Adam S. LABUDA and Krystyna (eds), *Malarstwo gotyckie w Polsce*, vol. 2. *Katalog zabytków*, Warszawa, DiG, 2004, p. 129.

² Eighteen of the preserved stained glass panels are exhibited in the National Museum in Kraków and three panels are stored in the Dominican Monastery.

³ Lech KALINOWSKI, "Die ältesten Glasgemälde der Dominikanerkirche in Krakau", in Lech KALINOWSKI and Helena MAŁKIEWICZÓWNA, *Ars Vitrea. Collected Writings on Mediaeval Stained Glass*, Kraków, PAU, 2016, p. 127-138. See also Lech KALINOWSKI and Helena MAŁKIEWICZÓWNA, "The Thirteenth-century Stained Glass Crucifixion Panel of the Dominican Church in Cracow", in Lech KALINOWSKI and Helena MAŁKIEWICZÓWNA, *Ars Vitrea. Collected Writings on Mediaeval Stained Glass*, Kraków, PAU, 2016, p. 139-153.

Life of the Virgin.⁴ They depict *the Throne of Grace*, scenes of *the Annunciation*, the *Coronation of the Virgin* and the *Adoration of the Magi* (each scene consisting of two panels).

The scene of the *Annunciation* consists of a left panel representing the Angel⁵ and a right panel depicting the Virgin Mary⁶ (fig. 1). Probably they originally decorated the windows of the chapel of the Annunciation (currently the Rosary Chapel), erected around 1440. However this cannot be verified due to the lack of any information about the appearance of the Gothic chapel.⁷ Presumably in the 17th century the stained-glass windows were moved from church windows to the cloisters windows.⁸



Fig. 1. Kraków, National Museum and Dominican Monastery, stained-glass panels depicting the Angel and the Virgin Mary at the Annunciation, c.1440. D. Podosek, © Corpus Vitrearum Polska.

From the 19th century, there have been two major renovations of the stained glass panel depicting the Virgin Mary. The first, at the turn of the century, involved the realization of the project of Stanisław Wyspiański (the famous Polish Art Nouveau artist), who proposed the reconstruction of the missing fragments of the panel and closing the original oval composition into a rectangle with an ornamental border. The second renovation was to take place after the Second World War, when the severely damaged panel was handed over to the stained glass studio of S. G. Żeleński in Kraków. However, this work was not carried out and the panel perished. Between 2016 and 2018, that is over 60 years from its disappearance and 30 years since its rediscovery, the necessary conservation treatment was carried out.

⁴ Dobrosława HORZELA, "Piętnastowieczny witrażowy cykl maryjny i jego miejsce w wystroju kościoła Dominikanów w Krakowie", in Monika JAKUBEK-RACZKOWSKA and Juliusz RACZKOWSKI (eds), *Claritas et Consonantia. Funkcje, formy i znaczenia w sztuce średniowiecza*, Toruń, Wydział Sztuk Pięknych Uniwersytetu Mikołaja Kopernika w Toruniu, 2017, p. 149-174.

⁵ Stained glass panel depicting the Angel is exhibited in the Gallery of Decorative Art in the National Museum in Kraków.

⁶ Stained glass panel depicting the Virgin Mary is stored in the Dominican Monastery in Kraków.

⁷ HORZELA 2017.

⁸ Danuta CZAPCZYŃSKA-KLESZCZYŃSKA and Tomasz SZYBISTY, "Korpus witraży z lat 1800-1945 w kościołach rzymskokatolickich metropolii krakowskiej i przemyskiej. Tom I. Archidiecezja krakowska, dekanaty krakowskie", in Wojciech BAŁUS and Tomasz SZYBISTY (eds), Kraków, Imedius, 2014, p. 152.

The Virgin Mary Annunciate

The stained glass panel was painted with glass-paint on clear, yellow and light violet glass contrasted with flashed red glass. The Virgin Mary is presented in a kneeling pose against a background of red fabric, surrounded by two ornamental borders (medieval and early 20th century).

The current arrangement of the figure kneeling and facing the angel, who is announcing the message from God, is the result of arrangement proposed by Stanisław Wyspiański at the end of the 19th century. It is certain that the stained glass panel was already in a bad condition. The only surviving documentation – a watercolour made by Ludwik Łepkowski between 1864-1865, shows significant destruction of the panel. Numerous interventions consisting of the replacement of broken panes with glass panes removed from other stained-glass windows rendered illegible the composition and iconography of the Virgin Mary. Moreover, the glass pane depicting the Virgin Mary's hands came from another panel, placed there for a restoration. On the Łepkowski's watercolour it is located in the panel presenting the image of the Angel at "the Annunciation". The fragment closest to the original arrangement of glass pieces is the upper part of the stained-glass window, which depicts the head of the Virgin Mary with a nimbus and a dove symbolizing the Holy Spirit above.

Research Goals

As mentioned, between 2016 and 2018 conservation treatment and instrumental analysis of the panel depicting the Virgin Mary was performed. The chosen analytical techniques, such as X-ray Fluorescence scanning (MA-XRF), Scanning Electron Microscopy – Energy Dispersive Spectrometry (SEM-EDS), X-ray Powder Diffraction (XRPD), led to the recognition of the state of preservation of glass and paint layers⁹. As a result of conservation, the construction of the panel was stabilized, cracks bonded, glass losses filled with glass infills, corrosion processes slowed down. Infills of medieval glasses were painted neutrally using vitreous paints. A significant part of the lead matrix has been replaced as well as two saddle bars and titanium-zinc frame were installed, which improved the stability and stiffness of the construction of the stained-glass window.

However, the irreversible results of corrosion processes visible as the matt surface of the glass, discolouration, a corrosion crust covering both sides of the glass panes, still affect the reception of the work. In particular, degradation of the paint layers (numerous losses of the contour lines and almost entirely deteriorated shading) led to the loss of readability of the depiction. The significant degree of deterioration of medieval glass and paint layers contributed to the decision not to retouch the losses on the object, but to reach for digital techniques.

Several goals have been set to achieve with the use of the digital tools. The first, was to develop the most accurate digital documentation of the condition of the glass and paint layers, and to recognize painting techniques used by the workshop of the Dominican Master of the Life of the Virgin. In addition to photographs in transmitted and reflected light, macro photographs, microscopic images (Hirox RH2000) and a high resolution orthophoto map were also taken. The second goal was to make the Virgin Mary depiction clearer despite such significant deterioration. For this purpose, RTI technique was used, with its possibilities in imaging the texture of the examined objects. The obtained results of all the techniques led to the last of the goals – a virtual reconstruction of the Virgin Mary depiction. To develop the projects Adobe Photoshop graphic editor was selected.

The main conservation objective was to conduct only the necessary treatment and maintain the current state of preservation of the paint layer. Any form of reconstruction on the object itself (such as using the separate sandwich glass or retouching with cold paints) was rejected. The only reasonable option, which respected all the processes and changes that the panel was subject to and provided broad opportunities, was the virtual reconstruction. The use of digital image processing tools makes possible a treatment which cannot be physically conducted on the object itself or whose realization would affect its original substance excessively. The improvement of the readability of the composition or even the restoration of the original appearance of the stained-glass window can be achieved. These tools are increasingly used in stained glass conservation practice. Another comparable example is the 2013-14

⁹ Edyta BERNADY, Marta KAMIŃSKA, Michał PŁOTEK and Małgorzata WALCZAK, "The investigation of 15th century paint layers on two stained-glass windows from the Dominican Monastery in Krakow (Poland)", *Glass Technology - European Journal of Glass Science and Technology Part A*, 59 (2), 2018, p. 46-53.

digital restoration of the stained-glass window of “The Birth of Mary” from the Carmelite Church in Boppard (Germany).¹⁰

Methods

In order to prepare full visual documentation of the condition of glass and paint layer of the Virgin Mary Annunciate, photographs and macro photographs using the digital camera and microscopic images using Hirox RH2000 digital microscope were taken. Also a high resolution orthophoto map was prepared.

Hirox RH2000 microscope (New Hirox HD 3D Digital Microscope System) is an optical digital microscope equipped with a variety of lenses, as well as specialized software. It provides valuable information about the analysed material. The Hirox microscope was used mainly for surface imaging, recognition of the technology and state of preservation of glass and paint layers. However it was also helpful in reading the traces of painted composition. Instrument used for the research was equipped with two lenses: 20x-160x with adapters and a 35x-2500x revolver lens. Photographs of the dismantled glass panes were taken in reflected and transmitted light, with and without polarization.

In order to make the painted depiction easier to recognize RTI/PTM was applied. RTI (Reflectance Transformation Imaging) derived from the PTM (Polynomial Texture Mapping) imaging is a popular technique for imaging the texture of objects. This technique is increasingly used for documenting and analysing many types of objects, from paper documents to sculptures. The final image is a combination of a series of photos taken from the same point, but illuminated by different light direction. It can be prepared using two algorithms HSH (Hemispherical Harmonics) and PTM (Polynomial Texture Map). In both cases, every pixel of the image carries information about the colour (RGB) and information about the direction of light, which allows to obtain a map showing the distribution of the surface normals. The RTIViewer program enables the analysis of the obtained result with the possibility of changing the angle of the lighting and to choose proper rendering mode.¹¹ The possibilities of active change of the lighting and special image processing allow to detect more surface details than any photograph taken in side light. In case of the panel depicting the Virgin Mary two rendering modes worked best, the Specular Enhancement and Diffuse Gain. First mode separates the RGB colour of the image from light reflections, which allows the observation of both layers simultaneously or separately, revealing the details of the surface of the object. Second algorithm only increases the contrast of the observed image.¹²

To achieve better resolution of the final RTI image of the stained-glass window depicting the Virgin Mary Annunciate, it was divided into two parts. Canon EOS 7D camera was used, with the exposure time of 1 and 1.5 s. The angles of the lighting were determined by means of black spheres. The final images were prepared in the HSH-algorithm. Moreover imaging of three glass panes (depicting the Virgin's Head, her nimbus and part of the yellow border) was conducted. Pieces were chosen based on differences in texture characteristics. In this case, a specially designed dome and Fujifilm mirrorless camera were used. The exposure time was 1s. The final images were prepared in the PTM-algorithm.

Results

Elaboration of the digital documentation was initiated by taking photographs of the panel's condition before conservation. Photographs and macro photographs in transmitted and reflected light were taken. Partial dismantling of the lead matrix executed during the treatment, allowed for detailed microscopic analysis of several medieval glass panes. Preparing the orthophoto map and RTI was the last part of the documentation, made after conservation.

¹⁰ Boppard Conservation Project - Glasgow Museums, “A Digital Restoration of the Birth of the Virgin Panel”, 2014, <https://boppardconservationproject.wordpress.com/2014/09/24/a-digital-restoration-of-the-birth-of-the-virgin-panel/>, [August 28, 2019].

¹¹ Gianpaolo PALMA, Massimiliano CORSINI, Paolo CIGNONI, Roberto SCOPIGNO and Mark MUDGE, “Dynamic Shading Enhancement for Reflectance Transformation Imaging” *ACM Journal on Computing and Cultural Heritage*, 3 (2), 2010, <http://culturalheritageimaging.org>, [March 18, 2018]. See also “Cultural Heritage Imaging | Reflectance Transformation Imaging (RTI)”, <http://culturalheritageimaging.org/Technologies/RTI/> [August 28, 2019]; and Alexander M. DITTUS, “Reflectance Transformation Imaging of Glass Objects”, in Hannelore ROEMICH and Lauren FAIR (eds), *Recent Advances in Glass and Ceramics Conservation*, Paris: International Council of Museums - Committee for Conservation (ICOM-CC), 2016, p. 145-154.

¹² “Guide to RTIViewer”, 2010, p. 11-14, http://culturalheritageimaging.org/What_We_Offer/Downloads/rtiviewer/RTIViewer_Guide_102.pdf [March 18, 2018].

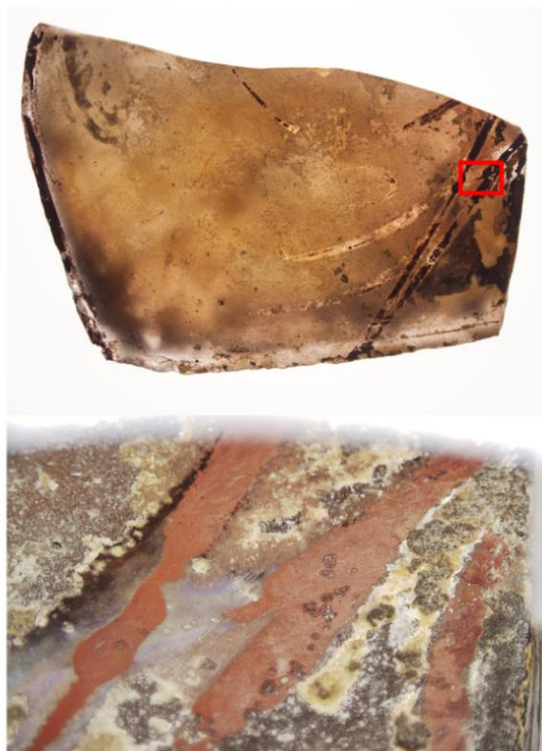


Fig. 2. Microscopic image in reflected light of medieval paint layer (Hirox RH2000 digital microscope with revolver lens). E. Bernady, M. Momot.

For the microscopic analysis using the Hirox RH2000, heavily corroded glass panes with almost illegible paint layer were chosen. The observations revealed a lot of valuable information about the condition of glass and the paint layers. They showed the extent of glass corrosion under the paint layer and allowed to measure the depth of corrosion pits into the structure of glass, among other things.

The possibility of observing the glass panes in reflected and transmitted light was crucial to show surface features of the analysed pieces. Partially preserved contour lines and traces of shading paint were accurately documented (fig. 2). Figure 2 also shows the corrosion pits going through the trace line paint.

To document the condition of the painted depiction of the examined panel, the use of revolver lens was also very helpful. Changing the angle of observation and rotating of the lens allowed for highlighting the traces of paint layers preserved on the surface of the glass.

Besides the documentation of the state of preservation of the panel, the Hirox RH2000 microscope led to recognition of the painting techniques. Despite the numerous losses of paint

layers it was possible to notice some details of ornaments remaining in the texture of corrosion crust or traces of vitreous paint covering back of the glass panes. However, it was only possible to examine under the Hirox microscope pieces dismantled from the stained glass panel. Thus, important parts of the composition, such as the Virgin's face or nimbus, required the use of other techniques to recognize the painted details.

For this reason the RTI/PTM was performed. The opportunity to carry out imaging of the entire medieval part of the stained-glass window as well as individual glass panes gave significant results.

At first, RTI of the stained-glass window divided into two parts was performed. The series of digital photographs were developed using HSH-algorithm. Observations of the final images were made in the Specular Enhancement rendering mode. Changing the direction of the lighting revealed many texture details of medieval glass panes, allowing to identify the painted composition even at more deteriorated parts. An example of the obtained results is presented in fig. 3. Observation of that fragment was focused on recognizing the drawing of the border pane. RTI was able to significantly improve readability of the drawing, which was partially visible in the corrosion pattern.



Fig. 3. Photograph in reflected light and RTI SE image (HSH). E. Bernady.

Afterwards, imaging of the three individual glass panes was also conducted. As mentioned above, pieces depicting the Virgin's head, her nimbus and part of the yellow border were chosen. Final images were developed using PTM-algorithm. The obtained images were analysed in Diffuse Gain and Specular Enhancement rendering modes. Due to the high resolution of the final images, they allowed for better illustration of painting details present on selected glass panes. Despite the severe deterioration of chosen pieces, it was possible to notice more details of the Virgin's face as well as the design of the nimbus etched in the thin layer of the shading paint.

The results obtained led to the recognition of the partially preserved depiction of the Virgin Mary. A thorough analysis of all the images of the panel, together with analysis of the style of the Virgin Mary in depictions of the *Adoration of the Magi* and the *Coronation of the Virgin* (also made by the workshop of Dominican Master of the Life of the Virgin), contributed to the development of a virtual reconstruction of the deteriorated depiction. Reconstruction projects were made in Adobe Photoshop on the basis of the orthophoto map. The high-resolution image was prepared from the assembly of a series of photographs of the stained glass panel. It was possible to achieve the resolution of 0.07mm of the final orthophoto map. The virtual restoration projects were focused primarily on the reconstruction of the current composition of the panel. All historical additions have been left, including glass pieces added during the last conservation and the present shape of the lead matrix. Projects included mainly the reconstruction of the contour drawing and restoration of red colour of flashed glass (fig. 4).



Fig. 4. Digital reconstruction of the Virgin Mary: (a) orthophoto map; (b) digital reconstruction of the contour lines and restoration of red colour of background glass panes. Photo: P. Gąsior, B. Mitka, image: E. Bernady.

Conclusion

As the paper has presented, selected digital techniques have led to the accomplishment of all goals. The results allowed the preparation of complex visual documentation of the stained-glass window condition, including the degree of glass deterioration and current state of preservation of paint layers. Moreover, they led to the recognition of the illegible details of the painted composition, such as detailed features of the Virgin Mary depiction, patterns etched in the thin layer of shading paint, traces of the paint layer on the reverse of the glass panes. Together with the stylistic analysis of the other stained-glass windows from the same workshop, achievements enabled the development of virtual reconstruction projects. The use of an orthophoto map creates many possibilities for further image analysis and future museum exhibitions.

Despite the bad state of preservation of the depiction, the virtual reconstruction shows precision and attention to detail of the workshop of Dominican Master of the Life of the Virgin.

Based on the example of the stained glass panel depicting the Virgin Mary Annunciate, the potential of digital techniques as valuable tools of documentation and analysis in the hands of art conservators was shown. They allow us to document not only the state of preservation, but also the technological aspects, such as painting techniques. The virtual restoration and reconstruction give a wide range of possibilities of presenting the stained-glass windows as well as carrying out the conservation treatment, which on the physical object has to be restricted or cannot be undertaken for some reason. These methods allow us to perform actions without interfering with the original substance of the artwork. Digital documentation and virtual reconstruction are both valuable sources of knowledge for specialists, conservators or historians, but they can also be significant for education of non-specialist recipients about the importance of heritage preservation.

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4.3

The Stained Glass Conservation of Trinity Church, Wall Street

Brianne Van Vorst and Drew Anderson

La conservation des vitraux de l'église de la Trinité, Wall Street – Résumé

Quand on pense à Trinity Church à New York, sa façade en grès vue de Wall Street ou du cimetière emblématique nous vient à l'esprit. À l'intérieur, l'église abrite plus d'une centaine de fenêtres en verre teinté et au plomb datant de la construction du bâtiment original des années 1840 jusqu'à l'époque de l'ajout arrière introduit dans les années 1960. Cet article explore l'identité des vitraux de l'église de la Trinité et comment cette identité a été maintenue pendant le programme de conservation.

L'identité de ces fenêtres est explicitement fondée sur leur conception, d'origine, leur état et leur histoire de conservation. La fenêtre du chœur à l'extrémité ouest est la plus ancienne fenêtre figurative de Manhattan (vers 1845) et la seule fenêtre figurative de l'église principale de Trinity. Les bas-côtés et les vitraux des parties hautes sont de la même date et sont typiques de l'esthétique et de la palette de couleur évoquant des pierres précieuses du milieu du XIX^e siècle : un fond losangé mis en valeur par des bordures peintes. L'architecte de Trinity, Richard Upjohn, était responsable de la conception du bâtiment ainsi que d'une partie importante de la conception des vitraux. L'implication de l'architecte dans la conception du vitrail est peu rare. Upjohn était un designer talentueux, mais pas un vitrier. L'énigmatique Abner Stephenson semble être apparu de nulle part pour réaliser les fenêtres. Les vitriers étaient une rareté à New York en 1844, mais Stephenson était véritablement un choix hors du commun, peintre sur verre compétent - son travail possède un style spécifique et montre une compréhension claire des matériaux et de la technique -, mais certains aspects de la mise en œuvre des fenêtres à Trinity suggèrent qu'il pourrait avoir été un vitrier inexpérimenté.

Aujourd'hui, nous voyons que l'état des fenêtres a été affecté par la modification de l'environnement extérieur de l'édifice : une ligne de train surélevée et plus

tard un métro sous l'église semblent avoir provoqué un mouvement important dans les maçonneries et dans les fenêtres elles-mêmes. Les sources documentaires ont révélé que les ruptures du verre dues au mouvement de la pierre, les actes de vandalisme et les campagnes d'entretien ont contribué à une multitude d'interventions sur ce vitrail au cours des 175 dernières années.

Les enquêtes effectuées par les auteurs pour procéder à l'état des lieux ont donné des preuves des restaurations : réparations lourdes avec raccords et bretelles de plombs ; réparations à l'aide de feuilles de cuivre ; compléments mal peints ; remplacement de panneaux entiers ; peinture à froid appliquée n'importe comment sur des fenêtres entières ; bordures aux verres anachroniques ; traces dues à la pulvérisation de peintures et différents types de vitrages de protection non ventilés. Des dégradations classiques telles que des ruptures de plombs non traitées, des pertes de peinture, des barlotières manquantes ou cassées et des déformations de panneaux ont également été observées sur les fenêtres. Les relevés ont révélé quatre baies des parties hautes avec leurs réseaux d'origine. L'inaccessibilité de ces baies de l'extérieur témoigne de leur ancienneté et donne un aperçu du passé.

Une approche axée sur la conservation a été mise en œuvre pour préserver les conditions existantes dans la mesure du possible et améliorer les éléments qui ne fonctionnaient pas correctement sans diminuer l'identité inhérente au vitrail.

Tous les aspects de ce projet ont été pris en considération pour l'entretien continu et les futurs conservateurs. Une documentation complète était nécessaire pour brosser un tableau très clair de ce qui était conservé et des matériaux spécifiques utilisés. La campagne de conservation a assuré un long avenir aux vitraux de l'église de la Trinité avec un impact minimal sur son identité établie de longue date.

The Stained Glass Conservation of Trinity Church, Wall Street – Abstract

When one thinks of Trinity Church in New York, its sandstone façade seen from Wall Street or the iconic graveyard come to mind. Inside, the Church holds over one hundred stained and leaded glass windows dating from the original 1840s building construction through to the time of the rear addition introduced in the 1960s. This paper explores the identity of the stained glass in the primary structure of Trinity Church, and how it was maintained during the recent conservation program.

Trinity's architect, Richard Upjohn, was responsible for the building design as well as a significant part of the stained glass scheme. The enigmatic Abner Stephenson appeared as if from nowhere to fabricate

the windows. The identity of the stained glass is built upon and inextricably linked to its design: reflecting Victorian stained glass iconography and jewel-toned color palette; construction: the windows in the main part of the church were fabricated on site; and its conservation history: continued maintenance intended to preserve one of the building's most distinguishable qualities. The Chancel window at the west end is remarkable as the oldest figural window in Manhattan and the sole figural window in Trinity's main church. Condition surveys carried out by the authors showed physical evidence of the previous restorations: heavy repairs with cumbersome mending and strap leads; copper foil repairs; poorly painted restoration infills; wholesale replacement of panels; indiscriminate cold paint applied across entire windows; borders made

of glass not available at the time of the original fabrication; back spray from interior painting and various types of unventilated protective glazing. Typical degradation such as untreated breaks, paint loss, missing or broken saddle bars and bowing were also seen throughout the windows. The surveys revealed four bays of entirely original clerestory tracery. The inaccessibility of these bays from the exterior evidenced their originality and provided a glimpse into the past. The project was also met with a uniquely American challenge: asbestos.

A conservation-focused approach was implemented to preserve existing conditions wherever possible and improve upon the elements that were not functioning properly. Consideration was given throughout all aspects of this project to ongoing maintenance and future conservation. Extensive documentation was required to paint a very clear picture of exactly what was conserved, and which specific materials were used. The conservation campaign has ensured a long future for the stained glass at Trinity Church with minimal impact to its long-established identity.

The Character of Trinity Church

The history of Trinity Church spans three hundred years. The iconic building situated at 75 Broadway is the third Trinity Church built on this site (fig. 1). The current structure was begun in 1839 and finished in 1846. The identity of the building and its stained glass comes from those responsible for its creation: architect Richard Upjohn and glazier Abner Stephenson. They created the first example of Gothic Revival



Fig. 1. Trinity Church, exterior. Photograph by Trinity Church and reprinted with their permission.

architecture in New York and the earliest surviving American-made figural stained glass in Manhattan. The identity of the stained glass is built upon and inextricably linked to its design: reflecting Victorian stained glass iconography and jewel-toned color palette; construction: the windows in the main part of the church were fabricated on site; and its conservation history: continued maintenance intended to preserve one of the building's most distinguishable qualities. Trinity Church has been designated a National Historic Landmark since 1976.¹

Richard Upjohn came to America in 1829 as a carpenter.² By 1833 he was marketing architectural plans and elevations. In 1834 he moved to Boston and worked for various architects as a draftsman while marketing his own designs. During these early years, he befriended the rector of Trinity Church, Boston: Dr. Jonathan Mayhew Wainwright. Wainwright was called to fill a vacancy at Trinity Church, Wall Street.³ By the time he arrived, the second Trinity Church on Wall Street (c. 1788-90) was in disrepair with a dangerously sagging roof. Upjohn was called to New York to assess the building in 1839.⁴ The repair of the existing building was not possible, and Upjohn submitted plans for a new church in 1839.⁵ Construction started that year.

¹ National Register of Historic Places, Trinity Church, New York, NY #76001252.

² Everard UPJOHN, *Richard Upjohn: Architect and Churchman*, Columbia University Press, New York, 1939, p. 23.

³ UPJOHN 1939, pp. 31-47.

⁴ UPJOHN 1939, p. 48.

⁵ UPJOHN 1939, pp. 49-50.



*Fig. 2. Trinity Church, window C219, Chancel stained-glass window. 2020.
Photograph by Whitney Cox, reprinted with permission of Trinity Church.*

Abner Stephenson was hired to fabricate the stained glass. Glaziers were a rarity in New York in 1844, but Stephenson seems an unusual choice. The archives do not contain any information regarding his training or pedigree. Stephenson immigrated to New York with his family and arrived on 20 May 1836, on the ‘South America’ out of Liverpool, England. On the ship’s registry, he listed his age as 24 and profession as a “Herald Painter.” Stephenson’s 1844 naturalization paperwork lists his former nationality as English. It is unknown how he and Upjohn met. In fact, very little is known about him other than the aforementioned details. Trinity is the only confirmed building still containing glass fabricated by Stephenson that we have identified. The original glazing contracts between Abner Stephenson and Trinity Church exist in Trinity’s archives.⁶ The windows were fabricated on the church’s grounds.⁷

Surviving drawing fragments illustrate the breadth of Upjohn’s involvement in the stained glass, a role unusual among American architects of this period.⁸ A previous article outlines that after several solicitations for the design of the Chancel window, it was ultimately Upjohn who designed it.⁹ The cartoon was drawn by artist Thomas Hoppin and the window was cut, painted and glazed by Abner Stephenson.¹⁰ The Chancel window depicts Christ flanked by six apostles (fig. 2). The lower register and tracery contain foliage and Christian symbols. The color palette, style of painting and elements of iconography appearing in the Chancel are echoed in the aisle and clerestory windows. These elements were a planned characteristic of the stained glass scheme.

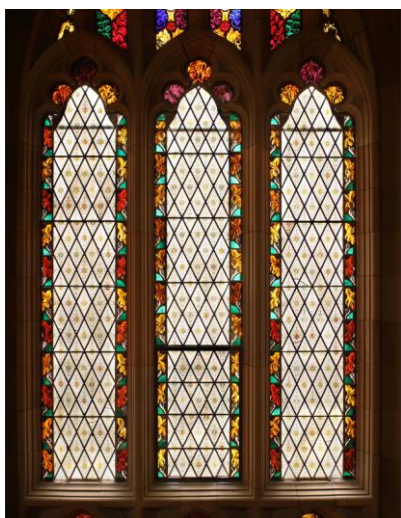


Fig. 3. Trinity Church, window A111, stained-glass aisle window. 2019. Photograph by Whitney Cox, reprinted with permission of Trinity Church.

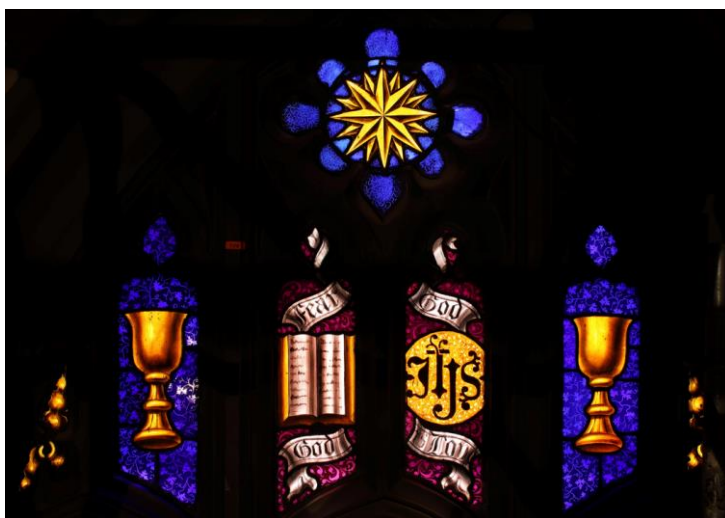


Fig. 4. Trinity Church, window B208, clerestory tracery, 2018. Photograph by Whitney Cox, reprinted with permission of Trinity Church.

The formulaic design of the sixteen aisle windows contain a printed quarry field within each lancet, surrounded by vertical colored borders (fig. 3). The quarries are colorless glass with an ornamental pineapple or pinecone, perhaps a bulb flower, with a small amount of silverstain in the center. The borders are comprised of various types of foliage, each section containing a colored accent piece. Every window has a unique tracery filled with jewel-toned colored glass painted with foliage and Christian symbols. The silverstain varies from pale yellow to rich amber throughout. It is noteworthy that the original aisle scheme still exists at Trinity. Diamond glazing is traditionally undervalued in the United States and has often been replaced with opalescent memorial windows in the early 20th century when the work of

⁶ “Memorandum of an Agreement,” contract, signed by Abner Stephenson and each member of the Building Committee, 1 July 1844, Trinity Wall Street Archives (TWSA). The Chancel window was a separate contract signed in October 1845. “Minutes of Building Committee of 3rd Trinity Church re: Stained-glass windows,” n.d. TWSA [1].

⁷ UPJOHN 1939, pp. 54-55.

⁸ The Upjohn collection of architectural drawings by Richard MICHELL and Hobart UPJOHN: Architectural drawings papers and records, 1827-1910. Dept. of Drawings & Archives, Avery Architectural and Fine Arts Library, Columbia University, New York, N.Y. K-13 1B.

⁹ Julie SLOAN, “‘The richest colors imaginable’: The stained glass of Trinity Episcopal Church”, Wall Street, NY (1846), *The Journal of Stained Glass*, vol. XXXVI, 2012, p 56-77.

¹⁰ *Ibid.*

designers like Louis C. Tiffany and John LaFarge flourished in popularity. At least once, Trinity Church considered replacing the existing stained glass with new (1932).¹¹ The change was never executed, implying that the church was self-aware of its fundamental identity.

The original clerestory lancets were replaced in 1967. Documentation in the Trinity archives from 1932 provides evidence of paint loss to lancets within the clerestory level,¹² further substantiated by a 1967 unpublished research paper.¹³ It is assumed that the aesthetic ramifications of paint failure triggered the replacement of the clerestory lancets. Only the original clerestory tracery glass survives and, like the aisle, is jewel-toned in color and painted with foliage and Christian symbols (fig. 4).

Upjohn and Stephenson were early in their careers at the time they received the commission for Trinity Church, but their combined efforts in design and style set the tone for the Gothic Revival style in America. The consecration of the Church and its windows was recorded in the May 1846 *New York Herald* article,¹⁴ which praises the ambitious colored and painted glass. Trinity Church quickly became a distinguished icon in lower Manhattan and has retained the majority of its original glazing, maintaining an ageless, yet period-distinctive, character.

Existing Conditions

Typical Conditions

The stained glass in the church was set in a glazing groove with mortar. The exterior, and in some cases the interior, of the windows were caulked over several times as part of “general maintenance” campaigns.¹⁵ Any natural stone movement was exacerbated by both the construction of elevated train lines (beginning in the 1870s) and the subway, run under Broadway directly in front of Trinity Church, in 1904. The impact of the subway was recognized by the city of New York, and in 1935 a report of examination of the church tower and Interborough Rapid Transit subway was published.¹⁶ The masonry moved significantly over time, especially at the east end of the building causing stress breakage throughout the windows. Breakage also ensued from vandalism. For example, on 30 September 1977 “a vandal threw rocks through practically all of the lower stained-glass windows on the north and south sides of Trinity Church.”¹⁷

Given these conditions, nearly all of the windows were restored, some several times. This included the cleaning, repair, replacement, and re-leading of the windows in at least six different decades (1914, 1932, 1946, 1977, 1990s).¹⁸ Although the intention during these campaigns was to maintain the original appearance of the stained glass, original materials were often sacrificed to improve aesthetics. The 1932 restoration included more than one thousand new diamonds and three hundred pieces of border.¹⁹ In cases where existing materials were retained, antiquated repair techniques (such as grozing glass to allow for a lead repair) irreversibly changed the original material. Protective glazing was inconsistently added over time, giving the exterior of the building an unbalanced façade. The only original lead identified was in four tracery openings in the clerestory level: no original lead survived in the aisle or Chancel.

