CHAPTER 1

Introduction

The aim of this study is to investigate the well-known and widespread problem of severe paint loss from stained glass windows made by many firms in the mid- to late-nineteenth century. This problem results in the fading of painted detail from the surface of the glass, in the worst cases leaving pieces completely blank, as well as 'ghosting' of areas where the paint has been lost (Figures 1 and 2). It has become known as the 'borax problem',[1] most likely due to a letter sent by William Morris to George Howard, around 1880, in which he writes:

> We (and I believe all other glass painters) were beguiled by an untrustworthy colour, having borax in it, some years ago, and the windows painted with this are going all over the country. Of course we have taken warning and our work will now be all right. We have given instructions to our man to take out the faulty glass, which we will – restore! – at once, and pay for that same ourselves – worst luck!
>
> Borax is the name of the culprit: the colour makers, finding that the glass-painters wanted a colour that would burn well at a lowish temperature, mixed borax with it to that end; but unluckily glass of borax is soluble in water, and hence the tears wept by our windows – and our purses. We use harder colour now, so that if any window of ours goes now it must be from other causes; bad burning or the like; I don't think as things go that this is like to happen to us.[2]

As Morris suggests, many (although not all) stained glass firms of the period experienced the problem of paint loss. Harrison suggests that James Powell and Sons suffered particularly badly, as did Burlison and Grylls, Lavers, Barraud and Westlake and C.E. Kempe and Co, while Heaton, Butler and

[1] Harrison, 1980: 51.
[2] MacKail, 1922: 59.

Figure 1: The entry into Jerusalem with blank pieces due to paint loss Detail from North aisle window n7, Sherborne Abbey

Figure 2: Head of Christ showing 'ghosting' due to paint loss Detail from East window, St Peter's Church, Conisborough

Bayne and Clayton and Bell apparently had fewer problems with their paint.[3] The problem was not confined to the English studios; many windows made by the important nineteenth-century Belgian studios of Capronnier and Bethune are suffering from severe paint loss,[4] and paint deterioration has been described as "the single most difficult problem facing conservators of stained glass in America".[5]

Later writers have also blamed the addition of borax for the failure of glass paints, with Newton commenting that "in the 19th C. some purveyors of paints added much too much borax with the result that the painted linework would dissolve in any condensation which occurred on the inside of the window!"[6] It is interesting to note, however, that borax is still used as an additive for glass

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3 Harrison, 1980: 52.
4 Caen et al, 2000: 25.
5 Sloan, 1993: 164.
6 Newton, 1982: v.

paints today, suggesting that the problem cannot be quite so simply attributed.[7] More generally, the use of “incorrectly formulated glass paint” which “did not fuse correctly with the glass” has been blamed for the failure of Saunders and Co windows at Cork, Skelton and Studley Royal.[8] Underfiring of the paint, as well as inconsistency of firing, has also been suggested as cause for failure, “as testified by variations within the bounds of a single window”.[9] Indeed, Morris’ letter offers “bad burning” as a further possible explanation for failure. However, few technical studies of the problem have been reported.

Stained glass in the nineteenth century

By the eighteenth century, the combined effects of the Reformation, the dissolution of the monasteries and then the prohibition of religious imagery in church windows in the sixteenth century, followed by the iconoclasm of the Civil War in the seventeenth century, meant that the previously long-established craft of stained glass production in England had all but disappeared.[10] Most new stained glass produced in the eighteenth century was either heraldic in nature, or created in the manner of oil paintings.[11] Towards the end of the eighteenth century, however, a new interest in older styles of stained glass emerged with antiquaries and collectors such as Horace Walpole and William Beckford,[12] and soon the gathering pace of the Gothic Revival, championed by architects such as AWN Pugin and George Gilbert Scott, created a great demand for stained glass in a medieval style. This increased demand was supported by a significant reduction in the price of stained glass; partly due to the repeal of the glass tax in 1845, but also to the adoption of the ‘mosaic’ style and the growth in

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[7] Personal communication, E. Wagg (Technical Services Manager, Reusche and Co)
[8] Lawrence and Wilson, 2006: 104-5.
[9] Newton and Davison, 1989: 99.
[10] Brown and Strobl, 2002: 8.
[11] Cheshire, 2004: 34; Harrison, 1980: Fig 1.
[12] Brown and Strobl, 2002: 9.

production.[13] Census figures show a rise in the number of people listed as 'Glass Stainer' in Great Britain to have been only three in 1831; 108 in 1841; and 531 in 1851;[14] this sudden increase in the number of firms working on stained glass by the middle of the nineteenth century suggests that a significant number were starting out with little or no experience of the craft and its history.

It was not only the craft of glass painting that had to be re-learned; even the process of making coloured glass of a suitable quality for medieval-style windows had to be re-discovered. The antiquarian Charles Winston is generally credited with the introduction of new 'antique' glasses, made by James Powell and Sons following analysis of medieval samples.[15] Winston also brought a scholarly approach to the study and restoration of medieval windows, deploring the practice of 'Restorations, which in nine times out of ten would be more truly called Destructions'.[16] In building and decorating new churches, Pugin's devotion to the *True Principles of Pointed or Christian Architecture* (London, 1841), also based on his careful study of ancient buildings, led to the design of windows closely following the medieval style. Just as Winston published detailed drawings of medieval glass paintings in his *Inquiry into the Difference of Style Observable in Ancient Glass Paintings* (Oxford, 1847), Pugin travelled extensively gathering medieval models for his new stained glass designs, which "set the highest standards in English stained glass."[17] In conjunction with John Hardman and Company, Pugin also instigated experiments with James Hartley and Company to improve the quality of glass supplied for their windows.[18] Thus the great achievements in nineteenth-century stained glass were largely based

[13] Cheshire, 2004: 163.
[14] Harrison, 1980: 12.
[15] Harrison, 1980: 23.
[16] Winston, 1865: 169.
[17] Shepherd, 2009: 22; Fisher, 2008: 77; Harrison, 1980: 15.
[18] Shepherd, 2009: 22; Fisher, 2008: 67.

on the imitation and re-discovery of the principles and methods of earlier artists and craftsmen.

The nature of glass paint and its deterioration

Glass paint, also known as vitreous paint, black paint or in Europe as 'grisaille', is a mixture of ground glass (often known as flux) and metallic oxides (pigments).[19] When applied to glass using a liquid medium (such as water or oil) and then fired, the particles of ground glass melt and fuse to the substrate glass, permanently holding the pigment particles in place.[20] This process is largely unchanged from medieval times, as described by the twelfth-century monk Theophilus in his treatise *De diversis artibus*:

> Take copper that has been beaten thin and burn it in a small iron pan, until it has all fallen to a powder. Then take pieces of green glass and Byzantine blue glass and grind them … Mix these three together … Then grind them on the same stone very carefully with wine or urine, put them in an iron or lead pot and with the greatest care paint the glass …[21]
>
> Now carefully lay the painted glass on [an iron plate covered with lime or ashes] close together … kindle a moderate fire in the kiln, and then later a bigger one … covering it long enough to make it slightly red-hot. Take the wood out at once and carefully block up the mouth of the kiln … until the kiln cools by itself. … Now take out the glass and test it to see if you can scrape off the pigment with your fingernail; if not, it is sufficient …[22]

In order for the glass paint to melt and fuse to the glass surface without the substrate glass itself melting and deforming in the kiln, the ground glass or flux used in the glass paint must have a lower melting temperature than that of the glass being painted on. It is assumed that Theophilus' "green glass and

[19] Elskus, 1980: 5.
[20] Elskus, 1980: 6; Verità et al, 2003: 347.
[21] Hawthorne and Smith, 1979: 63.
[22] Hawthorne and Smith, 1979: 66-67.

Byzantine blue glass" were lead silicate glasses;[23] Antonio da Pisa suggested the use of 'paternostri' (yellow beads of a lead silicate glass)[24] and Haudiquer de Blancourt's rather later *Art of Glass* specifically instructs the reader to make and use the lead silicate he calls 'rocaille' as flux.[25] Other materials, such as borax, were later added to the flux in order to make the paint more malleable, in other words, to further reduce the firing temperature.[26]

The type of glass painting described by Theophilus creates only dark (even opaque) areas on the glass, and is therefore used to produce the detailed outlines and shading of the image, while the colour and overall design of the panel is produced by the separate glass pieces held together by lead calmes. This is the so-called 'mosaic' method,[27] used throughout the medieval period (Figure 3). In the early fourteenth century the use of silver stain was developed, allowing artists to create areas of bright, transparent yellow on clear glass (Figure 4).[9] During the sixteenth century, transparent enamel colours were developed, offering the opportunity to create areas of several different colours within the same piece of glass (the 'enamel' method).[28] Enamel colours are very similar to black glass paints, except that the flux and metallic oxides are melted together before application, creating a coloured glass that is then applied and fired on to the surface of the substrate glass.[29] Black paint, silver stain and enamels were all used during the sixteenth and seventeenth centuries ('mosaic enamel'), while in the eighteenth century, the taste for more 'painterly'

[23] Schalm, 2000: 31.
[24] Verità et al, 2003: 347.
[25] Blancourt, 1699: 279.
[26] van Treeck, 2000a: 59.
[27] Winston, 1867: 5.
[28] Newton and Davison, 1989: 97; Winston, 1867: 6.
[29] Newton and Davison, 1989: 97.

Figure 3: 'Mosaic' style, using only black paint and coloured glass. Detail from Canterbury Cathedral window nII, ca. 1213-20

Figure 4: Painted and stained glass Detail from All Saints' Church, North Street, York, East window, fifteenth century

representations led to the creation of purely enamel paintings,[30] with the lead calmes serving only to join panes of clear glass (Figure 5); artists such as William Peckitt combined the painterly style with the use of pot-metal coloured glass (Figure 6).[31] During the Gothic Revival of the nineteenth century, glass painters largely returned to the 'mosaic' method of the medieval period, using black paint and silver stain, whilst further developing painting techniques, building up delicate shading and modelling using layers of paint in different application media.[32]

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[30] Cheshire, 2004: 34.
[31] Brighton, 1978, 2: 264.
[32] van Treeck, 2000b: 216; Newton and Davison, 1989: 98.

Figure 5: Pictorial 'painterly' style using enamels
Detail from New College, Oxford, West window, Jervais after painting by Joshua Reynolds, 1783

Figure 6: Combining 'painterly' style with coloured glass
Detail from Trinity College, Cambridge, library South window, Peckitt after design by Giovanni Cipriani, 1774-5

Although glass paints, if correctly fired, should theoretically "remain fixed for the lifetime of the glass",[33] many glass paintings of all periods in fact show evidence of deterioration of the paint layer. Such deterioration can be divided into two distinct forms: paint peeling or flaking, due to the formation of micro-cracks in the paint layer, and pulverisation (powdering) with associated corrosion of the paint layer.[34] Medieval glass paintings suffer from the additional problem of corrosion of the underlying glass, which may result in the glass paint surviving as a raised area; equally the reverse may occur, so that the painted area corrodes faster than the surrounding glass.[35] In the case of nineteenth-century glass paintings, the underlying glass is generally of a more durable composition, and so only the paint layer is likely to deteriorate. Many factors affecting the

[33] Elskus, 1980: 6.
[34] Verità, 1996: 66; Schalm, 2000: 10; Becherini et al, 2008: 239.
[35] Newton and Davison, 1989: 144.

durability of glass paint have been suggested, including the composition of the paint (the proportions of flux and pigment), the granularity and homogeneity of the paint (grain size and mixing technique), the firing process (especially the firing temperature), the thermal expansion properties of the glass and paint, the environment in which the glass painting is installed, and any cleaning or restoration processes that have been carried out.[36]

There have been relatively few detailed studies of the mechanism of deterioration of glass paints, particularly when compared to the large number of studies related to the deterioration of the glass itself. Study of paint loss from the thirteenth-century windows of the Sainte Chapelle in Paris concluded that the lead silicate glass used as flux in the glass paint had a very different coefficient of thermal expansion to that of the glass used as substrate; firing the two layers produced stresses between the paint layer and the substrate glass, later leading to the formation of micro-cracks between the glass and paint (Figure 7).[37] Centuries of exposure to the day-night temperature cycle of the building resulted in the propagation of the cracks, causing areas of the paint to crack and peel away from the glass.[38]

[36] Verità, 1996: 68; Verità et al, 2003: 347.
[37] Verità et al, 2003: 349-51.
[38] Becherini et al, 2008: 239, 248; Verità et al, 2003: 349-51.

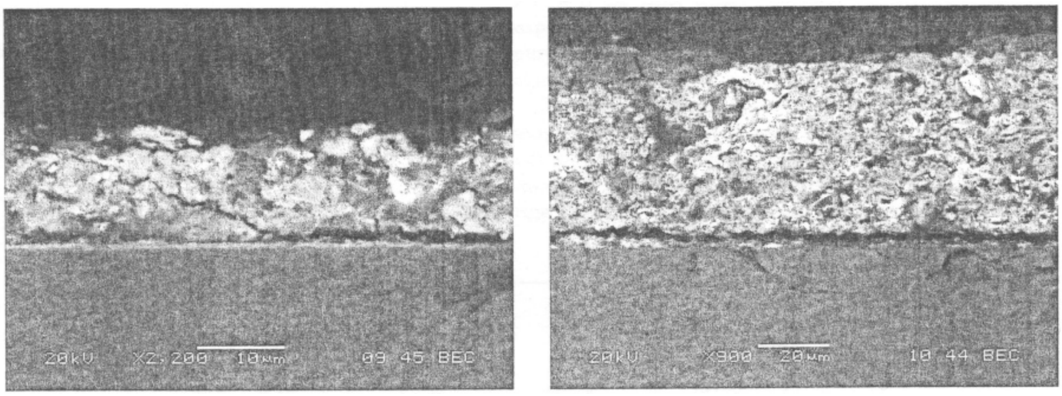

Figure 7: Scanning electron micrographs of cross-sections of glass paint layers (Sainte Chapelle, Paris) showing micro-cracks between paint and glass

Flaking of paint has also been ascribed to poor fusion of the paint to the glass during firing, due to the glass surface being too hard or smooth;[39] this might be the case if the melting temperature of the paint were too low relative to that of the glass, such that the paint appeared to form a well fired layer while the underlying glass remained too hard to form a strong bond with the paint layer. Underfiring of the paint may also result in a fragile layer which is only loosely bonded to the underlying glass.[40]

Pulverisation of paint was also noted in some samples from the Sainte Chapelle, which on examination under the scanning electron microscope showed evidence of corrosion of the upper part of the paint layer.[41] As fired glass paint is largely composed of a low melting glass, this glass is subject to the same corrosion process as any other type of glass. The corrosion process is complex, but essentially involves moisture leaching alkali metal ions (potassium or sodium) out of the glass, creating a silica-rich layer (the ‘gel layer’) at the surface of the glass and an alkaline solution on the surface. This alkaline solution can then attack the glass further, dissolving the silicate network

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[39] van Treeck, 2000a: 62.
[40] Verità, 1996: 68.
[41] Verità et al, 2003: 349.

and resulting in the formation of pits in the glass surface.[42] In the case of glass paint, corrosion leads to the loss of the glassy structure, causing the paint to become soft and vulnerable to further deterioration and loss.[39] The durability of glass, or its resistance to corrosion, is strongly influenced by its composition (glasses containing sodium being significantly more durable than those containing potassium) and also by its physical microstructure, the environment (especially the humidity) and the presence of micro-organisms.[43]

A study of the deterioration of nineteenth-century glass paintings produced by the Belgian firms of Capronnier and Bethune found that although some paint layers were well vitrified or melted (Figure 8), others had a granular appearance under the scanning electron microscope (Figure 9); these granular layers had relatively poor durability and a tendency to pulverise. The cause was found to be the use of paints with too much pigment and not enough flux to form a strong paint layer; attempts to apply the paint on top of a layer of low-melting flux were no more successful. Both studios improved the performance of their paints in later years by reducing the amount of pigment in their paints.[44]

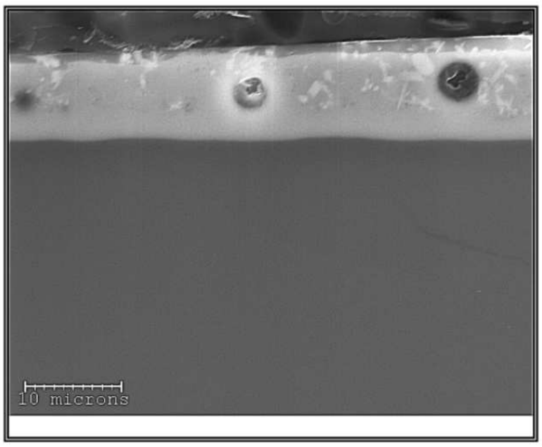

Figure 8: Well-vitrified paint layer

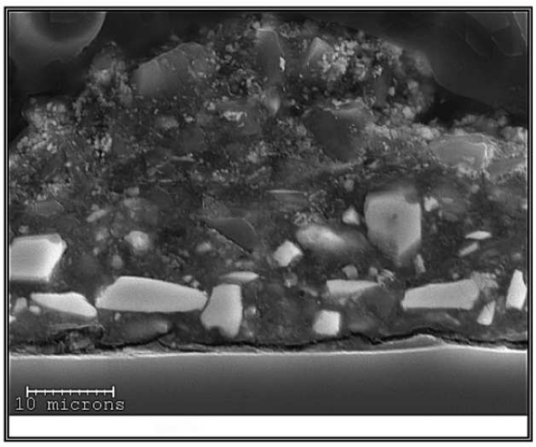

Figure 9: Granular paint layer

[42] Römich, 1999: 7; Newton and Davison, 1989: 136.
[43] Römich, 1999: 11; Drewello and Weissmann, 1997: 337.
[44] Schalm, 2000: 364, 374; Schalm et al, 2003: 605.