¹¹ With thanks to Building Conservation Associates, Inc for providing preliminary research. TWSA Property Management Collection, Box 539, File 5.

¹² With thanks to Building Conservation Associates, Inc for providing preliminary research. “Letter from Heinigke and Smith to Reverend Stetson.” TWSA Property Management Collection, Repairs 1924-1939, Box 539, File 5.

¹³ TWSA Property Management Collection, Box 539, File 5. Margaret H. TUFT, ‘The Stained Glass of Trinity Church, New York’, unpublished paper, 8 November 1967, Avery Library, Columbia University.

¹⁴ “Consecration of Trinity Church,” *New York Herald*, 22 May 1846, 1.

¹⁵ The word caulk relates to the application of a weatherproofing substance of any or all but not limited to the following materials: polyurethane, butyl, silicone, asbestos, latex, acrylic, vinyl.

¹⁶ Ralph A. CHAMBERS & Harry ENGLANDER, “Trinity Church, Broadway and Wall Street, New York City: report of examination of the church tower and Interborough Rapid Transit subway”, 1935, Avery Library, Columbia.

¹⁷ With thanks to Building Conservation Associates, Inc for providing preliminary research, substantiated in the TWSA Comptroller Collection, Box 651, file 2.

¹⁸ With thanks to Building Conservation Associates, Inc for providing preliminary research substantiated in the TWSA, 7 volume Trinity publication titled *A History of the Parish of Trinity Church in the City of New York*.

¹⁹ With thanks to Building Conservation Associates, Inc for providing preliminary research, TWSA Property Management Collection, Box 539, File 5.

The Aisle

Despite their previous re-leading, the aisle panels exhibited bowing in many places. Exterior bars were retroactively soldered onto the matrix but were not set into the stone and were not providing adequate support. The extent of previous repairs in the aisle windows varies from the sporadic replacement of individual pieces to the complete replacement of entire panels. Due to poor execution, some of the replacement pieces are easily identifiable, while others closely replicate the original pieces. Previous restorers repurposed quarries, often joining two different halves together with lead. There were many cumbersome mending leads. The south side of the aisle has typically been restored more often. Inconsistencies within the quarry design illustrate different hands at work during multiple restorations.

In the early–mid-20th century, a reredos was installed in front of north aisle window 114. It appeared that this window was only restored once before the reredos sheltered it from further intervention. Window 114 became the point of reference for identifying original quarries. The diamonds identified as the oldest (given the paint color, design, and condition) show no evidence of brushstrokes. The schedule of completion for the aisle windows, containing nearly 6,500 diamonds, was approximately ten months.²⁰ Given the lack of brush strokes and short production timeframe, it is our opinion that the original aisle windows were mass-produced, perhaps transfer printed. Diamonds identified as original exhibited lost or fragile paint.

The two east-facing aisle windows (101, 116) were replaced entirely in the past. The border pieces were sympathetic to the borders elsewhere in the aisle windows, but the quarries themselves were a very dark gray, entirely out of keeping with the rest of the windows.

Another notable aspect of the aisle windows is what we referred to as the “shoulder piece.” In nearly all of the panels, the corner quarries at the stone cusps were broken (likely during past removals) and a replacement piece inserted. In most cases, the replacement piece was clear glass with matte heavily applied; in a few cases, there was a re-purposed quarry. We do not know if the shoulder pieces were originally a continuation of the quarry design or the border design.

The Clerestory

Like the aisle, areas of the clerestory tracery had been restored multiple times. Given the height of the nave and documentation in the archives, work undertaken on the clerestory windows was done from the exterior side aisle roof. The four bays on the west end of the church do not have an aisle roof underneath the clerestory level. Thus, windows 208-211 were not accessible from the exterior and escaped restoration since their original installation. These are the only four tracery openings containing original lead.

The lack of proper interior access coupled with breakage resulting from stone movement led to dozens of replacement pieces and unsatisfactory repairs throughout the clerestory tracery. Aside from the small amount of original lead, the rest of the clerestory tracery was releaded in the 1940s and 1990s. The 1990s restoration entirely replaced approximately 13 panels. Regrettably, the replacement panels were made significantly smaller than their openings. Other panels treated during the 1990s restoration campaign used a combination of original glass and replacement pieces.

As mentioned above, clerestory lancets were entirely replaced in 1967. The 1967 windows were printed with a fleur-de-lis on yellow glass surrounded by a stylized foliage border: an interpretation of the original clerestory design. It is important to note that although the windows were replaced, the Victorian design of diamond quarries inside stylized borders was maintained. The lancets were all set into steel and bronze frames, many of which were ill-fitting, and voids were filled with backer rod and caulk.

The Chancel

The multiple interventions undertaken on the Chancel window were obvious by the size and condition of the lead and further evidenced by information in the archives and graffiti on the exterior of the stained glass. Noticeable replacement pieces permeate the window, as in the example of St Matthew’s head. The window had also been cold painted on many occasions with dark paint and/or shellac. In

²⁰ Stephenson’s contract was signed on 1 July 1844. The majority of the windows in the church were complete by May 1845 as per “Trinity Church, New York,” from *N.Y. Mirror*, [Baltimore] *Sun* (May 27, 1845), 1.

some areas, the cold paint was applied across the lightest areas of the window *in situ* and extended over the lead came. A photochrome from c. 1901 shows the presence of exterior glazing, suggesting that the abundance of light coming through the window required mitigation.²¹ This “smoke glass” was later removed and cold paint was applied, possibly to minimize glare. The glass paint was discovered to be fragile, and the fragility likely factored into the decision to apply cold paint in the past. The various applications of cold paint throughout the window have been affected by moisture and natural deterioration, causing a blotchy and inconsistent appearance.

Conservation

The CVMA guidelines and our condition surveys informed the conservation approach. All treatment prescribed during this campaign is re-treatable or reversible. Importantly, Trinity Church set goals of sustainability and greater thermal insulation of the overall building. Therefore, the stained glass conservation scope was designed from the outset to include environmental protective glazing in the Chancel and an adapted form of internal ventilation elsewhere.²²

Asbestos

Caulk and glazing putty containing asbestos is a particular problem in the United States. Caulk – rather than the traditional use of lime mortar pointing – has been used commonly in window settings for decades. Asbestos was added into building materials freely in the period from 1930 up through the 1970s. The health risks that Asbestos Containing Material (ACM) poses to humans has since been identified. ACM can become friable and inhaled when disturbed. In the State of New York, the disruption of friable ACM material triggers the need for abatement by specially trained and licensed professionals.

The glazing putty and caulk at Trinity Church tested positive for ACM. The effects of abatement became the main issue taken into consideration when determining the necessity of removing the windows. The risks were carefully weighed by the stained-glass consultants, project architects, and client.

Preliminary testing was conducted with the intention of softening the ACM. Softening the material would allow for its removal with hand tools, minimizing the level of force the abatement professionals would need to employ near the stained glass. A variety of solvents were tested. Although no single solvent was 100% successful (multiple campaigns of exterior caulking used different types of caulk), Dichloromethane based solvents had the greatest effect. The solvents softened areas of the caulk enough to remove layers of caulk with hand tools. Tools with oscillating blades were then used to free the windows at the groove.

The original conservation scope included necessary conservation treatments required for the longevity of the stained glass and stone and the introduction of new protective glazing. The success of the abatement test informed our decision to move forward with removal of the windows to permit conservation.

Aisle

After abatement and removal, the paint stability of each aisle panel was tested. Dismantling allowed access to the multitude of early lead repairs and poor replacement pieces within the center of the panels. After dismantling, both sides of the windows were gently cleaned with deionized water and cotton wool swabs. Pieces containing unstable paint were cleaned on the exterior non-painted side, and any stubborn putty was carefully mechanically removed.

Only the poorest painted restoration pieces (quarries of the wrong color glass or design) were replaced with appropriate substitutions. Thick mending leads were removed, and the glass was bonded using epoxy Hxtal NYI-1 and neutral cure silicone as often as feasible. Copper foil was introduced when bonding was not possible, and in some cases lead repairs were reintroduced. For example, where two

²¹ Library of Congress, LC-DIG-det-4a31840. Available online at <https://www.loc.gov/pictures/item/2016794157/> [accessed 1 December 2019].

²² As stated in the CVMA guidelines in section 3.2.1, protection is integral for long-term survival. Corpus Vitrearum, *Guidelines of the Conservation and Restoration of Stained Glass* (Nuremberg, 2004). Published online at <http://www.corpus-vitrearum.org> [accessed 1 December 2019].

different quarry pieces with different designs were jointed with lead, thinner lead or foil was used. The negative aesthetic impact of the replacement quarry fields in the two east-facing aisle windows (101, 116) was considered, and it was ultimately decided to replace them with a more sensitive restoration. The original traceries and existing border designs were retained and conserved appropriately.

The aisle windows were returned to the building with a bespoke protective glazing solution. An internally ventilated protective glazing system with bronze frames was unviable in the aisle due to time and budget limitations. Externally ventilated protective glazing was ruled out due to concerns of heat loss from the church interior, limited exterior jamb space and its inefficiency in reducing the risk of condensation.

With these factors in mind, a compromise was reached and a method of allowing air into the interspace was employed. This design was made possible because of the inconsistent “shoulder” pieces, all of which were unoriginal restoration glass. These pieces were removed and a vent was put in their place at the shoulder of each lancet. Two vents were introduced at the sill of each lancet; the half diamonds at the base were not releaded into the matrix but copper foiled and soldered proud of the matrix, angled to the interior to allow for some airflow. The open space was enclosed using bronze mesh to minimize insects or dust. Protective glazing of ½” laminated glass was installed against brackets (to ensure an even plane and reflection) on the exterior of the building.

The panels were re-leaded with the same size and profile as the existing lead came and steel rebar was inserted next to the heart in the two vertical leads between the quarries and borders for additional support.

Clerestory Tracery

Clerestory tracery panels with very minimal damage, including those in their original leading, remained *in situ* for treatment to avoid abatement. Panels that required significant conservation were abated and removed. The 1990s-made panels that were too small for their settings were removed and cleaned. Additional perimeter lead came was added to ensure the window fit properly into the groove. The 1840s panels that were severely broken were removed for treatment. Individual pieces were extracted and repaired without re-leading where possible. When the breakage or missing glass was severe, the panels were dismantled, treated and releaded with the same size and profile as was existing. The clerestory tracery panels received the same protective glazing treatment as the aisle windows.

The project included the replacement of the 1967 clerestory lancets. The goal of the replacement was to introduce a window design that was more sympathetic to the historic fabric while also allowing more light into the church. Newspaper articles and historic photographs revealed that the 1840s clerestory windows had various border designs surrounding a repeating quarry field design, the same design template as the aisle windows. It appears that the 1967 design was influenced by what remained of the original windows. We were able to isolate four designs from the historic photographs that were reinterpreted into the new clerestory. The new clerestory windows are intended to be identifiable as new work that harmonizes with the existing Gothic Revival character of Trinity Church. Thought to future conservation was given, and the windows were designed with bronze frames, internal ventilation, and protective glazing.

Chancel

All Chancel panels were abated and removed for treatment. Once the panels were brought to the studio for conservation, it became apparent that the mixture of glazing cement used was extremely hard. Ultimately, the safest way forward was through partial releading. Only areas with the most severe mending leads or poorly painted restoration pieces were dismantled for treatment. Thick mending leads were removed and edge-bonding was used as often as possible.

Consideration was given to removing the cold paint because it was unoriginal, heavily applied and flaking off. Philosophically, it was concluded that removing the cold paint would not return the window to its original design. The Chancel window has been darkened since its inception by various methods and removing the cold paint may eliminate the familiarity and identity of the window. From a technical standpoint, intervention was unsafe for the underlying glass paint. Solvents and mechanical means were tested for possible removal. We concluded that the removal of the cold paint could also remove the underlying glass paint, which in some cases was fragile. In order not to cause damage, the cold paint was

left intact. The existing, unoriginal fillet borders were replaced with antique glass lightly matted, to renew the original appearance of the border glass.

The immense value of this window to American stained glass heritage coupled with its fragile paint qualified it for environmental protection in the form of an internally ventilated protective glazing system. This system will prevent the formation of damaging cycles of condensation on the original glass, as well as protect the original glass from mechanical and atmospheric damage, maximizing its longevity.

The environmental protection includes ¾" heat-strengthened laminated glass set into the original glazing groove. The original stained glass panels are framed in bronze and brought slightly forward to create an interspace, mechanically fastened with screws to the interior stone jambs. Lead light shields obscure any light leaks. New bronze interior support bars remain at stack joints. Saddle bars were eliminated in areas where they were not attached to lead joints and obscured the design. Exterior bronze fins were added in their place for support.

Conclusion

In conclusion, the hugely recognizable appearance of the building as well as a continued tradition to preserve it, is what comprises Trinity Church's identity. Maintaining those recognizable qualities while improving certain elements, and working to time and budget limitations, was crucial. To maintain project momentum and meet the deadline, several conservation studios were involved.

Conservation measures such as removing mending leads and inappropriate restoration pieces allowed us to return the windows closer to their original 1840s appearance. This is echoed in the new windows in the clerestory level that are much more sympathetic to the original style. The conservation approach adhered to international guidelines and had positive impacts that outweighed the limitations.

This conservation project was undertaken on a high-profile building with an invested congregation and strong community. The Church opened for services on the completion date of Christmas Eve 2019. A full congregation participated in a Festive Eucharist, where they were able to appreciate the rejuvenated building without feeling a loss of its inherent and distinctive character.



5.1

La dalle de verre : évaluation de méthodes non invasives pour le diagnostic des œuvres menacées

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Dalle de verre: Evaluation of Non-Invasive Methods for Diagnosing Threatened Works – Abstract

The dalle de verre technique consists of thick slabs of coloured glass set in a matrix of reinforced concrete. In Switzerland, this technique made its way in the mid-1930s and the technique reached its peak in the 1950s to 1980s. After around 70 years, many of the works are in poor condition. The complexity of the problems affecting dalles de verre call for specific conservation approaches that must be determined on a case-by-case basis. So far, research has mainly focused on the analysis of larger historic structures, and there is still no suitable approach to the damage assessment of dalle de verre. The initial focus of a

research project initiated by the Vitrocentre Romont therefore was to develop a practical, non-invasive and inexpensive 'toolkit' for systematically documenting the preservation condition of dalles de verre in their structural, physical and climatic setting. Various instruments such as georadar, ultrasound and surface potential measurements have been tested. The measurements provided valuable information on the advantages and limitations as well as the costs of the methods used. This paper presents a synthesis of the results of the in situ and laboratory analyses and discusses the viability, practicality and effectiveness of the tested techniques

Betonverglasungen: Evaluation nicht-invasiver Methoden zur Diagnose gefährdeter Werke – Zusammenfassung

Betonverglasungen bestehen aus meist dicken farbigen Glasstücken, die in eine Matrix aus Stahlbeton eingefügt sind. In der Schweiz entfaltet sich diese Technik ab der Mitte der 1930er Jahre und erreicht ihren Höhepunkt in den 1950er bis 1980er Jahren. Nach rund 70 Jahren befinden sich viele Werke in schlechtem Zustand. Die Komplexität der Schäden und Schadensursachen erfordert spezifische Erhaltungsmaßnahmen, die von Fall zu Fall festgelegt werden müssen. Auf dem Gebiet der Erhaltung von Strukturen aus Stahlbeton hat sich die Forschung bisher vor allem auf größere historische Bauwerke konzentriert. Für die Analyse von Betonverglasungen

gibt es bisher noch keine geeigneten Methoden. Im Mittelpunkt eines vom Vitrocentre Romont initiierten Forschungsprojekts stand daher zunächst die Entwicklung eines praktischen, nicht-invasiven und kostengünstigen Instrumentariums zur systematischen Dokumentation des Erhaltungszustands von Betonverglasungen in ihrem baulichen, physikalischen und klimatischen Umfeld. Es wurden verschiedene Instrumente wie Georadar, Ultraschall und Oberflächenpotentialmessungen getestet. Die Untersuchungen lieferten wertvolle Informationen zu den Möglichkeiten und Grenzen sowie den Kosten der verwendeten Methoden. In diesem Beitrag werden die Ergebnisse der in situ-Messungen und Laboranalysen zusammengefasst und die Durchführbarkeit, Praktikabilität und Wirksamkeit der Methoden erörtert.

La technique de dalle de verre

Un vitrail en dalle de verre est constitué d'épaisse pièces de verre coloré serties dans une matrice de « béton armé ».¹ Étant étroitement liée aux développements de l'architecture vers le tournant du XX^e siècle, la dalle de verre a connu son premier âge d'or avec la reconstruction des églises après la Première Guerre mondiale ; l'apogée de cette forme d'art monumental se situe entre les années 1950 et 1980. La technique et les matériaux employés pour la fabrication des vitraux en dalle de verre ne changent pas beaucoup au cours des décennies qui suivent son invention autour des années 1930. C'est seulement à partir des années 1980 environ que des matériaux plus légers comme la résine époxy remplacent le mortier.

¹ Le mortier diffère du béton essentiellement par la taille de l'agrégat. Le béton est composé de ciment, sable, gravier, eau et adjuvants éventuels ; un mortier, par contre, ne contient pas de gravier. Selon cette définition, la plupart des dalles de verre sont composées de « mortier armé » et de verre coloré. Nous avons toutefois décidé d'utiliser le terme plus courant de « béton armé », même s'il n'est pas strictement correct.

En Suisse, l'artiste et peintre-verrier Alexandre Cingria (1879–1945) est l'un des premiers à créer des fenêtres avec cette technique, entre autres un grand vitrail pour le chœur de l'église du couvent des Cordeliers à Fribourg. Pour la majeure partie de ses réalisations, Cingria travaille étroitement avec le Français Jean Gaudin (1912–1945). Il faudra attendre le début des années 1950 pour voir apparaître les premiers ateliers en Suisse capable de fabriquer des dalles de verre. L'un d'entre eux est celui d'Aubert et Pitteloud à Lausanne. Cet atelier est chargé, en 1954, de réaliser les vitraux en dalle de verre de l'église catholique de Courfaivre, élargie et restaurée par l'architecte jurassienne Jeanne Bueche (1912–2000), qui fait appel à Fernand Léger (1881–1955) pour la conception des vitraux.²

Après environ 70 ans d'existence, de nombreuses dalles de verres présentent des dommages, parfois graves. Outre les dégradations spécifiques au mortier ou au béton, dues en partie à la qualité insuffisante des matériaux, les interactions physiques et chimiques entre le mortier et le verre présentent des défis techniques particuliers pour leur conservation. A ces difficultés s'ajoutent le fait que le diagnostic des dégâts, tout comme les mesures éventuelles de conservation à prendre, doivent être effectués sur l'objet lui-même.

Alors que la recherche s'intéresse depuis longtemps déjà à la rénovation des constructions historiques en béton,³ la conservation des dalles de verre n'a fait l'objet que d'un nombre limité d'études.⁴ Celles-ci se sont principalement concentrées sur le développement de méthodes et de matériaux pour la restauration des dalles de verre, en accordant peu d'attention aux méthodes employées pour l'analyse des œuvres. Jusqu'à aujourd'hui, aucune étude ne s'est penchée sur le recensement et le monitoring systématiques des dommages spécifiques à cette technique. C'est à cette thématique particulière que ce projet, initié par le Vitrocentre Romont, souhaite apporter des réponses.

Questions, buts et méthodes du projet

L'examen sur place des dalles de verre est un défi pour les conservateurs et restaurateurs. Les œuvres sont souvent difficiles d'accès et les dommages ne sont pas toujours facilement identifiables. Une analyse de l'état de préservation est toutefois le prérequis pour la planification des mesures de préservation. Bien qu'il existe des méthodes et des outils pour l'étude des structures en béton, les investigations sont généralement complexes, coûteuses et non adaptées à l'analyse d'œuvres d'art fragiles telles que les dalles de verre. En plus, les études se basent souvent sur des méthodes invasives, nécessitant un prélèvement d'échantillons (carottes de diamètre minimal de quelques centimètres).

L'objectif principal d'une collaboration de recherche interdisciplinaire entre le Vitrocentre Romont, la Haute école des sciences appliquées OST de Rapperswil et l'entreprise Geotest SA à Mont-sur-Lausanne était donc de mettre au point des méthodes pratiques, non invasives et peu coûteuses pour le relevé et la documentation systématiques des propriétés et des dommages, ainsi que pour l'identification des détériorations des dalles de verre dans leur cadre structurel, physique et climatique. Le deuxième but du projet, tout aussi important, était de déterminer l'état de conservation des dalles de verre examinées en combinant les méthodes testées avec l'analyse visuelle.

Nous avons étudié en particulier la position et le degré de corrosion des armatures, l'épaisseur de l'enrobage ainsi que les compositions du mortier et des verres. Pour l'analyse des propriétés du béton armé, nous avons testé et évalué diverses méthodes non invasives telles que le géoradar, les ultrasons et les mesures de potentiel électrochimique de surface.⁵ Étant donné que la majorité des instruments ont été développés pour l'étude de grandes constructions en béton, les approches ont été adaptées à l'analyse des structures plus fines et fragiles des dalles de verre. Les mesures ont été évaluées en termes de facilité d'application, de coûts et d'avantages. Les compositions du béton et des verres ont été identifiées sur des échantillons millimétriques par microscopie électronique à balayage en laboratoire. Une première tentative de caractérisation des verres par fluorescence des rayons X portable n'a, quant à elle, pas fourni de résultats pertinents.

² Pour un résumé sur l'histoire de la dalle de verre en Suisse, voir NOVERRAZ, SAUTEREL, WOLF 2021, p. 50–59.

³ Par exemple : BERTOLINI et al. 2011, p. 146–154; MARIE-VICTOIRE et al. 2016, p. 343–350; PÖRTNER 1997, p. 120–126.

⁴ Entre autres : ALBERT et al. 2014 ; CUZANGE et al. 2010, p. 176–182 ; DE VIS et al. 2013, p. 43–52 ; PEPI, BUCHNER, GEMBINSKI 2012, p. 3–12 ; SANDER et al. 2011, p. 48–53 ; ÜNAL&KÜHNE 2013, p. 343–350.

⁵ Par exemple : BREYSE (dir.) 2012 ; HUGENSCHMIDT 2010, p. 317–333.

Cette contribution présente une synthèse des résultats des analyses non invasives et discute de la praticité et de l'efficacité de l'approche développée. L'étude complète sera publiée ultérieurement dans une revue scientifique.⁶

Description des dalles de verre analysées

Dans le cadre de ce projet, nous avons pu étudier plusieurs dalles de verre du grand cycle de vitraux de Fernand Léger à l'église Saint-Germain-d'Auxerre à Courfaivre (canton du Jura) ainsi que le grand vitrail en dalle de verre d'Alexandre Cingria au couvent des Cordeliers à Fribourg (canton de Fribourg).⁷

Le cycle de Fernand Léger a été conçu pour les nouveaux collatéraux en béton armé de l'église de Courfaivre construits par l'architecte jurassienne Jeanne Bueche en 1954.⁸ Il se compose de dix médaillons encadrés de panneaux rectangulaires dans les fenêtres hautes de la nef et de deux vitraux en arc en plein-cintre dans le chœur. Cet ensemble figuratif est complété par des dalles de verre abstraites décorant les bas-côtés de l'église (fig. 1a). Le programme iconographique du cycle a été établi par l'architecte et le curé de l'église et élaboré en étroite collaboration avec l'artiste. La réalisation des dalles de verre est confiée à l'atelier de verriers Aubert et Pitteloud de Lausanne. Les médaillons ont un diamètre de 1,61 m ; ils sont tenus par un cadre rond métallique avec un profil en forme de « L » vissé dans la structure en béton armé. Les deux grands vitraux dans le chœur mesurent 3,06 m de haut pour 1,04 m de large. Ils sont montés avec un mortier de pose dans la feuillure de la baie depuis l'intérieur et scellés avec un mortier de pose. Les médaillons comme les grands vitraux dans les baies du chœur ont été moulés en une pièce. La face externe du panneau correspond à la face inférieure de la dalle de verre lors du moulage. Elle est lisse et montre des « marques de plis » suggérant que le panneau a été coulé sur des draps (fig. 1b). La face interne du panneau correspond à la face supérieure de la dalle de verre ; elle est légèrement rugueuse.



Fig. 1. Église Saint-Germain-d'Auxerre à Courfaivre, a) vue extérieure de la façade sud avec médaillons en dalle de verre, Fernand Léger, 1954 ; b) détail de la face externe du médaillon de l'Annonciation.

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Le grand vitrail d'Alexandre Cingria a été conçu pour la fenêtre axiale de l'église du couvent des Cordeliers à Fribourg et réalisé par Jean Gaudin entre 1936 et 1938.⁹ Il s'agit d'un vitrail tripartite monumental d'environ six mètres de haut et de deux mètres de large, consacré au thème de la Pentecôte. Environ 40 ans après sa création, l'église fait l'objet d'une grande transformation, lors de laquelle la majorité des ajouts des XIX^e et XX^e siècles sont effacés, y compris la dalle de verre de Cingria, déposée en 1978. Les 24 panneaux sont aujourd'hui conservés aux archives du couvent des Cordeliers (fig. 2a). Leurs épaisseurs varient entre 2 et 4 cm. Ils sont moulés individuellement. Chaque bord est rehaussé (à l'intérieur), formant une sorte de « cadre ». La face interne des panneaux est rugueuse ; elle correspond à la face supérieure de la dalle de verre lors de la fabrication. Les parties en béton armé plus larges sont sculptées (en relief) afin d'accentuer les formes. La face externe des panneaux correspond à la face inférieure lors du coulage. Est légèrement texturée et peut avoir été créée en versant le mortier sur une surface recouverte de textile, pour créer la texture désirée et faciliter le démoulage (fig. 2b).

⁶ HUGENSCHMIDT, WOLF, GOSSELIN (à paraître) ; GOSSELIN&WOLF&HUGENSCHMIDT (à paraître).

⁷ Les dalles de verres analysées sont décrites dans la banque de données en ligne du Vitrocentre Romont www.vitrosearch.ch. Nous renonçons donc ici à une description détaillée.

⁸ BUECHE 1957, p. 5–8.

⁹ RUDAZ 1997, p. 10–15.



Fig. 2. Archives du couvent des Cordeliers, a) quelques panneaux du vitrail en dalle de verre déposé en 1978, Alexandre Cingria, 1938 ; b) détail de la face externe du panneau 3b en lumière réfléchi.
© Couvent des Cordeliers, Fribourg, photos S. Wolf, Vitrocentre Romont.

Résultats et évaluation des analyses non-invasives

Position des armatures

La détermination de la position des armatures est une première étape importante dans le diagnostic des dégâts, car la corrosion des armatures peut entraîner un écaillage important au béton. La position des fers peut être déterminée avec précision et un minimum d'efforts à l'aide d'un aimant puissant et d'un papier fixé sur la dalle de verre, mais seulement jusqu'à une profondeur de 15–20mm. Les mesures avec le profomètre à induction avec analyse et interprétation automatisées ainsi qu'avec un géoradar donnent également des résultats fiables (fig. 3). L'avantage des deux dernières méthodes est qu'elles permettent de déterminer non seulement la position, mais également l'épaisseur de l'enrobage des fers jusqu'à une profondeur de 100mm (voir ci-dessous) ; en outre, les mesures peuvent être enregistrées et visualisées. Cependant, l'acquisition et le traitement de données sont chronophages, et les appareils, par ailleurs coûteux, ne peuvent être utilisés que par des spécialistes.



Fig. 3. Position des armatures dans le médaillon de l'Annonciation à Courfaivre déterminée avec un aimant (à gauche) et à l'aide d'un profomètre Hilti Ferroscan PS200 avec analyse et interprétation automatisées (à droite). © Auteurs.

Épaisseur d'enrobage

L'épaisseur de l'enrobage est un paramètre important puisqu'il permet d'évaluer le risque de corrosion des armatures dans les dalles de verre. L'épaisseur et la compacité du mortier régissent la cinétique de carbonatation et donc de la corrosion. En règle générale, les fers proches de la surface corrodent plus facilement que ceux bien enrobés de mortier. Ce paramètre peut être bien déterminé avec un profomètre à induction, manuel ou automatisé, ainsi qu'avec un géoradar. Les mesures, effectuées avec les deux techniques, ont fourni des valeurs cohérentes. A titre d'exemple, les armatures du médaillon de l'*Annonciation* se situent à une profondeur de 20–30mm ; dans certaines zones, les fers reposent directement sous la surface.

Le profomètre à induction est la moins coûteuse des deux méthodes. Cependant, le coût d'un appareil avec mesures et interprétations automatisées est de 10 000 à 15 000 CHF. Les mesures peuvent encore être réalisées par une personne préalablement formée, mais l'évaluation des résultats nécessite du temps et des connaissances sur les logiciels spécifiques.

Corrosion des fers d'armature

La seule méthode pour déterminer le degré de corrosion des armatures – outre l'analyse visuelle des fers apparents – est la mesure du potentiel électrique. Comme il était exclu de réaliser une connexion directe avec les armatures, car pour cela il faut dégager et percer une armature, les différences de potentiel ont été mesurées entre deux points à la surface. Le désavantage de cette approche non invasive est lié au fait que la surface doit être mouillée pour créer un contact optimal entre les deux électrodes. En outre, les résultats ne sont que qualitatifs et nécessitent être calibrés par d'autres observations ou mesures pour être pertinents. L'équipement est peu coûteux, mais les mesures et l'interprétation des données demandent une certaine expérience.

Les différences de potentiel enregistrées ont été validées à l'aide de l'examen visuel : selon notre dispositif, les zones avec des fers apparents et/ou fortement fissurées coïncident relativement bien avec celles ayant des valeurs de potentiel supérieures à 50 mV. Toutefois, les valeurs limites obtenues restent relatives à l'objet étudié et peuvent varier selon l'état de saturation en eau du mortier. Les tendances observées doivent être confirmées par d'autres mesures sur d'autres objets afin d'adapter la méthode si nécessaire.

Épaisseur des dalles de verre

L'épaisseur des dalles de verre peut être déterminée et documentée à l'aide du géoradar et des ultrasons ; les deux techniques ont été testées à Courfaivre. Après une calibration empirique, les deux méthodes fournissent des résultats quantitatifs fiables. Les épaisseurs déterminées avec les ultrasons correspondent aux valeurs mesurées avec le géoradar (fig. 4). Les mesures obtenues par ultrasons sont beaucoup moins chères et plus simples que celles réalisées par le géoradar. L'ultrason, cependant, ne permet que des mesures individuelles alors que le profil d'épaisseur d'une dalle de verre entière peut être mesuré et visualisé par géoradar.

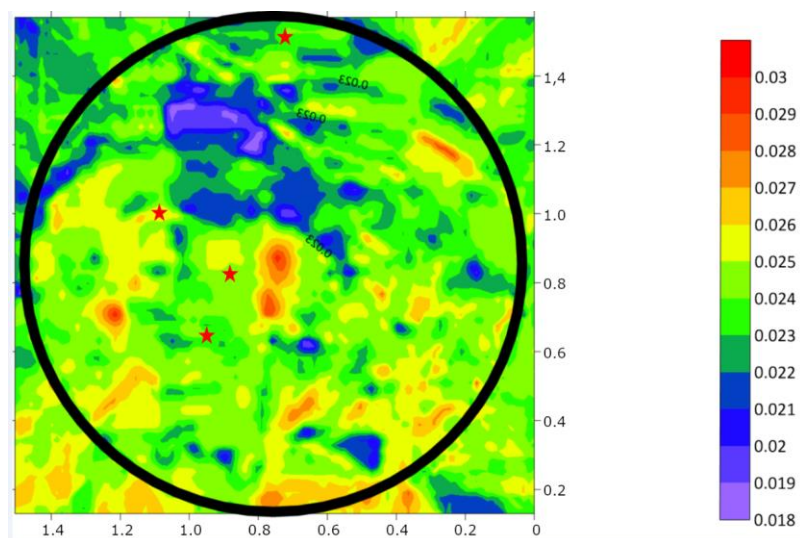


Fig. 4. Médaillon de l'*Annonciation* de Fernand Léger à Courfaivre, épaisseur (en mètres) du médaillon déterminée avec le géoradar. Les points mesurés par ultrasons sont indiqués avec une étoile.
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Propriétés du béton : fissures, porosité, humidité

La détermination des propriétés du béton armé est une problématique complexe, se basant généralement sur l'analyse de « carottes », échantillons de plusieurs centimètres forés dans le béton. Cependant, les méthodes non invasives telles que la thermographie, les ultrasons et le géoradar peuvent également fournir des informations sur les propriétés du matériau, en particulier sur ses hétérogénéités, telles que la densité et la porosité du matériau, les zones de fissures et les zones humides. Dans le cadre du projet, différentes méthodes (thermographie, géoradar, mesures de résistivité et du potentiel électrochimique) ont donc été testées pour leurs valeurs informatives en ce qui concerne les propriétés du mortier.

Les images thermographiques ont été enregistrées et évaluées à Fribourg et à Courfaivre. Sur l'image thermographique d'un panneau d'Alexandre Cingria, les différences de température observées – qui ne sont pas liées à la présence d'armatures – pourraient s'expliquer par des hétérogénéités dans le béton, par exemple par une porosité et/ou une humidité plus élevée ou par la présence de microfissures. Cependant, l'interprétation des images reste difficile et la question ne peut pas être résolue sans investigations supplémentaires (la technique récente de résonance magnétique nucléaire du proton, H^1 NMR, portable et non destructive, pourrait être une technique à explorer pour évaluer les différences de porosité des mortiers). Les images thermographiques obtenues sur les dalles de verre à Courfaivre n'ont pas été exploitées car estimées peu pertinentes. En revanche, les mesures du géoradar, dont l'atténuation du signal électromagnétique est fortement influencée par le degré de saturation en eau du mortier, ont fourni des résultats estimés plus fiables sur l'indication des zones à forte humidité interne.

La mesure du potentiel électrique fournit également des informations indirectes sur le degré de corrosion des armatures et sur les fissures cachées dans le béton, mais le manque de référentiels ou de valeurs comparatives (base de données) fait encore défaut pour pouvoir interpréter les résultats. La méthode de mesure de résistivité n'a, quant à elle, pas fourni des résultats complémentaires.

Même si toutes les méthodes testées sont potentiellement adaptées à la caractérisation du béton, leur apport ne peut être évalué de manière concluante à l'heure actuelle. En tout état de cause, il serait intéressant de poursuivre et de développer certaines techniques, notamment la thermographie et le potentiel électrique sur d'autres vitraux en dalle de verre.

Composition du mortier et des verres

La caractérisation chimique du mortier et des verres peut être effectuée de manière fiable en laboratoire à l'aide de l'analyse par microscopie électronique à balayage. La condition préalable à l'analyse en laboratoire est le prélèvement d'échantillons. La méthode n'est donc pas non destructive, même si des échantillons de quelques millimètres suffisent pour l'analyse. Dans certains cas, un prélèvement d'échantillons semble toutefois légitime, notamment lorsque des fragments de mortier ou de verre sont déjà détachés, comme c'était le cas pour le vitrail d'Alexandre Cingria. Les analyses en laboratoire sont toutefois assez coûteuses et nécessitent de l'expérience dans le domaine de la caractérisation des matériaux. Une autre limitation réside dans le fait qu'un certain nombre d'échantillons représentatifs est nécessaire pour obtenir des résultats représentatifs eux aussi.

Réflexions et perspectives

Les deux campagnes de mesures menées dans le cadre du projet ont permis d'acquérir des informations sur la faisabilité, les avantages et les coûts des méthodes non invasives utilisées pour étudier des vitraux en dalle de verre. La combinaison des différentes méthodes s'est avérée être un outil efficace pour l'identification des matériaux, la documentation et la cartographie des dommages de manière non invasive et *in situ*. L'étude a montré que certaines techniques, comme le géoradar, présentent des avantages en terme d'informations sur les armatures et le béton, malgré les inconvénients de temps et coût consacrés (temps de mesure, interprétation par un spécialiste). Toutefois, les résultats illustrent que la méthodologie n'est pas perfectionnée à tous les égards et que certains problèmes restent non résolus. La caractérisation des propriétés du béton par des méthodes non invasives s'est avérée particulièrement difficile, même si plusieurs méthodes se sont révélées prometteuses.

Il est évident que les résultats de cette étude doivent encore être validés par l'étude d'autres dalles de verre afin de confirmer et préciser les limitations mises en évidence dans ce projet. Il est également clair que l'examen visuel reste indispensable dans l'analyse des dégradations. Les études non destructives et

micro-invasives ne peuvent pas le remplacer, mais sont complémentaires en rendant « visibles » les dommages qui se trouvent sous la surface et sont cachés à l'œil nu.

Nous espérons pouvoir poursuivre les recherches dans un projet de suivi qui nous permettra de développer les techniques d'analyse et d'agrandir la base de données en étudiant d'autres objets, possiblement plus détériorés, afin de répondre aux questions qui demeurent ouvertes.

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5.2

Against the Dying of the Light: Enamel Analysis and the Conservation Problems of Art Nouveau Windows

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Contre la mort de la lumière. Analyse de l'émail et problèmes de conservation des fenêtres Art nouveau – Résumé

L'utilisation de l'émail est l'une des caractéristiques typiques du vitrail catalan Art nouveau. En comprendre les causes de dégradation permet d'adopter des stratégies de conservation plus précises. L'article donne un aperçu historique de l'utilisation des émaux, ainsi que les résultats d'analyse chimique des échantillons et des matières premières originales utilisés par l'atelier Rigalt i Granell (Barcelone, 1861-1914). Les

échantillons historiques issus des vitraux catalans ont été réalisés par les ateliers les plus renommés de l'époque. Le verre et l'émail ont été étudiés par calorimétrie à balayage différentiel DSC, par microscopie électronique à balayage (MEB), par diffractométrie de rayons X (DRX) et par LA-ICP-MS. La stabilité de l'émail dépend de sa composition chimique ainsi que de plusieurs autres paramètres tels que le verre de base utilisé, la température du four, de son mélange à d'autres émaux, des conditions atmosphériques externes, etc.

Against the Dying of the Light: Enamel Analysis and the Conservation Problems of Art Nouveau Windows – Abstract

The use of enamel is one of the typical features of Catalan Art Nouveau stained glass. Understanding the reasons for enamel deterioration of that period may help in devising more precise conservation strategies. The current article gives some historical background of the use of enamels and the results of the chemical analysis of the samples and original raw

materials from the Rigalt i Granell studio. The historical samples from Catalan stained-glass windows analysed here were made by the most renowned studios of that time. The glass and enamel were investigated by DSC, SEM imaging, X-ray diffraction, and LA-ICP-MS. Enamel stability depends on its chemical composition, as well as on several other parameters such as the substrate glass used, the temperature of the kiln, whether it is mixed with other enamels or, external atmospheric conditions, etc.

Introduction

Enamels were applied to most of the stained glass made in Barcelona at the end of the 19th and beginning of the 20th century, one of the most relevant periods in quantity and quality. Since fired enamel is basically a finely ground coloured glass fused to the surface of a supporting glass, the mechanisms associated with glass corrosion also occur in the enamel. Most of the enamels show some decay, but the blue and green appear particularly affected.¹

The present document summarizes the results of long-term research on Art Nouveau enamels used in Catalan stained-glass windows. J.M. Bonet vitralls S.L. provided the original raw materials from Rigalt & Granell studio and also from historical windows covering the most renowned studios of the period: Rigalt, Bordalba, Amigó, Maumejean and Buxeres i Codorniu.

The first part of this research work, on the chemical and thermal properties of the Rigalt & Granell studio enamels, was published at the Corpus Vitrearum forum in Cambridge in 2017.² A low softening temperature lead-rich borosilicate glass (with zinc in some cases) was determined. Despite boron being mentioned in historical documentation as a source of instability,³ analyses proved that if the composition of the enamel is correctly chosen, this is not necessarily true. To obtain a well adhered

¹ Olivier SHALM, Veerle VAN DER LINDEN, P. FREDERICKX, S. LUYTEN, Geert VAN DER SNICK, Jost CAEN, and others, "Enamels in Stained-glass windows: Preparation, Chemical Composition, Microstructure and Causes of Deterioration", *Spectrochimica Acta - Part B Atomic Spectroscopy*, 64.8, 2009, 812–20.

² Martí BELTRAN, Jordi BONET, Trinitat PRADELL, "Properties of Modernist Enamels and Stained Glass from the City of Barcelona", in Sarah Brown, Claudine LOISEL, Aletta RAMBAUT, Ivo RAUCH, Sebastian STROBL, Sophie WOLF (publ.), *Stained Glass: Art at the Surface* (Cambridge, 3-5 Sept. 2017) The international scientific committee for the conservation of stained glass, York, 2017, p. 102–12.

³ Christopher WHALL, *Stained Glass work*, D. Appleton, New York, 1905, p. 112, p. 370; William MACKAIL, *The life of William Morris*, Haskell House Publishers, 1920, first published 1899, p. 59; Lewis F. DAY, *Windows. A book about stained glass*, B.T. Batsford, London, 1897, p. 85

layer required a good praxis, compatible compositions between enamel and substrate glass and adequate firing temperature ($\sim 580^{\circ}\text{C}$).⁴

Old Materials and Methods: Current Problems

Enamel is a crucial part in the conservation of the windows of this period, however the reasons for each alteration are not yet clear. This paint plays a relevant role in the aesthetics of the windows,



Fig. 1. Typical white aspect of enamel on a face painted by Amigó Studio, 1903. Sant Jaume of Calaf Church.

but it is also a characteristic feature of the Catalan windows of the period especially because 17th- and 18th-century enamelled stained-glass windows are so rare in the country. There is a great need to get a better understanding of the nature of enamel decay, leading to more accurate conservation plans that could preserve its otherwise vanishing identity.

Enamel deterioration appears in different phenomenon ranging from pitting to full vanishing.⁵ In order to build better strategies, it must be understood why well mixed, applied and fired enamel is decaying (fig. 1). Some altered enamel fades away due to what might be considered wrong practices of the painter: the use of poorly cleaned substrate glass, accidental-insufficient heat in the kiln, a random mixture of enamel or the use of too thick paint layers.

In Catalonia most craftsmen did not write about their own experience, so most of the old painting techniques are only known from the oral record. The exception is the few articles by Antoni Rigalt Blanc (1861-1914),⁶ probably the best Catalan artist working on stained glass at the end

of the 19th century. Despite the high quality of his articles, no manual such as those by Whall,⁷ Jaenicke,⁸ Oidtmann,⁹ was ever written by any of the Catalan professionals.

The best and only description about how paint was applied by a Catalan studio is written by him:¹⁰ "When it comes to making three or four [paint] layers, we begin by applying the first one dissolved in

⁴ BELTRAN, BONET, PRADELL, 2017, p. 112.

⁵ ALISON GILCHRIST, "Severe Paint Loss from Stained-Glass Windows: Causes and Conservation Challenges" in Sarah BROWN, Claudine LOISEL, Aletta RAMBAUT, Ivo RAUCH, Sebastian STROBL, Sophie WOLF (publ.), *Stained Glass: Art at the Surface*, The international scientific committee for the conservation of stained glass, York, 2017, p. 7–25; Stefan TRÜMLER, "Les vitraux néo-gothiques de l'église Sainte-Élisabeth à Bâle. Analyse et conservation des peintures" in Jacques BARTLET (publ.), *Grisaille, jaune d'argent, sanguine, émail et peinture à froid* (in Sites et fouilles de la région wallonne Commission royale des monuments, Liège 19-22 juin) Liège, 1996, p. 21–27; ALISON GILCHRIST, "The tears wept by our Windows", *Vidimus*, 64, December 2012, <https://www.vidimus.org/issues/issue-64/news/> [accessed December 2019].

⁶ NÚRIA GIL FARRÉ, "El taller de vitralls modernista Rigalt, Granell & Cia. (1890-1931)" Barcelona: Universitat de Barcelona. Departament d'Història de l'Art, 2013 [accessed 2 December 2019].

⁷ WHALL, 1905.

⁸ FREDERICK JAENICKE, *Handbuch der Glasmalerei* (P. Reff, ed.), Stuttgart. 1890.

⁹ HEINRICH OIDTMANN, *Die Glasmalerei*, J.P. Bachem, Köln, 1893.

water with a small part of potash silicate, the second one with gum and water, the third one with turpentine spirit and the fourth one with water. [...] It can also be made all with water, but it is a few of them who do that since the minor error leads to the total loss of the work.”

Before the work is finished, the back of the pieces is painted with *despulit*, also named *couberte*¹¹ in other publications, to soften the penetration of bright light. In the same text, Rigalt mentions that the enamel must be utilized only if its use is impossible to avoid and recommends its use on the external side.

This glazier generation defended the use of mosaic stained glass and blamed the use of enamel, or painted windows for the past degeneration of the craft. Nonetheless, Rigalt studio could not skip its use and some windows are fully painted.

Rigalt i Granell studio purchased many of the Adolphe Lacroix enamels. The French maker offered since 1858¹² a ready to use enamel, which was already thinly ground and had the right amount of flux. Some of the texts by the Catalan artist are influenced by the publications written by Lacroix, the formulation and recommendations for firing are similar. Lacroix describes that his product is finely ground and offers an economic advantage and saves time to the makers since they did not have to grind the colours themselves.

One of the peculiarities of Catalan stained glass, is that most of the raw materials used by the studios were imported from France, England, United States or Germany and, consequently, the possibility to combine glasses and enamels that were not chemically compatible was high.

Analytical Methods

The composition of the powders and replica enamels prepared from the *Rigalt, Granell & cia* workshop and historical enamels were analysed by LA-ICP-MS. Polished sections were observed both in reflected light with an optical microscope (OM), and back-scattered electron images (BSE) were also recorded in a scanning electron microscope (SEM). Microanalysis was obtained by an EDS attached to the SEM. Synchrotron X-ray microdiffraction (μ -XRD) were obtained from cross sections of the enamels at the ALBA Synchrotron Light (Cerdanyola, Spain). UV-Vis-NIR Transmittance and Diffuse Reflectance measurements were obtained using a double beam UV-Vis spectrophotometer.

Sampling and Results from Replica Enamels

Raw enamels were purchased by Xavier Bonet from *Granell & Cia* company in the late 1980's when the studio ceased working on stained glass. Green, blue, purple, red and yellow samples of the prepared enamel powder were taken as well as a sample of a *flux* used in the workshop.

Composition of original enamels shows that the enamel glassy phase is a high lead (zinc) borosilicate (60-70%PbO, 5-20%B₂O₃, 10-25%SiO₂, 0-5%ZnO) to which colourants and/or pigment particles were added. The composition, the colourants and the pigment particles determined are shown in Table 1. It is a dense transparent glass with a low softening temperature and a thermal expansion coefficient matching that of the substrate glass, while retaining a good resistance to water corrosion.

A borosilicate glass consists of a three-dimensional network built of silica (SiO₂) tetrahedral and metaborate (BO₃) trigonal units. The addition of network-modifiers like lead or zinc oxide to the borosilicate glass instead of depolymerizing the silica network gives rise to the formation of tetrahedral (BO₄) units responsible for the increase in the chemical resistance, decrease of the thermal expansion and enlargement of the softening temperature range. Depending on the type/amount of network-modifier, a maximum of (BO₄) units is reached and equilibrium is established between trigonal and tetrahedral borate units, lower or higher PbO (ZnO) content results in a degradation of the properties of

¹⁰ Antoni RIGALT, “Presentación de algunas muestras de vidrieras de color, y explicación de los procedimientos seguidos para pintar y construir las mismas, desde la aparición de este arte, hasta nuestros días”. *Memorias de La Real Academia de Ciencias y Artes de Barcelona*, 2 (3a época), 1900, p. 291–297.

¹¹ Barbara TRINCHEREAU, Claudine LOISEL, “The nineteenth-century restoration process of Louis Germain Vincent-Larcher at the Cathedral of Troyes”, in Sarah BROWN, Claudine LOISEL, Aletta RAMBAUT, Ivo RAUCH, Sebastian STROBL, Sophie WOLF (publ.) *Stained Glass: Art at the Surface*, The International Scientific Committee for the Conservation of Stained Glass, York, 2017, p. 60–75.

¹² Adolphe LACROIX, *Des couleurs vitrifiables et de leur employ pour la peinture sur porcelain, faïence, vitraux*, Chez A. Lacroix, Paris, 1872.

the enamel. The enamels used in the workshop, in particular those from Lacroix, have the right compositions for a soldering glass with softening temperature $\sim 580^{\circ}\text{C}$.

Table 1. Chemical composition (typical error 5%) of the replica enamels produced from the raw materials found in the Rigalt i Granell workshop determined by LA-ICP-MS. Sulphur was not measured. Crystalline pigment particles identified by XRD.

Color	Company	wt%										ppm										Colours	Pigment Particles
		B ₂ O ₃	SiO ₂	ZnO	PbO	Na ₂ O	MgO	Al ₂ O ₃	K ₂ O	CaO	Cr ₂ O ₃	MnO	Fe ₂ O ₃	CoO	CuO	SnO ₂	Sb ₂ O ₃	Se	Cd	Ni	Ag	Au	
Purple	E14	21.1	8.6	11.2	53.2	2.1	0.1	0.3	0.2	0.9			0.1			1.8					1112	2117	Ag-Au, SnO ₂
	E107	19.8	8.9	13.8	52.6	0.9		0.2	0.3	0.6			0.1			2.6					19	82	Ag-Au, SnO ₂
xRed	E23	16.6	9.3	14.0	40.8	0.8		0.3	0.1	0.6			0.0			7.6		2.0	8.0	19			CdS, CdS _{0.9} Se _{0.1} , CdSe, SnO ₂
	E25	12.1	7.9	9.9	62.7	0.4		0.4	0.2	0.4	3.5		0.1			2.3							PbO-Pb(CrO ₄), SnO ₂
	E124	17.8	7.5	13.7	56.7	1.4	0.2	0.5	0.1	0.7		1.2	0.1							10			Mn ³⁺
Yellow	E3	7.0	30.4	0.0	53.0	5.1	0.1	0.3	0.1	2.6	1.3		0.1										Cr ⁶⁺
	E4	16.2	7.2	13.8	59.4	1.0		0.5	0.2	0.4	0.5	0.6	0.1										Cr ⁶⁺
	E106	7.9	22.4	4.1	54.6	2.1		4.8	0.4	0.5			0.2			0.5	2.4			10			SiO ₂ , Pb ₂ (Sn,Sb) ₂ O ₇
	E119	20.4	8.2	13.9	53.4	1.1		0.2	0.3	0.5	0.5		0.1			1.4	0.0						Cr ⁶⁺
	E34	8.1	10.7	1.9	49.8	2.0	0.4	5.9	0.5	0.3	10.8		0.2	6.5	0.3	0.9	1.2			1269			Co(Al,Cr) ₂ O ₄ , Pb ₂ (Sn,Sb) ₂ O ₇
Green	E89	16.4	8.5	12.4	53.9	1.7		0.5	0.2	0.7	0.2		0.2	0.0	5.3	0.1				18			Cu ⁺ -Cu ²⁺ , Cr ³⁺
	E121	15.2	6.9	13.9	59.2	0.9		0.5	0.2	0.5	0.4		0.1	2.0		0.0	0.1			290			[Co ²⁺] ₄ Cr ³⁺
	E33	11.1	11.4	9.2	41.9	2.8	0.5	13.9	0.1	0.7			0.4	7.7		0.2	0.1			732			CoAl ₂ O ₄
Blue	E122	3.8	23.2	0.2	71.2	0.2		0.8	0.0	0.2			0.1	0.1		0.0				48			[Co ²⁺] ₄
	E114	15.4	8.7	15.1	57.3	0.6		1.4	0.3	0.4			0.0	0.3		0.5				28			SnO ₂ , CoAl ₂ O ₄
	E115	18.3	7.7	14.6	56.5	0.7		0.5	0.3	0.4			0.1	0.8		0.2				79			[Co ²⁺] ₄ , SnO ₂
Grisaille	E31	0.0	20.0	0.0	50.4	0.2		0.5	0.1	0.1		6.5	21.9							97			Fe ₂ O ₃ , Pb ₂ (Fe,Mn) ₂ Si ₂ O ₉ (Fe,Mn) ₂ O ₃ , FeMn ₂ O ₄
Flux	F1	9.2	9.2	0.1	80.1	0.1		0.9	0.0	0.2			0.1			0.1				2			

To ensure a good adherence the enamel has to be fired above the glass transition temperature but below the deformation temperature of the substrate glass. Considering that blown substrate glasses were of the soda-lime type ($\sim 15\%\text{Na}_2\text{O}$, $15\%\text{CaO}$ and $70\%\text{SiO}_2$) with a glass transition temperature of 575°C and deformation temperature of 615°C , the glaziers had a relatively narrow firing temperature range.

The *flux* found in the workshop is a high lead borosilicate glass ($85\%\text{PbO}$, $9\%\text{B}_2\text{O}_3$, $8\%\text{SiO}_2$) characterised by a very low softening temperature of 477°C . However, the composition is outside the balanced range and it is less stable and more susceptible to water corrosion. Although this *flux* was probably added to the enamels by the glaziers to increase their adherence, it made them less stable and more prone to deterioration.

Finally, the *grisaille*, is made of a high lead glass ($70\%\text{PbO}$, $30\%\text{SiO}_2$) mixed with iron oxide and manganese oxide particles. After firing, both iron and manganese oxides react with the glass producing iron-manganese lead silicate and oxide particles.

The enamels show a large variety of pigment particles and colourants:

Purple is based on the ancient recipe of Cassius and is a co-precipitate of gold nanoparticles and tin. The enamels contain silver-gold alloy nanoparticles. This formula is mentioned by Lacroix,¹³ Encyclopaedia Roret¹⁴ and Rigalt.¹⁵

Three different types of red enamels are found: (E23) contains cadmium sulphide selenide particles together with cassiterite; another (E25) contains particles of lead oxy-chromate, together with cassiterite; and (E124) associated with Mn III dissolved in the glass. The first selenium reds follow Franz Welz glass patents,¹⁶ manganese and chrome are mentioned at the Roret encyclopaedia (1913 edition)

¹³ LACROIX 1872, p. 5.

¹⁴ M.-E.-F. REBOULLEAU, M. Désiré MAGNIER et Adolphe ROMAIN *Peinture sur verre sur porcelaine et sur email*, L. Mulo, Paris, 1913 p. 81.

¹⁵ RIGALT 1900, p.291–297.

¹⁶ Franz WELZ, *Patent No. 417.676*, Unites States, 1892.

as *ferrate de chrome*¹⁷ and iron oxide particles. Selenium does not appear in these manuals, as it probably was a new recipe; nevertheless, it can be found in some 1919 publications stating its use.¹⁸

Three of the yellow enamels (E3, E4 and E119) contain hexavalent chromium, Cr VI, dissolved in the glass and E119 contains also cassiterite particles. E106 contains particles of lead-tin antimonate or Naples yellow.

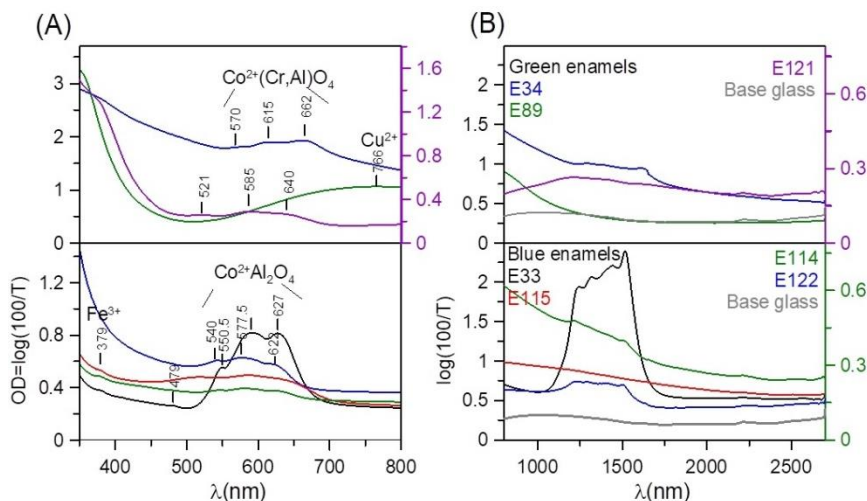


Fig. 2. (A) UV-Vis and (B) NIR absorption spectra corresponding to the green and blue enamels from the Rigalt i Granell workshop.

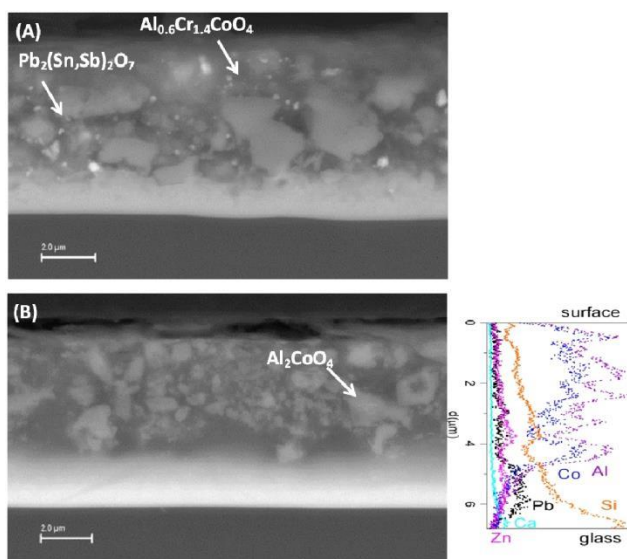


Fig. 3. SEM-BSE images of the cross sections of the (A) green (E34) and (B) blue (E33) enamels showing the presence of the particles cobalt-chromium aluminate and cobalt aluminate particles respectively. The accumulation of the particles near the surface of the enamel and the resulting chemical inhomogeneous layered microstructure are clearly seen.

Green enamel E34 contains cobalt-chromium aluminate together with some Naples yellow particles, while E121 contains Co II and Cr III ions dissolved in the glass (fig. 2A). E89 contains mainly Cu II dissolved in the glass.

All the blue enamels contain cobalt, Co II, either as particles of a cobalt aluminate (E33 and a few in E115) or dissolved in the glass (E122 and E114). E114 and E115 contain also cassiterite particles to increase the opacity. The UV-Vis-NIR spectrum of blue and green enamels show the three characteristic absorption peaks in the 500-650 nm range of Co II in tetrahedral coordination (CoO₄) responsible for the blue-green colour (fig. 2A), and also of an enhanced absorbance in the NIR range between 1250 and 1750 nm, especially high for those containing cobalt aluminate particles (an increase of 30 % for E33) and between 600 nm to 1000 nm by Cu II (fig. 2B).

It is also important to observe that the low density of the cobalt aluminate particles and, to a lesser extent the cobalt chromium aluminate particles, compared to that of the enamel glassy phase is a very relevant feature as the particles tend to float and accumulate on the surface (fig. 3), resulting in a layered structure, with a lead rich layer at the enamel-glass interface (~54 % PbO and negligible amounts of boron, fig. 3). SEM-BSE images of the cross sections of the (A) green (E34) and (B) blue (E33) enamels showing the presence of the particles cobalt-chromium aluminate and cobalt

¹⁷ M.-E.-F. REBOULLEAU, M. Désiré MAGNIER et Adolphe ROMAIN *Manuel Roret, Verrier. Glaces et cristaux*, L. Mulo, Paris, 1913, p. 65.

¹⁸ F. A. KIRKPATRICK et George G. ROBERTS, "Production of Selenium Red Glass", *Journal of the American Ceramic Society*, volume 2, issue 11, November 1919, p. 895-904.

aluminate particles respectively. The accumulation of the particles near the surface of the enamel and the resulting chemical inhomogeneous layered microstructure are clearly seen.

Sampling and Results of Historical Enamelled Stained Glass

Table 2. Chemical composition (typical error 5%) of the historical enamels determined by LA-ICP-MS. Sulphur was not measured

Location	Workshop	color	wt%																ppm											
			B ₂ O ₃	SiO ₂	ZnO	PbO	Na ₂ O	MgO	Al ₂ O ₃	K ₂ O	CaO	Cr ₂ O ₃	MnO	Fe ₂ O ₃	CoO	CuO	SnO ₂	Ag	Au	Cl	P	Ti	Ni	As	Sr	Zr	Sb	Ba		
Private house (Badalona) c.1900	Buxeres i Codorniu	yellow stain		70.1			18.2	0.1	0.6	0.4	8.3						1.3	0.7	12	154	1	1083	40	19	20	42				
		blue	5.2	28.3	8.1	42.2	4.9	0.1	3.6	0.1	1.2	1.8	0.4	1.9	1.6				0.2	192	139	467	179	132	10	77	2065			
		brown	0.2	53.2	0.0	18.9	12.5	0.1	1.3	0.3	6.1		1.4	5.2				0.5	256	284	21	980	85	18	149	270				
		purple	1.2	52.1	1.2	17.6	12.9	0.1	0.7	0.4	5.8		0.3	1.5			4.2	0.2	0.5	1.2	122	179	18	625	49	15	77	214		
		green	7.5	26.5	2.2	40.5	6.3	0.1	1.9	0.2	7.1	2.9	0.1	0.4	1.6	1.6			0.5	157	112	339	226	4823	10	126	741			
Casa Burés (Barcelona) 1900-1905		purple	0.1	62.7	0.1	4.5	8.1	0.2	1.2	0.8	9.8		1.2	0.9		0.1	9.0	0.0	0.9	0.1	105	306	42	384	67	39	302	506		
Església de Sant Jaume (Calaf) 1903	Amigó	red	0.4	63.9	0.5	6.9	11.4	3.4	1.1	0.5	7.4		0.6	3.4	0.1				0.1	176	513	359	436	39	53	52	184			
		green	0.6	50.4	0.2	27.1	4.4	1.8	2.3	0.4	4.0	1.4	0.7	4.4	1.2				0.1	2366	473	246	509	277	41	71	215			
		purple	0.5	64.9	0.1	8.9	9.9	3.3	1.5	0.6	6.8	0.5		0.5	0.5		1.1	0.1	0.3	1473	505	97	507	34	54	173	74			
Estació Nord (Barcelona) 1910-1912	Maumejean	green	15.7	15.8	1.9	61.3	1.4	0.0	0.8	0.1	0.8	0.2		0.1		1.6			0.1	212	128	2	88	15	11	328	115			
		yellow	14.5	15.0	7.5	58.4	1.5	0.0	0.5	0.1	1.0	1.3		0.1					165	97	1	79	11	8	433	74				
Palau Justícia (Barcelona) 1911-1914	Rigalt i Granell	purple	0.1	65.8	0.1	5.4	11.0	0.2	0.5	0.3	12.8		0.2	0.3			1.8	0.1	0.2	0.5	149	147	17	79	122	28	49	4529		
		Yellow stain		68.1			11.8	0.1	0.4	0.2	14.5		0.2	0.2				3.5	0.3	27	142	2	7	119	28	1	4946			
Seu Districte Sants Montjuïc (Barcelona) 1915	Rigalt i Granell	blue	0.2	60.2	0.1	5.3	10.5	0.1	3.1	0.1	12.3	3.8	0.2	0.2	2.9		0.1		0.6	38	175	3	5	55	29	1	111			

The enamels have been exposed to environmental conditions and they all appear corroded, with little exception. The samples cover all relevant makers and the most common colours. In many cases, the enamel layer is extremely thin (below 10 µm) with the consequent analytical difficulties. The chemical analyses are shown in Table 2 and the colourants, pigment particles and alteration compounds in Table 3.

Table 3. Colourants, pigment particles and alteration compounds identified in the historical enamels, determined by UV-Vis-NIR and µ-XRD

Location	Workshop	color	colourants	Pigment particles	Alteration compounds
Private house (Badalona) c.1900	Buxeres i Codorniu	Yellow stain		Ag ⁰	
		blue		(Cr,Co,Zn)Al ₂ O ₃	
		brown		Fe ₂ O ₃ , MnO ₂ , SiO ₂ , Pb ₂ (Fe,Mn) ₂ Si ₂ O ₉	PbSO ₄ , Pb(OH)Cl
		purple		Ag-Au ⁰	
		green	Cu ⁺ -Cu ²⁺	(Cr,Co,Zn)Al ₂ O ₄ , FeSiO ₄	
		grisaille		Fe ₂ O ₃ , MnO ₂ , Pb ₂ (Fe,Mn) ₂ Si ₂ O ₉ , SiO ₂	
Casa Burés (Barcelona) 1900-1905		purple		Au-Ag ⁰	SnO ₂
Església de Sant Jaume (Calaf) 1903	Amigó	flesh		Fe ₂ O ₃ , (Mn,Fe) ₃ O ₄ Spinel	
		red		Fe ₂ O ₃	
		green	Cu ⁺ -Cu ²⁺	(Cr,Co,Zn)Al ₂ O ₄	PbSO ₄ , CaSO ₄ ·(H ₂ O) ₂ , Pb(OH)Cl
		purple		Ag-Au ⁰ , Sn, (Cr,Co,Zn)Al ₂ O ₄	
		grisaille		Fe ₂ O ₃ , Pb ₂ (Fe,Mn) ₂ Si ₂ O ₉	
Estació Nord (Barcelona) 1910-1912	Maumejean	green	Cu ⁺ -Cu ²⁺ , Cr ³⁺	-	-
		yellow	Cr ⁶⁺	-	-
		grisaille		(Fe,Cu,Mn) ₃ O ₄ Spinel	-
Palau Justícia (Barcelona) 1911-1914	Rigalt i Granell	purple		Ag-Au ⁰	
		grisaille		(Fe,Cu,Mn) ₃ O ₄ Spinel, Pb ₂ (Fe,Mn) ₂ Si ₂ O ₉	PbSO ₄ , CaSO ₄ ·(H ₂ O) ₂
		Yellow stain		Ag ⁰	
Seu Districte Sants Montjuïc (Barcelona) 1915	Rigalt i Granell	blue		(Cr,Co)Al ₂ O ₄	
		grisaille		CuO, (Fe,Cu,Mn) ₃ O ₄ Spinel, Pb ₂ (Fe,Mn) ₂ Si ₂ O ₉	Pb ₃ (CO ₃) ₂ (OH) ₂ , CaCO ₃
		Matt grisaille		CuO, (Fe,Cu,Mn) ₃ O ₄ Spinel, Pb ₂ (Fe,Mn) ₂ Si ₂ O ₉ , SnO ₂	

1. Private house (Badalona)

This private house, located in Badalona, a coastal city close to Barcelona, hosts a collection of stained glass signed by *Buxeres i Codorniu*. The sample is part of an ornamental decoration with blue, brown, purple and green enamels, yellow silver stain and *grisaille*. The blue, green and purple paint contain cobalt and cobalt-chromium aluminate particles and silver-gold nanoparticles. The brown enamel contains the same particles as the *grisaille* but is richer in iron oxide particles and more vitrified. The alteration compounds determined are lead sulphate and hydroxyl-chloride.