Schalm examined the effects of firing and of paint composition on the quality of fired glass paint layers. Low firing temperatures resulted in granular paint layers, whereas higher temperatures gave well-melted layers.[45] The fired paint layers contained pores due to the presence of gas bubbles; the longer the firing time, and the higher the firing temperature, the larger the bubbles became, finally bursting out of the top of the layer leaving ‘pin-holes’.[46] A large number of interconnected pores in the paint layer might increase the rate of deterioration due to the penetration of water and pollutants into the paint layer.[47] In terms of the glass paint composition, the most important factor was found to be the ratio of pigment to flux, with ratios from 1:3 to 1:2 giving good quality fired paint layers.[48] A higher amount of pigment led to the formation of soft, granular layers, and even those with a pigment:flux ratio of 1:2 required either a soft (low-melting) flux or a high firing temperature for good performance.[49] Thus, it is clear that careful control of the paint composition and the use of appropriate firing processes for each particular paint composition are of great importance in achieving a well-vitrified, durable paint layer.

Approaches in this study

As discussed above, there are many different ways in which paint layers may degrade, and many factors influencing the likelihood of deterioration. Although glass paintings from all periods show some deterioration of the paint layer, those from the mid-nineteenth century appear to have been particularly vulnerable to severe paint loss, which has previously been ascribed variously to the addition of borax to the paint and to underfiring of the paint.

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45 Schalm, 2000: 294.
46 Schalm, 2000: 297-300.
47 Schalm, 2000: 305.
48 Schalm, 2000: 316.
49 Schalm, 2000: 311.

In this study it is intended to take a multi-disciplinary approach to investigating this phenomenon, looking at the historical background and undertaking a technical study before discussing conservation issues. As many windows, created by many different studios, over a period of several decades from the mid- to late-nineteenth century, are now suffering from paint loss, it was decided to focus on selected case study windows made by a single firm. The chosen firm was John Hardman and Company of Birmingham, "one of the best documented of all Victorian stained glass firms"[50] due to their substantial surviving archive, supporting the historical study. Hardmans were prolific producers of stained glass windows during the nineteenth century, including many which are now suffering from severe paint loss. Three windows, showing differing degrees of deterioration, were selected for detailed study: the previous West Window of Sherborne Abbey (1851, removed 1997; severe paint loss), the West Window of Beverley Minster (1859 and 1865; moderate paint loss), and the previous North Transept window of All Saints' Church, Emscote, Warwick (1889, removed when the church was demolished in 1967; paint in good condition).

[50] Harrison, 1980: 78.

CHAPTER 2

Historical Study

The historical study in this chapter covers two main areas: details of three selected case study windows made in the latter half of the nineteenth century by John Hardman and Company, and discussion of contemporary published glass paint recipes.

John Hardman and Company

John Hardman and Company was founded in 1838 by John Hardman Junior (Figure 10), who had previously been a partner in his father's button making business.[1] Having met the architect AWN Pugin (Figure 11) in 1837, Hardman began to make ecclesiastical metalwork to Pugin's designs, and their friendship and working relationship continued until Pugin's death in 1852.[2] In 1845, again at Pugin's suggestion and to his designs, Hardman began to produce stained glass.[3] With no prior knowledge of this medium, Hardman engaged the chief painter (Mr Hinckley) and two sons of the glass-painter Robert Henderson, for their skills "in the practical mixture of the yellow and brown stains, and in burning in the kilns."[4]

Pugin's desire to faithfully recreate the medieval style in stained glass led him to set up the workshop with Hardman, that he might "have his glass executed more immediately under his own care, and the direction of one whose views for the progress of medieval art were entirely in accordance with his own".[4] Pugin

[1] Eatwell and Gosling, 2004.
[2] Powell, 1866: 523; Fisher, 2008: 17.
[3] Fisher, 2008: 63.
[4] Powell, 1866: 524.

Figure 10: John Hardman Junior (1811 – 1867), photograph ca. 1860

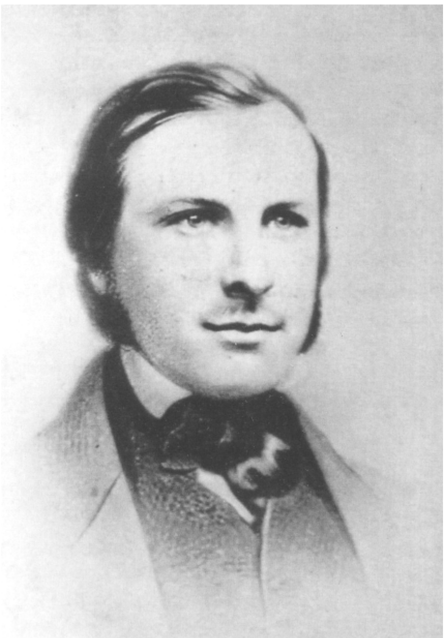

Figure 11: AWN Pugin (1812 – 1852), photograph ca. 1840

was meticulous in following medieval design principles, whether in drawing his own cartoons, supervising those drawn by others, or checking the painted work carried out in the Hardman studio.[5] His study of medieval windows led him to realise, very early in the enterprise, that the glass available at that time bore little resemblance to the richness of colour available to medieval glaziers. Between 1845 and 1849 Hardman obtained glass from suppliers local to Birmingham: William Perks, Smith and Pearce and Lloyd and Summerfield;[6] however, in 1849 James Hartley & Co of Sunderland became their major glass supplier,[7] beginning a close working relationship that would continue for many years. At Hardman's and Pugin's request, Hartley carried out many experiments attempting to produce glasses, especially ruby and white, which would match samples of old glasses acquired by Pugin.[8] At around the same

[5] Shepherd, 2009: 43–50.
[6] Shepherd, 2009: 36; BA&H MS175A/4/3/6/1.
[7] BA&H MS175A/4/3/6/4.
[8] Fisher, 2008: 67; Shepherd, 2009: 51–58.

time, the antiquarian Charles Winston was also carrying out experiments with the glassmaker Powells of London, and with similar results;[9] although Winston's work is rather better known, Hartley's work no doubt contributed to Pugin and Hardman's early success.

After Pugin's untimely death, his pupil and son-in-law (and John Hardman's nephew) John Hardman Powell (1827 – 1895) took over as chief designer for stained glass.[1] Powell continued to design in the Pugin tradition, while developing his own rather softer and more expressive style.[10] Hardmans was a prolific producer of stained glass windows in the later nineteenth century, installing over 1800 windows between 1866 and 1900,[11] including commissions as far afield as America, Canada and Australia.[12] As a major producer, Hardmans was also a major employer of artists, designers and craftsmen; in 1866 Powell wrote "For the last few years as many as from 80 to 100 hands have been employed, and in nearly every instance Birmingham youths have been taken as apprentices".[13]

Powell was succeeded as chief designer by his son, Dunstan John Powell (1861 – 1932).[1] The last member of the Hardman family to be involved in the firm, John Tarleton Hardman, retired in 1936;[14] the firm continues today (under the ownership of Neil Phillips) as Pugin, Hardman and Powell, with premises in Frederick Street in Birmingham's 'Jewellery Quarter'.

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[9] Harrison, 1980: 23.
[10] Eatwell and Gosling, 2004; Fisher, 2008: 81.
[11] Fisher, 2008: 83.
[12] Fisher, 2008: 142–47.
[13] Powell, 1866: 525.
[14] Fisher, 2008: 158.

The Hardman Archive

Following a fire at the Hardman premises in 1970, a substantial (though not complete) archive of material was acquired by Birmingham City Council.[15] It is now housed partly at Birmingham Archives and Heritage, in Birmingham Central Library (the written records) and partly at Birmingham Museum and Art Gallery (graphic material, including designs, cartoons and warehouse books). The written records have recently been re-catalogued by Birmingham Archives and Heritage, greatly facilitating access to this important collection. Unfortunately the material held by Birmingham Museum and Art Gallery remains un-catalogued, and the condition of the cartoons in particular is such that these remain effectively inaccessible (Figure 12).

Figure 12: The Hardman cartoons at the Birmingham Museum and Art Gallery off-site store

The major archive records consulted at Birmingham Archives and Heritage during this study were:

- Glass Sales Day Books (1845-54 and 1863 onwards)
- Glass Letters (incoming) (1845 onwards)

[15] Fisher, 2008: 214.

- Glass Copy Letter Books (outgoing) (1865 onwards)
- Glass Purchase Invoices (1845-51) and Purchase Ledgers (1912 onwards)

At Birmingham Museum and Art Gallery, the Warehouse Books (small scale drawings as a record of the windows on completion) and the collection of designs were examined. These collections, and the cartoon collection, run from 1866 onwards.

Case studies

Three windows made by John Hardman and Company during the nineteenth century will be described in detail: the West Window of Sherborne Abbey (1851, removed 1997), the West Window of Beverley Minster (1859 and 1865) and the North Transept window of All Saints Church, Emscote, Warwick (1889, removed 1967). Other Hardman windows in these buildings will also be introduced as supporting information.

Sherborne Abbey

The Abbey Church of St Mary, Sherborne, Dorset, was established in the eighth century, although the present building dates to the twelfth century. Rebuilding and remodelling continued until the fifteenth century; following the Reformation the building was used as a hospital and then as a private house. The Abbey underwent a major restoration between 1849 and 1858 under the architect R C Carpenter, during which a number of stained glass windows were commissioned from John Hardman and Company.[16]

[16] RCHME, 1952: 200; Shepherd, 1994-5: 316.

Figure 13: Sherborne Abbey

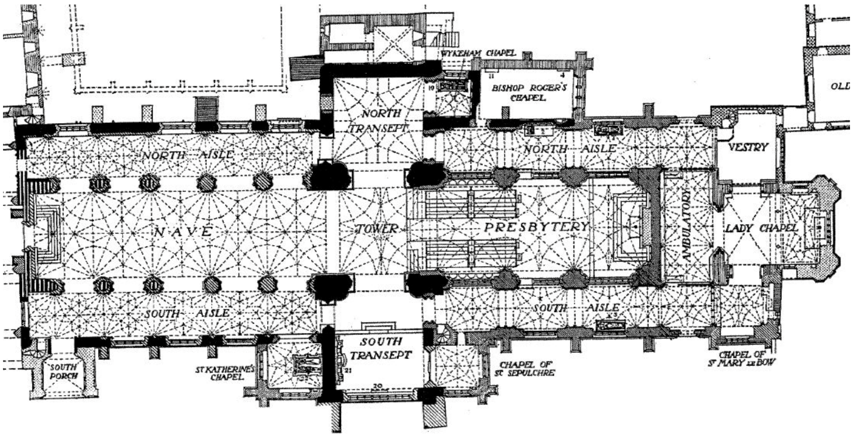

Figure 14: Ground plan of Sherborne Abbey

The first Hardman Glass Sales Day Book (November 1845 – January 1854) includes the windows ordered by Carpenter for Sherborne:

> A large West Stained Glass Window of 27 lights and 85 pieces of tracery £301 (June 12, 1851)[17]
>
> 3 windows of Stained Glass for North Aisle of 4 lights each £210 (July 23, 1851) Subjects in above 3 windows The Twelve Apostles[18]
>
> 1 window of Stained Glass subject groups for South Transept of 4 lights £70 (July 23, 1851[18] [note: this actually refers to a fourth North Aisle window]
>
> A Stained Glass Transom Window of 8 lights and tracery, for South Transept Window £320 (April 19, 1852) Subject The ‘Te Deum’[19]

[17] BA&H MS175A/4/3/7/1: 118.
[18] BA&H MS175A/4/3/7/1: 119.
[19] BA&H MS175A/4/3/7/1: 143.

Correspondence between Pugin and Hardman shows the direct involvement of Pugin in the design of these windows, with the cartoons for the west window being drawn by Frederick Hill and John Hardman Powell.[20] The difficulty of fulfilling the large order in the short time demanded by Carpenter, as well as the relative inexperience of Powell in preparing the cartoons, is also clear from these letters. However, both Carpenter and Pugin appear to have been pleased with the final results, with Carpenter writing to Hardman "Mr Pugin has written to me to say the work makes a splendid job"; "let me tell you how much I like the Sherborne glass"; "altogether it is very fine".[20]

The West Window of Sherborne Abbey depicts figures of Old Testament Prophets in its 27 main lights, with decorative roundels in the tracery lights (Figure 15). The lack of canopies, which might be expected over the figures, has been explained by the relatively short window lights, making the figures almost fill their openings.[21] The rather repetitive design of the tracery lights was commented upon by Carpenter, who wrote to Pugin that "in the West window the effect is much injured by a row of red stars which glare unfortunately & the people say look like railway signals. I have spoken about this to Hardman who says an alteration shall be made."[22] It is not clear whether any such alteration was in fact made.

[20] Shepherd, 2009: 226.
[21] Shepherd, 1994-5: 319; Fisher, 2008: 75.
[22] Shepherd, 1995-4: 320; Shepherd, 2009: 226.

Figure 15: Sherborne Abbey former West window

Problems of water penetration and paint loss of the West window were noted in the 1970s by the Abbey architect Kenneth Wiltshire, although no actions were taken at that point.[23] A full survey undertaken by Wiltshire in 1989 noted that the leadwork was in poor condition, and there were "a considerable number" of broken and missing glass pieces, leading to "appreciable water penetration"; in addition, "many of the faces, inscriptions and swags can no longer be read".

[23] Wiltshire, 1995: 1.

The supporting masonry was also reported to be in need of considerable repair. Wiltshire offered four (costed) options for the window: A to clean, repair and re-instate; B to add backplates to strengthen the missing painted detail to “enable it to be fully and properly ‘read’ as originally intended”; C and D to replace the window with a new one, either following a competition for the design or to commission a particular artist.[24] It is interesting to note that the estimated costs for repair are around one third of those for replacement; however, the parish decided that they would prefer to replace the West window rather than incur “substantial expense on a window that we felt was of no spiritual significance and, it seemed to us, of little aesthetic significance either”.[25] The commissioning process followed, culminating with a design by John Hayward representing the ‘Incarnation’. The Salisbury Diocesan Advisory Committee, while supporting the removal of the existing window, did not support the Hayward design, and so the matter was referred to the Salisbury Consistory Court.[26] The removal of the window was opposed by both the Council for the Care of Churches and the Victorian Society. [27] After a somewhat acrimonious hearing at the Consistory Court, followed by an appeal by the Victorian Society to the Court of Arches, the Vicar and Churchwardens won the case and the right to replace the window.[28] The Pugin-Hardman window was removed and donated to the Worshipful Company of Glaziers; it is now in storage in the London Stained Glass Repository, while the Hayward Incarnation window was installed in the Abbey in 1997 (Figure 16).[27]

[24] Wiltshire, 1989: 1-2.
[25] Earls-Davies, 1995: 3.
[26] Woods, 1995: 5, 7-8.
[27] Hayward, 1997: 95.
[28] All England Law Reports, 1996: 782.