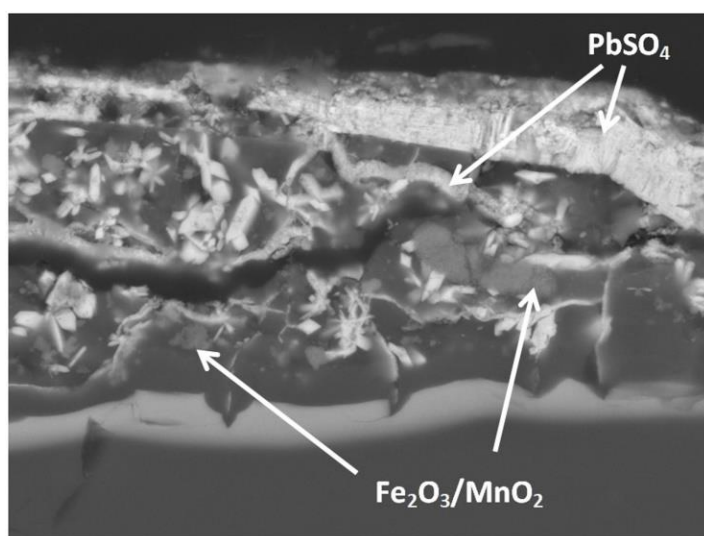
2. Casa Burés (Barcelona)

The private residence of the family of Francesc Burés i Borràs was built in 1900 by the architect Francesc Berenguer i Mestres. The skylight is remarkable for its size, beauty and design. It was built by *Antoni Bordalba*, a stained glass maker who worked in a few important commissions, such as the windows of Cercle del Liceu private club, and who has been studied lately by art historians.¹⁹ It has little enamelled glass, mainly a few minor details painted with a thin layer of purple of Caussius enamel worked with a badger brush, the enamel shows pin holes all over the surface.

3. Sant Jaume Church of Calaf

This late 16th-century church has a set of windows made in 1903 by the *Amigó's* workshop, a studio run by Eudald Ramon Nonat Amigó i Dou (1818-85) and considered the technical innovator of stained glass in the mid-19th century.²⁰ The enamels from this studio are often referred to as weak and unstable.²¹ The windows are very characteristic of the religious work of this studio; a central figure of a saint standing under canopies and surrounded by complex geometric patterns. Some were severely damaged by hail storms and many fragments fell fourteen meters to the nave ground floor. The church was also partly burned during the Spanish civil war.

The fragment of stained glass analysed belongs to a complex painted design of a face, painted with carnation and red enamels for the skin and lips, green and purple draperies and tracing and modelling



grisailles. Carnation, like the *grisaille*, contains iron and manganese oxide particles, while the red lips contain only iron oxide particles. The green and purple enamels contain copper II and cobalt-chromium or zinc aluminate particles and silver-gold alloy nanoparticles respectively. The alteration compounds determined are lead and calcium sulphates and lead hydroxyl-chlorides (fig. 4). The pieces appear very fragmentary, on one side only *grisaille* was painted and on the other tracing *grisaille*, modelling *grisaille*, and enamel are mixed.

Fig. 4. SEM-BSE images of the contour *grisaille* in a sample of enamelled glass from the Sant Jaume Church of Calaf (C13) showing the presence of large cracks filled with lead sulphate (anglesite, $PbSO_4$). Analysis shows the presence of kentrolite/melanotekite and different particles as iron and manganese oxides and also lead manganese silicate. Some alterations in the surface with lead sulphates particles can be observed.

¹⁹ Núria Gil, "La decoración con vidriera artística en el mueble domestico modernista catalán", *Virtuosismo Modernista. Tècniques del moble*, Associació per a l'Estudi del Moble i Museu del Disseny de Barcelona, Barcelona, 2019, p. 131-147.

²⁰ Sílvia Cañellas & Núria Gil, "La Fábrica de Vidrieras de los Amigó", *Cuadernos del Vidrio*, núm. 3, Real Fábrica de Cristales de la Granja. Fundación Centro Nacional del Vidrio, Diciembre 2014, p. 42-59.

²¹ Sílvia Cañellas & Núria Gil, "El taller Amigó de la tradició al progrés. El camí cap al vitrall modernista", Lluís Bosch, Mireia Freixa, *CDf International Congress*, Barcelona, 2017.

4. Estació del Nord (Barcelona)

The train station made in 1861 was reformed by the architect Demetri Ribes i Marco,²² between 1910 and 1915, incorporating in the waiting rooms a set of windows with a floral *coupe de fouet* style pattern made by *Maumejean*²³ workshop. The windows have always been interior and not affected by atmospheric corrosion. The maker, *Maumejean* a large French stained glass studio; originally located in the city of Pau, which also opened offices in Paris, Madrid, San Sebastian, and Barcelona. In Catalonia the studio was located in Rambla Catalunya 120 for only two years.

The sample is an acid etched copper red flashed glass with yellow and green enamel and black tracing *grisaille*. The green and yellow enamels are fully amorphous and the colourants are Cu II and Cr VI. The piece was badly broken with large losses and during a conservation campaign in 1991 a new copy was made starting from the original pieces. The enamel is simply applied with a brush and not thinned with a badger brush; it looks mildly cloudy but does not show any other sign of decay.

5. Palau de Justícia (Barcelona)

The large skylight was made in 1908 by the *Rigalt i Granell* workshop.

The full building is a design by the architects Domenech Estapà and Enric Sagnier. The sample was obtained during the full restoration of the stained glass carried out in 2009. The skylight was covered by a glass roof, as usual. Since it was quite difficult to reach for maintenance, dust and dirt deposited and accumulated for decades.

The sample is part of the silver stained pattern that has a light purple background which in some parts appears to be vanishing. The *grisaille* and paint are applied to the internal side of the panels while yellow silver stain is applied at the exterior side. The purplish enamel is very thin, containing silver-gold nanoparticles applied diluted and worked with a badger brush. The *grisaille* contains iron copper manganese oxide particles. The alteration compounds found are lead and calcium sulphates.

6. Seu del Districte de Sants Montjuic (Barcelona)

Large set of windows drawn by the artist Francesc Labarta (1883-1963) and built also by the studio of *Rigalt i Granell* in 1914. The windows installed in the main facade of a very busy street with dense traffic were vandalized during a riot in May 2014. The external side of the enamels shows a whitish appearance. The glass sample consists of a mixture of blue and green enamel applied over a yellow cathedral glass. The blue and green enamel has cobalt chromium and zinc aluminate particles and dissolved copper II; it appears mixed with some *grisaille* painted motives, with iron manganese copper oxide and copper oxide particles. On the other side, a matt *grisaille* containing also tin oxide particles to reduce the light entering the building is present (fig. 5). The alteration compounds found are lead and calcium carbonates.

Mechanisms of Alteration

The historical enamels appear to be depleted in lead, boron and zinc, enriched in silicon, calcium and sodium; lead and calcium sulphate, lead hydroxyl-chloride or lead and calcium carbonates precipitated within the cracks and bubbles. Lead sulphate is found in the Palau de Justicia and in the church of San Jaume de Calaf and in the private house in Badalona; lead sulphate is a typical alteration compound in an atmosphere rich in sulphur dioxide. Chlorine which in some cases result also in the formation of lead hydroxyl-chloride precipitates is related either to the proximity to the seashore (Badalona and Barcelona) but also perhaps to the effect of the smoke from candles. Phosphorous is also found in most of the enamels and is related to the presence of bird droppings. Basic lead carbonate and calcium carbonate are found in the stained glasses from Seu del Districte de Sants Montjuic, which although nowadays is integrated to Barcelona, for a long time it was in a suburb area. The enamels from Estació del Nord, being placed inside buildings appear mainly unaltered.

²² <http://invarquit.cultura.gencat.cat/Cerca/Fitxa?index=0&consulta=&codi=40487> Inventory of Catalan architectural Heritage. (Last visited 25/11/2019).

²³ Benoît MANAUTÉ, *Flambe ! Illumine ! Embrase ! La place de la manufacture de vitrail et mosaïque d'art Mauméjean dans le renouveau des arts industriels franco-espagnols (1862,1957)*, UPPA, 2012, p. 58-60.

This alteration is in good agreement with atmospheric corrosion of a lead glass involving an interdiffusion controlled lead leaching and silica dissolution and reprecipitation. Atmospheric sulphur, carbon and nitrogen dioxide gases are dissolved in water incorporated to the enamel and metal sulphates and carbonates precipitate. Boron and nitrates are highly soluble while on the contrary, calcium and lead carbonates or sulphates are highly insoluble.

After only 162 hours of exposure to moisture, typical leached thicknesses of $1\text{--}2\text{ }\mu\text{m}$ ²⁴ are found for historical glasses in laboratory corroding conditions. Considering the thickness of our enamels (10–50 μm) the corrosion layer might build up in a relatively short period (months to few years) after continuous exposure.

The historical enamels show less saturation of colour than the replicated ones due to the presence of lead and calcium sulphate or carbonate precipitates which are white. This is the very common white appearance of enamel, especially noticeable on the external side with reflected light.

Temperature variations will also promote the formation of cracks and favour the solubility/recrystallization cycle of the alteration compounds (of particular importance for calcium sulphate) precipitated in cracks.

Besides corrosion, some painting practices, like mixing *grisaille* and enamel, which has been found in the Amigó and Buxeras i Codorniu stained glass, or adding more *flux* to a ready-to-paint enamel, are bad practices. The consequent modification of the enamel chemistry may result in a material of reduced stability.

The enamels containing pigment particles with a lower density (blue and green cobalt and chromium aluminate pigment particles) than the glassy matrix give rise to a layered structure (fig. 5B) with the particles floating in a lead poorer glass over a lead richer enamel-substrate glass reaction layer. The leakage of lead will affect the stability of these enamels more drastically advancing the surface flaking.

Another source of instability is the greater absorption in the near infrared region of the blue cobalt centres (CoO_4) or by Cu II; an effect which is more dramatic when the enamel contains cobalt aluminate particles (fig. 2). This enhanced absorbance will produce an increase in the overall temperature of the enamel and also a thermal mismatch between particles, enamel glass and substrate glass.

Conclusions

The enamels are made of a lead-zinc borosilicate glass (60–70%PbO, 5–20%B₂O₃, 10–25%SiO₂, 0–5%ZnO) characterised by a low sintering temperature and softening point, while keeping a reasonable stability against water corrosion, mixed with a wide variety of colourants and pigment particles.

The analysis of the historical enamels shows that the whole thickness of the enamels independently of the colour is affected by atmospheric corrosion. Boron, lead and zinc are depleted from glass shortly after its exposure to the atmosphere, while the enamels appear to be silicon, sodium and calcium enriched. Lead leaching from the enamel in the presence of humidity and of atmospheric gases/pollutants results in the subsequent precipitation of lead and calcium sulphates and carbonates. The difference between the corrosion precipitates is related to the atmosphere of the environment. The resulting products are mainly leached to the surface where they are dissolved and rinsed by rainwater and therefore do not generate a crust or corrosion layer, but some precipitate inside cracks and bubbles as lead and calcium sulphates, carbonates hydroxyl-chlorides and also phosphates, which are white yellowish reducing the colour saturation of the enamels.

The chemical composition of the blue and green enamels is the same. Nevertheless, the blue and green enamels containing cobalt and cobalt chromium aluminate particles show a layered microstructure, with a lead depleted layer with pigment particles floating near the surface and a lead enriched interface at the substrate glass. This heterogeneity is expected to be in part responsible for the enhanced flaking of the enamels exposed to weathering. The enhanced absorbance in the Near Infrared of enamel containing (CoO_4) or Cu II causes an increase in the temperature of these enamels which may be responsible for the formation of cracks and tension between the glass and the enamel.

²⁴ Susan WOOD and J.R. BLACHER, "Corrosion of lead glasses in acid media: I, leaching kinetics", *J. Am. Ceram. Soc.* 61, 7–8, 1978, p. 287–292.

Some paint practices, such as the addition of *flux* to the enamel or the mixture of enamel and *grisaille* give rise to a more unstable composition which might be the reason for the low stability of the paints in some of the studios of the period.

The conservation of the enamelled stained glass will require better protection from humidity and atmospheric gasses and the use of a filter of infrared light, especially important in Mediterranean climates.

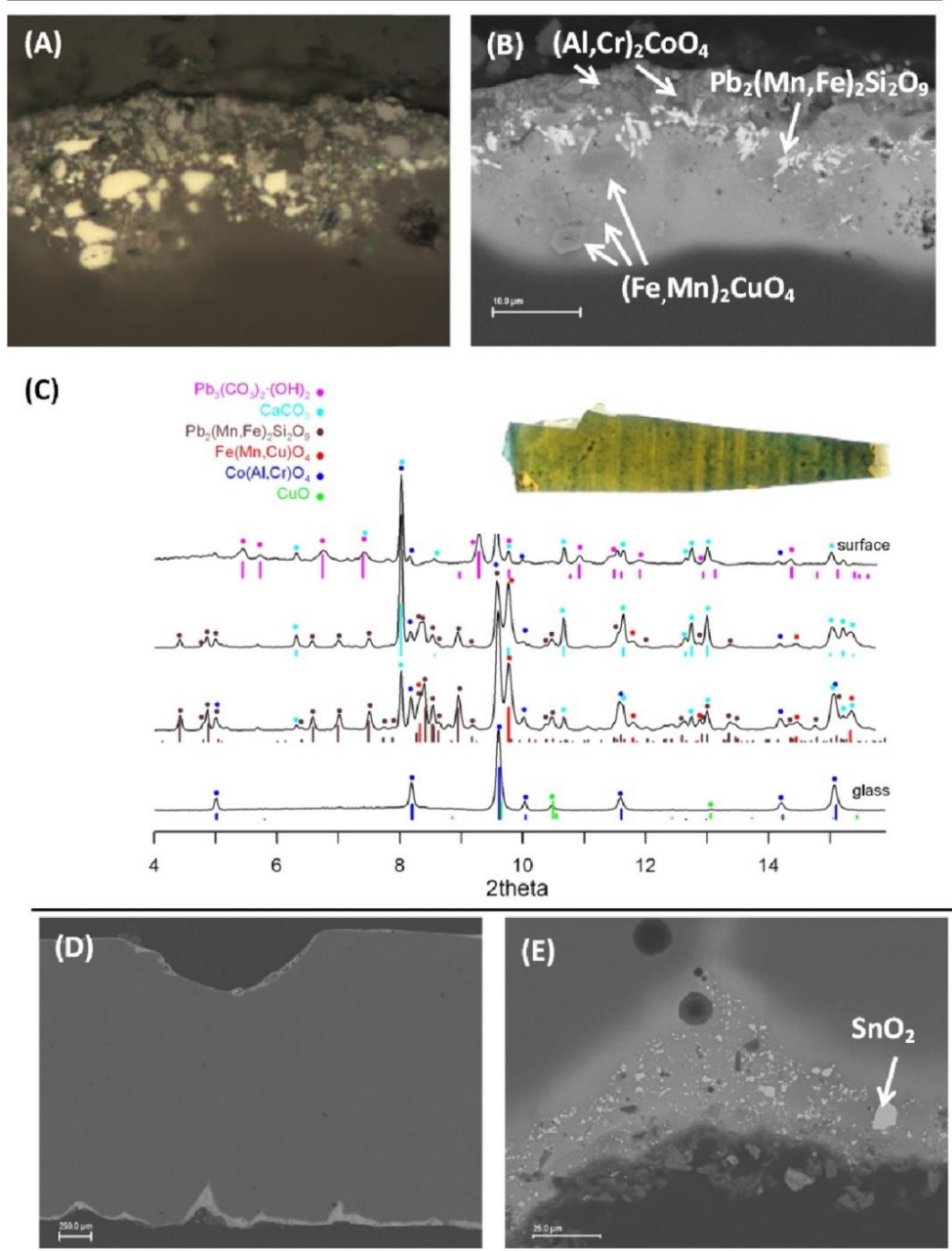


Fig. 5. (A) Blue enamel mixed with grisaille over a yellow glass fragment from the Seu del Districte Sants-Montjuic by Rigalt & Granell; (B) SEM-BSE image showing the presence of particles of $(Al,Cr)_2CoO_4$ from the blue enamel and of $Pb_2(Mn,Fe)_2Si_2O_9$ from the grisaille (C) μ -XRD patterns obtained across the enamel layer showing the enamel and grisaille particles, $(Al,Cr)_2CoO_4$, $Fe(Mn,Cu)O_4$, CuO and $Pb_2(Fe,Mn)_2Si_2O_9$, and also the presence of $CaCO_3$ and $Pb_3(CO_3)_2(OH)_2$ compounds on the surface. (D) and (E) SEM-BSE images showing the grisaille and blue enamel on the internal side and grisaille with SnO_2 particles outside a cathedral glass.

5.3

Grisaille Production: Some Examples from the 14th to the 20th Centuries

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Production de grisaille : quelques exemples du XIV^e au XX^e siècle – Résumé

La grisaille était traditionnellement fabriquée par les vitriers et les verriers à l'aide d'un verre à base de plomb mélangé à des métaux brûlés (fer ou cuivre). À partir de 1855 environ, ces matériaux ont commencé à être produits de façon industrielle, ce qui a conduit à la création de formules nouvelles et standardisées. L'objectif principal de ce travail est d'analyser les matières premières de cette peinture à base de verre pour mieux comprendre leur évolution au fil du temps.

Des fragments de vitraux de la cathédrale de Léon (Espagne), de la cathédrale de Nidaros (Norvège), de l'église du Saint-Esprit à Madrid (Espagne), de la cathédrale d'Uppsala (Suède), de l'église de Grodziec (Pologne), de l'Atelier de Restauration de Canterbury (Royaume-Uni et France) et échantillons

de vitraux belges, ont été étudiés. Les chronologies des échantillons se situent entre le XIV^e et le XX^e siècle. Les fragments ont été analysés par la technique PIXE (particle-induced X-ray emission) et les résultats ont été comparés avec les données disponibles dans la bibliographie.

Les résultats préliminaires concernant la composition des échantillons permettent d'identifier l'apparition de différents métaux au début du XIX^e siècle, comme les oxydes de cobalt, de chrome et de manganèse. Ces nouveaux composés apparaissent généralement avec les oxydes de fer ou de cuivre, qui sont les principaux colorants identifiés dans les échantillons plus anciens. En général, la composition des verres de base présentait moins de PbO que prévu dans les recettes historiques, et les proportions entre le verre de base et les agents colorants n'ont pas beaucoup changé avec le temps.

Grisaille Production: Some Examples from the 14th to the 20th Centuries – Abstract

Grisaille was traditionally produced by glaziers and glass-painters using a lead-based glass mixed with burned metals (iron or copper). From around 1855, these painting materials started to be industrially produced leading to the creation of new and standardized formulas. The main objective of this work is to analyse the raw materials of this glass-based paint for better understanding their evolution throughout time.

Stained-glass window fragments from the Cathedral of Léon (Spain), Nidaros Cathedral (Norway), church of the Holy Spirit in Madrid (Spain), Uppsala Cathedral (Sweden), church of Grodziec (Poland), Restoration atelier of Canterbury (UK and France) and samples from Belgian

stained-glass windows, were studied. The chronology of the samples is between the 14th and 20th century. The fragments were analysed by PIXE (particle-induced X-ray emission) and the results compared with previous ones in the literature. As preliminary results regarding the sample's composition, it was possible to identify the appearance of different metals, such as cobalt, chromium and manganese oxides in the samples from the beginning of 19th-century. These oxides usually appear together with iron or copper oxides, which are the main colouring agents in the older samples. In general, base glasses presented a lower content of PbO than expected from the historical recipes, and the proportions between the base glass and the colouring agents did not change much through time.

1. Introduction

Grisaille is a glass-based paint applied in the production of stained-glass panels, generally used for the creation of outlines and shadows.¹ These paints appear typically in dark colours (black, brown) and are the oldest painting materials and the most used in stained-glass windows.² Written sources, such as the 12th-century *De diversibus artibus* by Theophilus,³ describe the production of grisailles by mixing metal oxides (Fe₂O₃ and/or CuO), as colouring agents, with a ground lead-based glass, responsible for the

¹ MACHADO et al. 2019.

² SCHALM 2000.

³ HAWTHORNE & SMITH 1979.

adhesion of the grisaille to the glass substrate.⁴ The mixture thus obtained is applied on the glass substrate after being mixed with a vehicle, such as vinegar and water, which will give the necessary plasticity to paint, and gum Arabic as a temporary binding agent.⁵ After being fired at temperatures between 650°C and 700°C, an opaque and heterogeneous layer of colourless glass with metal oxides dispersed is formed on the top of the glass panel.⁶

Table 1 – Data sources of the grisaille samples studied in the bibliography

Country	Chronology	References	Country	Chronology	References
France	10th century	BETTEMBOURG 1991	Portugal	15th century	VILARIGUES et al. 2009 FERNANDES et al. 2008 VILARIGUES et al. 2004
	13th century	VILARIGUES et al. 2019 BETTEMBOURG 1991 PEREZ Y JORBA 1991 PEREZ Y JORBA 1984 VERITÀ 2003 VERITÀ 2010		16th century	VILARIGUES et al. 2009 VILARIGUES et al. 2019 FERNANDES et al. 2008
	16th century	VERITÀ 1996		20th century	VILARIGUES et al. 2009 FERNANDES et al. 2008
Germany	13th century	BETTEMBOURG 1991	Belgium	17th century	SCHALM et al. 2010
	14th century	BETTEMBOURG 1991 VERITÀ 2010		19th century	SCHALM 2000 VILARIGUES et al. 2019
	15th century	MARSCHNER 1996 BETTEMBOURG 1991		20th century	VILARIGUES et al. 2019
Italy	13th century	VERITÀ 2010	Low Countries	15th century	VILARIGUES et al. 2019
	14th century	VERITÀ 2010 VERITÀ 1996 BOLLATI et al. 2010		16th century	VILARIGUES et al. 2019
	15th century	VERITÀ 1996 PLAISIER et al. 2017 ÉCHARD et al. 2008	Switzerland	17th century	VILARIGUES et al. 2019
	16th century	VERITÀ 1996.		16th century	MACHADO et al. 2017
	19th century	ALBERTA et al. 2011		17th century	VILARIGUES et al. 2019 MACHADO et al. 2017
Spain	13th century	CARMONA et al. 2006 PALOMAR 2013	Czech Republic	13th century	ČÍLOVÁ, et al. 2015
	15th century	PALOMAR 2013		14th century	ČÍLOVÁ, et al. 2015
	16th century	PRADELL et al. 2016 CARMONA et al. 2006		15th century	ČÍLOVÁ, et al. 2015
	17th century	PRADELL et al. 2016	Poland United Kingdom	15th century	BERNADY et al. 2018
	19th century	PRADELL et al. 2016		13th century	SPENCER et al. 2018
	20th century	PRADELL et al. 2016 GARCÍA-HERAS 2005 PALOMAR 2013 CARMONA et al. 2010			

⁴ MACHADO et al. 2019.

⁵ MACHADO et al. 2019; SCHALM 2000; PRADELL et al. 2016.

⁶ SCHALM 2000; MACHADO 2016.

Investigations concerning stained-glass windows have been growing over the years;⁷ however, they have mainly focused on the materials characterization of the glass substrate, with few studies of the painting materials. Since 1984, only 27 published studies were found on grisaille painting, shown in Table 1.

In these studies, the main metals responsible for the colour were iron and copper oxides (Fe_2O_3 , CuO), used individually or in combination. Zinc was also found in older grisailles (15th century),⁸ as well as cobalt, chromium and manganese in recent ones (19th and 20th centuries).⁹ These metal oxides are mixed with a base glass described as a high lead-silica glass with different proportions between the lead oxide and silica content. Some authors also identified the use of borax since the 17th century.¹⁰

In VILARIGUES et al. 2019, a first spatiotemporal study of the grisailles compositions was made. Some conclusions were drawn regarding the colouring agents used, being identified the iron oxide as the favourite used and with the highest proportions in central and western Europe. The eastern European countries were the ones where a higher content of copper was used together with iron, in a ratio iron:copper of 1:1 or 1:2. It was also compared the proportion between the base glass and the colouring agents, seeing that it is constant over the centuries in around 40-50 %, except on the 15th and 17th centuries, when the grisailles presented up to 80 % of base glass.

In this study, selected grisaille samples will be characterized and compared with grisaille compositions from the literature (Table 1), with the aim of tracing the evolution of this glass-based paint composition based on its provenance (country where it was produced) and chronology.

2. Materials and methods

2.1. Historical grisailles

Twenty-one grisaille samples were chosen to be chemically characterized from seven different collections: Joost Caen's private collection (JC), Belgium; Cathedral of León (CL), Spain; Holy Spirit Church of Madrid (HSC), Spain; Nidaros Cathedral (NC), Norway; Uppsala Cathedral (UC), Sweden; Church of Grodziec (CG), Poland; and from the Restoration atelier of Canterbury (LS), France and UK. The chronology of the samples is between the 14th and 20th centuries. The samples are represented in fig. 1.

To have a better spatiotemporal map of the grisaille compositions and a greater representativeness, grisaille compositions from the literature were also selected for comparison. Only the studies with specific compositions of the grisailles filling the spatiotemporal gaps were selected. The studies were selected from the ones shown in Table 1: MARSCHNER 1996, VERITÀ et al. 2003, VILARIGUES et al. 2004, FERNANDES et al. 2008, VERITÀ, 2009, ČÍLOVÁ et al. 2015, MACHADO et al. 2017, BERNADY et al. 2018, SPENCER et al. 2018, and VILARIGUES et al. 2019.

In this study (sample analysis and literature) compositions from the 13th to the 20th centuries were compared from thirteen different European countries (Portugal, Spain, France, Belgium, Germany, Low Countries, Switzerland, Italy, Czech Republic, Poland, Sweden, Norway, United Kingdom).

2.2. Analytical techniques

The chemical compositions from grisaille samples were obtained by μ -PIXE. Whenever possible the samples were cut with a steel wire with a diamond point and mounted in epoxy resin (Araldite 2020) from Huntsman™ and polished with up to 4000 grit with a SiC paper, to analyse by internal beam. An external beam was used for the samples that could not be mounted in resin. Further details on sample preparation and analysis can be found elsewhere.¹¹

To better compared the results, as well as the compositions taken from the literature, concentration ratios were calculated: regarding the proportion between lead oxide and silica in the base glass (e.g. $\text{PbO}/(\text{PbO}+\text{SiO}_2)$), regarding the proportion of the different colouring agents (the colouring agents considered were Fe_2O_3 , CuO , CoO , MnO , Cr_2O_3 (e.g. $\text{Fe}_2\text{O}_3/(\text{Fe}_2\text{O}_3+\text{CuO}+\text{CoO}+\text{MnO}+\text{Cr}_2\text{O}_3)$), and the proportion between the base glass (BG) and the colouring agents (CA) (e.g. $(\text{PbO}+\text{SiO}_2)/((\text{PbO}+\text{SiO}_2) +$

⁷ PALOMAR 2018; Teresa PALOMAR et al. 2018; CORRÊA et al. 2018; ADLINGTON & FREESTONE 2017; LEGRAND et al. 2019.

⁸ VILARIGUES et al 2009; MARSCHNER, 1996.

⁹ PRADELL et al. 2016; VILARIGUES et al 2009; SCHALM et al. 2003; CARMONA et al. 2009; GARCÍA-HERAS et al. 2005.

¹⁰ PRADELL et al. 2016.

¹¹ MACHADO et al. 2020.

($\text{Fe}_2\text{O}_3 + \text{CuO} + \text{CoO} + \text{MnO} + \text{Cr}_2\text{O}_3$)). Afterwards, averages of the results for the different grisailles were calculated for each country and century.

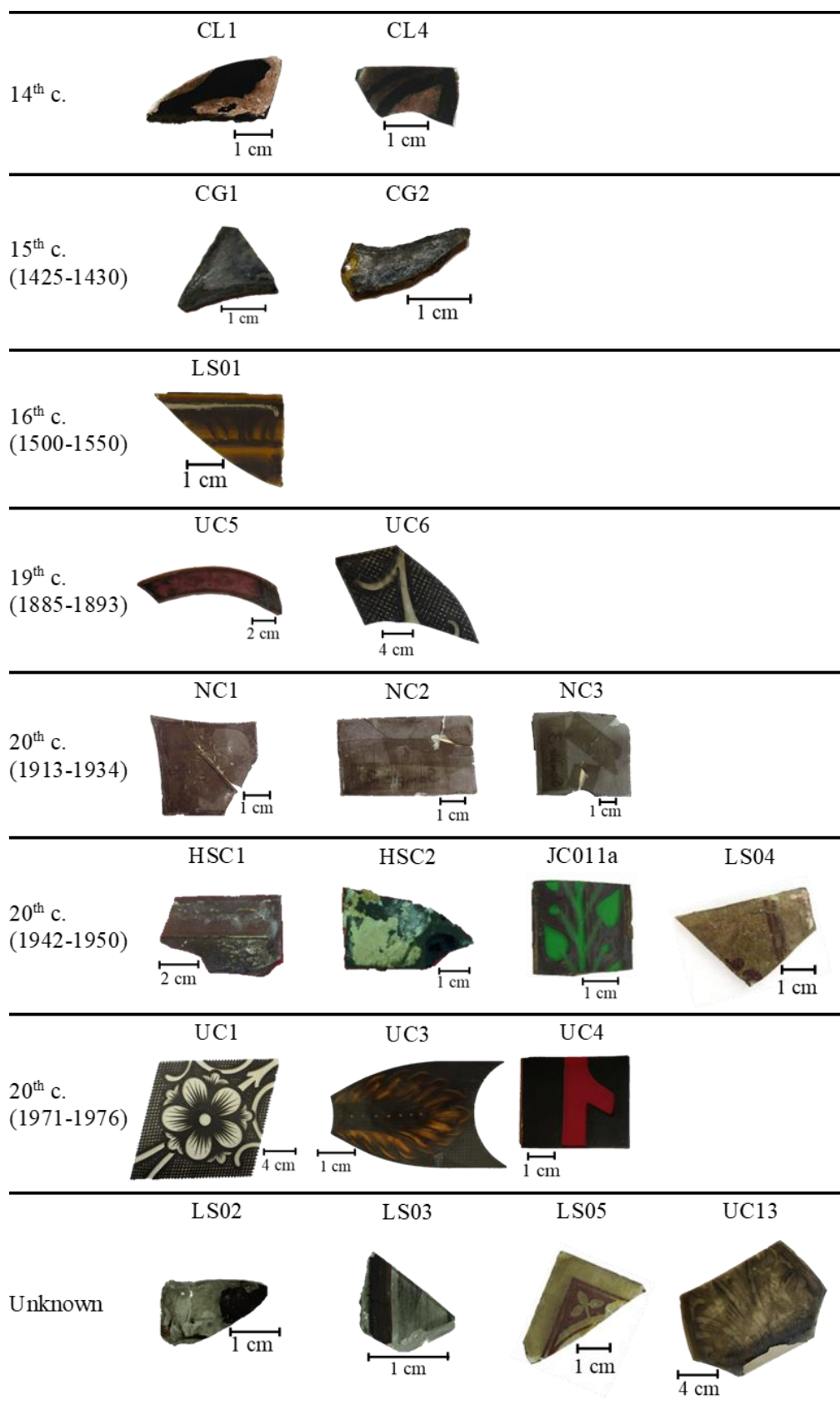


Fig. 1. Selected samples to be analysed in this study.

3. Results and discussion

The distribution of the different colouring agents in the grisailles according to their provenance and chronology is represented in fig. 2. It is possible to see that the iron oxide is the main colouring agent used in most of the countries and across the centuries. The iron presents a more than 50 wt. % concentration in the western and southern-western European countries (United Kingdom, Low Countries, Belgium, France, Switzerland, Spain, Portugal), as well as in the Polish grisailles. However, copper oxide was preferentially used in central and south central European countries (Germany, Italy, Czech Republic).

Further research may reveal how these geographical preferences reflect different relations between the countries, not only in commercial trade of raw materials but also in knowledge transfer between countries.

In the northern countries (Norway, Sweden) it was possible to see the appearance of other different colorants in higher proportions, for example, the chromium, cobalt and manganese oxides, together with iron and copper oxides. This is related to the chronology of the grisailles from this period as they are all from the 19th and 20th centuries where it is also possible to see the appearance of the use of these metal oxides.

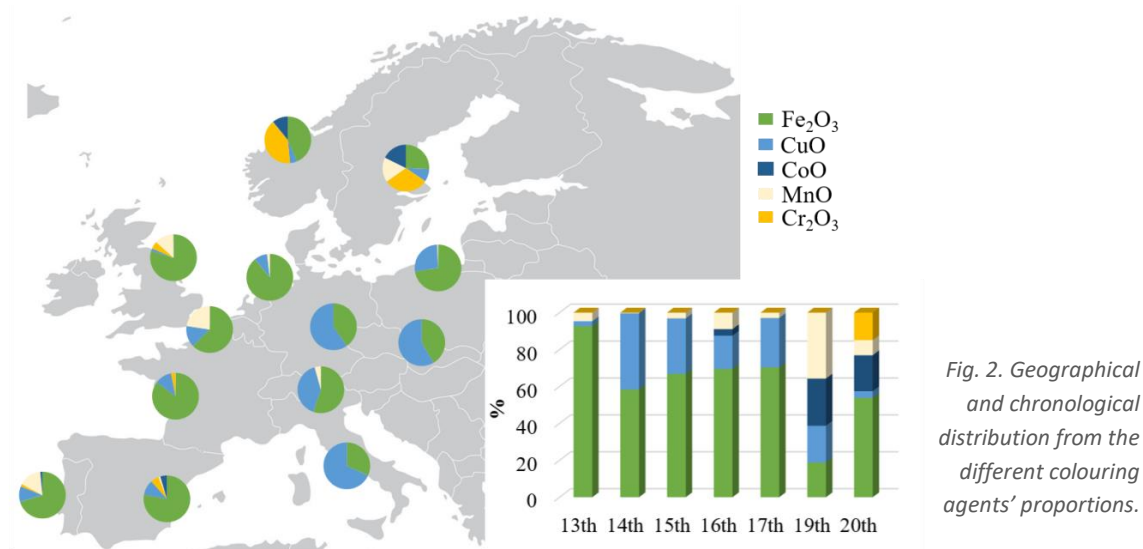


Fig. 2. Geographical and chronological distribution from the different colouring agents' proportions.

Regarding the base-glass compositions, fig. 3 shows the results from the proportions between the different base-glass components (PbO and SiO₂). In this case, they are not directly related to a geographical distribution showing a great variety of proportions.

Eight countries (Portugal, Belgium, Low Countries, Switzerland, Czech Republic, Poland, Norway, United Kingdom) have more than 50 wt. % of SiO₂, and only five countries (Spain, France, Germany, Italy, Sweden) have higher amounts of PbO. If these compositions are compared with the historical recipes from each country, it is possible to detect a higher amount of silica in the historical grisailles than the expected one. In the historical written sources, base glasses used to present proportions of lead oxide and silica of 1.5 to 3, but historical grisailles presented a ratio PbO:SiO₂ is around 1 (fig. 3).¹² Nevertheless, these results can be explained either by the volatilization of the lead during the firing process, leaving the final grisaille with a lower content of lead, or due to a degradation process by acid attack. In the latter, lead ions can interact with compounds from the atmosphere (CO₂, SO₂, etc.) to form soluble products that would be cleaned by the rain leaving a silica-enriched glass.¹³

From the chronological point of view, it is observed a higher proportion of SiO₂ (~60-70 wt. %) on 16th, 17th and 20th centuries. This can be related with addition of new components to the grisailles

¹² MACHADO et al. 2019.

¹³ VERITÀ 2010.

composition, such as the borax, that can decrease the melting temperature without a high amount of PbO.¹⁴

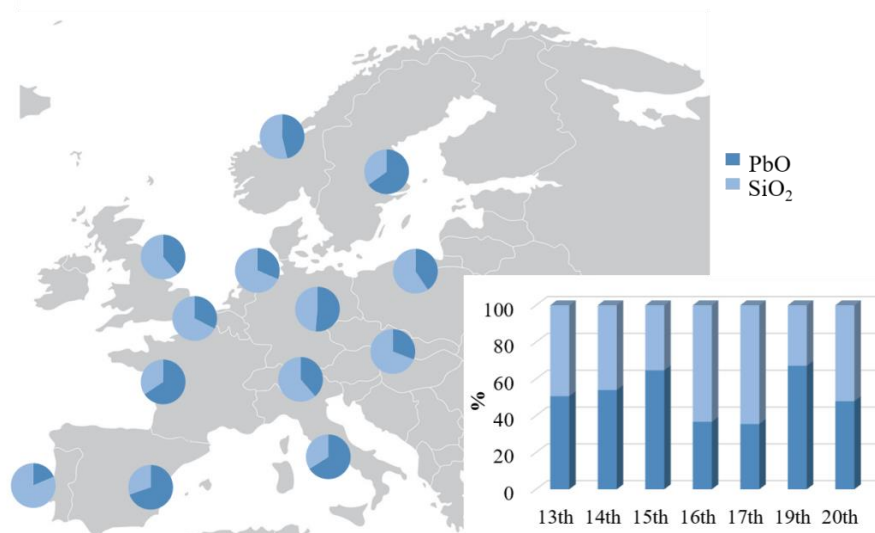


Fig. 3.
Geographical and
chronological
distribution from
the different base
glass components
proportions.

The comparison between the proportion of the two different elements of the grisailles, the base glass and the colouring agents, was also made. It is shown in fig. 4.

The graph shows that the average for the proportion of base glass to colouring agents is around 60-80 wt. % all over the different centuries, being higher on the 13th, 19th and 20th. These results are contrary with the ones obtained by VILARIGUES et al. 2019, that showed the highest amount of base glass to colouring agents (up to 80 wt. %) in grisailles from the 15th and 17th centuries. The different result is related to the low number of samples analysed. To have a better representativeness, it is necessary to compare a higher number of samples.

Regarding the geographical distribution it is possible to observe that in most of the countries, except in the Czech Republic, the proportion of base glass to colouring agents is more than 50 wt. %. This implies a higher stability of the grisailles. Higher ratios of colouring agents induce a porous grisaille being more susceptible to abrasions, humidity and degradation processes.¹⁵

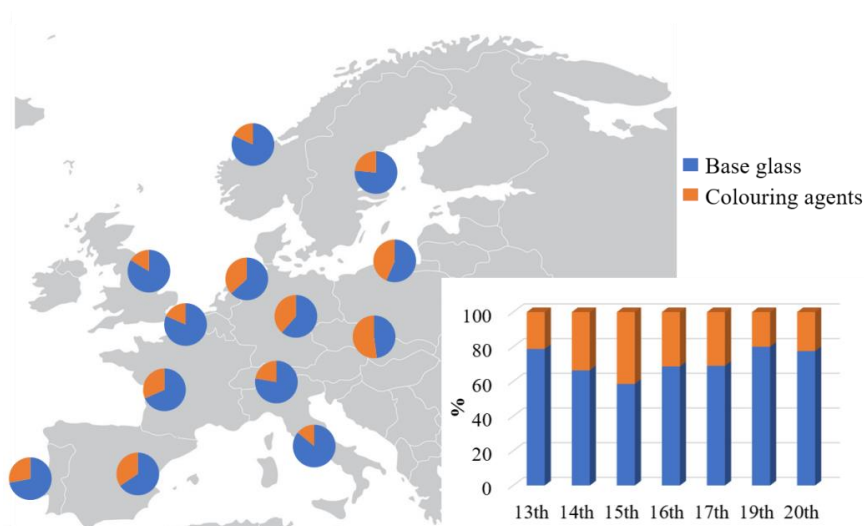


Fig. 4.
Geographical and
chronological
distribution of the
proportions between
the base glass and
colouring agents.

4. Conclusions

In the present study, it was possible to draw some conclusions regarding the spatiotemporal evolution of grisaille paint production, reflected in its changes in composition.

¹⁴ PRADELL et al. 2016.

¹⁵ PALOMAR 2018; BETTEMBOURG 1991.

The iron oxide was the most used colouring agent, except in central and south central European countries, where copper oxide was favoured. In the northern grisailles the cobalt, manganese and chromium oxides were also identified as colouring agents; however, this relates to modern grisailles (19th and 20th centuries). The base glass composition was generally uniform ($\text{PbO}:\text{SiO}_2$ 50-60 wt. %) except during the 16th, 17th and 20th centuries when the proportion was lower (35-50 wt. %). In the proportion between the base glass and the colouring agents, the differences between the different centuries were not remarkable (60-80 wt. %) except on the 15th-century samples when they were lower than 60%.

When comparing all the results, it was possible to observe that the samples from 16th and 17th centuries presented similar compositions. However, this happens because almost all studied samples from these centuries have the same provenance (Low Countries and Switzerland). For a more representative study, samples from each country with different chronologies would be needed, but their scarcity and high value of them makes this difficult to achieve.

To conclude, this study was the first step towards establishing patterns of evolution in the grisaille production and composition, as well as, towards the creation of a database of grisaille compositions that will be useful for a better understanding of stained-glass windows and their painting materials.

5. Acknowledgements

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5.4

Physico-Chemical Insights into Sanguine and Carnation based on Reproduced Historic Recipes

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Aperçu physico-chimique de la sanguine et de la carnation à partir de recettes historiques reproduites – Résumé

La carnation (aussi connu sous le nom de « Jean Cousin ») et la sanguine sont deux types de peintures vitreuses à base d'oxyde de silicium (Si), d'oxyde de plomb (Pb) et d'oxyde de fer (Fe). Utilisées depuis la fin du XV^e siècle, elles produisent une gamme unique et lumineuse de tons chair et d'orange. Malheureusement, sur les vitraux historiques, ces peintures présentent parfois de sévères dégradations. Afin de bien comprendre les couches de décoration de surface gravement détériorées et complexes, et donc de pouvoir appliquer un traitement de conservation approprié, il est essentiel de comprendre clairement les comportements et les différences entre la sanguine, la carnation et la grisaille colorée.

D'un point de vue terminologique, la carnation est la peinture transparente de couleur chair, tandis que celle à l'aspect opaque de couleur orange brique est appelée sanguine. Lors de la première étape de l'étude, une différence de dommages entre ces deux peintures a été constatée. La sanguine s'effrite généralement à partir du centre et survit mieux sur les bords, en particuliers près des grisailles. Contrairement à la carnation qui se décolore sur une zone plus générale, parfois jusqu'à ce qu'il ne reste que l'irisation à la surface du verre qui prouve son existence antérieure. Ces propriétés, associées à leurs couleurs spécifiques, permettent de les distinguer aisément des autres types de peintures sur verre.

Physico-Chemical Insights into Sanguine and Carnation Based on Reproduced Historic Recipes – Abstract

As a follow-up to the study of Sanguine and Carnation, executed and submitted by Anne Catherine Perreau, the physico-chemical approach will be discussed in this contribution. As mentioned in her abstract, in order to understand properly the sometimes severely deteriorated and complex layers of surface decoration and hence to fulfil a proper conservation treatment, it is essential to clearly understand the behaviour, the differences and the manufacturing processes of Sanguine, Carnation and coloured grisaille. The various series of mockups prepared by A.-C. Perreau were based on historic recipes. A detailed observation of grainsizes,

Dans la deuxième étape de l'étude, l'accent a été mis sur les différentes strates, obtenues lors du processus de sédimentation d'où se forment ces peintures. Ainsi, la sédimentation a été reproduite sur différents échantillons en utilisant les recettes développées par les moines Antoine et Maurice écrites dans le livre de Pierre Le Vieil. Ces échantillons ont été étudiés en appliquant plusieurs techniques microscopiques. Les observations révèlent que la couche supérieure présente plus de similitudes avec une couche de carnation, alors que la couche juste en dessous ressemble plus à une sanguine. En comparaison, les deux dernières couleurs obtenues lors des deux dernières étapes de sédimentation, présentent plus de similitudes avec la grisaille. De plus, il devient clair que les couches séparées pendant le processus de sédimentation ont une taille de grains différente et contribuent de façon inhérente aux caractéristiques respectives et distinctes de la carnation et de la sanguine. L'étude a permis d'établir que la carnation est toujours une peinture vitreuse, où le pigment est entouré d'un fondant, mais aussi qu'il y a une interaction avec le support comme si la peinture rongait la surface du verre. Ainsi, la transparence de la carnation pourrait s'expliquer par la diffusion des grains de pigment dans le verre. Ce phénomène diffère de la sanguine où les plus gros grains restent en surface, arrêtant la dispersion de la lumière, et expliquant un aspect opaque.

distributions, representations and glass surface – paint interface was done by using high performance optical microscope (ZEISS) and a digital microscope (HIROX). All these mockups were analysed by applying SEM-EDX and a few were selected for RAMAN spectroscopy. The obtained results will be outlined in this presentation. In extension of this study a selected number of 16th century stained glass panels from STAM museum of Ghent, Belgium were scanned by MA-XRF (BRUKER) in order to evaluate the presence of Carnation and Sanguine. During this contribution it will be demonstrated how MA-XRF can contribute in reading sometimes heavily deteriorated Stained Glass.

Introduction

Carnation (also known as Jean Cousin) and sanguine are both types of vitreous paints made from silicon oxide (Si), lead oxide (Pb), and iron oxide (Fe).¹ They have been in use from the late 15th-century and produce a unique luminous range of flesh tones and oranges (fig. 1).² This colouration is produced by the small iron oxide particles (Fe_2O_3) selected during a sedimentation process which happens in their production.³ In historic fragments, the depth of Carnation layers has been measured to around $5\mu\text{m}$.⁴



Fig. 1. Ghent, Belgium, STAM Museum: panel showing the feast at Joseph's house: the amazement of his brothers at being seated according to their age, Southern Low Countries, second half of the 16th century (09019).

© STAM Museum.

¹ Olivier SCHALM, "Characterization of the paint layers in stained-glass windows: main causes of the degradation of nineteenth century grisaille paint layers", PhD thesis, Universitaire Instelling Antwerpen, 2000. p. 269.

² Ângela SANTOS & Márcia VILARIGUES, "Sanguine Paint: Production, Characterization, and Adhesion to the Glass Substrate, Studies in Conservation", 64:4, 221-239, DOI: 10.1080/00393630.2018.1482708, 2019, p. 221.

³ Joost M. A. CAEN, *The production of stained glass in the County of Flanders and the Duchy of Brabant from the XVth to the XVIIIth centuries: materials and techniques*, Harvey MILLER (Publ.), 2009, p. 254.

⁴ Olivier SCHALM, "Une étude historique et chimique de peinture de verre « rouge Jean Cousin »", in : *Dossier de la Commission royale des monuments, site et fouilles*, 3- Grisaille, jaune d'argent, sanguine, émail et peinture à froid, technique et conservation, Forum pour la conservation et la restauration des vitraux, Liège 19-22 juin 1996, 1996, p. 161.

In most historical texts, two different fired products are identified. Writers often observe an application of a thin flesh colour layer of carnation, also named *sanguine transparent* or *Jean Cousin*, which is applied on the external side of window glass⁵ and is visible in reflected light as iridescent marks.⁶ This layer is different to sanguine, also named *sanguine opaque*, which is usually applied on the internal side and recognisable by a unique bright orange brick colour.⁷ However, some exceptions to this pattern have been observed on historical stained-glass windows. The choice between which one of those paints has been applied, varies depending on the production time, the size of the panel, and the location for which it has been made.⁸ The use of these paints helped artists achieve optical effects which added realism to the painting's style. However, over time stained glass often faces adverse circumstances and can suffer from alterations, breaks, or humidity. These effects can increase the difficulty to distinguish carnation from sanguine, and both from other types of paint on historic glass.

Consequently, to properly understand severely deteriorated and complex layers of surface decoration and hence fulfil a proper conservation treatment, it is essential to clearly understand behaviours and differences between sanguine, carnation and coloured grisaille. The aim of this contribution is to present the outcome of the on-going physico-chemical investigation of sanguine and carnation via a set of reproduced historical recipes.

Carnation and Sanguine: Appearance

Firstly, It seems important to observe alterations of sanguine and carnation, to work towards understanding the behaviour of these paints on stained glass over time. During visits to various museums, some very specific damage phenomena have been observed. It has been in particular the case for the stained-glass collection held at the STAM museum in Gent, where observations were made by glass painter Anne-Catherine Perreau and conservator and art historian Aletta Rambaut.



Fig. 2. Ghent, Belgium, STAM Museum: panel showing a view from reverse and front side of a detail of the Annunciation, from Southern Netherlands, second half of the 16th century (09011). © STAM Museum.

⁵ Joost M. A. CAEN 2009, p. 273.

⁶ Irène PORTAL, *Sanguine et Jean-Cousin : deux matériaux utilisés pour rendre les carnations dans les vitraux : histoire des termes, nature des matériaux* ; mémoire d'étude de l'École du Louvre (1^{re} année de 2^e cycle), Paris, 2010-2011, vol. 2, p. 16.

⁷ Joost M. A. CAEN 2009, p. 254, 273.

⁸ Joost M. A. CAEN 2009, p. 273-274.

To start with, a difference in damage between sanguine and carnation has been noticed. Sanguine is really fragile, particularly if it is applied in a thick layer. Scuff marks have often been observed, as if the layers have been scraped by somebody. Also, some form of corrosion, similar to that which occurs with grisaille, was seen and can cause paint to crumble into micro pieces. The particular nature of sanguine corrosion causes it to start deteriorating from the centre outwards and means that it survives better near grisaille paint. It leaves a very light pink transparent layer on the surface, or just a mark. In contrast, carnation seems not to crumble, but it leaves an iridescent mark which indicates its presence on the external side. However, sometimes it is not possible to see by eye the presence of the paint in flesh tone when it is observed from the front side, as it is already partially missing. It is possible that the layers are so fragile and so thin that they can be damaged by the atmospheric condition and lose their colouration (fig. 2).

Another form of damage to carnation and sanguine can be experienced when they are applied on top of a grisaille. In this case they often survive better than the grisaille itself. When the grisaille corrodes and flakes off, it can take with it the carnation or the sanguine and looks like a negative image of the drawing. Probably because of the difference in characteristics of the two paints, carnation and sanguine seem to have a better grip to the glass surface than some grisaille paints.

Reproduction of Historic Recipes

Secondly, in order to understand the main differences among sanguine, carnation and coloured grisaille, a focus was placed on the sedimentation phenomenon which occurs while separating the pigments into different layers. It is often mentioned in old recipes that after collecting the top layer from the sediment process, the layers underneath can be used for creating the effects of drapery, wood, and so on.⁹ Therefore in the following step of the investigation and in order to understand the colours produced in each sedimentation step, various tests were made by applying the different layers produced during the sedimentation process. At the end they were compared to one another. The sedimentation was reproduced using the recipes developed by the monks Antoine and Maurice as recorded in the book of Pierre Le Vieil. These recipes were recreated with the help of conservator Ângela Santos at the VICARTE Research Unit of NOVA University in Lisbon and Anne-Catherine Perreau.¹⁰

For this test series, the paint was applied with a smear-shading brush made of squirrel hair and smoothed with a badger brush. The paint was diluted with deionized water only. The glass support was a microscope lab slide, brand Deltalab, Eurotubo®. The prepared painted glass slides were fired at 620°C, holding for 30 minutes.

Microscopic Evaluation of the Test Series

Purely with the naked eye, evaluation of these test pieces makes clear that a difference can be noticed between the two top layers compared to the others beneath. The two upper layers are brighter and more luminous than the others. Additionally, it was observed that the very top layer of the solution is more transparent but paler than the next, which is semi-transparent and more colourful. The two bottom layers are completely opaque, with warm colours, but are not luminous.

If these four reproduced layers are compared to the paints occurring on old stained glass, some similarities in the luminous coats can be observed. First of all, the use of the different colours that were reproduced according to historic texts can be distinguished by the experienced naked eye. Additionally, according to the terminology, it can be deduced that the top layer shows more similarities with a carnation layer, whereas the layer just underneath looks more a sanguine. In comparison, the last two colours obtained from the last two sedimentation steps, show more similarities to grisaille paint.

In order to gain a deeper understanding and put forward more objective differential features between these types of paint, some of the test samples were further investigated by applying different microscopic techniques. This part of the study was conducted at the KIK-IRPA laboratories in Brussels, Belgium and executed by Helena Wouters. The microscopic techniques used include optical microscopy (ZEISS, Imager-M1), Digital microscopy (HIROX), and scanning

⁹ Pierre LE VIEIL, *L'art de la peinture sur verre et de la vitrerie*, Impr.de L.-F. Delarour, Paris,1774, p. 128.

¹⁰ Pierre LE VIEIL 1774, p. 127-128.

electron microscopy coupled to X-ray detection, SEM-EDX (ZEISS, EVO 15LS; Oxford Instruments, AzTec).

From the microscopic observations, the size selection of the pigment grains which occurs during the sedimentation process¹¹ could be established. In fig. 3 a schematic overview of the different separation layers obtained as a result of the sedimentation process of the paint is shown as photographic record of the surface of the respective mock-up, as well as observed by the applied microscopic techniques. The different measurements makes clear that the bottom layer of the sedimentation (fig. 3, 4th layer) represents the residue of the recipe with the biggest grains and has an heterogeneous appearance. Just above this residual layer, after the stratum's separation between the previous layer and the two following, the remains of bright pigments are found. As has been presented in fig. 3, 3rd layer, this resulted layer is more homogeneous with a visible demarcation between the grains and the glass surface. The observed consistency is comparable and identical to coloured grisaille. This feature explains the opacity of the paint.

The following layer above, shows even more interesting features and is indicated as the second layer in fig. 3. Interestingly, although the individual grains can still be seen under the optical microscope, the layer is very thin ($\approx 0.5\mu\text{m}$) as derived from the cross-section in the SEM-EDX. In this particular layer, surprisingly, the amount of iron is measurably higher than that of lead. Additionally, it was observed that the layer is so thin that the demarcation between the glass and the paint is more difficult to distinguish compared to the cases before, and above all, under the optical microscope the pigment appears less dense. Also some black areas are detected which showed the beginning of transparency, a feature which did not appear in the previous layers beneath (third and fourth layer in fig. 3). Finally, looking at the very top layer (first layer in fig. 3), it can be noticed that the grains are even smaller, so small that they can be barely distinguished. They appear like tiny red dust on the surface of the glass, and the density of the pigment is very light, which explains the increased transparency of the paint. Looking to the cross-section of this layer under the SEM-EDX microscope, it can be noticed that the layer is even thinner than the layer just above. The area delimiting the paint and the surface of the glass appears cloudier, as if something is happening between the two materials.

In order to comprehend better the interaction of the glass and the carnation paint of the first layer (fig. 3), also other carnation pigments, like the one produced by Debitus studio in Tours, and an unknown paint made by Leonie Seliger, director of Canterbury Cathedral Studio in Kent, were measured under the SEM-EDX.

In the research executed by Irène Portal,¹² a theory about the function of the small particle size was introduced and explained, suggesting that because of the micro size of the iron oxide particles, some of them can enter the surface of the glass when melting occurs during the firing process. The iridescence observed on the surface of the glass could be a partial reflection of these micro particles. From our observations, shown in fig. 4, we can confirm her theory and have demonstrated that carnation is still a vitreous paint, with pigment surrounded by flux, but there is an interaction with the glass as if the paint was eating into the surface.

Added to this, the analysis of the samples shows that the transparency of the carnation could be explained by the diffusion of the pigment grains into the glass. This differs from sanguine where the bigger grains still remain on the surface, stopping the dispersion of the light, and explaining an opaque appearance. This interaction with the glass could also explain why those pigments survived better than other vitreous glass paints when they were applied directly to the substrate.

¹¹ Olivier SCHALM 2000, p. 243-268.

¹² Irène PORTAL 2011, p. 55.

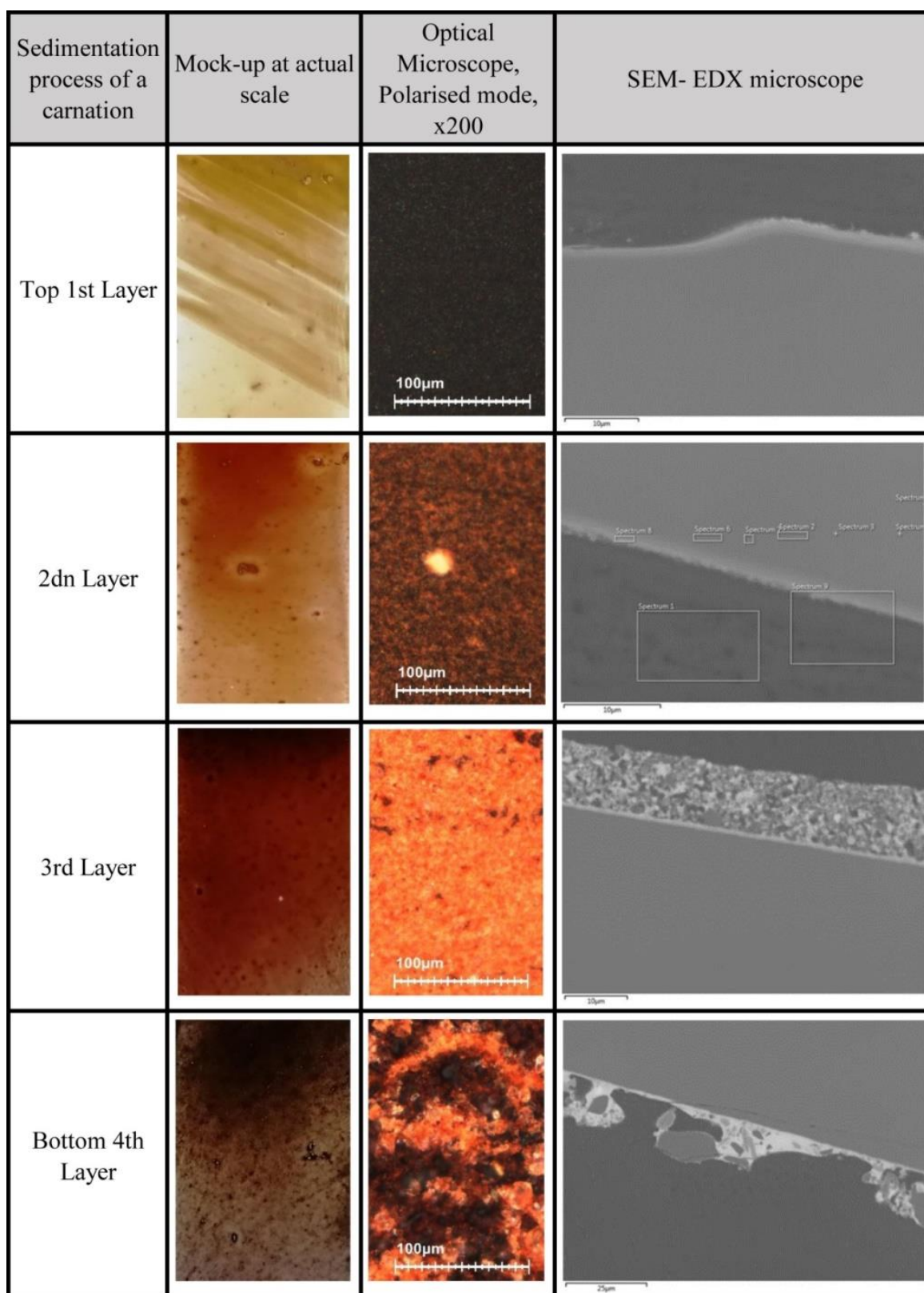


Fig. 3. Schematic overview of the different sedimentation layers with corresponding observed appearance, respectively, the actual scale photograph, optical microscopic view and the back-scattered electron image recorded in the SEM-EDX. The samples of the four layers were reproduced by Â. Santos and A-C. Perreau according to the Monks Antoine and Maurice's recipe and prepared on Deltalab, Eurotubo®'s microscope lab slide, fired at 620°C-holding 30 minutes. ©KIK-IRPA, A-C. Perreau, Helena Wouters.

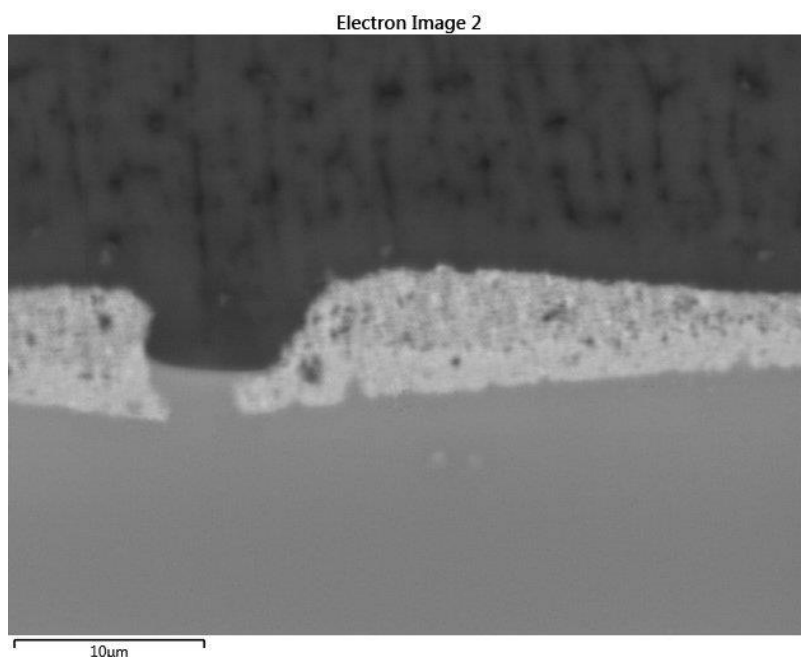


Fig. 4. Back-scattered electron image of a cross-section of glass substrate with the bottom layer of the sedimentation paint. Sample made by A-C. Perreau: Debitus carnation rouge on non-tinted side of a 3mm float glass, fired at 680°C - holding 20 minutes. The granular white layer corresponds to the paint layer, while the light grey zone represents the glass carrier.
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Conclusions

The investigation was executed in order to clearly understand differences between sanguine, carnation and coloured grisaille and their remarkable deterioration behaviour. Carnation (also known as Jean Cousin) and sanguine are both types of vitreous paints in use from the late 15th century and produce a unique luminous range of flesh tones and oranges.

Throughout the study, a difference in damage phenomena between sanguine and carnation has been noticed. In particular, sanguine starts to deteriorate from the centre outwards and leaves a very light pink transparent layer on the surface. In contrast, carnation seems not to crumble but it leaves an iridescent mark which indicates its presence on the external side.

The sedimentation procedure, which is the basic production of the glass paint, was recreated using the recipes developed by the monks Antoine and Maurice. The prepared test series was investigated by applying different microscopic techniques. The results have shown that sanguine and carnation are two different paints produced during a separate stage of the long sedimentation process. Specific features could be established and makes them distinguishable. In general, sanguine is more opaque while carnation is more transparent. The transparency of the carnation is due to the size of the particles in the layer and the subsequent penetration effect of the smallest micro-pigment grains into the surface of the glass. Sanguine has bigger pigment grains in the layer which sits on the surface of the glass, giving it its increased opacity. The study is still going on and is specifically currently undergoing enlargement by the application of elemental X-ray analysis of the different test series. By the time of the presentation at the Forum, we hope to show you how the presence of carnation and sanguine on heavily deteriorated stained glass can be evaluated by applying macro scanning X-ray fluorescence (MA-XRF), so that those glass paintings can literally be read.

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FP. 1

La restauration des vitraux de la chapelle royale du Château de Versailles

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Restoration of the Windows in the Royal Chapel of the Palace of Versailles – Abstract

The royal chapel of the palace of Versailles has been built between 1700 and 1710 with three levels of windows. The upper one is called the attique, the second level is the tribune and the lowest one is called rez-de-jardin. The windows are made up with wide colourless sheet of glass framed with small panels of stained glass and set into an ornamented metalwork. For this work of art as well as for the hall of mirrors, Louis XIV ordered the use of plate glass instead of blown glass. At this time, the manufacture of glass by casting and polishing is an innovative process vouching for a major expertise while the manufacture of blown glass has reached its height. However, after the 18th century, broken glass pieces have been replaced during successive restorations. Despite detailed documentation, no information could be found about the changes made and today it is difficult to tell the proportion of original glass panels left. The last restoration (2017-2020) included

the complete removal of all the bays in order to restore them in the conservator's studio. A preliminary study was carried out in 2015 allowing the Laboratoire de Recherche des Monuments Historiques (LRMH) to initiate the protocol of analyses in order to know the glass composition and then identify their origins as no distinction can be made on the mere observation. The analyses were done on site on the glass panels with a portable X-ray fluorescence spectrometer. An ancient glass with engravings was used as a reference sample. These analyses were coupled with thickness measures to separate plate glass sheets from blown ones. The results allowed the discrimination of several groups of glass panels originating from different periods: panels from the 17th–18th centuries (original glass), from the 19th and the 20th centuries. This work has been useful to increase the knowledge on the glass windows of the royal chapel and was also helpful for their removal in order to be restored.