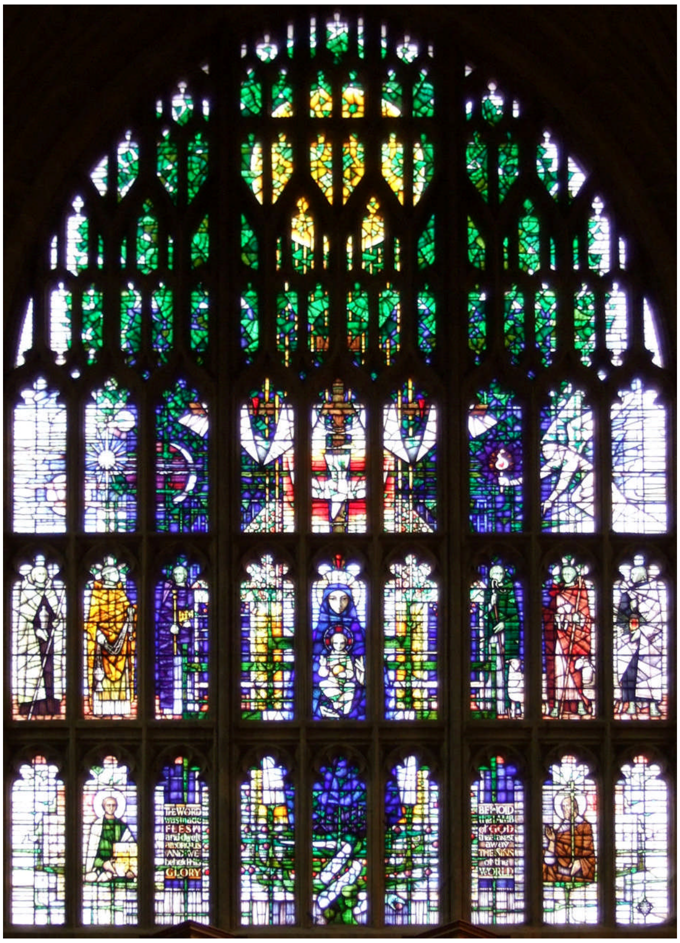

Figure 16: Sherborne Abbey West window: the Incarnation; John Hayward, 1997

Several of the expert witnesses testifying in the Consistory Court Case offered opinions as to the cause of the loss of paint from the Hardman window, resulting in the reported difficulty of 'reading' the window. Alf Fisher (stained glass consultant) stated that "the vast mass of paint, at least 80%, is disastrously and irretrievably lost"[29], due to "underfiring of the paint, the addition of borax, or more likely a combination of both".[30] Agnes Holden (Victoria and Albert Museum) stated that the "paint has suffered considerable loss both to the line work and the modelling" such that "reading the iconography and identifying particular prophets is now impossible", also suggesting that the loss is "due to

[29] Fisher, 1995: 5.
[30] Fisher, 1994: 2.

the inclusion of borax" as well as "poor firing of the glass paint".[31] Three main lights and six tracery panels from the West window were made available by the Trustees of the London Stained Glass Repository for examination during this study, and these will be discussed in Chapter 3: Technical Study.

An indication of problems with the painting of these early Hardman windows in Sherborne Abbey appears in correspondence regarding the North Aisle Apostle windows. On 16th September 1865, only 14 years after the windows were installed, the Rev. E Harston wrote to Hardman:

> A curious and mortifying circumstance has happened here with which I feel it right to acquaint you.
>
> A workman employed this week in dusting this Abbey Church disobeyed his orders and dusted the glass of your windows in the North Aisle containing the 12 Apostles – one of whose faces he has entirely obliterated so that nothing now remains but a piece of clear transparent glass where the face should be, showing the wire guard through it from the outside.
>
> I believe you erected these windows in 1850 or 51 during the life of the late Vicar Mr Parsons. And they have stood quite well to this time – and how a workman with a feather brush (clumsy and stupid though he was) could so entirely obliterate the features of S. James, and more or less damage some of the other faces – is a mystery which we cannot understand, assuming that the colouring was burnt in as usual.
>
> Can you at all suggest an explanation of the injury? The man excused himself by saying that the glass was damp, & being a north wall, this is true of the masonry – but how came the pigment to be so easily got off? I shall be glad to hear from you on the subject – and whether you can remedy the damage.[32]

[31] Holden, 1995: 2.
[32] BA&H MS175A/4/3/22/331A

Hardman's reply, dated 18th September 1865, placed the blame firmly on the glass paint used:

> We are exceedingly sorry to hear that the color of the faces of the Apostles at Sherborne has become soft & we will of course make them good. The reason is that about 1850 the seller[?] who had made our color for 12 years previously, became very ill, he did not tell us so but went on supplying us for some months with inferior color, without giving us the least reason to suspect its being changed. It was only after sixty[?] works had been executed that we detected the fault, as at first it appeared all right after the burning. It has been a very serious loss & annoyance to us (as of course we are bound to make all good) & more anxiety to those who had works from us at that period. Our foreman shall come down & make a report when we will arrange to make all necessary repairs.[33]

The "necessary repairs" were made in October 1866, and entered into the Glass Sales Day Book as "Faces, hands and feet of the 12 Apostles restored" [no charge].[34] No indication is made of how the restoration was carried out, but sadly it has proved as impermanent as the original (Figure 17).

Figure 17: Sherborne Abbey North Aisle window n9 showing almost total paint loss

[33] BA&H MS175A/4/3/20/1: 121.
[34] BA&H MS175A/4/3/7/2: 215.

<u>Beverley Minster</u>

According to Bede and the Anglo-Saxon Chronicle, St John of Beverley founded a church at Beverley in the late seventh century and was buried there.[35] The present building, however, dates from the thirteenth century (the eastern arm), with the fourteenth-century nave continuing the 'Early English' style, completed by the fifteenth-century Perpendicular West front.[36] Major restorations were carried out in the eighteenth century, under Nicholas Hawksmoor, and in the nineteenth century, under Sir George Gilbert Scott.[37]

Figure 18: Beverley Minster

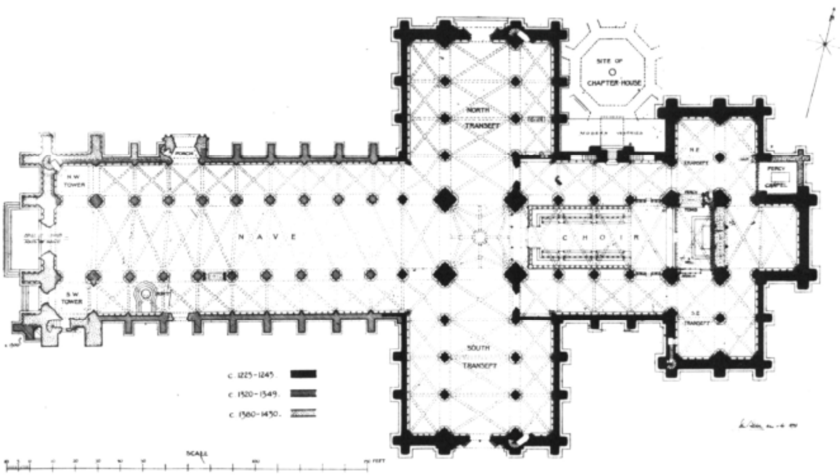

Figure 19: Ground plan of Beverley Minster

[35] Pevsner, 1972: 169.
[36] Miller et al, 1982: 9-10; Heritage Gateway, 2006; Palliser, 2008: 7.
[37] Pevsner, 1972: 171–72; Miller et al, 1982: 11; Palliser, 2008: 7.

The nineteenth-century restoration of the Minster included the installation of many new stained-glass windows, the only remaining medieval glass in the building having already been gathered together into the East window.[38] Between 1857 and 1920 some 14 windows were commissioned from John Hardman and Company, along with others by Clayton and Bell, Ward and Hughes, and Powells of London.[39] Among the earliest Hardman windows, and certainly the largest, is the Great West window, which depicts the early history of Christianity in Northumbria in a combination of scenes and standing figures (Figures 20 and 21).[40]

Although the Great West window was designed (presumably by John Hardman Powell) in 1856,[41] the funds for its creation were raised by public subscription, leading to the unusual situation of the upper half (tracery and upper row of main lights) being installed in 1859, when £550 had been raised,[42] with the lower part being completed in 1865 once the remaining £400 had been collected.[43] Hardman was clearly proud of the design, using the greater mullions to separate the single figures from the groups, such that "each of these groups will come out distinctly as a picture in itself framed as it were by the large figures in the centre and side lights";[44] "I think I may safely say, if it is carried out it will be one of the finest windows in the Country."[41] He also urged "that the whole work go on together and not be done in detached parts, it will then be treated as a whole, whereas if done at different times there is always danger of its suffering from different ideas coming across the mind as from a little different style of

38 Nolloth, 1930: 21; Pevsner, 1972: 174.
39 Pycock, 1996: 6–12.
40 Pycock, 1996: 16; York Glaziers' Trust, 2009: 4.
41 BA&H MS175A/4/3/19/1: 423.
42 BA&H MS175A/4/3/12/7; MS175A/4/3/22/206.
43 BA&H MS175A/4/3/7/2: 170; MS175A/4/3/22/342.
44 BA&H MS175A/4/3/19/1: 421.

Figure 20: Beverley Minster Great West Window

drawing".[45] However, this was not to be, as the full amount could not be raised at once; as the then vicar, the Rev. Day, commented, "No one will give a second donation till they see some of the results of their first generosity";[46] "Our idea is when the public see the longer half done that <u>then</u> they will cheerfully come forward to help to complete" [emphasis in original].[47] With the upper half installed, Rev. Day wrote "to say how much pleasure the window gives. The

[45] BA&H MS175A/4/3/19/1: 473.
[46] BA&H MS175A/4/3/22/144.
[47] BA&H MS175A/4/3/22/186.

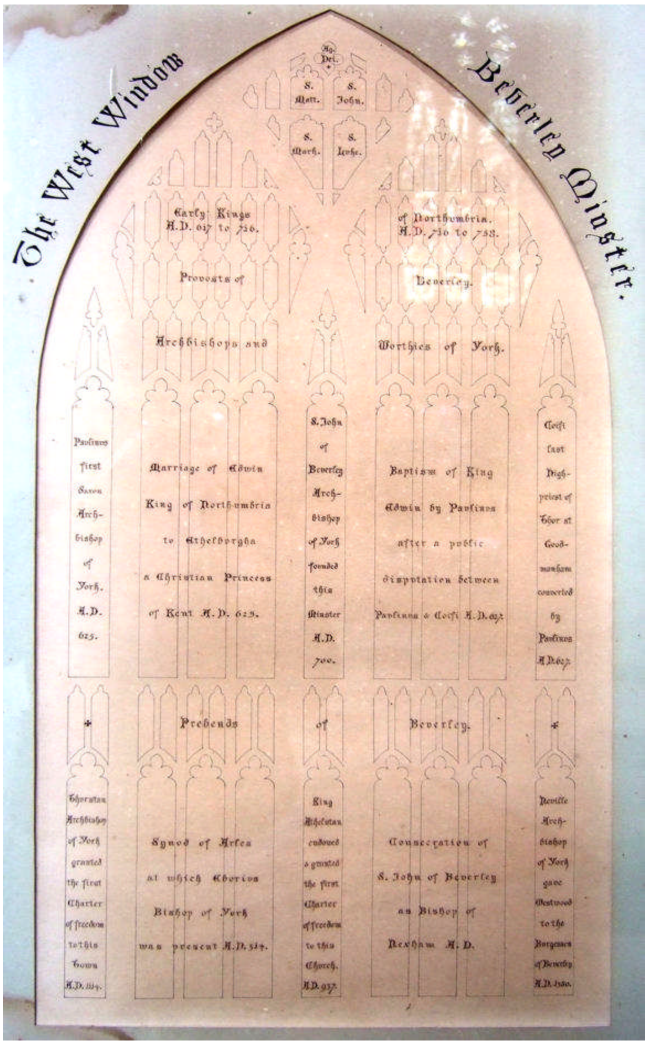

Figure 21: Subjects of Beverley Minster w1 (as displayed in Beverley Minster)

committee (as many as I have seen) all profess themselves as most thoroughly satisfied. ... for colour & general effect as well as beauty of detail we are very much obliged to you."[48] A full colour framed design of the whole window supplied by Hardmans was then used to canvass for further donations;[48] this design was returned to Hardmans in 1865 to assist with the completion of the window,[50] and is now once again held at the Minster.[49] When the window was finally completed in 1865, the then Rev. Trollope wrote that "The window is very much admired, and I think justly so."[50]

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[48] BA&H MS175A/4/3/22/206.
[49] York Glaziers' Trust, 2009: 5.
[50] BA&H MS175A/4/3/22/342.

Later commentators were not always quite so enthusiastic about the West window; Hiatt, in particular, commented somewhat harshly that “In looking at the Beverley [West] window it is only just to remember that it was produced long previous to the revolution in the art of manufacturing stained glass, which we owe to William Morris and Edward Burne-Jones. The glass is good enough of its kind and for its time, but its time was one in which colour in glass was only scarcely under control.”[51] Nolloth, however, wrote that “The great west window, with its rich glass …. forms a fine termination to the [westward] prospect.”[52]

Quinquennial surveys of the fabric of the Minster carried out since 1989 have occasionally noted areas of concern with the glazing, however no detailed survey of the windows was carried out until 2007.[53] The 2007 report highlighted both structural failings within the main lights of the West window and problems with the glass paint, said to be “generally soft with much loss of the trace line across the window giving a ghostly appearance”.[54] A more detailed condition report carried out in 2008 again noted the structural failings, mostly due to the panels being overlapped rather than stacked on top of each other, resulting in a lack of support for the upper panels; over time this has been exacerbated by loss of mortar pointing and breakage of the copper ties which should hold the panels to support bars.[55] These structural problems have resulted in cracks to both lead and glass as well as water penetration to the inside.[56] In addition, the report notes significant loss of painted detail in the lower section of the window, especially evident in the faces and architectural canopies; paint loss from the

[51] Hiatt, 1898: 112-13.
[52] Nolloth, 1930: 20.
[53] York Glaziers’ Trust, 2007: 2.
[54] York Glaziers’ Trust, 2007: 15.
[55] York Glaziers’ Trust, 2008: 2, 4, 6.
[56] York Glaziers’ Trust, 2008: 9, 11.

upper section was “curiously far less advanced”.[57] Suggested reasons for the deterioration were given as the use of “non traditional fluxes” (the use of borax), incompatibility of the glass paint with the glass substrate, “over-zealous cleaning” and glass corrosion, caused by environmental conditions (specifically condensation on the inner glass surface).[58] Possible reasons offered for the difference between the two tiers were differences in the glass or paint used, or different environmental conditions between the two parts.[59] Concern for the condition of the window and its continuing deterioration led to the removal of four panels for more detailed study (including sample analysis) and a conservation trial during 2009; the results of this work will be discussed in Chapter 3: Technical Study.

As mentioned previously, a further 13 windows were commissioned from Hardmans for Beverley Minster, the earliest (1857) and latest (1920) both occupying the south window of the south-west transept (panels from the earlier ‘Jesse’ window being moved to the west wall of the transept to make way for the East Riding War Memorial windows depicting ‘The age-long conflict between good and evil’).[60] Table 1 gives a summary of the Beverley Hardman windows and the condition of their paintwork, taken from the Quinquennial Survey of the windows carried out by the York Glaziers’ Trust in November 2007 (full details in Appendix 1); the ground plan of the Minster with the windows numbered according to the CVMA system is given in Figure 22.

[57] York Glaziers’ Trust, 2008: 11, 12.
[58] York Glaziers’ Trust, 2008: 11.
[59] York Glaziers’ Trust, 2008: 12.
[60] Pycock, 1996: 10; BA&H MS175A/4/3/9/10: 108.

Window no. (CVMA)	Position	Date	Condition (2007)
s17-19	South-west transept, West wall	1857 / 58 / 63	Much paint loss
wl	West window	1859 / 65	Soft paint, much loss (worse in lower 1865 section)
s28	West wall	1870 / 71	Soft paint, extensive loss
n29	West wall	1870 / 71	Soft paint, extensive loss
s20	South aisle	1877	Paint soft, some loss
s21	South aisle	1884	Paint stable, well fixed
s22	South aisle	1889	Paint stable, well fixed
s23	South aisle	1892	Paint stable, well fixed
s24	South aisle	1905	Paint stable, well fixed
s25	South aisle	1905	Paint stable, well fixed
n23	North aisle	1910	Good glossy paint
n28	North aisle	1917	Paint stable, some grizzling
n6	North-east transept, North wall	1918	Good glassy paint
s15	South transept, South wall	1920	Paint stable, some grizzling

Table 1: Summary of Hardman windows in Beverley Minster and their condition[61]

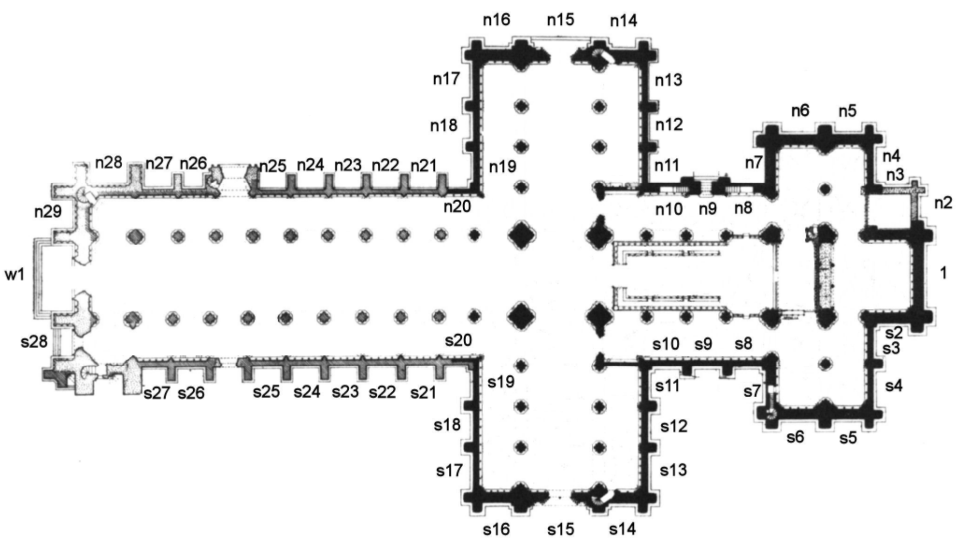

Figure 22: Ground plan of Beverley Minster with windows numbered according to the CVMA system

[61] Pycock, 1996: 7-16; York Glaziers' Trust, 2007: 12-18.

Table 1 clearly shows that all of the earlier windows, created between 1857 and 1877, show paint loss to some degree. In contrast, those windows created after 1884 have stable, well-fixed paint (albeit with some ‘grizzling’, possibly due to over-firing of the paint). This suggests that something changed around 1880; possibly in the window manufacturing process or materials, possibly in the environment of the Minster in which they were installed. Alternatively, it is possible that that the manufacturing process simply improved over time, finally producing durable painted surfaces around 1880.

<u>All Saints’ Church, Emscote, Warwick</u>

All Saints’ Church, Emscote, was built between 1854 and 1856 by the architect James Murray, consecrated in 1861, and originally consisted of a nave with one aisle and small chancel (Figures 23 and 24).[62] The church was much enlarged between 1866 and 1872 with the addition of the north aisle and sanctuary (architects Bodley and Garner), and raising of the roof to insert the clerestory in 1873; these and many other additions to the fabric of the church were funded largely by donations from Miss Marianne Philips (Figures 25 and 26).[63]

Between 1860 and 1923, stained glass was installed in 16 windows at nave level and 7 windows in the clerestory.[64] Of the nave windows, 12 windows as well as 2 single lights (each in 2-light windows where the other light was already filled with glass by Heaton and Butler) were commissioned from John Hardman and Company, including the 4-light West window (depicting ‘All Saints’) and the two 4-light transept windows (a ‘Jesse’ tree in the North transept and ‘The sealing of the souls’ in the South transept). The East window was by Clayton

[62] Pevsner, 1966: 451; Burr and Rowbotham, 1915: 3.
[63] Pevsner, 1966: 451; Burr and Rowbotham, 1915: 9.
[64] WCRO DR224/61; BA&H MS175A/4/3/7/2 – 6; BA&H MS175A/4/3/9/11.

Figure 23: All Saints' Church, Emscote ca.1860

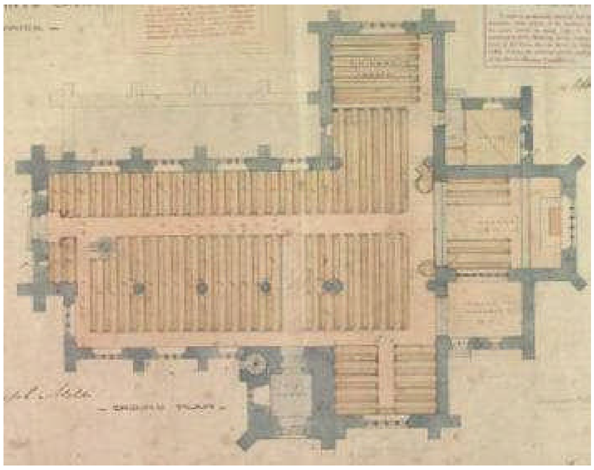

Figure 24: Original ground plan of All Saints' Church

Figure 25: All Saints' Church, Emscote, ca. 1961

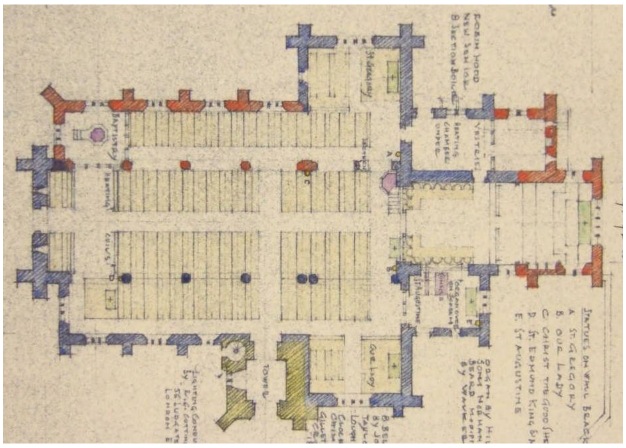

Figure 26: Ground plan of All Saints' Church, 1958

and Bell and the clerestory windows all by Heaton and Butler. A summary of the Hardman windows, their subjects and dates, is given in Table 2 (full details in Appendix 1) and a ground plan with the windows numbered according to the CVMA system in Figure 27.

Window no. (CVMA)	Position	Date	Subject
s2 light a	Chancel, South wall	1923	Crucifixion
s3	Chancel, South wall	1884	St Peter and St Thomas of Canterbury
s6	South transept	1889	Sealing of the souls
s8	South aisle	1874	St Edward and St Dubritius
s9	South aisle	1885	St Frideswide, St Alban and St Etheldreda
s10	South aisle	1871 (a and c) / 1885 (b)	St Chad, St Edmund and St Cuthbert
w1	West window	1871	All Saints
n2 light b	Chancel, north wall	1870	Our Lord treading the wine-press
n7	North transept	1889	Tree of Jesse
n8	North transept	1885	St Gregory the Great
n9	North aisle	1875 (b) / 1878 (a and c)	St Aidan, St Columba and St Ninian
n10	North aisle	1884	St David, St Edith and St Winifride
n11	North aisle	1877	Venerable Bede, St Germanus and St Dinoth
n12	North aisle	1871	Martyrdom of St Andrew, St Thomas and St Peter

Table 2: Hardman windows made for All Saints' Church, Emscote[64]

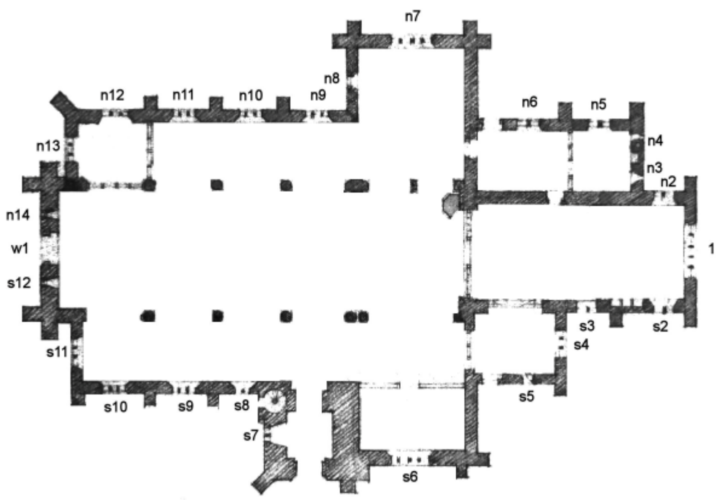

Figure 27: Ground plan of All Saints' Church, Emscote with windows numbered according to the CVMA system

The sheer number of Hardman windows installed in the church, as well as several additional designs for figures which were apparently not used (Figure 28), suggest that the relationship between Hardmans and the vicar of Emscote, the Reverend Thomas Bourne Dickins, was an important one for both parties. Dickins seems to have donated several of the windows himself, with others donated by the parishioners either as a group or individually, notably Miss Philips (the West window) and Mr G H Nelson (the two Transept windows, in memory of his parents).[65] In several cases memorial inscriptions were inserted into windows some years after their original creation, leading to some confusion in the guide books as to their dates and donors. Fittingly, the last window to be installed (the Crucifixion in Chancel window s2, 1923, Figure 29) was a memorial to the Rev Dickins from his daughter Gertrude Amelia, sited opposite the earliest Hardman window (Our Lord treading the Wine-Press in Chancel window n2, 1870, Figure 30), a memorial from the Rev Dickins to his eldest son Thomas B T Dickins.[66]

[65] Burr and Rowbotham, 1915: 4 – 8.
[66] BA&H MS175A/4/3/7/2: 598; Burr and Rowbotham, 1915: 4; BA&H MS175A/4/3/9/11: 158.

Figure 28: Various designs of figures for the nave aisle windows

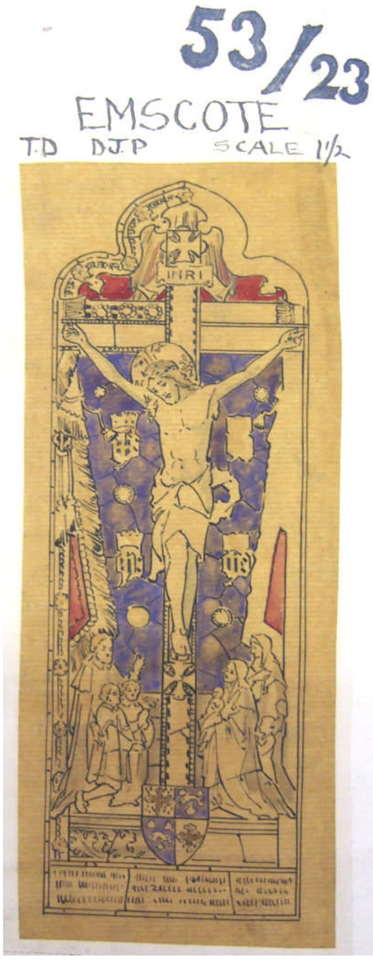

Figure 29: s2 light a, Crucifixion (1923) as recorded in the Hardman Warehouse book

Figure 30: n2 light b, Our Lord treading the Wine-Press (1870) as recorded in the Hardman Warehouse book

Unfortunately the many later additions to the original church building seem to have caused structural problems. As early as 1922 an 'Urgent Appeal' was launched to raise £2,000 for repairs to the tower,[67] and in 1960 the church architects stated that "The building construction is faulty throughout; demolition and rebuilding would be recommended if this were practicable. The alternative is unceasing maintenance with the intention of gaining on the decay".[68] The second Quinquennial Report in 1963 noted that the condition of the walls still

[67] WCRO DR224/70/4.
[68] WCRO DR465/1.

gave cause for anxiety; however, “The windows are in reasonably good order”.[68] The church was demolished in 1967 and the windows dispersed to St Chad, Smethwick; Salford Priors; St John, Swansea; Dusson of Borley; Silvester of Warwick; Buttery of Uttoxeter and All Saints Junior School.[69] Mr Buttery, now of York, has the two 4-light transept windows (Figure 31) as well as several smaller panels; two panels were made available for examination in this study and will be discussed in more detail in Chapter 3: Technical Study.

Figure 31: South and North Transept windows for All Saints’ Church, Emscote as recorded in the Hardman Warehouse book

[69] WCRO DR553/3.

Hardman's glass paint suppliers

Hardman's reference to his supplier of 'color' in his letter regarding the Apostle windows at Sherborne suggests that the company bought in their glass paints rather than making their own. Unfortunately the records of purchase orders in the Hardman Archive are rather incomplete; bundles of purchase orders survive from 1845–51, then the first surviving bound Purchase Ledger is Volume 18, 1912–18. Suppliers in the intervening period can only be surmised from correspondence.

Purchase invoices between 1845 and 1848 show Hardman's main supplier of glass paint to be Wm H Pankhurst, China, Glass and Earthenware Colour Manufacturer of Hope Street, Shelton. In September 1847 Pankhurst invoiced for 16 lbs Best Black for Glass, 24 lbs Brown Shaddow and 2 lbs Flux for Glass; in March 1848 for a further 22 lbs Brown Shaddow and 4 lbs Black.[70] However, Pankhurst seems often to have suffered from financial difficulties; the Hardman archive contains many letters begging Hardman to make payments and to buy colours from him. In September 1847 Pankhurst urged Hardman to pay his invoice, writing "Nothing but poverty would induce me to write you for payment for colour sent you on Tuesday last …".[71] In 1848 a Mr Williams of Hanley wrote on Pankhurst's behalf to ask Hardman to make payment for paint sent over and above an order made: "Mr Pankhurst and his family are in distress and I have rendered them pecuniary assistance, and he has asked me for further aid…".[72] In 1851 Pankhurst wrote "I have taken the liberty of sending you 10 lbs Brown Shaddow as you have formerly had from me and I hope you will forgive me for so doing – it is a very long time since I was favoured with an

[70] BA&H MS175A/4/3/6/2 and MS175A/4/3/6/3.
[71] BA&H MS175A/4/3/22/3.
[72] BA&H MS175A/4/3/22/5.

order from you … I am greatly in need of cash – your kindness will ever be remembered …”.[73] It is not clear whether or not Hardman ever made payment for this colour, but there is no further correspondence from Pankhurst in the archive after 1851. It seems likely, however, that Pankhurst was the supplier blamed by Hardmans for the ‘inferior color’ used at Sherborne.

The reason for Hardman’s no longer favouring Pankhurst with orders seems to be the arrival of Francis Emery of Cobridge as a new colour supplier. Emery introduced himself by letter in June 1849, enclosing samples and a price list, and stating that he had “for some time supplied to Messrs Ballantine & Allan of Edinburgh, Mr Spence of Liverpool, the St Helens Glass Company Lancashire and others”.[74] Emery’s prices were somewhat lower than Pankhurst’s, and orders for Purple Brown and Auburn Brown were placed in 1849, 1850 and 1851.[75] The correspondence file indicates occasional problems with the supplied colours; letters of 1854 mention problems with the firing of Dark Brown No 3,[76] and in 1857 problems with Brown Shade No 2.[77] At this time Francis Emery was very ill, and confined to the house for long periods; by 1858 his son Joseph P Emery had taken over the firm, which by 1860 was known as ‘Emery and Son’ (although Francis had died by then, probably in 1858).[78] There were problems with a batch of Glass Black supplied in 1860, which “burns so very differently” from that supplied previously. Thereafter correspondence is confined to acknowledgements of orders and payments, with Emery and Son doing well enough to have printed their own memorandum and letterhead (Figure 32). Changes in their products are evident from a letter of June 1871,

[73] BA&H MS175A/4/3/22/51.
[74] BA&H MS175A/4/3/22/11.
[75] BA&H MS175A/4/3/6/4, MS175A/4/3/6/5 and MS175A/4/3/6/7.
[76] BA&H MS175A/4/3/22/103.
[77] BA&H MS175A/4/3/22/166.
[78] BA&H MS175A/4/3/22/166, MS175A/4/3/22/187, MS175A/4/3/22/228.