La restauration des vitraux de la chapelle royale du Château de Versailles – Résumé

Construite entre 1700 et 1710, la chapelle royale du château de Versailles comporte 24 grandes baies entre l'attique et la tribune et un peu plus de 10 baies en rez-de-jardin. Elles sont composées de verres incolores (glaces) entourées de bordures en vitrail et d'une serrurerie constituée de parcloes vissées. Lors de la commande des verres pour la chapelle royale comme pour la grande galerie (galerie des glaces), Louis XIV exige l'emploi de glaces : des plaques de verre incolore de grandes dimensions et plus épaisses que le verre à vitre. A cette époque, la fabrication du verre par coulage et polissage est une technique innovante, attestant d'un savoir-faire d'excellence. En parallèle, la technique traditionnelle du verre soufflé est également à son apogée. Après le XVIII^e siècle, au cours des restaurations successives, les verres cassés vont être remplacés. Malgré une documentation détaillée, aucun relevé précis indiquant ces changements n'a été réalisé et il est difficile de dire aujourd'hui la proportion de glaces d'origine restantes. Un nouveau projet de restauration a débuté en 2017 et prévoit la dépose

complète des baies pour une restauration en atelier. Lors de l'étude préalable en 2015, une série d'analyses a été initiée par le Laboratoire de recherche des monuments historiques (LRMH) afin de déterminer la composition des verres et identifier les différences significatives entre les verres d'origine et de restauration, différences invisibles à l'œil nu. Ces analyses ont été faites in situ par spectrométrie de fluorescence X portable sur 24 panneaux et sur un verre ancien utilisé comme référence. Elles ont été couplées avec des mesures d'épaisseurs afin de déterminer la proportion de verres soufflés et de verres coulés. Ces premiers résultats ont permis de discriminer plusieurs groupes de glaces en fonction de leur période de fabrication : les verres d'origine datés de la fin du XVII^e-début du XVIII^e siècle, des verres du XIX^e siècle et des verres du XX^e siècle. Une campagne d'analyse systématique des glaces a donc été lancée pendant la restauration afin de cartographier les glaces de la chapelle royale. En raison des contraintes de chantier, il s'est avéré essentiel de réaliser cette cartographie en amont de la dépose afin d'identifier les glaces d'origine, et favoriser ainsi leur dépose et donc leur conservation.

1. Introduction

Construite entre 1700 et 1710, la chapelle royale du château de Versailles comporte sur ces trois niveaux de baies, 24 grandes baies entre l'attique (niveau haut) et la tribune (niveau intermédiaire) et un peu plus de 10 baies en rez-de-jardin (fig. 1). Elles sont composées de verres incolores, appelés glaces, entourées de bordures en verre mis en plomb. La serrurerie métallique très ornementée est constituée de parcloes vissées. Lors de la commande des verres pour la chapelle royale, comme pour

celle de la grande galerie (galerie des glaces), Louis XIV exige l'emploi de glaces : des plaques de verre incolore de grandes dimensions et plus épaisses que le verre à vitre¹. À cette époque, leur fabrication par coulage et polissage est une technique innovante, attestant d'un savoir-faire d'excellence^{2,3}. En parallèle, la technique traditionnelle du verre soufflé est également à son apogée. Après le XVIII^e siècle, au cours d'interventions d'entretien ou de restauration, les verres cassés seront remplacés. Malgré une documentation détaillée, aucun relevé précis indiquant ces changements n'a été réalisé. L'observation visuelle ne permet pas de différencier les verres. Le projet actuel de restauration de l'ensemble des verrières, débuté en 2017, a bénéficié d'une étude du Laboratoire de recherche des monuments historiques (LRMH) pour identifier les verres d'origine des verres de restauration à l'aide de la spectrométrie de fluorescence X portable⁴.



Fig. 1. Vue intérieure des vitraux de la chapelle royale de Versailles avant la restauration. Chaque verrière est composée de grandes glaces incolores et d'une bordure de panneau en verre mis en plomb.
© Claudine Loisel, 2015.

2. Projet de restauration et mise en place des analyses in situ

Le projet de restauration des verrières de la chapelle royale de Versailles a été engagé par la Direction régionale des Affaires culturelles d'Île-de-France. Les travaux ont été dirigés par l'architecte en chef des monuments historiques Frédéric Didier, en charge du monument. En 2015, l'étude préalable des vitraux a été confiée à Isabelle Baudoin, restauratrice qualifiée, en collaboration avec le LRMH. De 2017 à 2020, le projet de restauration a été attribué à l'atelier Vitrail France dirigé par Emmanuel Putanier et aux ateliers Saint-Jacques pour la partie serrurerie. Dans le cadre de ce chantier d'exception, des précautions pour la mise en sécurité des personnes ont été mise en place. En effet, la présence d'amiante identifié dans les mastics de restauration du XX^e siècle et de minium (peinture au plomb) sur la serrurerie ont entraîné le conditionnement des espaces de travail pour la sécurité des hommes et de l'environnement.

¹ MARAL 2011, p. 389.

² HAMON 2005.

³ VELDE 2013, p. 563-572.

⁴ LOISEL et al. 2015 p. 42.

Les analyses par spectrométrie de fluorescence X portable ont été réalisées in situ en face interne et/ou en face externe avant les opérations de dépose (fig. 2). Les relevés des baies ont été fournis aux restaurateurs avant la dépose afin de les aider à repérer les niveaux de difficultés.

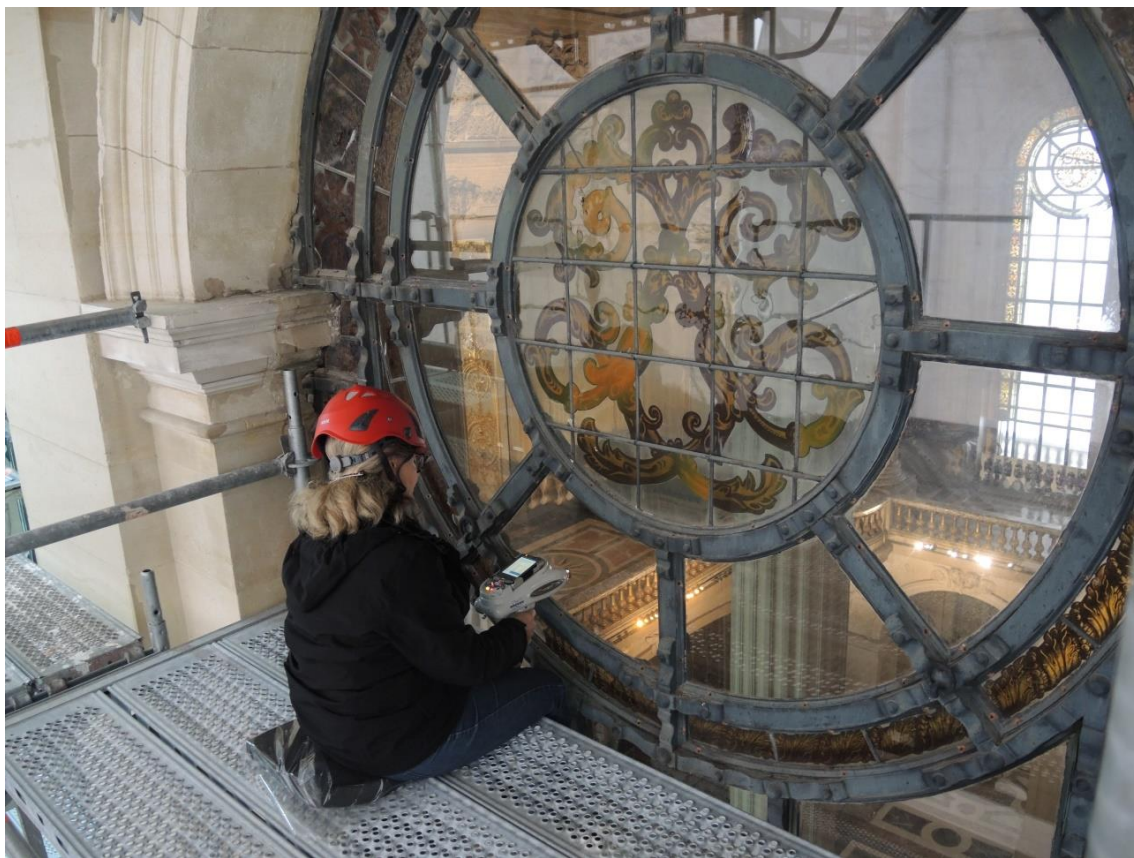


Fig. 2. Analyses par spectrométrie de fluorescence X (Tracer III-SD Bruker) réalisées sur la face externe des glaces constituant les verrières. © Barbara Trichereau, 2019.

3. Techniques analytiques

Les analyses scientifiques choisies pour cette étude sont la spectrométrie de fluorescence X portable et les mesures d'épaisseurs des verres. Ces deux techniques présentent l'avantage d'être non invasives et non destructives et peuvent être utilisées *in situ*. Chaque verre a fait l'objet de trois analyses chimiques et trois mesures d'épaisseur pour s'assurer de la validité des résultats.

3.1 Spectrométrie de fluorescence X portable

La spectrométrie de fluorescence X portable permet d'obtenir une composition chimique élémentaire des matériaux. Les analyses ont été réalisées au contact des vitraux de la chapelle Royale de Versailles avec le modèle Tracer III-SD (Bruker) (fig. 2) dont la source est un tube de Rhodium (Rh). La surface analysée est d'environ 10mm². Cet appareil permet de détecter les éléments chimiques à partir de l'aluminium dans le tableau périodique. Le temps d'analyse est de 2 minutes à deux voltages différents : 15 KeV/55 µA pour l'excitation des éléments légers (Al à Fe) et 40 KeV/36 µA pour l'excitation des éléments plus lourds (Co et au-delà). Afin de s'assurer de la stabilité du faisceau, un échantillon de verre standard (NIST 620) est analysé avant chaque série de mesure.

3.2 Mesures d'épaisseur de verre

Les mesures d'épaisseur de verre ont été réalisées à l'aide d'un appareil ultrason 45MG (Olympus) avec une sonde piézo-électrique mono-élément avec ligne de retard adaptée pour la gamme d'épaisseur des verres (<http://www.olympus-ims.com/en/45mg/>). La vitesse de propagation des ondes dans la matière est fonction de la densité et de la composition du matériau traversé. Une calibration sur un verre d'épaisseur connue a été préétablie. L'eau est utilisée comme couplant pour permettre le passage des ultrasons.

4. Résultats

Le mode opératoire mis en place dans le cadre de l'étude préalable a pu être déployé sur l'ensemble des verrières. Afin d'avoir une référence chimique, des analyses ont tout d'abord été réalisées sur un verre présentant des gravures anciennes et donc fabriqué avant 1720. La composition chimique élémentaire des verres, associée à leur épaisseur, a permis de différencier les verres d'origine des verres de restauration, aucune différence n'étant visible à l'œil nu.

4.1 Verres des XVII^e et XVIII^e siècles (verres d'origine)

Les verres des XVII^e et XVIII^e siècles sont des verres riches en potassium et en calcium. Ces verres sont également composés de fer, de manganèse, et d'éléments traces tels que le brome, le strontium ou encore le rubidium. Quatre sous-groupes peuvent être envisagés en fonction des compositions en manganèse, brome et plomb :

- Verres avec brome, manganèse et plomb ;
- Verres avec brome, manganèse, sans plomb ;
- Verres avec brome, sans manganèse ni plomb ;
- Verres sans brome, sans manganèse ni plomb.

Pour ce dernier sous-groupe, une présence importante de rubidium a été détectée contrairement aux autres sous-groupes.

Tous ces verres étant d'origine, il est primordial de tout mettre en œuvre pour pouvoir les conserver *in situ*. Par ailleurs, des graffitis avec dates et signatures ont pu être observés sur plusieurs panneaux. Ces témoignages précieux racontent l'histoire du monument.

4.2 Verres du XIX^e siècle

Ces verres présentent une très grande qualité de fabrication ; il s'agit de verres composés de calcium, de fer et d'arsenic avec parfois quelques traces de plomb. L'absence de potassium renforce l'hypothèse d'un verre du XIX^e siècle. La présence d'arsenic dans la composition des verres n'étant pas courante, il a pu être utilisé pour le polissage⁵ et donc être présent à l'état de trace en surface, malgré les nettoyages successifs. La composition de ces verres est très proche de celle obtenue par Dungworth sur des verres incolores du XIX^e en Angleterre⁶.

4.3 Verres du XX^e siècle

Il existe plusieurs compositions de verres du XX^e siècle : trois sous-groupes peuvent être identifiés. Le premier comporte les verres feuilletés, constitués de deux verres assemblés à l'aide d'une résine, l'un est composé majoritairement de zinc avec du calcium, du potassium et du baryum ; l'autre présente une composition majoritaire en calcium. Le deuxième sous-groupe est constitué des verres composés de calcium et non feuilletés. Leur composition est très homogène et ils ont pu être identifiés comme des verres du XX^e siècle car cette composition est identique à celle d'un des deux verres du verre feuilleté. Le troisième sous-groupe est celui des verres coulés sur bain d'étain. Ils sont composés majoritairement de calcium avec des traces de fer et d'étain.

4.4 Épaisseur des verres

L'épaisseur des verres est un paramètre important. Le croisement des données conduit aux résultats suivants : les verres de faible épaisseur, inférieure à 3mm, et contenant du potassium sont des verres anciens soufflés ; les verres ayant une épaisseur supérieure à 4-5mm et contenant du potassium sont des verres coulés d'origine. Enfin, les verres sans potassium sont des verres de restauration, soufflés si l'épaisseur est inférieure à 4mm et coulés si supérieure à 5mm.

5. Conclusions

L'utilisation de la spectrométrie de fluorescence X portable a permis d'identifier les verres d'origine de la chapelle royale de Versailles. Les résultats ont également mis en évidence des interventions aux XIX^e et XX^e siècles avec des changements de glace. Les verres montrent des compositions chimiques élémentaires différentes suivant les époques : des verres riches en potassium et en calcium (produits aux XVII^e

⁵ LOISEL et al. 2015, p. 42.

⁶ DUNGWORTH 2012, p. 7-25.

et XVIII^e siècles) et des verres riches en calcium sans potassium (produits au cours des XIX^e et XX^e siècles). L'utilisation couplée de la spectrométrie de fluorescence X et des mesures d'épaisseurs des verres a permis d'élaborer des relevés essentiels pour programmer et faciliter la dépose des panneaux. Elle a aussi permis d'approfondir la connaissance technique et historique de ces verrières en identifiant des interventions d'entretien et de restauration depuis 1710. Toute la documentation autour de la restauration du XXI^e siècle participe à la connaissance et la transmission de cet édifice majeur.

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FP. 2

Challenges with the Exhibition of Stained Glass: A Discussion among Researchers, Conservators, and Craftpersons

Virginia C. Raguin

Distinguished Professor of Humanities, Emeritus, College of the Holy Cross

Défis dans l'exposition du vitrail – un colloque entre chercheurs, conservateurs et artisans - Résumé

Dans le monde contemporain des musées, l'exposition de vitraux, en particulier de panneaux historiques, est remise en question par les tendances modernes. Les musées s'éloignent des galeries permanentes qui présentent des périodes historiques ; ils valorisent des espaces plus changeants, favorisant souvent les expositions thématiques juxtaposant les cultures et les médiums. Les exigences physiques de l'exposition du verre rendent ces œuvres beaucoup moins susceptibles d'être incluses dans un tel mélange. Il est peu probable que les professionnels des musées préconisent des dépenses supplémentaires pour un média qu'ils considèrent comme spécialisé. En outre, souvent des conservateurs ne sont pas familiers avec les approches conceptuelles exigées pour des fenêtres médiévales ou de la

Renaissance où la connaissance de la religion, le patronage et le cadre original devraient être évoqués. En effet, la forte présence de l'iconographie chrétienne dans le milieu du verre exacerbe encore sa marginalisation. Si nous facilitons la mécanique de cette exposition, nous pourrions peut-être atténuer cette situation. Avec l'aide des collègues, ce poster présente des schémas d'exposition temporaire et à long terme artificiellement conçu. Il met l'accent sur la disponibilité de panneaux LED pratiques et peu coûteux comme sources lumineuses et matériaux contemporains qui peuvent être utilisés efficacement. En outre, les critères d'exposition au niveau des musées peuvent être différents de ceux d'une église qui souhaiterait afficher des fenêtres historiques à partir d'un site maintenant détruit ou inaccessible. Pour les puissants et les impuissants, aidons à allumer la lumière !

Challenges with the Exhibition of Stained Glass: A Discussion among Researchers, Conservators, and Craftpersons – Abstract

The exhibition of stained glass in museums and even in some areas of functioning buildings is dependent on ensuring its visibility. This poster strives to encourage cooperation especially among members of the Corpus Vitrearum and members of the Forum who have been involved with display of windows in venues other than their original positions. The hope is to encourage us to be proactive and to realize that our colleagues in museums and preservation agencies are unfamiliar with the medium of stained glass. Invariably when people are confronted with new experiences, especially if they are in positions of

authority, they avoid them. We need to seize the opportunity that has opened up with access to light sources that do not bring heat; the LED has liberated possibilities of display. If there were some approved models in circulation, possibly even through a website, institutions may learn that stained glass could be exhibited without prohibitive expenses. Glass from an abandoned church might be incorporated in the entrance way of another building. Paintings, drawings and windows may be brought together in the same exhibit. Experience has shown that viewers are invariably fascinated by the medium and not at all intimidated by unfamiliar, or religious, subject matter. This poster has been developed with cooperative colleagues, for whom I am most grateful.

Fear and Neglect

The exhibition of stained glass in museums and even in some areas of functioning buildings is dependent on ensuring its visibility. In the contemporary world of museums, displaying stained glass, especially historic panels, is challenged by trends in exhibition philosophy. Museums are moving away from permanent galleries that profile historic periods to more changeable spaces, often favoring thematic displays juxtaposing cultures and mediums. The physical demands of exhibiting glass make it far less likely to be included in such a mix. Museum professionals are unlikely to advocate additional expense for a medium which they see as specialized. Most curators possess expertise in the areas of the decorative arts – furniture, silver, or porcelain. This makes them unfamiliar with the approaches demanded for the display of medieval or Renaissance windows where knowledge of religion, patronage, and original setting should be evoked. In addition, we are witnessing increasing criticism of the period and material we study as “Euro-centric” and not in line with the present need to understand global cultures. Indeed, the strong presence of Christian iconography in the medium of glass further exacerbates its marginalization. We are faced with professionals and a public who are untrained, and a political climate that sees Christianity as both a dominant culture and unchanging. Thus, the fascinating display of different approaches to affective piety, theological discourse, and political and social self-identity is less and less before the public. This poster presents schemes of temporary and long-term

artificially designed display. It will focus on the availability of practical and low-cost LED panels as light sources and contemporary materials. Museum-level criteria may not be necessary for a church which would wish to display historic windows from a now destroyed or inaccessible site. For the powerful and the powerless, let us help to turn on the light!

Several missed opportunities

I have been working over many years, benefiting from the expertise of Corpus Vitrearum colleagues, to catalogue the collections of windows in the J. Paul Getty Museum and the Los Angeles County Museum of Art. Two recent exhibitions at the Getty Museum should have showcased stained glass brilliantly. In November 2019, *Balthazar: A Black African King in Medieval and Renaissance Art* focused on the *Adoration of the Magi* in manuscripts and paintings including the Getty's Book of Hours from Provence, France, about 1480–90; Georges Trubert. Studio of Jean Bourdichon, Andrea Mantegna, painting, Italy, about 1495–1505, Ottonian manuscript from Regensburg, Germany, about 1030–40, Rubens study for the head of Balthazar about 1609–11. Stained glass in the Los Angeles County Museum of Art could easily have been included. An *Adoration of the Magi* from the canton of Glarus, Switzerland, dated 1612 – complete with an inscription establishing that it was given by Caspar Gallaty Knight; His Royal Majesty of France and Navarre appointed [him] Field Colonel 1612) Switzerland, canton of Glarus. Small, only 35.6 × 22.9cm (14 × 9in.), a light box with the panel could have been a striking complement to the small-scale manuscripts. The panel was part of the William Randolph Hearst Collection (45.21.35).

The second exhibition was of drawings: *Marks of Collaboration: Drawings in Context* February 5–April 14, 2019 at the Getty Center. *Ecce Homo*, the King Caspar, the Virgin and Child and the Arms of the Families Kündig and Pfyster. Murer's drawing is part of a large and important series of stained glass donors' windows designed for the cloister of the Cistercian abbey of Rathausen (canton Lucerne). Sixty-seven panels were fabricated before 1611 by Franz Fallenter, after the designs of Daniel Lindtmayer, Hans Heinrich Wagman, and Christoph Murer, among others. The window after the drawing is preserved in Schloss Heidegg, Switzerland and bears initials of Fallenter and date (FF 1593). The Los Angeles County Museum of Art owns four well-preserved panels from Rathausen, including a stunning *Adoration of the Magi*, with the same signature (FF). None were included in the exhibit. As stained glass, it presented too foreign a material and a challenge to engage in the mechanics of installation. Alas, a moment of reunion that, from our standpoint as historians of glass, should have been an essential element, was thwarted.

Collegial Communications

Linda Canon of Glasgow reports a number of installations of stained glass in museum settings: <https://lindacannonstainedglass.com/museum-work/>. In 2019 she couriered, and helped to install, seven Pre-Raphaelite works of art (tapestry, stained glass, prints, drawings and a painting) from the Whitworth Art Gallery in Manchester to the Mitsubishi Museum in Tokyo. She reports that the exhibition was a three month and three venue traveling exhibition, and her "very simple display method worked a treat, despite some very dodgy wood composite materials being provided. The trick is to maximize the ventilation top and bottom within the case to a) to get rid of acetic acid fumes and b) to get rid of any heat buildup" (fig. 1). She states "In my experience, as long as you follow these two rules, everything is fine. The Tokyo exhibition box could not have been made any simpler nor cheaper. If you give the problem to specialist museum designers, you can pay mega-bucks for something which looks no better and may well not work."

Her last comment is something that I believe can find resonance with many Forum and Corpus members. In museums the exhibition designer can be very territorial about seeking help from professionals with long-standing experience outside the museum. Even more, site of worship are hard pressed to funding or expertise and are often intimidated by what they see and "becoming a museum." The need to be encouraged to display historic treasure through the simplest, but also safest means possible.

Léonie Seliger, of Canterbury reports on long experience of installing windows outside of their architectural settings. She also commented on her admiration for the Vitromusée Romont in Switzerland. It uses 360-degree accessible displays, even some panels hanging at eye level suspended on chains in the middle of their display spaces, with no safety barriers at all. We agree that it is marvelous that in Switzerland people can be trusted not to abuse that trust!

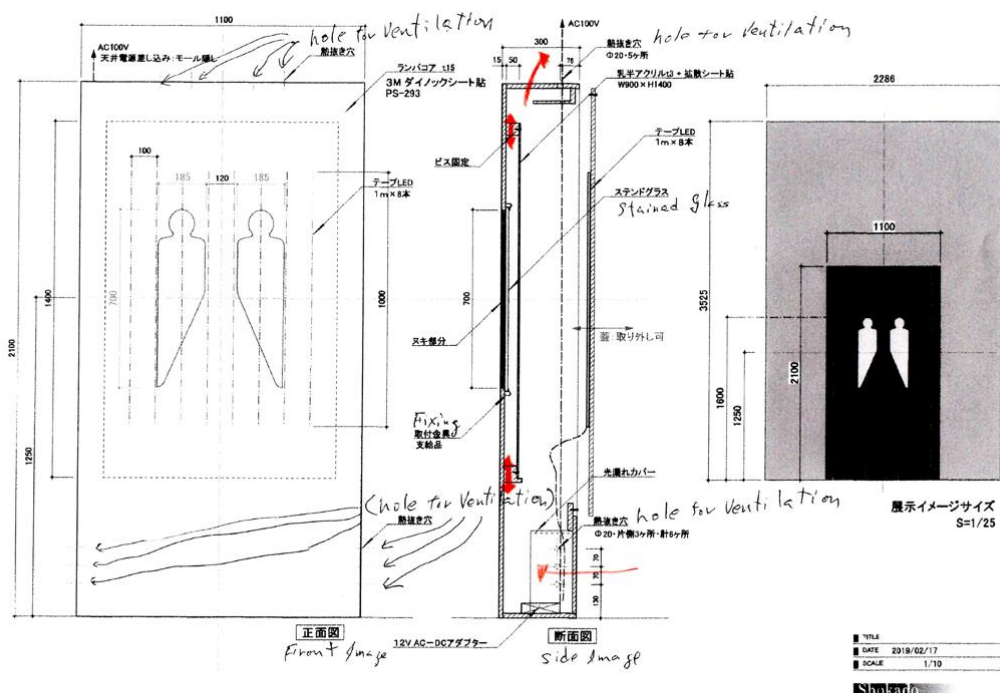


Fig. 1. Diagram of light box for Pre-Raphaelite stained glass, Mitsubishi Museum in Tokyo, 2019.
Courtesy of Linda Canon.

Lighting: “All of displays at Canterbury used LED light panels with low heat development which was easily controlled via hidden ventilation slots. In addition, Canterbury still uses many of the LED light panels in its working light benches in the conservation studio. The modern ones have a very good life span. The color is not daylight, but slightly warmer than daylight. Canterbury found that daylight LEDs actually look too cold.”

Safety: “The Crypt display had to have laminate safety glass in front of the stained glass to prevent people touching. The Crypt is a large space with many side chapels and pillars, so although cathedral volunteers are always somewhere in that space, they did not necessarily always have a direct sight line of the displays. We had to clean the safety glass at least once a week; a lot of people did not realize it was there due to the low ambient light, and tried to touch the stained glass.”

Popular reception: “The free-standing single panel display was part of The Ancestors, a legacy of the *Radiant Light* exhibition at the Metropolitan Museum in New York (fig. 2). They very kindly donated to us their display case for our panel after their exhibition finished. The original inspiration came from a display I had seen about forty years ago in Frankfurt, which kick-started my fascination with medieval stained glass, and I am glad to report that it had the same effect on others: the freestanding panel was one of the most popular displays at the Getty, the Metropolitan, and again in Canterbury, with people spending on average significantly longer looking at it than they did looking at the displays that could only be seen from one side. The Ancestors were displayed without safety glazing, as the exhibition was always closely invigilated, and we installed discreet railings (not yet in place on the images) to prevent people from mounting the plinth of the exhibition tower. The high levels of ambient light in the Chapterhouse would have created very large reflections on safety glazing.”

Others are in communication, including Kathy Jordan, at Willet Hauser, and President of the American Glass Guild 2020-21, who communicated her enthusiasm for seeing more glass displayed in sites other than architectural openings. Janet Lipstreu, General Operations Director, Whitney Stained Glass Studio, Inc., Cleveland has reinstalled Tiffany windows in new setting through the use of LED sheets. The shift from incandescent bulbs to LED made a significant difference on viewing a large Wisteria window and an Apple Blossom laylight in the Nemacolin Resort, Farmington Pennsylvania. Like others she recommends a rheostat for intensity and the ability to move from warm or cool light. Don Samick, of Lamb Studios, Midland Park, New Jersey has also been involved in the new ways to install and illuminate.

Virginia C. Raguin USA, in cooperation with International Corpus Vitrearum colleagues.



Fig. 2. The Ancestors, free-standing display of Canterbury windows, developed by the Metropolitan Museum of Art for the exhibition Radiant Light, 2014-2015. Reproduced courtesy of the Chapter, Canterbury Cathedral.



FP. 3

La conservation préventive des vitraux : la verrière de protection

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Preventive Conservation of Stained Glass: Protective Glazing – Abstract

In order to protect stained-glass windows there is an efficient and lasting method of preservation: external protective glazing. This new glazing which is placed in the bay opening becomes a new hermetic closure for the building.

The stained-glass window takes place inside the building, a few centimeters away from the external protective glazing. This apparatus protects the stained-glass window, on both sides, from condensation, meteorological conditions, air pollution and vandalism.

The conclusions of the European project VIDRIO N°EVK4-CT-2001-45 (2002-2005) validated the efficiency of the system.

The first French protective glazing was implemented in 1979 in the Sainte-Jeanne-d'Arc church in Rouen. They are now systematically installed in every major building.

Multiple execution parameters must be taken into consideration in order to propose the most suitable protective glazing. Those parameters can be divided into two categories. The first ones are those which are fundamental for a good operation of the system: a ventilation from the inside of the building, a space in between the two glasses larger than 3.5cm, a condensation water evacuation pipe and an adjustment

to the architecture. The second ones are the aesthetically pleasing parameters: style of protective glazing, type of positioning, filling of lateral daylight. Although the first ones are unchangeable, many options exist for the second ones.

There are three main styles of protective glazing: white glass used in panels (laminated or not), stained white glass imitating the patterns of the stained-glass window and thermoformed glass (laminated or not), also imitating the stained-glass window.

The choice of the style is purely aesthetically pleasing.

There are two preferred types of positioning: either the stained-glass window is slightly moved inside the building and the protective glazing sits in its initial place, or the stained-glass window stays in its initial rabbet and the protective glazing is slightly moved towards the outside of the bay.

This choice depends on the constraints which are imposed by the building architecture.

In 2018, a project called ReViVe (Recensement des Vitraux avec Verrières de protection – Inventory of stained-glass windows with external protective glazing) was initiated by the LRMH. The purpose of this project is to produce an inventory and a documentary study of external protective glazings in order to create inventory tools (an interactive map and an inventory form).

La conservation préventive des vitraux : la verrière de protection – Résumé

Dans le domaine du vitrail, il existe un procédé de conservation préventive efficace et durable : la verrière de protection. Cette nouvelle verrière positionnée dans l'ouverture de la baie devient la clôture étanche de l'édifice. Le vitrail ancien est installé à quelques centimètres de la verrière de protection à l'intérieur de l'édifice. Ce dispositif permet de protéger le vitrail ancien, sur ses deux faces, de la condensation, des phénomènes météorologiques, des polluants atmosphériques et du vandalisme. Le projet européen VIDRIO (2002-2005) a permis de valider l'efficacité de ce système. En France, la première verrière de protection a été mise en place en 1979 à l'église Sainte-Jeanne d'Arc de Rouen. Elles sont aujourd'hui systématiquement installées sur les édifices majeurs. Différents paramètres de mise en œuvre doivent être étudiés pour proposer la verrière la plus performante. Ils peuvent être classés en deux catégories : les paramètres essentiels au bon fonctionnement du dispositif (ventilation par l'intérieur de l'édifice, espace inter-verrières supérieur à 3,5cm, présence d'un conduit d'évacuation

des eaux de condensation, adaptation à l'architecture) et les paramètres esthétiques (modèle de verrières, type de positionnement, comblement des ajours latéraux). Si les premiers sont immuables, il existe différentes options pour les seconds. Ainsi, trois principaux modèles de verrières sont possibles : le verre blanc ou incolore (feuilleté ou non), le verre blanc mis en plomb et le verre thermoformé (feuilleté ou non). Le choix du modèle est purement esthétique. Quant aux types de positionnement, il en existe deux : soit le vitrail est avancé vers l'intérieur de l'édifice et la verrière de protection est dans la feuillure originelle du vitrail soit le vitrail reste dans sa feuillure originelle et la verrière de protection est avancée vers l'extérieur de la baie. Ce choix répond le plus souvent aux contraintes du bâtiment. En 2018, le projet « Recensement des Vitraux avec Verrières de protection » (ReViVe), a été initié par le LRMH. Ce projet a pour but de réaliser un recensement et une étude documentaire des verrières de protection ainsi que de créer des outils de recensement (carte interactive et fiche de recensement) et de conseil à la mise en œuvre.

1. Historique

Alors qu'en Allemagne et au Royaume-Uni, les verrières de protection sont déjà utilisées depuis le milieu du XIX^e siècle (sur les cathédrales d'York et de Cologne), elles commencent à être utilisées en France à partir des années 1980, au moment où des chantiers utilisant des films organiques de polymère pour protéger les vitraux sont encore en cours. Les premières verrières de protection de France, posées sur l'église Sainte-Jeanne-d'Arc de Rouen, datent de 1979. Quant à la première cathédrale à bénéficier de tels dispositifs, il s'agit de celle de Coutances, en 1982.

Un article rédigé par Isabelle Pallot-Frossard, intitulé « Petite histoire des verrières de protection ou comment le vitrail échappe à la clotûre »¹ et paru dans *Monumental* en 2004, résume la naissance de ces verrières et l'utilisation progressive qui en est faite en Europe depuis le XIX^e siècle.

2. Principe de fonctionnement

Le principe de fonctionnement d'une verrière de protection est relativement simple. L'objectif principal est de diminuer très fortement l'altération des verres et des plombs. Il s'agit d'isoler la verrière en lui ajoutant une verrière supplémentaire à l'extérieur. Elle permet en effet de créer une circulation d'air ou ventilation naturelle autour du vitrail. L'air étant à la même température des deux côtés du vitrail, le phénomène de condensation est supprimé. La verrière de protection permet donc de supprimer l'apport en eau sur la face externe et d'empêcher la condensation de se former sur la face intérieure du vitrail où se trouvent principalement les peintures (grisailles, émaux, peintures à froid).