Figure 32: Emery and Son letterhead from 1871

enclosing samples and stating that “Some of the colors may p’raps be too hard for your purpose so we have sent samples of two soft fluxes which will soften the colors & most likely make them suitable”.[79] This suggests either that Hardmans preferred softer colours (which would fire at a lower temperature) than other stained glass workshops, or that Emery was sending unmodified ceramic colours (which would fire at a higher temperature). The correspondence becomes very sparse after 1872, although occasional letters confirm that Emery continued to supply Hardmans with glass colours.[80]

In April 1870 Hardmans wrote to Hancock and Son, Diglis Color Works, Worcester, requesting samples of “warm shades”, in particular Amber.[81] The samples received were “quite what we wanted”[81] and presumably Hancocks then began supplying Hardmans, although evidence for this is scanty; letters of 1873, 1874 and 1877 from Hancocks refer to orders filled.[82] By 1912-18 Hardmans were still buying “glass colours” from Emery and “colours and stains”

[79] BA&H MS175A/4/3/22/457.
[80] BA&H MS175A/4/3/20/15.
[81] BA&H MS175A/4/3/20/6.
[82] BA&H MS175A/4/3/22/505A, MS175A/4/3/22/528B, MS175A/4/3/22/595A.

from James Hancock & Son.[83] However, they were also buying flux, oxides and silver sulphide from local Birmingham companies Alex E Tucker and P Harris & Co,[84] suggesting that Hardmans were making, or attempting to make, their own glass paints by this time. Perhaps Hardmans were trying to mimic Emery or Hancock colours, as suggested by an invoice from Tucker for "Analysing no. colours".[85]

It is interesting to note that the early suppliers of glass paints to Hardmans, Pankhurst and Emery, were based in the Staffordshire Potteries area and were presumably, therefore, also supplying colours to pottery and porcelain manufacturers; the colours used for glass and ceramics are very similar in terms of their composition and manufacture. Both firms were also relatively local to Hardmans (in Birmingham), as were many of their other suppliers (with the notable exception of Hartley & Co glassmakers in Sunderland).[86] An advertising and trade journal of 1893 noted the "high and entirely reliable character of the productions which emanate from [Emery's] Waterloo Colour Works, Cobridge … at the present day no individual in the trade holds a higher character for the quality of its goods".[87] Emerys were still in business by the mid-twentieth century, as shown by paint samples dating from the 1940s (Figure 33).

[83] BA&H MS175A/3/2/2/1: 181–82.
[84] BA&H MS175A/3/2/2/1: 103, 118.
[85] BA&H MS175A/3/2/2/1: 103.
[86] Fisher, 2008: 67.
[87] Anon, 1893: 63.

Figure 33: Samples of glass paint from Joseph P Emery Ltd, dating from the 1940s

Hancock & Son would presumably have been supplying colours to the Worcester porcelain manufacturers but also had their origins in Staffordshire, John Hancock having started out making colours for Wedgwood.[88] Hancocks were later taken over by Johnson Matthey & Co. Ltd, as shown by the packaging of paint samples from 1939 and 1947 (Figures 34 and 35).

Figure 34: Hancocks Glass Shading Brown H986, distributed by Johnson Matthey (1939)

Figure 35: Johnson Matthey Glass Shading Brown H986 (1947)

[88] Hancock, 1881?: v.

Historical glass paint recipes

Although the Hardman archive shows that Hardmans were mainly buying glass paint from colour suppliers, rather than experimenting with their own recipes, it does not give any detail as to the composition of the paints they were buying. However, there are many surviving publications related to the art and craft of stained glass, such as Neri's *L'Arte Vetraria* (Florence, 1612), translated by Merret as *The Art of Glass* (London, 1662), and especially Le Vieil's *L'Art de la peinture sur verre et de la vitrerie* (Paris, 1774).[89] It may therefore be instructive to study English publications of glass paint recipes from the nineteenth century and earlier, in order to gain some insight into the knowledge of the time.

As explained in the introduction, glass paint is generally composed of metallic oxides (pigments) in combination with a low-melting glass powder (flux), such that, when fired in a kiln, the flux particles fuse to the surface of the substrate glass, holding the pigment particles in place. This basic composition was unchanged from early medieval times to the late seventeenth century; the twelfth-century monk Theophilus described the use of a mixture of equal parts of copper metal, green glass and Byzantine blue glass (probably a lead glass), ground fine and mixed with wine or urine.[90] The 1699 translation of Haudicquer de Blancourt's *De l'art de la verriere* described the use of 'rocaille' as a flux, being a lead glass prepared from 'fine white sand' (silica) and 'minium' (red lead), fused in varying proportions between 1:3 and 3:1.[91] Blancourt gave a single recipe for black glass paint, being 3 parts ground scales of iron from the

[89] Caen, 2009: 82-83; Schalm, 2000: 16-17.
[90] Hawthorne and Smith, 1979: 63.
[91] Blancourt, 1699: 278-79.

black-smith's anvil with 1 part rocaille and a little calx of copper (copper oxide).[92]

In the eighteenth century, the development of enamel colours for porcelain, metal and glass led to the amalgamation and adaptation of recipes from these various fields. Dossie's 1758 publication *The Handmaid to the Arts* promised to teach "A perfect knowledge of the materia pictoria: or the nature, use, preparation, and composition, of all the various substances employed in painting … including those peculiar to enamel and painting on glass".[93] Dossie described two fluxes, equally of use for enamelling and glass painting: Flux number 1 ("moderately soft" and "very cheap"), composed of 1 pound lead glass, 6 oz pearl ashes (similar to potash or potassium carbonate) and 2 oz sea salt (sodium chloride); and Flux number 2 ("soft flux for common purposes"), composed of 1 pound lead glass, 6 oz pearl ashes, 4 oz borax (sodium borate) and 1 oz arsenic.[94] Dossie explains the use of borax, stating that "Borax is a salt of very peculiar qualities; amongst which, is that of promoting vitrification, and the fusion of any glass when vitrified, in a greater degree than any other substance known … Its use is not much known in common practice; though of the greatest consequence to the art of enamelling; as … a set of softer colours may be produced by the aid of it, than can be otherwise had …"[95] Thus, the addition of borax, and to a lesser extent pearl ashes, sea salt, and arsenic, would form a softer flux (which would therefore fire at a lower temperature) than lead glass (made from 2 pounds red lead to 1 pound flint powder or white sand)[94] alone. A black paint could be made by combining 6 parts of either flux

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[92] Blancourt, 1699: 273.
[93] Dossie, 1758: title page.
[94] Dossie, 1758: 275.
[95] Dossie, 1758: 245-46.

with 1 part of zaffer (cobalt oxide) and small amounts of glass of antimony, scarlet ochre and magnesia.[96]

In the early nineteenth century, as interest in stained glass increased, so did the publication of glass paint recipes, both in terms of the number of publications and the number of recipes included in each publication. Wynn's 1818 *Receipts for enamel colours* listed eight recipes for flux (Table 3) and two recipes for black paint, both based on iron and cobalt oxides. Wynn also noted that the colours must be adapted to match the level of heat required for the particular substrate glass to be used; thus the mixed colours could be made harder by adding more of the oxides, and made softer ("or to shine more when burnt") by adding more flux, especially a very soft flux "such as No. 8".[97]

Flux No. 1	Red lead	8 parts	Flux No. 5	Flint glass	6 parts
	Calcined borax	1½		Flux, No. 2	4
	Flint powder[98]	2		Red lead	8
	Flint glass[99]	6			
No. 2	Flint glass	10	No. 6	Flux, No. 2	10
	White arsenic	1		Red lead	4
	Nitre[100]	1		Flint powder	1¼
No. 3	Red lead	1	No. 7	Flux, No. 4	6
	Flint glass	3		Colcothar[101]	1
No. 4	Red lead	9½	No. 8	Red lead	6
	Borax not calc.	5½		Borax not calc.	4
	Flint glass	8		Flint powder	2

Table 3: Flux recipes given by Wynn[102]

[96] Dossie, 1758: 300-1.
[97] Wynn, 1818: 264.
[98] Flint, calcined and powdered; silica. Wynn, 1818: 264-5.
[99] Lead-potash glass; 3 parts sand, 2 parts lead oxide, 1 part potash. Pellatt, 1849: 34.
[100] Potassium nitrate, also known as saltpetre.
[101] Brown iron oxide.
[102] Wynn, 1818: 267.

All of Wynn's fluxes are based on lead glass, with Flux No. 3 being a version of 'rocaille'. Additions of borax, arsenic and nitre were made to soften the fluxes; the large number of recipes given reflects the fact that Wynn was reporting his "most valuable selections from the experience and labours of above twenty years".[97] Different fluxes were suggested for different colours, with Flux No. 4 suggested for black and brown shades.

Wynn's publication also contains an early warning regarding the use of borax, made in an editorial comment at the end of the article by Mr A Tilloch:

> In the foregoing communication borax is mentioned as an ingredient in the composition of the fluxes. It does give them very easy fusion, but we should fail in our duty did we neglect to caution artists against a profuse use of this flux. It can hardly be employed in any quantity whatever without danger to the durability of the work; having a great tendency to effloresce in the atmosphere. Indeed this can hardly, if at all, be prevented where borax enters the composition of colours used for painting on glass.[103]

In 1832, Porter's *Treatise on the Origin, Progressive Improvement and Present State of the Manufacture of Porcelain and Glass* was published as part of *Dr Lardner's Cabinet Cyclopedia*, and was cited by Charles Winston as "a small but clever popular work".[104] Study of the Bristol glass-painter Joseph Bell's notebooks has shown that he was using Porter's *Treatise* as a source for recipes.[105] Porter noted the similarity between the materials and methods used for painting on porcelain and on glass,[106] and commented on the unreliability of many previously published works.[107] He went on to recommend

[103] Wynn, 1818: 276.
[104] Winston, 1867: 15.
[105] Cheshire, 2004: 108.
[106] Porter, 1832: 292.
[107] Porter, 1832: 293.

> A fluxing compound, very generally used, is made by the union of thirty-two parts of flint glass with twelve parts of pearl-ash, and two parts of borax; which composition will fuse at a medium heat. If it should be required to render this more fusible, such an effect may be gained either by substituting for the pearl-ash four parts of red oxide of lead, or by increasing proportionally the dose of borax; and if, on the other hand, it is desired to produce a hard flux, this end may be attained by omitting the borax altogether, and adding an equal quantity of common table salt.[108]

The composition of these fluxes is similar to those suggested by Dossie, discussed above. Porter stressed the need to match the fusibility of the flux to the particular oxide used, "that the flowing of all in fusion may take place as nearly as possible together."[108] For outlines and shading, Porter recommended use of "the saffron-coloured oxide of iron" ground with "an equal weight of soft flux".[109]

In the 1840s, two German publications on glass painting and staining were translated into English for publication in *Weale's Quarterly Papers on Architecture*, and again cited as sources for enamel compositions by Winston.[110] Gessert's *Rudimentary treatise on the Art of Painting on Glass or Glass-Staining* (1844) distinguished between 'fused' and 'mixed' colours, that is, colours in which the flux and oxide are melted together before application (commonly known as enamel colours) and those in which the flux and oxide are simply mixed (commonly known as grisaille or black glass paints).[111] Gessert recommended different fluxes for different colours, with six different fluxes given in the fourteen recipes just for black mixed colours; these are summarised in Table 4.

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[108] Porter, 1832: 294.
[109] Porter, 1832: 296.
[110] Winston, 1867: 18.
[111] Gessert, 2000: 6.

Art. 15	Crystallized borax Minium [red lead] Pounded glass	1 part 1 1	Art. 20	Sand Litharge Borax	1 3 ⅓
Art. 17	Lead glass Gum arabic	2 ¼	Art. 21	Sand Litharge Borax	1 part 2¾ ⅜
Art. 18	Pure white sand Litharge [lead oxide]	1 3	Art. 22	Sand Litharge Borax	1 2 ¼

Table 4: Fluxes for black mixed colours given by Gessert[112]

The flux recipes given in Articles 20 – 22 are all variants of that in Article 18 (itself comparable to 'rocaille'), although it is worth noting that Gessert directed the borax to be added as a powder to the powdered lead glass, rather than being melted with it. The associated recipes for black colours used oxides of copper, iron, manganese, cobalt and antimony in various combinations.

Fromberg's *Rudimentary essay on the Art of Painting on Glass* (1845) also distinguished between pigments coloured by mixture and by combination,[113] and advanced complex theories as to the correct composition of fluxes such that the expansibility of the paint matched that of the substrate glass. Three general-purpose fluxes for pigments coloured by mixture are given (Table 5).

[112] Gessert, 2000: 9-12.
[113] Fromberg, 2000: 15.

No. 1	Silica	1 part	No. 3	Silica	2 parts
	Oxide of lead	3		Oxide of lead	6
				Calcined borax	1
No. 2	Silica	3			
	Oxide of lead	8			
	Calcined borax	1			

Table 5: Flux recipes for pigments coloured by mixture given by Fromberg[114]

Fromberg commented that Flux No. 1 is identical to Blancourt's 'rocaille' and that "it was formerly used as a glaze for common pottery-ware";[114] however, he advised that Flux No. 2 or No. 3 should be preferably used, having greater stability.[115] Fromberg gave three recipes for black paint; iron oxide alone, a mixture of copper, manganese, cobalt and iron oxides, or a mixture of copper, iron and manganese oxides; each mixed with powdered flint glass or flux.[116]

Thus, it is clear that the nineteenth-century glass-painters were using a much wider range of materials, as well as more complicated mixtures, than their medieval predecessors, both in terms of the metal oxides used as pigments and, particularly, of the fluxes. Lead silicate glasses of varying compositions still formed the starting point, but additions of borax, pearl-ashes, common salt, arsenic and nitre were common. The relative amounts of oxides and flux in the glass paint mixture also varied widely. When combined with the variability in composition of naturally-occurring starting materials, as well as relatively crude manufacturing processes, the variation in composition of different batches of paint, not to mention the variation between manufacturers following different recipes, must have been considerable; and would have had significant effects on the firing process.

[114] Fromberg, 2000: 21.
[115] Fromberg, 2000: 22.
[116] Fromberg, 2000: 67.

Firing painted glass

Once prepared, the painted glass must be fired to fuse the paint to the base glass. The firing process is critical to the permanence of the colour; as Hancock stated, "However well colours for glass are made, one precaution must be kept constantly in mind: they *must be fired well*" [emphasis in original].[117]

Blancourt described a furnace suitable for firing painted glass (Figure 36). The painted glass was placed in an earthen pan with the fire built below it, and chimney above, such that the smoke and flames were drawn around the pan.[118] The fire was built of charcoal, and the heat was increased until the colours on trial pieces placed in the furnace were judged to be sufficiently melted. The fire would then be continued for "twelve or fourteen hours", then left to go out and the furnace cooled.[119]

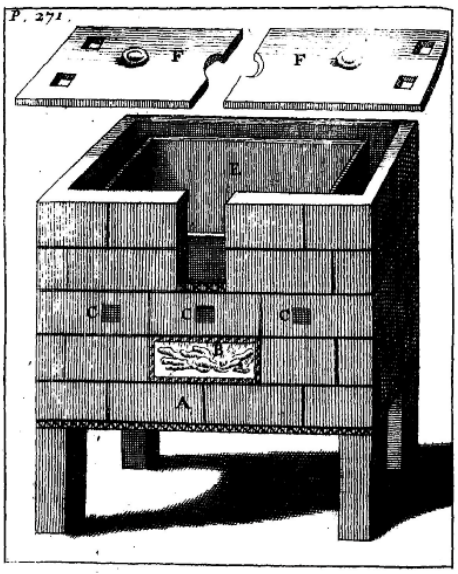

Figure 36: Blancourt's furnace for firing glass

Dossie suggested the use of a 'coffin' or 'muffle' inside the furnace to hold the painted glass, allowing for its inspection or removal without opening the door of

[117] Hancock, 1881?: 122.
[118] Blancourt, 1699: 271-72.
[119] Blancourt, 1699: 284-85.

the furnace.[120] Porter directed that the muffle and furnace should have a viewing tube “to examine the state of the glass from time to time during the process of firing” and that the fire should be managed so as to slowly achieve a dull red heat of the glass in the centre of the kiln, and then increased “so that the whole contents of the kiln may be made to acquire a uniform white heat”.[121] Gessert suggested the use of ‘watchers’, small pieces of glass placed vertically at the top of the kiln, which would begin to bend once the kiln had reached a sufficient heat.[122] Fromberg described the correct temperature as “a moderate cherry-red heat”, noting not only that the appearance of cherry-red might be altered by the surrounding light level, but also that any test pieces placed in the muffle would only give an indication of the temperature in that area, not necessarily elsewhere in the muffle.[123] Fromberg does, however, describe the use of a pyrometer, developed by Wedgewood and Brogniart for the improved control of their porcelain firing kilns.[124]

In addition to the control of the temperature of the furnace, the fuel used in the fire may have had an effect on the firing. Dossie noted that the use of a coffin or fixed muffle inside the furnace allowed the use of pit coal as fuel, being cheaper than charcoal; “but where the open muffle is used, charcoal alone should be employed: as the fumes of mineral coal are very detrimental to some colours”.[125] Similarly, Porter stated that it was usual to use coke or charcoal, as coal contained sulphur and “might have an evil effect upon the colours”.[126] Hancock described two pieces of glass, painted by the same hand and with the

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[120] Dossie, 1758: 234.
[121] Porter, 1832: 302-3.
[122] Gessert, 2000: 59.
[123] Fromberg, 2000: 93.
[124] Fromberg, 2000: 94.
[125] Dossie, 1758: 307.
[126] Porter, 1832: 303.

same colour; in one case, the glass was poor and had deteriorated while the colour was perfectly sound, and in the other, the glass was good while the colour was "full of holes, and partly eaten away".[127] In this second case, the "colour had not had sufficient fire, or had been sulphured in the burning".[127] Thus the firing process, as well as the glass paint used, is of great importance to the durability of the fired paint.

[127] Hancock, 1881?: 123.

CHAPTER 3

Technical Study

In this chapter, the three case study windows introduced in Chapter 2: Historical Study will be discussed in more detail, focussing on examination of their current condition and analysis of their chemical composition.

Sherborne Abbey West Window

As discussed previously, the Pugin-Hardman West Window (w1) was removed from Sherborne Abbey in 1997 to make way for a new window. Since that time, the window has been held in store at the London Stained Glass Repository. Three main light panels, 2d (Moses), 2e (Joshua) and 2f (Aaron), as well as six tracery lights D1 – D6, were made available for examination and analysis during this study (Figures 37 – 41). Outline condition reports were prepared for each of the panels, and these are given in Appendix 2. For the purposes of this study, however, only panel 2d (Moses) will be discussed in detail, as representing the condition of the whole window.

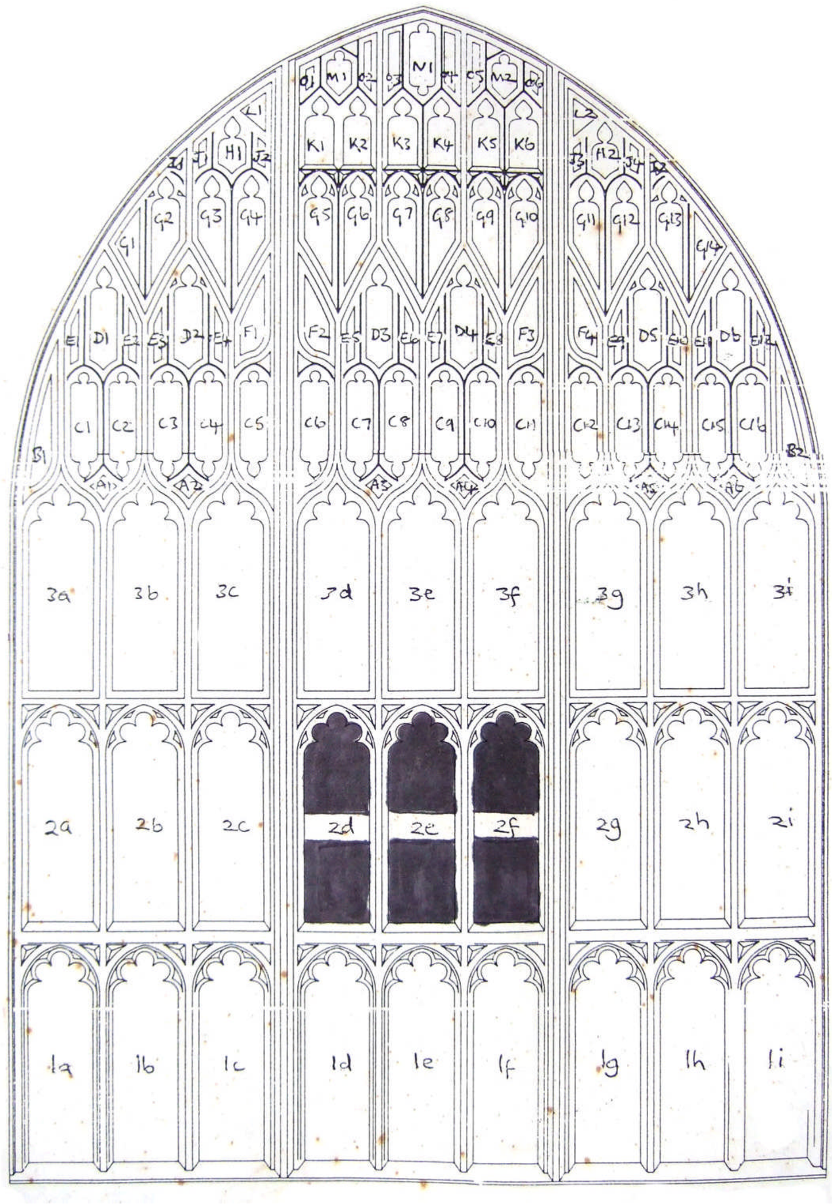


Figure 37: Schematic diagram of Sherborne Abbey former West window with CVMA numbering of panels

Figure 38: Sherborne Abbey w1 panel 2d (Moses)

Figure 39: Sherborne Abbey w1 panel 2e (Joshua)

Figure 40: Sherborne Abbey w1 panel 2f (Aaron)

D1 D2 D3 D4 D5 D6

Figure 41: Sherborne Abbey w1 tracery lights D1 – D6

<u>Condition of panel 2d (Moses)</u>

The figure of Moses is depicted with his traditional ‘horns’ of light, holding a rod and tablets with the numbers I to X, representing the Ten Commandments.[1] Overall, the panel is in a rather poor condition, with several cracked or missing pieces of glass, many lead and solder fractures, and much surface dirt. The most severe problem with panel 2d, however, as can be seen from Figure 38, is the loss of painted detail. Very little paint survives on the face, hands and tablet of the commandments, leaving only ‘ghosted’ images with some flesh-tone shading. Other areas, however, seem to have survived slightly better, such as the pattern on the halo, areas of the diapered background, and some of the drapery (Figures 42 – 44). This suggests that there is some difference between the paints used, or their application, in these different areas. It is noticeable that the best preserved areas throughout the panel are those painted on a deep yellow potmetal glass, used for Moses’ undergarment. For some reason, these pieces are all reversed, such that the main painted detail is on the outside face rather than the inside; this reversal, and the better preserved paint on these yellow pieces, are also noticeable in the drapery of panel 2f (Aaron, Figure 40).

[1] Hall, 1996: 213.

Figure 42: Detail showing paint lost from face but preserved around halo

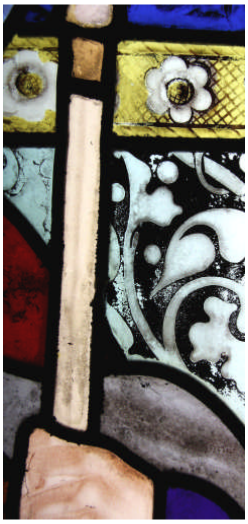


Figure 43: Detail showing paint lost from hand but preserved on background

Figure 44: Detail showing paint lost from tablets but preserved on drapery

When viewed in reflected light, the surviving paint can be seen to be rather reddish brown in colour (Figures 45 and 46). Even those areas on the front face which appear to have survived relatively well show some deterioration, possibly salt efflorescence, of the painted surface (Figure 47). The reverse face shows the extensive use of back-painted shading as well as the detail on the reversed yellow pieces, both of which appear to be in relatively good condition. Interestingly, there is no back-painted shading on the face or hands (presumably due to the use of flesh-tone shading in these areas), which could partly explain why these areas stand out for their paint loss; even though the drapery areas have lost their surface paint, they retain some of their modelling in the back-paint.

Figure 45: Sherborne Abbey w1 2d, inside face (reflected light)

Figure 46: Sherborne Abbey w1 2d, reverse face (reflected light)

Figure 47: Detail of deteriorated paint on inside face (reflected light)

Figure 48: Detail of paint on reverse face (reflected light)

Figure 49: Detail of shading on reverse face (reflected light)

Viewing the paint surfaces under a digital microscope (Veho Discovery VMS-004) shows the paint on the inside face of the panel to be loose and powdery, rather than a coherent layer (Figure 50). Where the layer does survive, as in the area shown in Figure 47, the microscope image shows the surface to be full of pinholes (Figure 50c). This broken surface will allow ingress of water and other contaminants which can attack the paint layer, causing further deterioration.

(a) *(b)* *(c)*

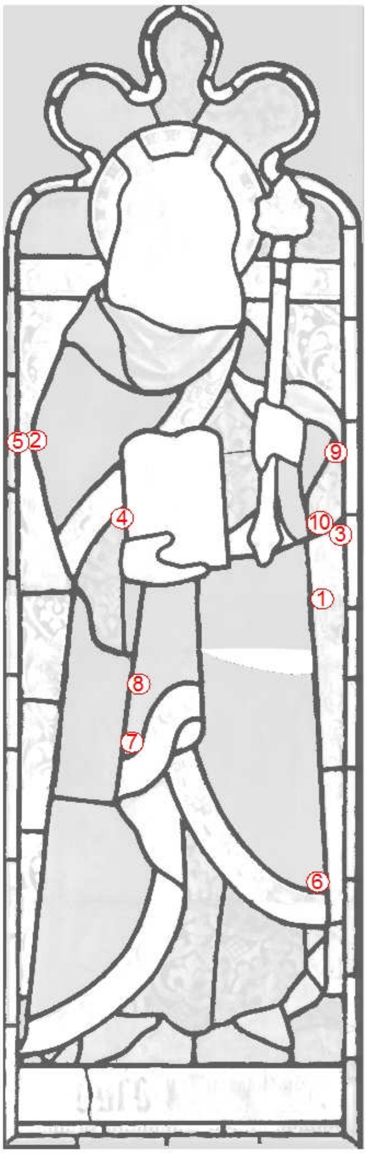
Figure 50: Paint surfaces on the inside face viewed under a digital microscope (reflected light)

The paint surfaces on the reverse face are generally in much better condition than those on the inside face, however, viewed under the digital microscope they can also be seen to contain pinholes in the painted surface (Figure 51). In fact, the paint surfaces on the reverse face appear very similar to the best-surviving of the paint surfaces on the inside face; this might suggest that the same paint and firing conditions were used for both, but that the paint on the reverse face has remained nearer to its original condition, while that on the inside face has deteriorated over time.

Figure 51: Paint surfaces on the reverse face viewed under a digital microscope (reflected light)

<u>Sampling and analysis</u>

In order to examine more closely the physical structure of the paint layers, and to determine their chemical composition, small samples were taken from various pieces. The panel was partly dismantled, taking advantage of already broken glass pieces and fractured solder joints across the centre of the panel, to allow access to suitable pieces (where the piece had surviving paint at the edge, and where the removed sample corner would be hidden under the surrounding lead leaves). Unfortunately it was only possible to sample a limited selection of types of glass in this way; in particular, the face, hands, tablet and inscription, where paint loss was particularly severe (thus very little paint remained), were not sampled. The locations and descriptions of the samples taken are given in Figure 52.



Sample 1	clear glass with traceline paint on front face
Sample 2	flake of traceline paint from clear glass
Sample 3	clear glass with traceline paint on front face
Sample 4	yellow potmetal glass with traceline paint on reverse face
Sample 5	clear glass with traceline paint on front face
Sample 6	red flashed glass with (some) shading paint on both sides
Sample 7	red flashed glass with (some) shading paint on both sides
Sample 8	red flashed glass with (some) shading paint on both sides
Sample 9	yellow potmetal glass with traceline paint on reverse face
Sample 10	yellow potmetal glass with traceline paint on reverse face

Figure 52: Diagram of Sherborne Abbey panel 2d; sample locations and descriptions

The sample preparation and analysis was carried out in the University of York Nanocentre. The samples were embedded in ‘Polyfast’ resin (Struers) by heating powdered resin to 180 °C at 25 kN pressure in a LaboPress-3 machine (Struers). The samples were held in the correct orientation using Scan-dia plastic clips (Agar Scientific); the surface of each mounted sample was then ground to expose a cross-section and polished to a 3 micron finish.

Unfortunately the mounting process caused some of the samples to be damaged; however, most showed at least some of the painted edge (Figures 53 and 54).

Figure 53: Sherborne sample 1; note sample held in plastic clip within the embedding resin

Figure 54: Sherborne sample 9; sample partly damaged in mounting process

The polished samples were examined using an FEI Sirion XL-30 Scanning Electron Microscope (SEM) equipped with a Thermo Noran Ultra-Dry Energy Dispersive X-Ray Spectrometer (EDS) and NSS Spectral Analysis System v.2.3 (Thermo Fisher Scientific). The combination of SEM and EDS allows both imaging and elemental analysis of samples, based on the emitted electrons and X-rays respectively. The linked technique is particularly useful for non-homogeneous samples, such as those examined in this study, as the elemental analysis can be targeted to particular areas of interest within the image (for example, the paint layer or the underlying glass). Although the detector used is theoretically capable of detecting all elements above atomic number 4 (Be), in practice the signal obtained from very light elements is extremely weak. In particular, although several attempts were made to detect the signal for boron

(B, the characteristic element of borax) this proved impossible. The presence, or absence, of borax in the samples analysed cannot therefore be confirmed.

Due to time constraints, only a limited number of samples (1, 4, 5, 6, 9) from the Sherborne panel were analysed. No visible paint remains were found on the edges of Sample 6 (red flashed glass with some shading paint), however, all other samples showed surviving paint layers which could be imaged and analysed. In all images, the base glass is at the bottom of the image, with the paint layer above; in some images the embedding resin can be seen at the top. Under the electron microscope, the paint layers appear rather deteriorated (as expected), with large variations in thickness of layer across the sample (Figure 55). On closer inspection, surviving areas of paint are granular in appearance (Figures 56 – 58), and in many areas large particles can be seen within the paint layer (Figures 59 and 60). Samples 1 and 5 in particular contain numerous vertical micro-cracks through the paint layer, often running from the surface of the paint right down to the interface with the glass (Figure 60).