Les objectifs principaux² des verrières de protection sont de :

- protéger la face externe du vitrail des agressions de l'environnement : polluants atmosphériques et phénomènes météorologiques (pluie, vent, grêle, etc.) ;
- protéger les vitraux des chocs extérieurs ;
- supprimer le phénomène de condensation en face interne ;
- limiter les variations thermiques responsables de la dégradation des peintures et des verres

La mise en place d'un dispositif préventif permet également un gain financier sur le long terme en limitant les futures opérations de restauration sur l'œuvre.

L'efficacité de ces verrières a été prouvée grâce au projet européen VIDRIO qui s'est déroulé de 2002 à 2005.³ Le but de cette recherche était de déterminer les conditions optimales de fonctionnement des verrières de protection des vitraux et d'évaluer leur efficacité *in situ*. Ce projet a montré l'efficacité et la durabilité de ce système de conservation préventive.

3. Paramètres de mise en œuvre

Il est difficile de parler de typologie de verrières car il existe une multitude de paramètres qu'il est possible de combiner. En effet, chaque verrière de protection doit s'adapter à la baie qui la reçoit et c'est le respect de l'architecture qui doit primer. Il convient donc de créer la verrière la plus adaptée pour chaque baie, en définissant de manière optimale les paramètres de positionnement.

Certains paramètres sont immuables dans l'optique d'un fonctionnement optimal du dispositif, notamment la ventilation du vitrail par l'air intérieur de l'édifice, un espace inter-verrière d'au moins 3,5cm, l'adaptation à l'architecture, l'étanchéité de la verrière et la présence d'un conduit d'évacuation des eaux de condensation sur la verrière de protection.

La préservation de la serrurerie ancienne s'avère également cruciale. Dans le cas où le vitrail ancien reste à sa place d'origine sur la serrurerie ancienne, elle est optimale.

D'autres paramètres comme le modèle de verrières, le type de positionnement, le comblement des jours latéraux, répondent à des impératifs purement esthétiques et n'influencent pas sur le bon fonctionnement du système.

¹ PALLOT-FROSSARD 2004, p 90-100. Consultable sur <http://www.lrmh.fr>.

² PALLOT-FROSSARD 2006, p. 80. Consultable sur <http://www.culture.gouv.fr/culture/min/index-min.htm>.

³ ETCHEVERRY 2004, p. 100.

3.1. Différents modèles de verrières

Le dispositif peut prendre différents aspects esthétiques suivant le modèle de verrières choisi. Il existe trois modèles principaux : le verre blanc mis en plomb, avec la même technique et à l'image du vitrail, le verre thermoformé (feuilleté ou non), réplique parfaite de l'aspect extérieur du vitrail et le verre blanc ou incolore posé en grandes plaques (feuilleté ou non).

Le verre blanc mis en plomb se veut comme un vitrail transparent. Le panneau de protection reproduit le réseau de plomb du vitrail qu'il protège. Composé de verre soufflé blanc de quelques millimètres d'épaisseur pouvant être patiné ou recuit pour atténuer la brillance des verres et inséré dans un réseau de plomb, il a l'avantage, en plus de protéger, de proposer un aspect esthétique intéressant en imitant le vitrail.

Le verre thermoformé est une technique mise au point et brevetée par Hervé Debitus, Atelier Debitus à Tours.⁴ Le procédé consiste à transférer l'empreinte de la face externe des panneaux sur un verre moderne (« float glass ») résistant *via* la technique du thermoformage. Ce verre a pu être plus ou moins patiné pour redonner les nuances de la coloration des verres et dessiner le réseau de plomb pour guider la lecture.

En 2005, dans le cadre de la restauration des vitraux de la cathédrale de Strasbourg, un prototype comprenant ces deux modèles de verrières de protection a permis de comparer leur effet esthétique *in situ* et de décider à échelle réelle (fig. 1). La verrière de protection en verre mis en plomb sera sélectionnée.



Fig. 1. Strasbourg, cathédrale Notre-Dame, prototype des verrières de protection, à gauche en verre mis en plomb et à droite en verre thermoformé. © LRMH, Claudine Loisel, 2005.

Quant au verre blanc ou incolore, il s'agit d'une simple vitre. S'il assure une protection mécanique contre le vent et les eaux de ruissellement, il présente néanmoins une certaine brillance. Cette brillance peut toutefois être atténuée par des patines ou des recuissons et progressivement par l'empoussièrement et l'usure du temps. Les verres blancs / incolores sont généralement feuilletés pour éviter les

⁴ Brevets INPI : de base N°9403918, et de perfectionnement N°1351107.

chutes de verre en cas de casse, dans un établissement qui reçoit du public. Dans le projet de restauration des vitraux du charnier de l'église Saint-Étienne-du-Mont, le choix s'est porté sur ce type de verrière en verre incolore ultra clair, feuilleté (fig. 2).



Fig. 2. Paris, église Saint-Étienne-du-Mont, vitraux du charnier, à gauche avec verrière de protection en verre incolore feuilleté, à droite avec grillage et sans verrière de protection.
© Manufacture Vincent-Petit, 2019.

3.2 Différents types de positionnement

Le vitrail peut être positionné de deux façons différentes : soit il est déplacé vers l'intérieur de l'édifice et la verrière de protection est installée à l'emplacement originel du vitrail, soit il reste à sa place et la verrière est déplacée vers l'extérieur. Le choix du type de positionnement est fait en tenant compte de l'épaisseur des meneaux et la configuration d'éventuels chapiteaux.⁵ Il prend également en compte l'état de conservation de la serrurerie originelle.

Si la verrière de protection se positionne à la place du vitrail ancien, l'étanchéité est maximale. Dans le cas où le vitrail resta à sa place, la verrière de protection est reculée et son étanchéité doit être renforcée au niveau du calfeutrement.

4. ReViVe : projet de recensement des verrières de protection

Suite à la demande d'architectes, de conservateurs et de restaurateurs, le Laboratoire de recherche des monuments historiques (LRMH) a lancé un projet pour réaliser une étude documentaire sur la pose de verrières de protection en France et mettre au point des outils de recensement et de conseil pour leur mise en œuvre⁶.

Intitulé ReViVe (Recensement des Vitraux avec Verrières de protection), ce projet a pour but de :

- recenser l'ensemble des verrières de protection posées sur les monuments historiques de France ;
- renforcer le conseil aux professionnels sur les paramètres de mise en œuvre ;
- réaliser des outils de recensement utilisables par tous les acteurs de la chaîne opératoire du patrimoine.

⁵ C'est le cas à la cathédrale Notre-Dame de Strasbourg où les chapiteaux sculptés de motifs végétaux sont débordants.

⁶ RELIER 2018.

Ce projet a pour l'instant permis de créer une carte (fig. 3) regroupant deux-cent quatorze édifices protégés dont les vitraux pourront être transmis dans toute leur intégrité aux générations futures. Il a également permis la création de fiches techniques interactives pour chaque pose de verrière de protection. C'est la première étape vers la possibilité d'un recensement participatif. L'ambition du LRMH, *via* ReViVe, est aussi d'exprimer l'importance d'une valorisation internationale de ce procédé de conservation préventive qui permet à tous les acteurs concernés d'apporter leur pierre à l'édifice de la sauvegarde du patrimoine commun de l'humanité.

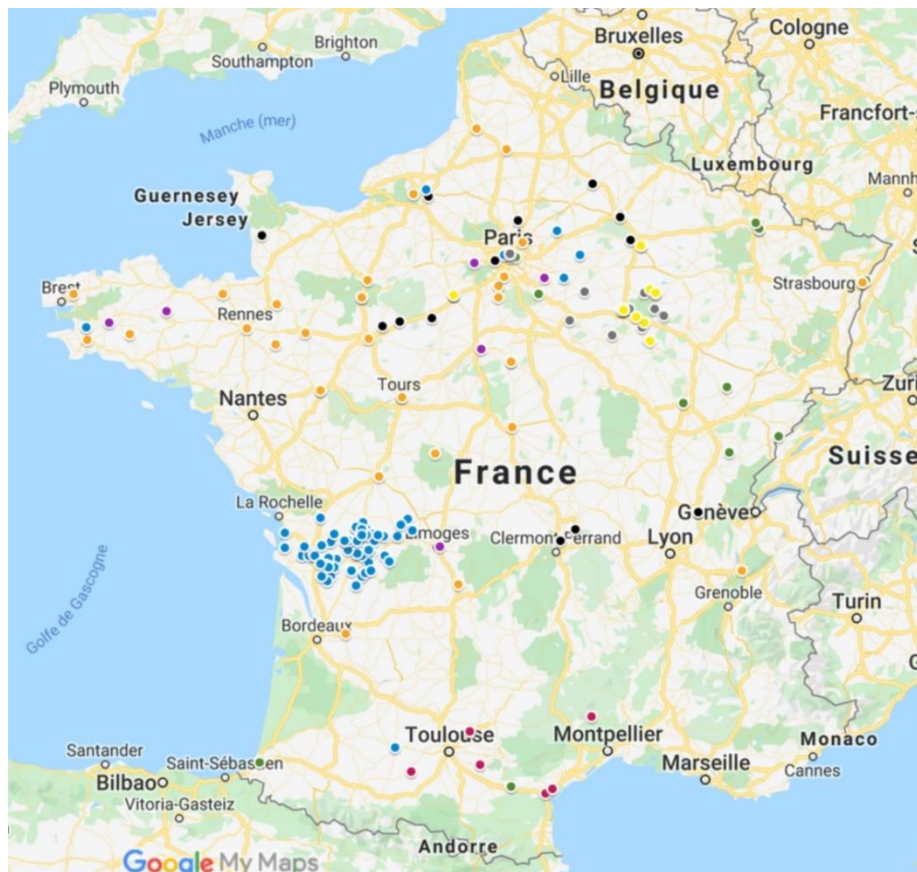


Fig. 3. Carte du recensement des vitraux de France avec verrière de protection, projet ReViVe, 2019.
Les couleurs correspondent aux différents ateliers qui ont fait les verrières de protection
© Adèle Rellier, 2019.

5. Conclusions

Les verrières de protection ont fait leur preuve. Efficaces et durables, elles sont essentielles pour préserver les vitraux comme l'ont démontré les études récentes sur la conservation préventive *in situ* des monuments historiques.

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FP. 4

Preserving Idols in Stained Glass: Conservation Assessment of Napier Waller's Stained-Glass Windows at the Australian War Memorial

Jacqueline Jordan

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Préserver les idoles dans le vitrail : évaluation de la conservation des vitraux de Napier Waller au Mémorial australien de la guerre – Résumé

Créées en 1947, la jeunesse relative des vitraux commémoratifs du 'Hall of Memory' du Mémorial australien de la guerre, à Canberra, signifie qu'ils sont physiquement stables pour le moment. Comprendre l'identité des vitraux est essentiel pour travailler à leur conservation future. Les éléments clefs ayant une signification particulière, comme le symbolisme esthétique et la fonction commémorative des vitraux, ont été identifiés et situés dans la nature physique des vitraux. Une analyse du cycle de vie des

matériaux complexes s'appuyant sur la littérature et les normes internationales a abouti à l'établissement des priorités pour la conservation des vitraux. La stratégie de conservation qui en résulte cherche à atténuer les risques et à fournir des opportunités pour améliorer la valeur des vitraux grâce à une gestion de la conservation appropriée et à une intervention sur le long terme. L'identité significative et complexe de ces vitraux, combinée au potentiel de croissance de l'expertise en conservation des vitraux en Australie, donne aujourd'hui à cette recherche une pertinence pour éclairer les stratégies de conservation dans les années à venir.

Preserving Idols in Stained Glass: Conservation Assessment of Napier Waller's Stained-Glass Windows at the Australian War Memorial – Abstract

Created in 1947, the relative youth of the commemorative windows in the Hall of Memory at the Australian War Memorial, Canberra, means they are physically stable for now. Understanding the identity of the stained-glass windows is vital for their future preservation. Key elements of significance of the stained glass, including aesthetic symbolism and commemorative function, were identified and located in the physical nature of the lights. A life-cycle

analysis of the complex materials with reference to international literature and standards culminated in establishing the priorities for conserving the windows. The resulting conservation strategy seeks to mitigate risks and provide opportunities to enhance the windows' value through appropriate conservation management and intervention in the long term. The windows' significant and complex identity combined with the potential for growth in stained glass conservation expertise in Australia give this research relevance today to inform conservation strategies in the coming years.

Introduction

The stained-glass windows built into three walls of the Hall of Memory (HoM) at the Australian War Memorial are unique and nationally significant artworks that require a specific conservation strategy. Commissioned by the Memorial Board in 1937, and championed by the Memorial's founders Colonel J.L. Treloar and C.E.W. Bean, the windows were created in collaboration with First World War (WWI) veteran and prominent artisan Mervyn 'Napier' Waller.¹ Fifteen lancets are each painted with a unique figure idolising the Australians who served in WWI. Meaning is imbued in each figure by the use of symbolic imagery, all crafted in an illuminating art-deco rectilinear design.

Due to the long lifecycle of the materials, the windows' condition have not been monitored regularly. However, in taking a long term view of their preservation, it was essential to determine the identifying traits to inform priorities for future conservation activities. Understanding significance embodied in materials, deterioration processes, and stained glass conservation practice were the core elements of this research.

This study investigated the integrity of material and non-material aspects significant to the value and longevity of the stained-glass windows using several sources of data. The approach was based on desk research, followed by examination of the windows, consultation with stakeholders, and a discussion of considerations to support the Memorial with informed decision-making.

¹ Jennifer WELLINGTON, *Exhibiting War: The Great War, Museums and Memory in Britain, Canada and Australia*, Cambridge University Press, Cambridge, 2017, p. 278.

Research Background

Several factors have constrained conservation attention for these windows. Firstly, historical condition and conservation documentation within the Memorial was sporadic and diffuse. Secondly, as artistic architectural decorations, stained-glass windows are awkwardly placed between the disciplines of heritage architecture and fine art. Thirdly, decision-making regarding stained glass conservation in Australia has been limited by the complexity of the material and its significance, and the lack of a national body of stained glass conservation guidelines.² These gaps in understanding formed the foundation for this research.

Creating the Windows

Waller was an academy-trained artist, who fought in the First Australian Imperial Force, and lost his dominant arm in the battle of Bullecourt, France during WWI. He went on to train in Victorian Arts and Crafts stained glass techniques at the Tower of Glass studio in Dublin, United Kingdom, and then mosaic craft in Italy in the late 1920s. He was engaged by the Australian War Memorial's founders to decorate the focal point of the building with commemorative artwork to evoke a sense of spiritual connection and tribute to those who served and died in WWI.

Waller designed the figures under the direction of the Memorial's board and founders. High-grade³ leads were used, along with Antique flashed glass sourced from Miller, Beal & Hider Ltd, in London as early as 1940.⁴ The panes were hand-painted by Waller in several layers with assistance from his wife Christian Waller, who was an independent stained glass artist, then assembled by a local glazier. The three lights are 5.2 by 7.4 meters each, and consist of approximately 9000 panes of glass (fig. 1).

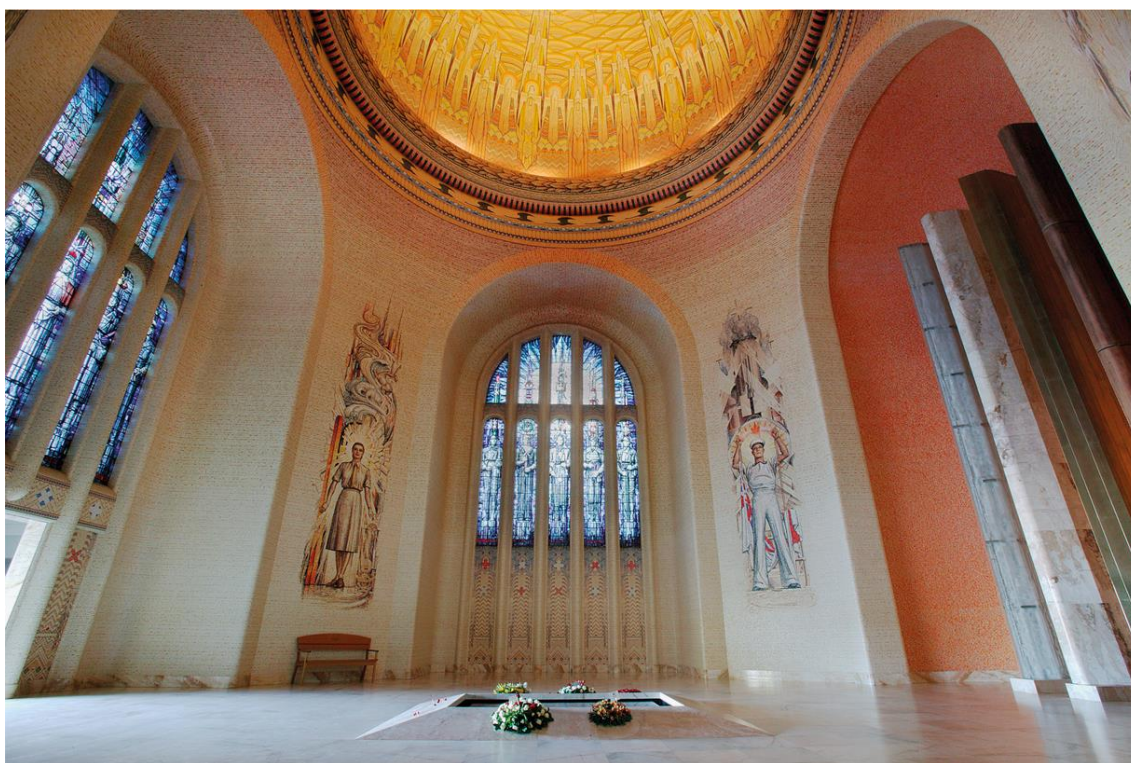


Fig. 1. Australian War Memorial, Hall of Memory stained-glass windows, west bay, interior. © AWM, 2011.

² Bronwyn HUGHES, *Stained Glass Conservation and Restoration Research and Workshop Practice in USA, Britain and France*, Bronwyn Hughes [unpublished], 1994.

³ XRF Analysis by J. Jordan and G. Bailey 2018 confirmed the composition is akin to modern "restoration grade" leads specified by The Stained Glass Association of America (SGAA), *Standards And Guidelines For The Preservation Of Historic Stained (And Leaded) Glass Windows*, The SGAA, Buffalo, NY, 2012.

⁴ The Australian War Memorial (AWM), *File Rn: 234/005/013: Purchase Of Glass For Stained-glass windows In The Hall Of Memory*, Australian War Memorial, 13/05/1939.

Significance of the Windows

The stained-glass windows embody the culmination of Napier Waller's and Australia's experience and mourning of the FWW. They are some of the largest memorial windows in Australia, being unique in their use of iconographic representation of common people serving in war.

The windows were created following the tradition of memorialization in stained glass. Waller's training links the artwork to the Arts and Crafts movement in the UK and Europe, and are extraordinarily executed in a characteristically art deco style. The artists' intent and cultural context have been preserved and continue to provide perspective into both the national consciousness of post-war Australia and current commemorative culture.

Dilemma and the Focus of Conservation

The original fabric holds undeniable significance, and should be preserved. However, the point of unacceptable damage must be defined to determine the point at which materials are repaired or reconstructed and to what degree. Ethical and theoretical approaches were explored to understand the tension between maintaining the functional requirements of the windows and traditional ideas of authenticity embodied in original fabric.

Two determinants of significance are considered vital here in considering replacement or restoration of original materials. Firstly, the significance of the stained-glass windows is not exclusively dependent



on the original fabric, but on the symbolic function as part of the HoM. This priority is inherent in the creator's intent and must be respected in establishing the ideal state.⁵ Secondly, as the architectural context is critical to the windows' significance, and failure of the building fabric has the potential to damage the stained glass, the windows will require relatively frequent and interventive conservation to maintain their significant attributes. As such, conservation must retain significance held within the painted image as embodiment of symbolic identity and physical stability as embodiment of functional identity. This will minimise the impact of deterioration of original fabric on deterioration of the windows integrity and authenticity of significance.

Lifecycle Analysis

To determine the primary risks to the preservation of the stained-glass windows, the deterioration mechanisms were identified and the lifecycle of each major component examined. This included review of both historical documentation and current condition assessment with materials analysis by the researcher and colleagues. Literary review included examination of the production techniques and materials of the Arts and Crafts tradition along with Waller's own methods (Memorial archives), followed by investigation of two historical condition reports.⁶

Fig. 2. Australian War Memorial, Hall of Memory stained-glass windows, west bay, exterior, Loyalty, showing iridescence on panels 3 to 5, taken by J.Jordan, 5 July 2018.

⁵ Barbara APPELBAUM, *Conservation Treatment Methodology*, Barbara Appelbaum, Lexington, Kentucky, 2010.

⁶ Sue BASSET, 'Stained-glass windows in the Hall of Memory', Condition Report in *Conservation of Stained-glass windows in Hall of Memory*, AWM file RN: 89/0435, 29/01/1989, Australian War Memorial [unpublished], 1989.

The current condition was assessed visually and instrumentally with climate monitoring and materials analysis (including X-ray Fluorescence and Fourier Transform Infrared). All activities were compiled and thoroughly documented for future reference including photographic overlays, supported by a discussion of the potential type and timeline of future points of failure.

Overall the windows are in a fair condition. The painted surface displays some fading (currently stable), minor iridescence (fig. 2), and several broken panes. Interestingly, the metallurgy of the leads has resulted in the solder joints failing preferentially (contrary to common deterioration of the leads around the joints).⁷

Conservation Needs

The defining elements of the artwork include the visual functions of artistic and symbolic depth, and the ceremonial function in the architectural context of the HoM, where Australia's Unknown Soldier is entombed. Hence, the windows must be retained in situ, and the risks of the architectural environment must be accepted and managed where possible. Risks to the loss of intangible significance hinges on the maintenance of education and ceremonial programs. Preservation is recommended through regular condition surveys to monitor ongoing changes, preventive maintenance to preserve existing materials, and conservation interventions to restore and reconstruct the painted image (judged from normal viewing distance) and stabilise of structural components.

Stakeholder interviews indicated an enthusiasm and commitment of Memorial staff to ensure all necessary preservation steps are taken. Interventions required over the next three years will include exterior cleaning, putty replenishment, glass and solder crack stabilisation. Monitoring programs will include putty condition monitoring, vibration monitoring for future major construction that is the Memorial Development Project (2020-2027), in addition to biennial condition surveying (for the first 5 years to assess deterioration rates), further deterioration product identification, and spot cleaning to minimise damage from pest activity.

Conclusions and further research

This study informs conservation management decision-making by discussing the identity of the stained-glass windows, their significance, the necessities of their architectural context, their physical lifecycle, and the opportunities and restraints of their management. The recommendations highlight the priorities for conservation, appropriate preventive monitoring and maintenance, and potential challenges for the future.

Future research is encouraged to further develop ethical theory of architectural artworks, and develop stained glass best practice for Australia. National resources and information are scarce and further exploration is required to develop an appropriate framework to preserve significant stained glass works such as these.

Authorship and Acknowledgements

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⁷ Rolfe ACHILLES & Neal VOGEL, 'The Preservation and Repair of Historic Stained and Leaded Glass', *33 Preservation Briefs*, Heritage Preservation Services, National Parks Service, U.S. Department of the Interior, 2007.

APPENDIX – APENDICE – ANHANG – APÈNDIX

Text en català de les Directrius per a la conservació i restauració de vitralls (Corpus Vitrearum/ICOMOS, Segona edició, Nuremberg 2004)

1. Introducció

1.1. L'objectiu de les presents directrius és el de definir els principis deontològics que regeixen la conservació i restauració de vitralls de totes les èpoques. Aquestes directrius són concebudes com a text de referència per als restauradors i per als experts en conservació, i serveixen també com a introducció i font d'informació per a particulars i organitzacions responsables de la conservació de vidrieres.

1.2. Les primeres directrius van ser redactades l'any 1989 pel Comitè Internacional del Corpus Vitrearum per a la conservació de vitralls, associat amb el comitè científic internacional de vitralls de l'ICOMOS. Les versions originals del present document han estat redactades en anglès, francès i alemany. Les traduccions en altres llengües han de ser realitzades pels respectius comitès nacionals del Corpus Vitrearum i aprovades pel Comitè Internacional per a la conservació. El Corpus Vitrearum és una organització acadèmica internacional que té per objectiu la recerca sobre vidrieres històriques i la publicació dels seus estudis. El Comitè de Conservació promou la conservació i la restauració de vitralls d'acord amb aquestes directrius, coordina les recerques i fomenta l'intercanvi professional.

1.3. Les directrius defineixen els principis específics de la conservació de vitralls i no repeteixen els principis generals que ja figuren en altres codis deontològics reconeguts a nivell internacional. En relació a aquests darrers, cal referir-se a la *Carta internacional sobre la conservació i la restauració de monuments i llocs* (Carta de Venècia, ICOMOS, 1964),¹ al document que té per títol *Le Conservateur-Restaurateur: une définition de la profession* (Comité de conservation de l'ICOM, grup de treball sobre la formació en conservació i restauració, Copenhaguen, 1984),² l'*ICOM Code of Professional Ethics* (ICOM, Buenos Aires, 1986),³ i les *Línies Directives sur l'éducation et la formation a la Conservation des Monuments, ensembles et sites* (ICOMOS, Colombo, 1993).⁴

1.4. En relació al present document, els mots «vidriera» i «vitrall» inclouen tant vitralls pintats o acolorits com vidrieres ornamentals de vidres incolors emplomats o posats en cinta de coure del tipus Tiffany, en formigó i altres menes de vitralls, tant els conservats *in situ* com els que hagin estat traslladats a un museu o a una col·lecció particular.

1.5. El valor intrínsec d'un vitrall és el mateix que té tota altra obra d'art o monument del patrimoni i, com a conseqüència, la seva conservació mereix el mateix nivell d'atenció i professionalitat, deixant de banda la seva antiguitat i valor al mercat. Un vitrall no pot ser considerat de forma aïllada; per tant, el seu context històric i material, que comprèn també la seva col·locació a lloc i el seu marc arquitectònic i mediambiental, han de ser presos en consideració en qualsevol projecte i acció de conservació. La conservació de vidrieres implica, així, la col·laboració, dins d'un equip pluridisciplinari, d'especialistes que han d'incloure, com a mínim: restauradors qualificats i experts, historiadors de l'art, arquitectes, científics, tècnics de la construcció i —on se'n facin càrrec— representants de les organitzacions governamentals responsables de la protecció de monuments i patrimoni cultural. La tria dels professionals involucrats en el procés de conservació de vitralls hauria de tenir per base la formació inicial d'aquests, la seva formació professional continuada, els seus coneixements i la seva experiència; cal tenir sempre present abans la qualitat de la intervenció que qualsevol consideració econòmica.

1.6. El present document pretén tractar cada un dels components d'un projecte de conservació o de restauració de vitralls. Tot i que alguns aspectes secundaris podrien ser considerats inadequats per a un

¹ Text en català: www.icomos.org/venicecharter2004/catala.pdf (consulta 22 novembre 2018).

² Text en francès: <http://ealbendea.files.wordpress.com/2014/07/leconservateur-restaurateur.pdf> (consulta 22 novembre 2018). Text en anglès: www.icom-cc.org/47/about/definition-of-profession-1984/#.W_U46uhKg2w (consulta 22 novembre 2018).

³ Text en anglès: <http://archives.icom.museum/ethics.html#intro> (consulta 22 novembre 2018). Text en castellà: http://archives.icom.museum/ethics_spa.html#intro (consulta 22 novembre 2018).

⁴ Text en francès: <http://www.icomos.org/charters/education-f.pdf> (consulta 22 novembre 2018). Text en anglès: <http://openarchive.icomos.org/1679/1/AG1993.pdf>, p. 159-162 (consulta 22 novembre 2018).

projecte en concret, cap dels principis que seguiran han de ser descartats a priori i han de mantenir-se com a part imprescindible dels conceptes bàsics del projecte integral de conservació/restauració.

2. Recerca i documentació

2.1. La primera etapa en un projecte de conservació comprèn un estudi de la història de l'obra, de la seva funció, dels seus materials i tècniques, dels tractaments que ha patit, i també de les seves condicions actuals de conservació. Com que aquesta feina es correspon amb el tipus de recerca realitzada pels equips del Corpus Vitrearum, és altament beneficiós coordinar aquestes tasques prèvies amb el Corpus Vitrearum. Allí on es jutgi necessari, s'han de fer també estudis tècnics i anàlisis científiques dels diferents materials constituents de l'obra, dels productes d'alteracions i dels depòsits superficials. Les bases del pla de conservació i restauració són fixades pels resultats d'aquest estudi preliminar, que és alhora el que defineix els objectius generals de la intervenció, les seves diverses etapes tècniques i l'estratègia de conservació a llarg termini. A partir d'aquest document, s'estableixen els requisits del projecte, que poden també servir de base d'avaluació durant i després de la intervenció.

2.2. És imperatiu documentar de manera completa totes les etapes, des de l'estudi preliminar fins als treballs, i això inclou el detall de les tècniques i material de conservació i restauració utilitzats. Tot prèstec de qualsevol plafó per a una exposició temporal ha d'anar acompanyat d'un informe escrit redactat per un restaurador. El propietari, les institucions públiques —quan hi intervenen— i el restaurador, han d'assegurar la conservació a llarg termini i l'accessibilitat als documents.

3. Conservació preventiva

3.1. La noció de conservació preventiva és fonamental per tal d'assegurar la preservació de les vidrieres, tant si són conservades *in situ* com si estan fora del seu context arquitectònic. En aquest sentit, la creació d'un entorn sa i estable és un dels elements principals a tenir present. La vigilància i el control regular dels vitralls i del medi on es troben, al costat d'un detallat pla de conservació, són els fonaments que fan possible la conservació preventiva dels vitralls.

3.2. Vidrieres de protecció

3.2.1. Els vitralls conservats *in situ* són particularment sensibles a les agressions mecàniques i mediambientals; en conseqüència, la instal·lació de vidrieres exteriors de protecció constitueix una part important de tota operació de conservació preventiva. El sistema de vidrieres de protecció té com a objectiu principal alliberar l'antic vitrall de la seva funció de barrera d'estanquitat de la intempèrie i alhora protegir-lo contra les agressions mecàniques i mediambientals i finalment el d'evitar la condensació en la superfície dels vidres antics. Per les seves pròpies característiques, cada obertura és única i el disseny de la vidriera de protecció ha de tenir presents les necessitats específiques del vitrall concret i del seu entorn arquitectònic, així com també l'impacte físic i visual sobre el propi monument. Hi ha diversos sistemes de protecció que poden adaptar-se a casos particulars i que van des de sistemes en els quals la cambra d'aire té ventilació cap a l'exterior, fins a les vidrieres dites isotèrmiques, en les quals la ventilació es fa cap a l'interior de l'edifici; aquestes darreres són les que avui en dia són considerades com les més eficaces. El bon coneixement del funcionament i defectes dels diferents sistemes és imprescindible per tal de concebre el millor sistema per a un cas concret. La instal·lació de vidrieres de protecció pot minimitzar les intervencions de restauració o fins i tot fer-les innecessàries i facilitar el desmuntatge de plafons. La col·locació de xarxes de protecció pot aportar encara una garantia suplementària contra xocs mecànics, però cal tenir present el seu impacte visual.

3.3. Manipulació, transport, emmagatzematge i exposició

3.3.1. Els plafons dels vitralls han de ser manipulats de manera molt particular, per tant, només persones especialment formades poden fer-se càrrec del desmuntatge i manipulació.

3.3.2. Per al transport, és aconsellable embalar els plafons de les vidrieres en caixes, en posició vertical i ben fixes. Tot i això, poden ser transportats en pla aquells plafons que tinguin l'estructura de plom inestable, o la pintura fràgil, o siguin de petita mida o bé fragments solts; però sempre cal tenir present que tota la seva superfície ha de reposar sobre el suport. Un cop emmagatzemats, els plafons poden posicionar-se en vertical o bé en horitzontal, sempre que el suport es faci en tota la superfície.

3.3.3. La tria dels materials d'embalatge, emmagatzematge i presentació dels plafons ha de partir d'un bon coneixement de la seva estabilitat química, de les seves propietats d'emanacions gasoses, del seu poder d'absorció de la humitat i de les seves propietats d'abrasió.

3.3.4. Per a la presentació museogràfica, cal tenir cura de reduir al màxim els nivells lumínics i l'escalament degut als llums dins de les taules de llum, ja que això pot alterar negativament certs materials de conservació. Cal preservar els plafons del vitrall del contacte directe del públic mitjançant les barreres oportunes.

4. Conservació activa i restauració

4.1. *Els tractaments de conservació i de restauració* han de basar-se en un bon coneixement de la història de l'obra i en una veritable estratègia de conservació a llarg termini que permeti prolongar el seu manteniment gràcies a mesures de conservació preventiva. Les intervencions no han de ser aplicades de forma sistemàtica a tot el conjunt del plafó. En tot pla d'intervenció cal preveure un temps suficient per a la reflexió, la consulta de diferents especialistes i la documentació; això és aplicable a totes i cada una de les etapes del procés.