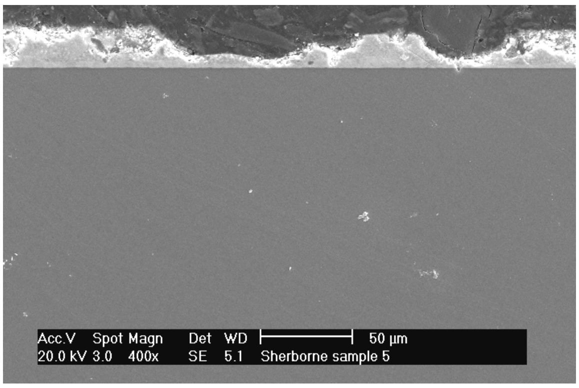


Figure 55: Paint layer from Sherborne sample 5 (clear glass with paint on front face)

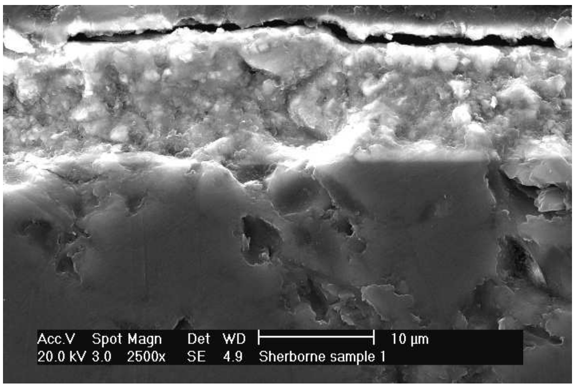


Figure 56: Paint layer from Sherborne sample 1 (clear glass with paint on front face)

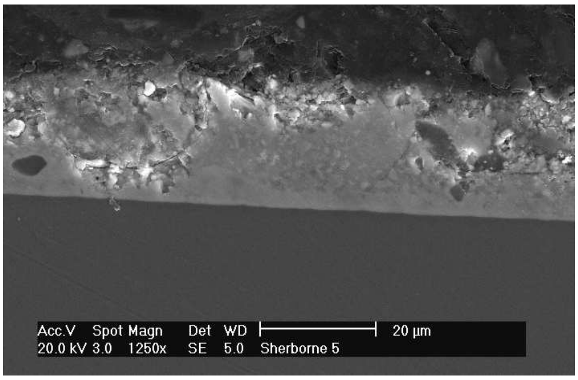


Figure 57: Paint layer from Sherborne sample 5 (clear glass with paint on front face) showing granular appearance

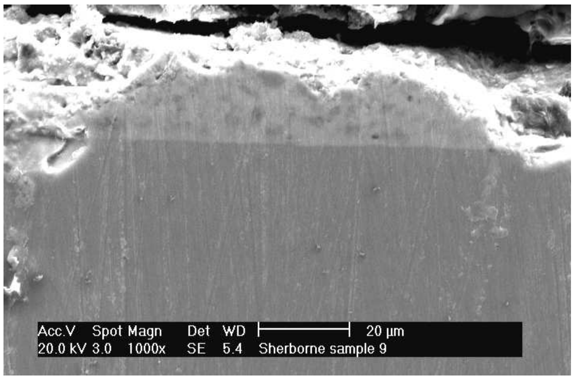


Figure 58: Paint layer from Sherborne sample 9 (yellow glass with paint on reverse face) showing granular appearance

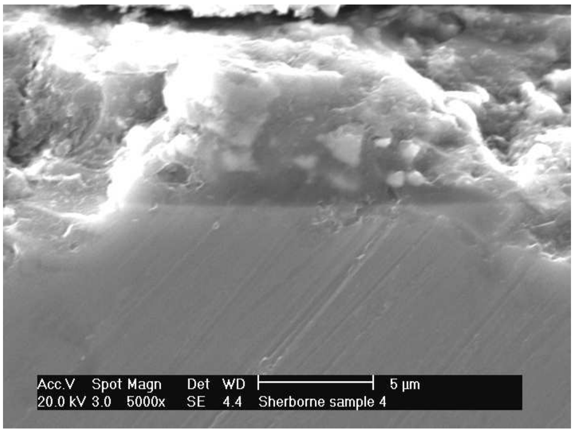


Figure 59: Paint layer from Sherborne sample 4 (yellow glass with paint on reverse face) showing large particles within layer

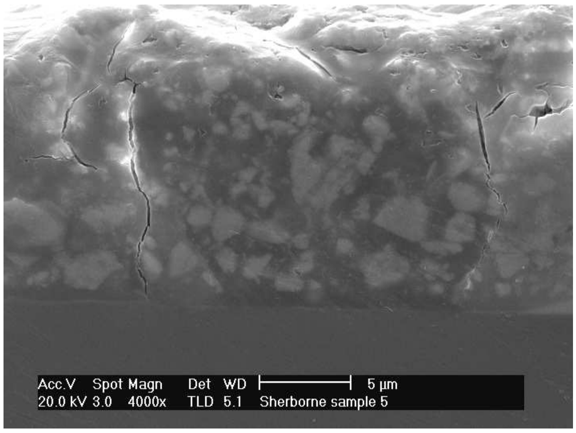


Figure 60: Paint layer from Sherborne sample 5 (clear glass with paint on front face) showing large particles and vertical cracks in layer

Results of the EDS analysis of the glass and paint samples are given in Tables 6 and 7, reported as weight percentages of the various oxides. As the paint layers are rather heterogeneous, the results obtained vary significantly across different areas of the samples; the values given are averages of several analyses which are given in full in Appendix 3. The variation in results means that the values given should be taken as a guide rather than exact compositions. By contrast, the homogeneity of the underlying glass results in rather more reliable compositions.

Table 6 shows that samples 1 and 5 (clear glass) have the same composition, which is a soda-lime silicate glass (containing sodium Na, calcium Ca and silicon Si). The clear base of sample 6 (red flashed glass) is also of very similar composition to samples 1 and 5. These compositions compare well with recipes of the time and other published data;[2] the presence of manganese (Mn) is probably due to its use as a decolouriser for the iron (Fe) present.[3] Samples 4 and 9 (yellow glass) also have the same composition as each other, however, these glasses are lead silicate (containing lead Pb and silicon Si) coloured with iron (Fe). The red flashed layer of sample 6 is also a lead silicate glass, but coloured with copper (Cu).

Table 7 shows that the paint used for all four samples analysed is essentially the same, being composed of a lead silicate glass mixed with iron oxide (Fe_2O_3) pigment, as would be expected from the recipes discussed in Chapter 2: Historical Study. The level of pigment is very high, approaching 50% of the paint by weight; thus the pigment and flux were mixed in the ratio 1:1, which corresponds to the maximum pigment loading possible to obtain a good quality paint layer, requiring the use of a soft flux in order that it can fill the small gaps between pigment particles.[4] Experimentation has shown that it is very difficult to obtain a durable paint layer with such a high pigment loading.[5] The ratio of lead to silica in the flux is around 1.5:1, suggesting that the flux was quite hard,

[2] Dungworth et al, 2010: 15, 21-22.
[3] Dungworth et al, 2010: 15.
[4] Schalm, 2000: 310.
[5] Schalm, 2000: 311-12.

		F	Na_2O	MgO	Al_2O_3	SiO_2	Cl	K_2O	CaO	TiO_2	MnO	Fe_2O_3	Cu_2O	PbO
Sample 1	Clear glass		10.1	1.1	2.7	68.8	0.2	0.7	14.8	0.2	0.3	1.5		
Sample 5	Clear glass		9.4	0.9	2.5	68.9	0.2	0.7	15.5	0.2	0.4	1.4		
Sample 4	Yellow glass	2.7	2.4		1.0	53.5	0.2	8.8			1.9	6.8		22.7
Sample 9	Yellow glass	1.1	2.3		1.0	52.8	0.2	8.6			2.3	7.0		24.4
Sample 6	Clear glass		12.9	0.7	1.2	71.1	0.1	1.3	11.8					
Sample 6	Red flash		2.7		0.9	58.0	0.1	12.1	8.8				1.9	15.4

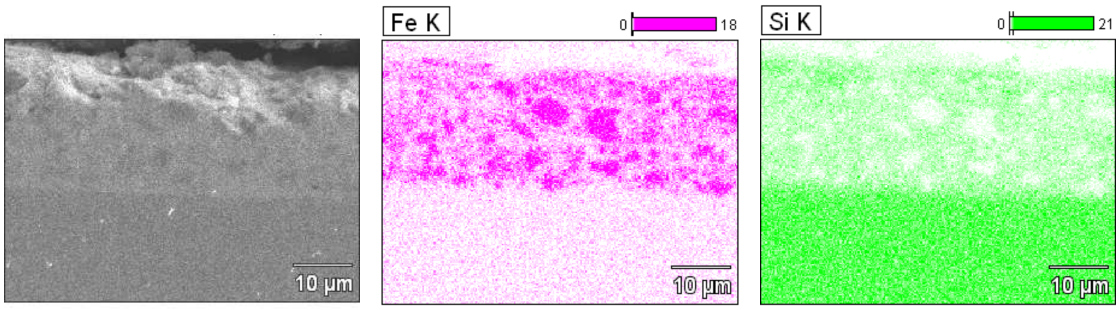
Table 6: Compositions of glass samples from Sherborne Abbey West Window panel 2d

	F	Na_2O	Al_2O_3	SiO_2	Cl	K_2O	CaO	Fe_2O_3	PbO	ZnO	Cu_2O	MoO_3
Sample 1	1.8		2.1	14.6	0.1	0.1	0.7	49.2	27.8	1.0	0.6	
Sample 4	1.2		1.3	24.5	0.2	0.3	0.9	50.5	18.9			1.8
Sample 5	1.3	1.0	1.2	21.1	0.3		1.4	48.1	25.4			
Sample 9	1.4	2.5	0.8	15.5	0.2	3.1		45.1	31.2			

Table 7: Compositions of paint samples from Sherborne Abbey West Window panel 2d

with a relatively low lead content. It is unlikely that borax (sodium borate $Na_2B_4O_7$) was added to soften the flux, as the amount of sodium present is very low.

The combination of SEM imaging and EDS analysis can be further used to investigate the chemical nature of the particles seen in the SEM images. Element maps (Figure 61) show these particles to be composed of iron, in other words, they are the iron oxide pigment particles embedded in the surrounding flux. The size of these particles suggests that the pigment was not very finely ground in production, which is also likely to lead to a rather granular paint layer.



(a) *(b)* *(c)*

Figure 61: Element maps of paint layer from Sherborne sample 9
(a) original image, (b) iron oxide pigment map, (c) silica flux map

It is interesting to note that the paint used for both clear and yellow glass has the same chemical composition, but has deteriorated to markedly different extents. This difference could be ascribed either to the different underlying glass (soda-lime silicate in the case of the clear glass, lead silicate in the case of the yellow glass) or to the different environment (the inside or outside face of the window). These points will be discussed further later in this chapter.

Beverley Minster West Window

As mentioned in Chapter 2: Historical Study, concern over the condition of the West Window of Beverley Minster led to the production of a detailed condition report by the York Glaziers' Trust in 2008, as well as a conservation trial of selected panels, carried out by the York Glaziers' Trust in 2009. The conservation trial included sampling for analysis by English Heritage's Research Department. The results of these studies are summarised below.

As explained previously, the West Window of Beverley Minster was made and installed in two parts, the upper section in 1859 and the lower section in 1865. The two parts have different degrees of paint loss, with the lower (1865) section showing more advanced deterioration. Therefore, two panels were selected for detailed analysis, panel 2a (Archbishop Thurstan) from the lower section, and panel 6d (part of the marriage scene of King Edwin) from the upper section (Figures 62 – 64)[1].

[1] York Glaziers' Trust, 2009: 10-11.

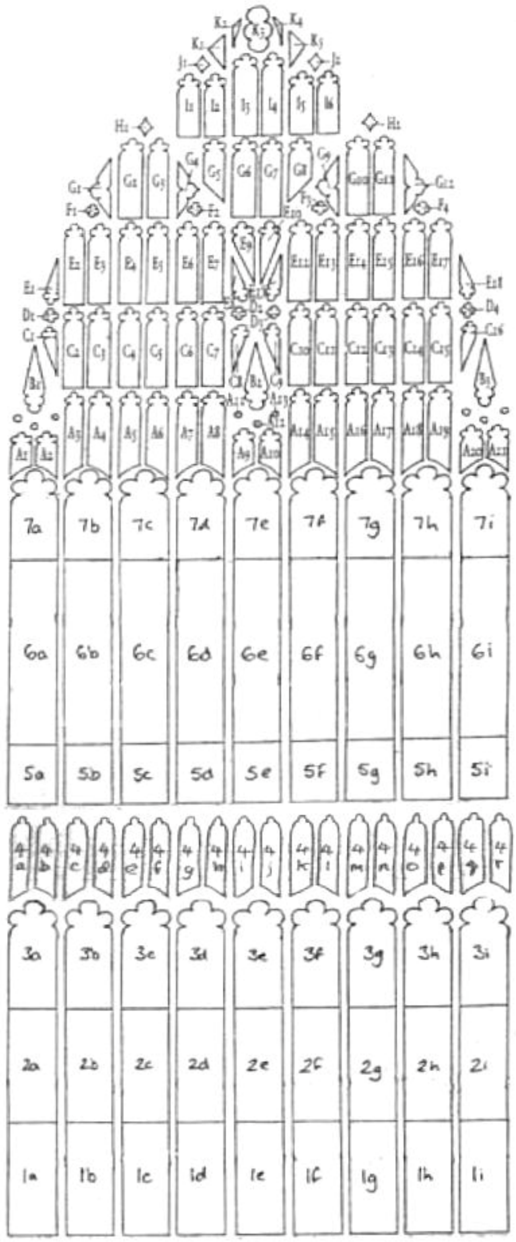


Figure 62: Schematic diagram of the West Window of Beverley Minster, showing CVMA numbering of panels

Figure 63: Beverley Minster w1 panel 2a (Thurstan)

Figure 64: Beverley Minster w1 panel 6d (part of marriage scene)

Condition of panels 2a and 6d

Panel 2a shows significant paint loss, particularly from areas of clear or lightly tinted glass, such as the face, hands and architectural surround; the red diapered background and modelling of the drapery have survived rather better. Panel 6d shows a similar pattern of loss, but to a much lesser degree; the lighter areas of the faces and hands appear somewhat faded, but the drapery retains its finely painted detail as well as deeply modelled folds. Viewed in reflected light (Figures 65 and 66) it is clear to see that the colour of the paint used for the two sections is quite different, with panel 2a appearing black whereas panel 6d is reddish brown. This difference in colour indicates that different pigments have been used in the two glass paints. The panels also have significant amounts of back-painting on the reverse face,[2] presumably carried out in the same paint as used for the front face of each respective panel.

Figure 65: Beverley Minster w1 panel 2a in reflected light

Figure 66: Beverley Minster w1 panel 6d in reflected light

Sampling and analysis

As the panels were partially (panel 2a) or fully (panel 6d) dismantled and re-leaded as part of the conservation trial, it was possible to take a large number of small glass samples from various locations in the panels for further analysis (Figures 67 and 68).

[2] York Glaziers' Trust, 2009: 13.

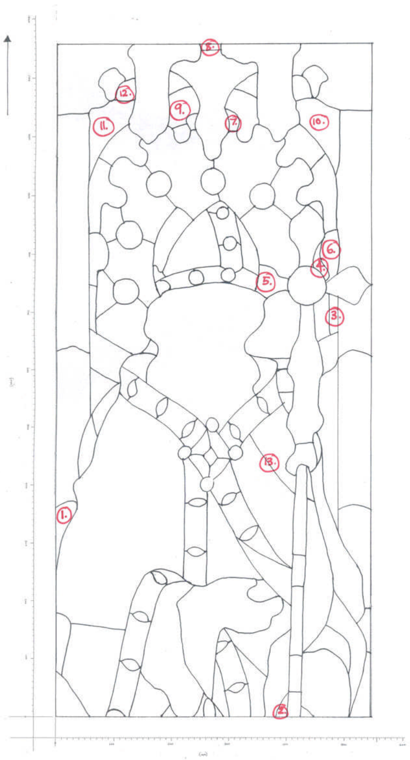


Figure 67: Location of samples taken from panel 2a

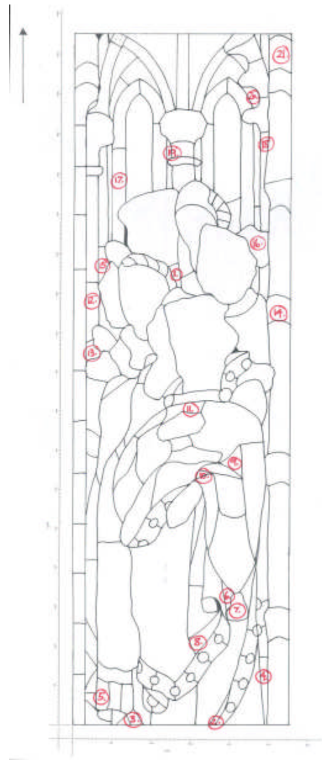


Figure 68: Location of samples taken from panel 6d

The samples were mounted as cross-sections into epoxy resin, and ground and polished to a 1 micron finish. The cross-sections were examined using an FEI Inspect F Scanning Electron Microscope (SEM), with chemical compositions of both substrate glass and paint layers determined using both an Oxford Instruments X-act SDD Energy Dispersive X-ray Spectrometer (EDS) and an EDAX Eagle II Energy Dispersive X-ray Fluorescence Spectrometer (ED-XRF).[3] Full details of the methods used are available in Dungworth et al (2010).