4.2. Accés a les obres, conservació *in situ* i tractament previ al desmuntatge

4.2.1. Per tal d'assegurar la seguretat de les obres conservades *in situ* en el temps que duri el seu examen i tractament, cal preveure que es pugui accedir al seu emplaçament amb una certa facilitat. En moltes ocasions això suposa la instal·lació de bastides fetes expressament per a aquesta feina i col·locades a les dues cares del vitrall, sense excloure, en casos particulars, altres mitjans d'accés. A causa dels riscos que suposa tot desmuntatge, segons la naturalesa i l'extensió de la intervenció i dins la mesura que els tractaments a fer ho permetin, la intervenció *in situ* ha de ser considerada com la primera opció. Si amb tot, els plafons han de ser desmuntats, cal vetllar per aplicar mesures totalment reversibles i no destructives per tal de consolidar provisionalment la peça.

4.3. Tractament de la superfície del vidre

4.3.1. Tot tractament de la superfície dels vidres i de la seva decoració ha de ser precedit d'un examen atent i complet per tal d'identificar els materials originals, els fenòmens i productes d'alteració, així com els dipòsits externs. Es pot establir, com a norma general, que els productes d'alteració són manifestacions de la història material de l'obra. L'objectiu principal del tractament de la superfície ha de ser el d'assegurar la conservació del vidre i no pas de recuperar a qualsevol preu la transparència amb l'eliminació de les alteracions i dipòsits de corrosió. En aquells casos en els quals sigui imperativa la neteja, s'ha de fer de manera controlada i localitzada, tenint sempre presents els possibles riscos que impliquen els mètodes i productes utilitzats. Cal absolutament evitar xopar o aplicar compreses a la totalitat de la peça.

4.3.2. La consolidació de grisalles només és aconsellable quan hi ha amenaça que desapareguin. En els casos en els quals la grisalla sembla fràgil però no està escatada ni fa polsim és millor adoptar mètodes de conservació preventiva. En cap cas s'ha de procedir a la recuita de vidres antics.

4.4. Tractament de llacunes i afegits

4.4.1. Les llacunes, els vidres tapaforats, les reorganitzacions i les addicions posteriors són testimonis de l'evolució històrica de l'obra i han de ser estudiats amb molta precisió i ben documentats en el marc de l'estudi preliminar de tota intervenció de conservació o restauració. Les reintegracions de llacunes de vidre o de pintura, les recol·locacions o reposicions d'antigues restauracions no s'han de realitzar si no tenen el suport d'un estudi d'història de l'art i d'història de les tècniques que justifiquin plenament aquestes accions. Les intervencions d'aquesta mena han de respectar principis d'intervenció mínima i de reversibilitat usals en matèria de conservació. Tota peça de vidre nova haurà de ser identificada amb un procediment permanent, amb indicació de data i signatura o amb altres sistemes de reconeixement.

4.5. Consolidació de l'estructura

4.5.1. Si el vitrall es conserva *in situ*, la seva conservació comprèn també el tractament d'elements d'estructura dels plafons i del marc arquitectònic del badiu en si mateix. És per això que cal la participació en l'operació d'especialistes dels altres materials implicats.

4.5.2. L'estructura sustentant d'un plafó de vitrall pot estar formada per tires de plom, de zinc o d'altres metalls, cinta de coure, formigó, màstic o encara d'altres materials. Deixant de banda la seva antiguitat, aquesta estructura és una part integrant de la mateixa concepció de l'obra i contribueix al seu valor artístic. La seva conservació és un objectiu essencial, tot i que s'hi poden preveure intervencions, fins i tot el seu recanvi, sempre que això sigui motivat per raons de conservació de l'estructura o per necessitats de conservació dels vidres. En certs casos es poden admetre intervencions selectives, si

aquestes són justificades per la necessitat de recuperar una certa llegibilitat de l'obra. En redreçar un plafó bombat s'ha de donar prioritat a la conservació de l'estructura abans que al seu recanvi. No és admissible xopar o escalfar un plafó per tal de restablir-li la forma. Posar o reposar màstic no sempre és necessari i això depèn de l'estat i del lloc de conservació futur del plafó. Si aquesta operació es demostra útil, s'haurà de fer de manera localitzada.

4.5.3. De la mateixa manera, si cal la reparació de peces de vidre fracturat, s'ha de tenir presents la durabilitat i les condicions de conservació del futur plafó per tal de triar els materials d'assemblatge més adients.

5. Impressum

Aquestes directrius van ser redactades per un grup de treball del *Comité International pour la conservation des vitraux* i van ser aprovades per l'*Assemblée générale du Corpus vitrearum international* en el XXII Col·loqui celebrat a Nuremberg (Alemanya) l'1 de setembre de 2004.⁵



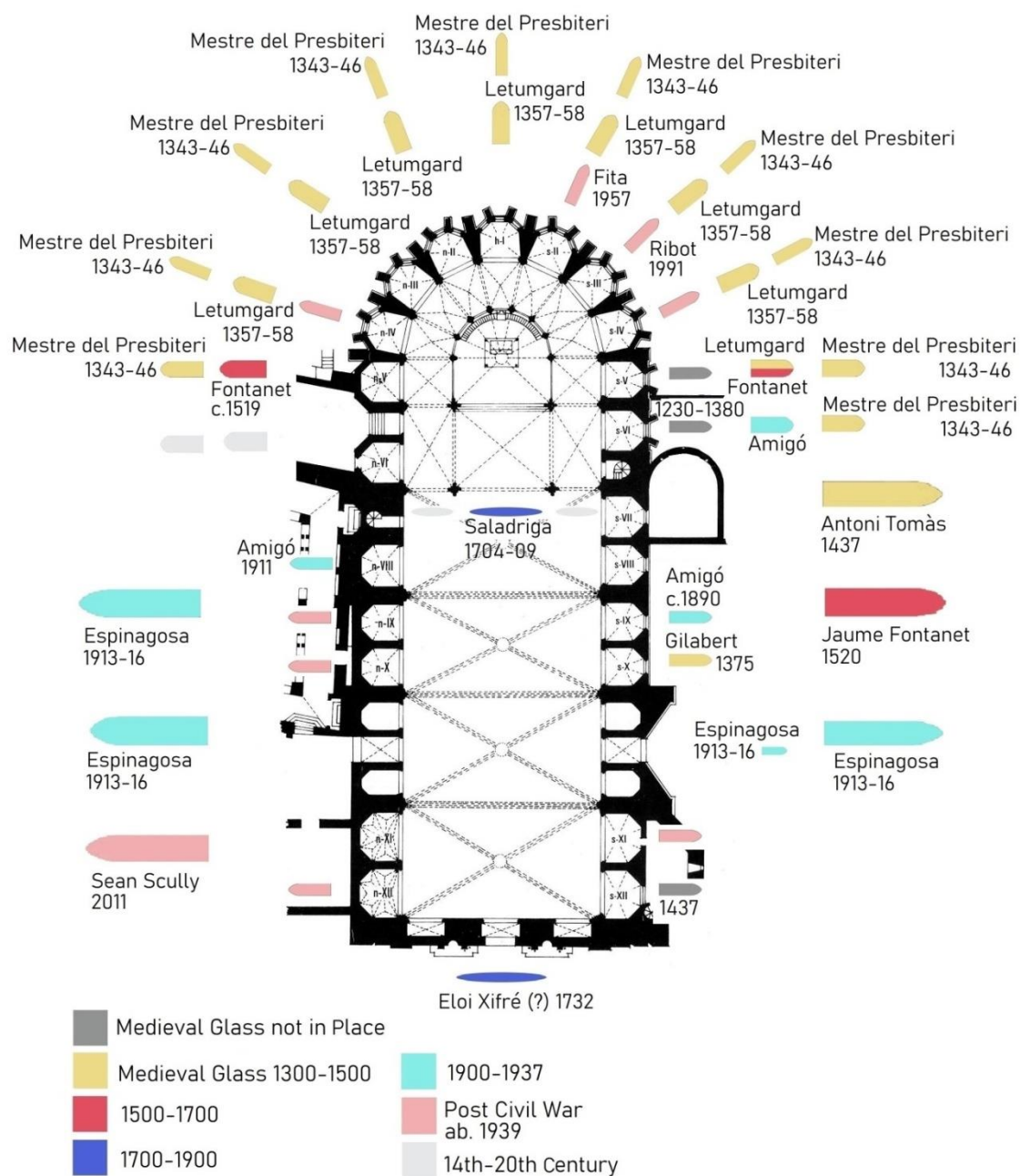
⁵ La traducció al català i les anotacions han estat realitzades per la secretària del Corpus Vitrearum de Catalunya, Sílvia Cañellas, amb el suport del vicepresident Antoni Vila i de la resta de l'equip, a partir de la versió en francès de les *Directives pour la conservation et la restauration des vitraux* (www.corpusvitrarum.org), el novembre de 2018. Ha passat per la revisió del Servei de Correcció Lingüística de l'Institut d'Estudis Catalans i ha estat enviada a el Comité scientifique international pour la conservation des vitraux du Corpus Vitrearum et l'ICOMOS.

VISITS

Scheme of Girona Cathedral's Stained-Glass Windows

Anna Santolària

Corpus Vitrearum Catalunya



Restauration of the Pedralbes Stained-Glass Windows

Montserrat Pugès i Dorca

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Abstract

The online publication of the reports on the restoration of the Pedralbes stained-glass windows marks the culmination of a long, arduous process. Over the course of more than 12 years, a multidisciplinary team of conservators-restorers, architects, glassmakers, metalworkers, stonemasons, art historians, physicists, geologists and biologists has worked to understand and deal with a diverse range of aspects related to the conservation and restoration of the 32 stained-glass windows worked on. This article offers a glimpse of the historical and artistic aspects of the stained-glass windows and the restoration's guiding criteria and methodology. The details and description of the work carried out by the team of professionals are provided in each of the reports. The 11th Forum for the Conservation and Technology of Historic Stained Glass, held in Barcelona, is an excellent opportunity to highlight this work among specialists in the sector.

Presentation

The Reial Monestir de Santa Maria de Pedralbes monastery was built in the 14th century by the monarchs of the Catalan-Aragonese Crown, Elisenda de Montcada and James II the Just. The monastery was opened in the spring of 1327 and just a few months later, after the king's death, Queen Elisenda joined the community of Poor Clares. For 37 years, she lived in the mansion she had built next to the monastery, to which she left most of her possessions to ensure their survival. At the queen's request, the monastery was granted the protection of the Consell de Cent, a consultative body belonging to the municipal government of the city of Barcelona, abolished in 1714 by the Nueva Planta Decree. This protective role played by the Consell de Cent continues today with Barcelona City Council, thanks to a contract signed in 1972, under which, among other things, it is obliged to conserve and restore the monastery. Through the Directorate of Architecture and a master plan drawn up for this purpose, yearly programmed projects and undertakings are planned, directed and carried out.

The stained-glass window restoration plan

In 1995, as part of the programme referred to above, work began on the restoration of the windows and rose windows in the church and the chapter house. To this end, a company of glassmakers was hired to restore the stained-glass windows and refurbish their protective coverings, which were visibly damaged from the outside of the building.

In 1998, continuing with this programme, plans were drawn up to restore one of the medieval stained-glass windows in the apse of the church, which had very different characteristics from those that had been worked on previously, which led to a change in the team make-up.

At that time, and in response to the new needs, the Directorate of Architecture requested the collaboration of the restoration specialists from the Archaeology Service (also part of Barcelona City Council), as it considered them to be familiar with this type of work given their prior experience and knowledge. The involvement of restoration specialists from the Archaeology Service, as well as other external collaborators, also meant a change of direction with respect to the work that had been started. Thus, the initial team of glassmakers was joined by professionals from other disciplines and fields, with the aim of covering aspects such as historical documentation and the identification of materials, which were necessary at one point or another in the process. Once the team was set up and the methodology established, a total of 32 of the 39 stained-glass windows conserved in the monastery (between the chapter house and the church) were restored between 1998 and 2010. At the time of writing – spring 2022 – the conservation-restoration work is under way on the two pieces still to be restored: the rose window on the church's north façade and the two windows on the east façade, overlooking the choir.

The monastery's stained-glass windows: artistic and historical aspects

The restoration has brought with it the possibility of studying the monastery's stained-glass windows, not only on the basis of their artistic characteristics but also, going a little further, through surviving written documentation, whether in the monastery's own archives or in others. In this regard, it is worth mentioning the work carried out by Anna Castellano (2011) in relation to the monastery's archives, through which she brought to our attention the presence of names of such renowned medieval glassmakers as

members of the Fontanet family and Terri de Metz, although we have not been able to discover who actually made the medieval stained-glass windows, which remains to this day an unknown quantity.

Meanwhile, the work of Sílvia Cañellas (2011) focused on studying the Pedralbes stained-glass windows as a whole, identifying timelines and establishing a 'small catalogue' that can be divided into three distinct periods, corresponding to the 14th, 17-18th, and 19th centuries. Each stained-glass window shares the same decorative arrangement across these three periods, with figures of saints in architectural niches in the lower parts of each lancet and panels with geometric decorations right up to the tracery. Cañellas also takes a special look at the pair of stained-glass windows located on the northeast side, which, despite differing from the rest in terms of their decoration (they are geometric, bichrome stained-glass windows), serve to explain a very characteristic moment in this art form.

Another study on the matter is by Flavia Bazocchi (2011), who explores the influences and patterns of the Pedralbes medieval stained-glass windows. Thanks to her rigorous documentary research, the author has opened the door to the possibility of finding unpublished archives containing information about our stained-glass windows.

The materials: glass, lead and putty. Some interesting facts

Most analysed medieval glass is sodic in nature, which gives it greater stability in terms of preservation. Red-coloured flashed glass, which has a potassic composition and is more sensitive to alteration, is a notable exception (Domingo Gimeno, 2001, 2011). This is essential for understanding why these stained-glass windows are in such good condition, as opposed to other severely weathered medieval stained-glass windows composed of potassium.

The manufacture of flat glass from cylinders was only used in the production of certain types of glass, specifically honey-coloured glass. The most commonly used form is from discs, which would have been about 40 cm in diameter.

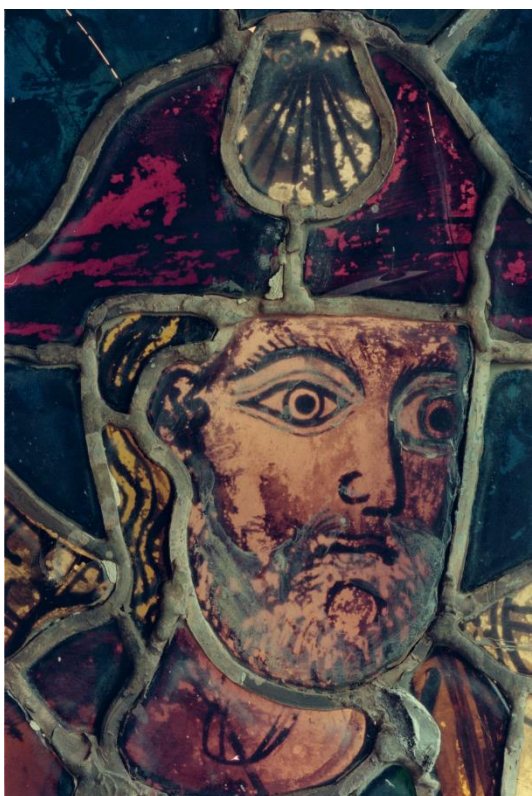


Fig. 1. Stained-glass window OII. Detail of the figure of Saint James, with grisaille painting and mostly original leadwork (backside). Photo: Josep Gri.

Exceptionally, the medieval stained-glass windows retain approximately 70% of the original leadwork. The medieval lead was fully preserved during the restoration process, as it was still malleable despite some cracking. This was not the case with the putty; most of it had to be replaced as it was extremely hardened or missing and thus made it impossible for the panels to regain their flat shape. Once analysed, the putty was recovered by manufacturing it as it was in the past, with calcium carbonate and linseed oil (Fig 1).

The supporting structure

The appearance and technique used to make the supporting structures might suggest that the iron fittings were the original ones (Lluïsa Amenós, 2011), but a more in-depth analysis has raised doubts about their dating. Due to the poor state of the anchorages and alterations in the stone of the windows, it was necessary to replace these elements.

The restoration work: criteria and methodology

The Reial Monestir de Santa Maria de Pedralbes monastery has been declared a Historic-Artistic Monument of National Interest¹. The criteria governing any conservation-restoration work on a monument of this kind are set out in Article 35,

¹ (D. 3-6-1931; Gaceta 4-6-1931), included in the Historic-Artistic Heritage Catalogue of the City of Barcelona (files 492 and 493; category A, chap. i), in the Special Plan for the Protection of Architectural Heritage and in the Catalogue of District 4 (element no. 49).

‘Criteria for intervention’, of the Catalan Cultural Heritage Law². The restoration was carried out following the criteria of minimum intervention and maximum respect for the original work, considering some changes with a view to improving the conditions of the building and its surroundings for future conservation.

All the original features and parts were preserved, as long as they were not detrimental to the original work. Reworked items were also preserved as they were considered to be witnesses to the passage of time and to the history of the work itself. If any additions were removed, they were thoroughly documented and appropriately stored.

The materials and products used were chosen on the basis of their reversibility and compatibility with the original work. They are either tested products – in the case of newly created materials such as the adhesive used in the glass joints – or traditional ones, such as the putty, whose compatibility is guaranteed. The materials, products and restoration processes were carefully considered in advance based on criteria of respect for the environment and people, discarding those whose disposal and use could be harmful.

The work followed a scientific methodology defined, broadly speaking, by prior knowledge of the pieces gained through historical and artistic study, the morphological and technological study of the stained glass, and the analysis and study of the types of alteration and their causes. This prior knowledge and the established criteria determined the steps to follow in the restoration process. The documentation of the whole process not only forms an essential part of the compilation of the projects carried out, in a descriptive sense, but also becomes a record for future restorations.

Given the good state of conservation of the Pedralbes stained-glass windows, there was very little doubt as to the possibility of keeping them in their original location, a fact that we wish to highlight, as these projects have a specific goal that has not changed over the years. Their conservation as works of art is not only for contemplative purposes, but is also closely linked to their function and to the understanding of the building in which they are located.

Although the restoration has shown complete respect for the original work, we cannot overlook some significant changes that we believe are entirely for the better. These include some notable changes to their appearance from the outside and their long-term maintenance. The framing of each panel and its placement on site as an individualised feature make it easier to carry out maintenance work without affecting the whole of the window. Compared to its initial position, the stained-glass windows are set back by 5 cm and placed on iron crosspieces using tongues fixed with metal pins to keep them in place. This 5 cm gap between the stained glass and the protective glass creates an air chamber that prevents condensation. The sides of the stained glass are fitted with lead wings to prevent natural light from entering. Openings at the top and bottom of the window create a draught through the chimney effect. When viewed from the outside, it is possible to contemplate the stonework of the tracery, until now hidden by the protective coverings.

Restoration work

In order to provide a precise description of the restoration work carried out, we will limit ourselves to explaining the structure of the restoration reports, which can be viewed on the Barcelona Archaeology Service website at <https://ajuntament.barcelona.cat/arqueologia/barcelona/publicaciones-comunicación/vitralles-de-pedralbes/>

There is one report for each stained-glass window. Their structure follows that of the work process. Firstly, an analysis was carried out, and the work to be done on the window was determined based on an initial study of the piece and data collected on its state of preservation, together with the established restoration criteria. In some cases, an in-depth study of the alterations observed and their causes was conducted in order to complete the restoration guidelines. The information gathered is displayed graphically, in the form of work maps drawn up with coloured legends that make it easier to see the general scope of each alteration observed in the stained-glass window. The graphic information is accompanied by a description of each alteration, together with an assessment of the effect on the stained-glass window, either as a whole or on a particular feature (figs. 2-3).

² It is also included in the Athens Charter of 1933, the Venice Charter of 1931 and the Charter of Restoration of 1971.



Fig. 2. Application of zeolite dressing with AB57 to remove the lime coating. Photo: Josep Gri.



Fig. 3. Removal of the dressing by lifting the Japan paper. Photo: Josep Gri.

Due to various issues, which could be summarised as deriving from technological and computer changes, the reports on the restoration of the stained-glass windows could not be published until relatively recently. Out of a planned total of 32 reports, 11 are currently available, mostly on 19th century stained-glass windows.

It is also worth mentioning that the general guidelines of the project are to be included in an introductory report entitled *Studies and preliminary work*, which will compile all the information prepared to draw up the 1998-2010 Stained-Glass Window Restoration Plan. Meanwhile, to bring the plan to a close, work is being done to prepare a final volume of conclusions and ending remarks.

By way of conclusion

The restoration has been a great opportunity to get to know these stained-glass windows from top to bottom. The great research and documentation work carried out by the Institut d'Estudis Catalans (AINAUD et al 1997), the only documentation we had when we began the Restoration Plan in 1995, must be complemented today with the above-cited works. It is not only technology that has brought innovations; taking the pieces down, observing them closely and working for months often provides a wonderful time for reflection, communication and discussion among the professionals involved, without which it is very difficult to produce reliable results and conclusions. Restoration has brought to light post-Spanish Civil War reworkings and also evidence of medieval tracery combined with 19th century lancets. Thus, the presence of medieval glass in virtually all the stained-glass windows in the church makes the whole a unique work due to its unity in the conception and execution of the original decorative programme.

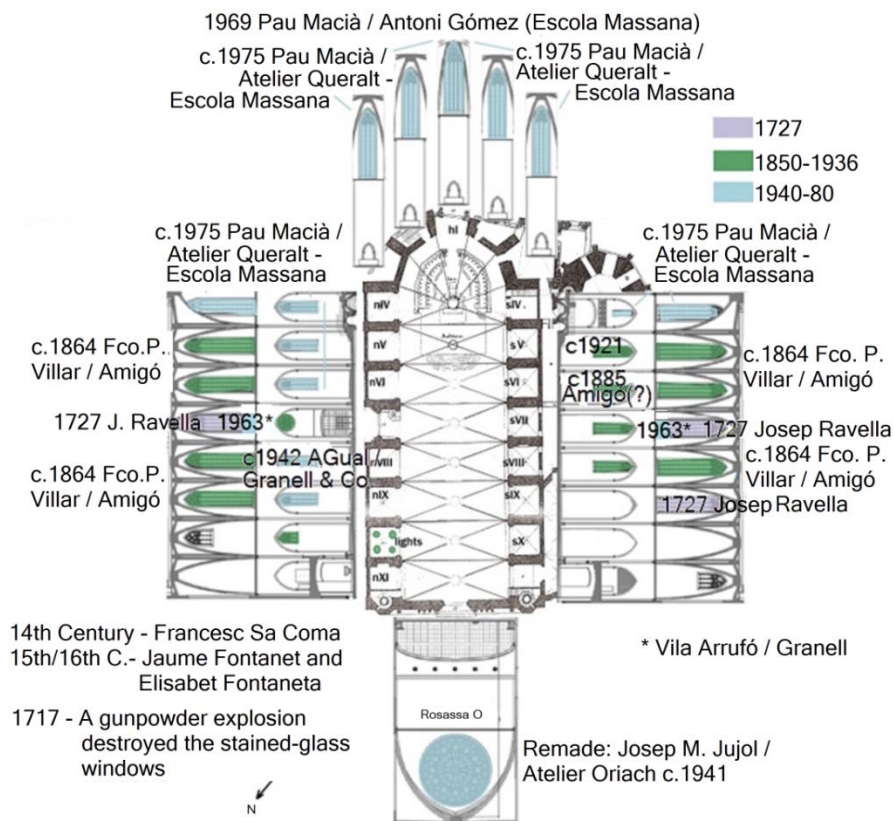
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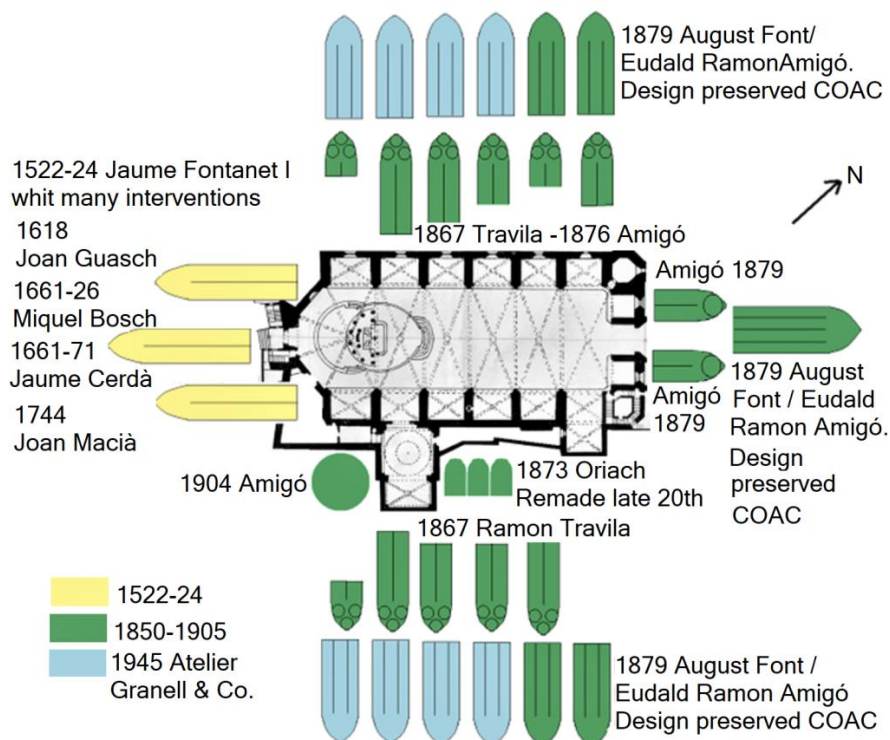




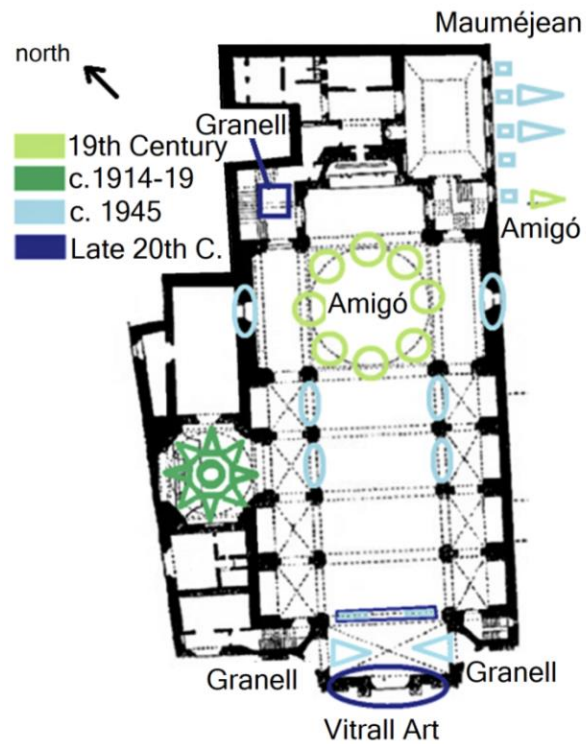
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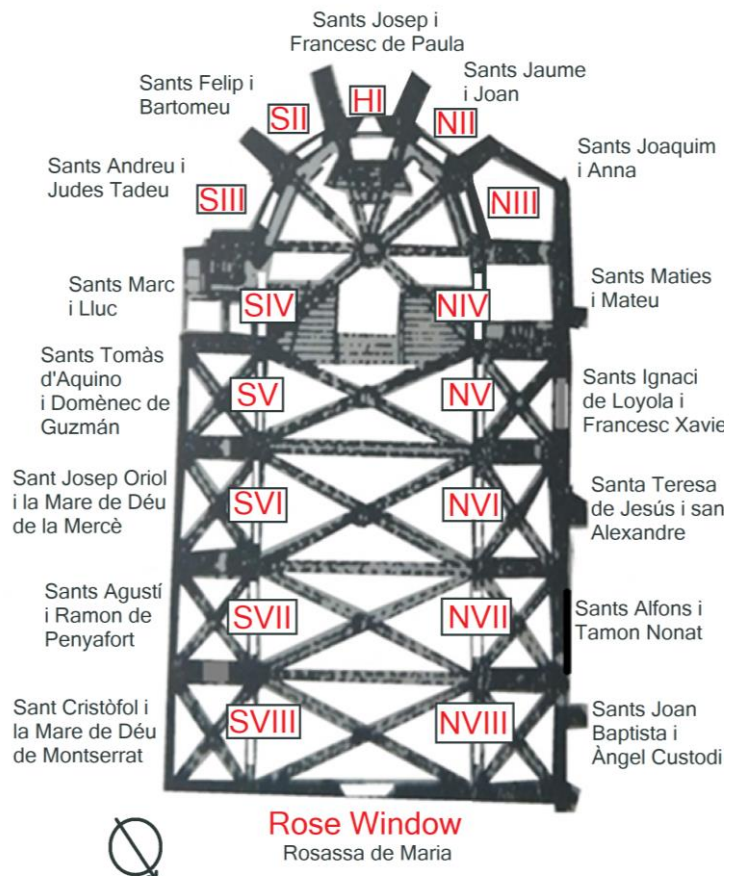
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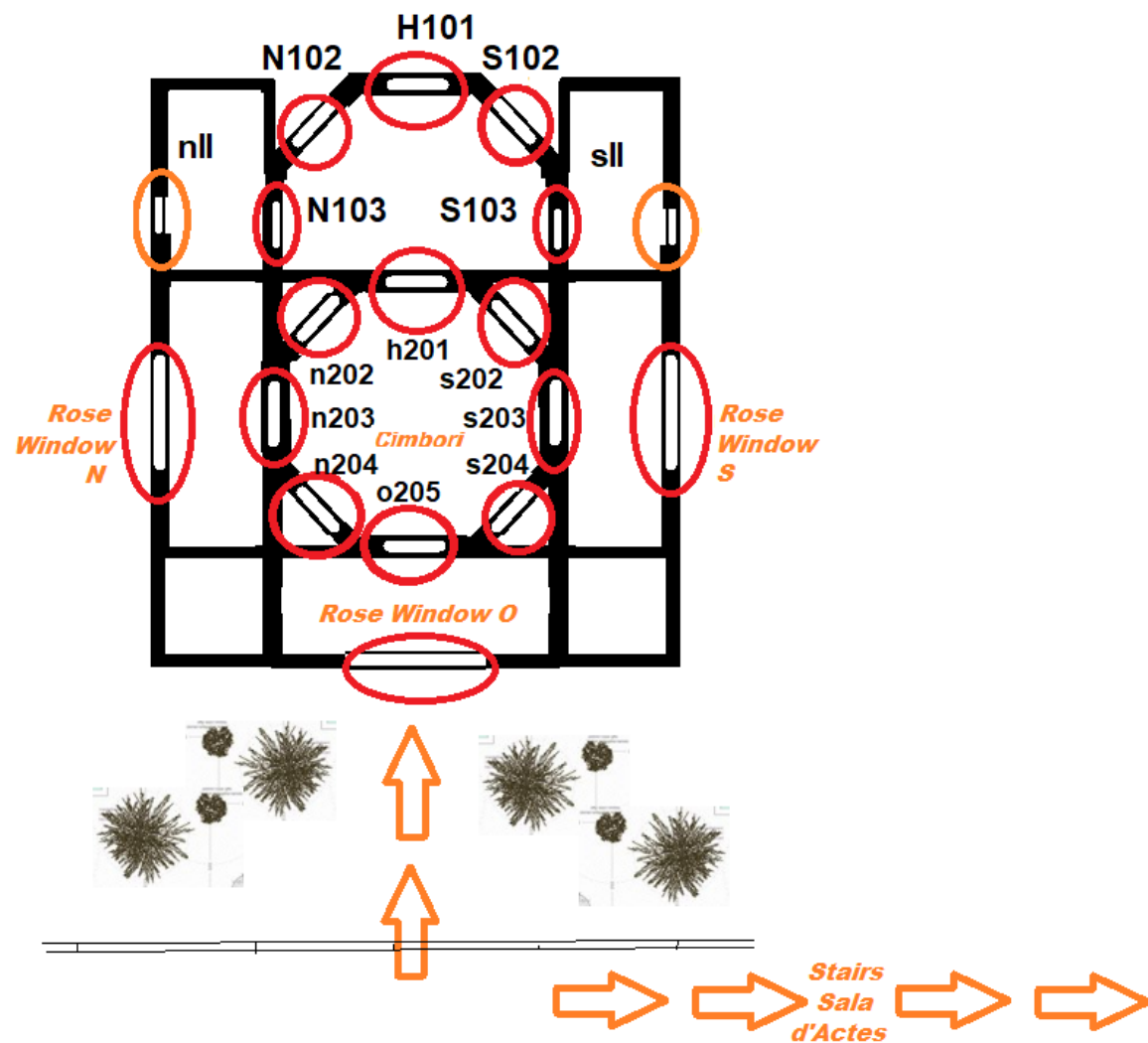
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Església de Sant Ramon de Penyafort



Capella del Seminari Conciliar de Barcelona



19th-Century Stained-Glass Windows:

H101, N102, N103, S102 and S103 by Amigó Studios and Claudio Lorenzale, painter.

Dome and rose windows by Amigó Studios and Elies Rogent, architect.