The substrate glasses were found to have a range of compositions, broadly described as soda-lime silicate, flint glass (potassium-lead silicate) and hybrid glasses (having compositions somewhere between soda-lime silicate and potassium-lead silicate). Small amounts of metals were added to create coloured glasses; iron (Fe) for green, blue and yellow glasses, cobalt (Co) for

[3] Dungworth et al, 2010: 6.

blue, copper (Cu) for green and for the flashed ruby glasses.[4] There were no particular differences between the glasses used for the two sections of the window, with all compositional types appearing in both sections; indeed, almost identical compositions were found for the same type (colour) of glass in the two different sections.[5] With the exception of the hybrid glasses, the compositions corresponded well with glasses of the same period found at other sites and with glass-making recipes of the time.[6]

The paint layers were found to contain silica, lead and various metal oxides (Table 8), as expected. The paint on panel 2a was found to have quite different composition from that on panel 6d, as suspected from their different colours; panel 6d paint being coloured by large amounts of iron oxide (Fe_2O_3, giving the reddish-brown appearance), whereas panel 2a paint contained smaller amounts of iron oxide along with cobalt (Co), chromium (Cr), manganese (Mn), nickel (Ni), copper (Cu) and zinc (Zn) oxides (giving the black appearance). The panel 2a paint could be further divided into two groups, with samples 2, 5, 7 and 13 containing chromium, zinc and antimony (Sb), while samples 6, 9, 10 and 12 do not.[7] This might suggest that different batches of paint were being used for these different areas (in turn, perhaps indicating that different painters were at work); samples 6, 9, 10 and 12 all correspond to areas of the architectural background to Archbishop Thurstan, while 2 and 13 are drapery, 7 is diaper background and 5 is part of the Archbishop’s crozier. The panel 6d paint varies widely in terms of the pigment content, from 15 to 30% iron oxide, perhaps suggesting that the pigment was mixed with more or less flux, depending on the

[4] Dungworth et al, 2010: 10.
[5] Dungworth et al, 2010: 21-22.
[6] Dungworth et al, 2010: 15-16.
[7] Dungworth et al, 2010: 12.

wishes of the painter; however, there does not appear to be a simple correlation between the level of pigment used and the painted area.

Although the analytical techniques used in this study were capable of detecting boron, no boron was found in any of the paint samples; thus it seems unlikely that borax was used in their formulation.[8] The compositions seem to be largely in line with recipes of the time, with the flux component (lead and silica) accounting for around 60% (panel 6d) to 75% (panel 2a) of the formulation; in other words, the pigment and flux were mixed in approximate ratios 1:2 to 1:3, which has been found to be the optimal range for glass paint.[9] The composition of the flux seems to vary somewhat; however, this may partly be due to the subsequent deterioration of the paint. On average, the ratio of lead to silica is between 1:1 (panel 6d) and 1.5:1 (panel 2a), suggesting that a softer flux (higher lead) was used for the panel 2a paint. Overall, however, there is no obvious problem with the chemical composition of the paints which might help to explain their deterioration.

[8] Dungworth et al, 2010: 17.
[9] Schalm, 2000: 316.

Sample	SiO_2	PbO	Na_2O	MgO	Al_2O_3	P_2O_5	SO_3	K_2O	CaO	Cr_2O_3	MnO	Fe_2O_3	CoO	NiO	CuO	ZnO	Sb_2O_3
2a2	21.7	56.4	2.7	0.3	1.1	0.7	0.3	0.7	1.1	1.2	1.0	5.5	4.5	0.2	0.6	1.5	0.3
2a5	25.4	52.8	3.8	0.3	1.3	0.4	0.4	0.2	1.6	0.6	0.8	4.8	3.7	0.3	0.7	1.8	0.4
2a5	25.6	49.8	4.1	0.4	1.4	0.3	0.2	0.3	1.5	0.9	2.1	7.1	3.2	0.3	0.5	1.6	0.5
2a6	33.3	41.9	3.9	0.2	1.0	0.5	0.2	3.8	2.5	<0.1	1.9	6.6	2.9	0.1	0.3	<0.1	<0.2
2a7	24.3	49.5	2.4	0.3	1.8	0.9	0.7	0.2	2.0	0.7	1.0	6.7	5.3	0.4	1.3	1.3	0.6
2a9	32.2	37.2	4.1	0.4	1.4	<0.2	0.7	3.4	2.7	<0.1	2.4	9.8	4.4	0.3	0.2	<0.1	<0.2
2a10	28.5	42.0	3.4	0.3	1.3	<0.2	0.6	4.5	1.1	<0.1	2.8	7.9	6.1	0.4	<0.1	<0.1	<0.2
2a12	47.7	24.4	8.1	0.3	1.0	<0.2	0.8	<0.1	7.5	<0.1	0.9	3.9	4.1	0.3	<0.1	<0.1	<0.2
2a13	26.6	51.9	2.6	0.3	0.9	<0.2	0.8	3.5	0.9	0.6	1.0	4.5	3.0	0.2	0.3	1.3	0.5
2a13	27.5	47.4	2.7	0.2	1.1	0.2	0.6	4.0	1.1	0.6	1.5	7.4	2.6	0.2	0.3	1.2	0.6
6d6	31.8	22.9	5.1	0.2	2.2	0.5	0.7	1.3	2.6	<0.1	0.2	30.6	0.4	<0.1	0.7	<0.1	0.2
6d7	24.9	34.0	1.6	0.2	2.8	0.3	0.4	4.5	2.7	<0.1	0.3	26.0	0.8	<0.1	0.7	<0.1	<0.2
6d8	36.9	31.0	6.3	0.2	2.6	0.3	0.6	0.7	4.8	<0.1	0.9	15.1	0.3	<0.1	<0.1	<0.1	<0.2
6d9	34.6	28.4	2.7	0.3	2.3	0.3	0.9	6.7	4.3	<0.1	0.3	15.3	1.4	<0.1	1.6	0.1	0.2
6d11	25.7	25.6	5.3	0.2	2.6	0.4	0.4	1.5	2.4	<0.1	0.8	32.8	1.4	<0.1	0.5	<0.1	<0.2
6d12	26.9	37.2	1.8	0.2	2.9	0.3	0.5	5.2	3.1	<0.1	0.2	20.9	0.3	<0.1	0.3	<0.1	<0.2
6d13	23.2	34.9	1.3	0.3	2.3	0.3	0.5	5.1	2.6	<0.1	0.3	28.3	0.4	<0.1	0.2	<0.1	<0.2
6d14	23.9	31.1	1.4	0.2	1.8	0.3	0.4	4.5	1.7	<0.1	0.2	32.3	0.6	<0.1	1.0	<0.1	<0.2
6d15	26.2	35.8	5.1	0.2	3.3	0.3	0.4	0.5	4.3	<0.1	0.1	23.2	0.3	<0.1	<0.1	<0.1	<0.2
6d17	24.7	31.3	4.9	0.1	2.5	0.3	0.4	0.2	3.1	<0.1	0.3	31.4	0.4	<0.1	<0.1	<0.1	<0.2
6d17	33.6	24.5	7.8	0.2	3.3	0.2	0.4	0.2	4.1	<0.1	0.7	23.4	0.9	<0.1	<0.1	<0.1	<0.2
6d18	29.3	35.3	3.4	0.2	3.4	0.3	0.6	3.3	3.8	<0.1	0.4	18.5	0.9	<0.1	<0.1	<0.1	<0.2
6d20	24.6	43.1	2.2	0.3	2.3	0.3	0.5	4.1	3.1	<0.1	0.2	18.3	0.6	<0.1	<0.1	<0.1	<0.2

Table 8: Composition of glass paint from Beverley Minster samples as reported by Dungworth[192]

(note that '<' indicates signal below the minimum detection limit for that oxide)

192 Dungworth et al, 2010: 23-24.

Examination under the Scanning Electron Microscope showed that the paint layers were very heterogeneous, containing particles of varying sizes as well as empty pores (Figure 69). The detector used in this study was capable of distinguishing between areas of different atomic mass, with lighter areas appearing darker and heavier areas appearing brighter (due to their stronger X-ray signal). Many samples showed significant deterioration of the surface layer, with darker areas towards the paint surface indicating the loss of heavier elements due to corrosion (the action of water leaching out alkali metals from the glassy phase)[1] (Figure 70). Bright areas indicate areas of heavier elements, probably lead, formed as a result of re-deposition within pores (Figure 71). Some samples showed almost complete breakdown of the paint layer (Figure 72). However, there was no obvious difference in the extent of deterioration between samples from the two panels which could explain their visibly different levels of paint loss.

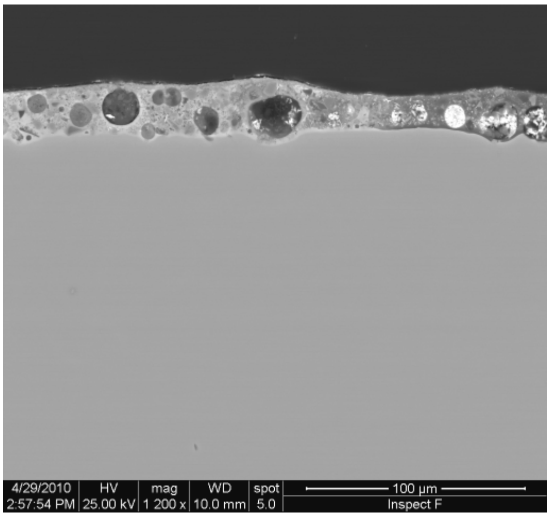


Figure 69: Cross-section of panel 6d sample 13; heterogeneous layer including large particles and pores

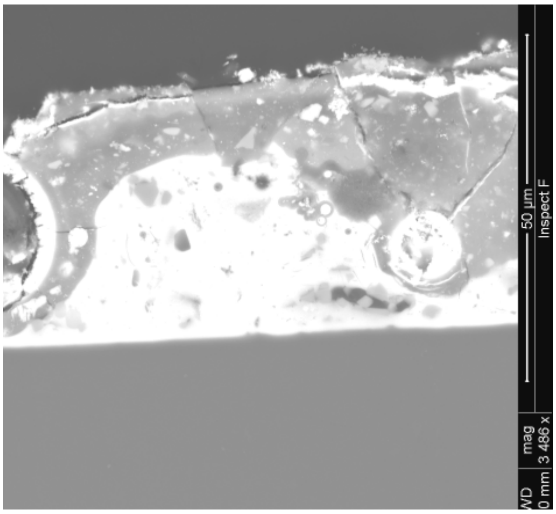


Figure 70: Cross-section of panel 2a sample 5; darker area indicates corrosion, bright areas indicate re-deposition of lead

[1] Newton and Davison, 1989: 136.

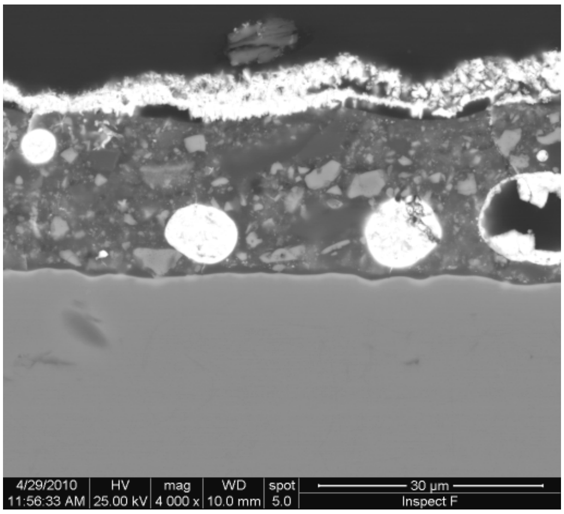


Figure 71: Cross-section of panel 6d sample 10; heterogeneous paint layer with large pores containing re-deposited lead

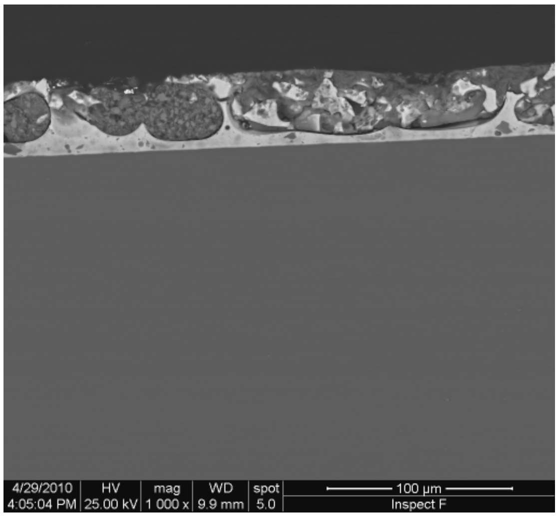


Figure 72: Cross-section of panel 6d sample 15; complete breakdown of paint layer

All Saints' Church, Emscote, Warwick

Two panels formerly in All Saints' Church, Emscote, were made available for examination during this study. The Virgin and Child quatrefoil (Figure 73) was the top tracery light of the North Transept 'Jesse' window n7, made by Hardmans in 1889 (Figure 74). The St Aidan quatrefoil (Figure 75) was presumably one of the tracery lights of window n9, which contained standing figures of St Aidan, St Columba and St Ninian; however the provenance of this panel is not clear, as the figures were made at different times, and the tracery is not explicitly mentioned in the Hardman Archive. Condition reports were completed for both panels, and these are included in Appendix 2; further discussion here will be confined to the Virgin and Child panel only.

Figure 73: Virgin and Child quatrefoil from All Saints' Church Emscote window n7

Figure 74: Design for North Transept 'Jesse' window n7

Figure 75: St Aidan quatrefoil, presumed to be from the tracery of All Saints' Church Emscote window n9

<u>Condition of panel</u>

The Virgin and Child panel is generally in a good condition, although several pieces of glass have suffered physical damage. The leadwork is sound, and the painted detail appears strong and in good condition (Figures 76 and 77). Viewed in reflected light, the paint appears reddish-brown in colour, with slightly different appearance across the panel, suggesting that some alteration has occurred to the paint surface (Figure 77).

Figure 76: Detail of Virgin and Child panel

Figure 77: Detail of Virgin and Child panel

Figure 78: Virgin and Child panel (reflected light); note redder areas in lower part

Viewing the paint surface under a digital microscope (Veho Discovery VMS-004) shows some signs of paint loss (Figure 79) and ‘crizzling’ of the paint surface (Figure 80) as well as areas where the paint surface appears to be in excellent condition (Figure 81).

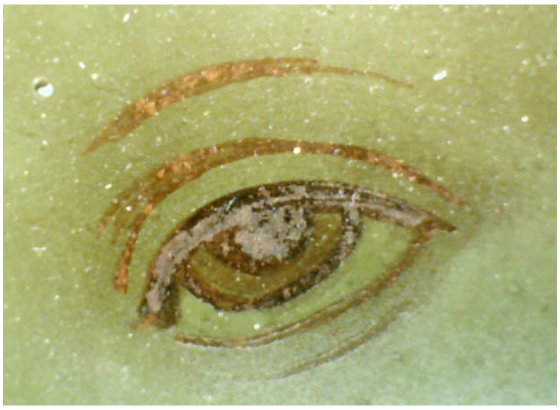


Figure 79: Detail viewed under digital microscope (reflected light): loss of paint

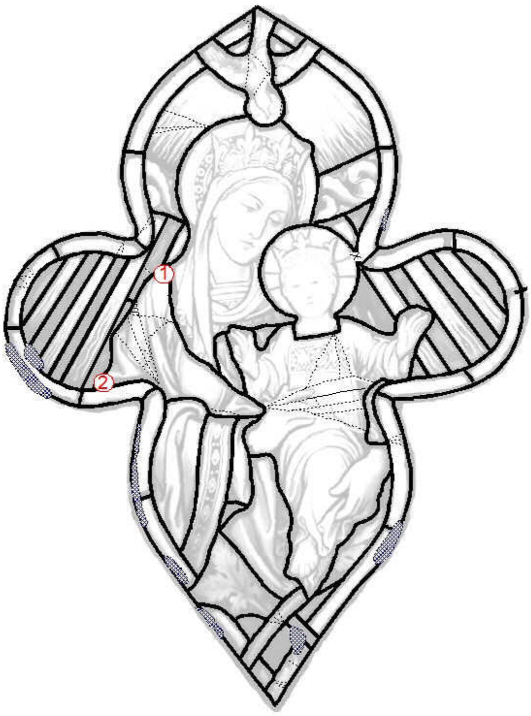
Figure 80: Detail viewed under digital microscope (reflected light): 'crizzling' of paint surface

Figure 81: Detail viewed under digital microscope (reflected light): good paint surface

Thus, although the painted surface of the All Saints' Emscote panel is in much better condition than those of Beverley Minster and Sherborne Abbey, it is not perfect, and some deterioration has occurred.

<u>Sampling and analysis</u>

In order to further investigate the structure and composition of the paint used, two small samples were taken from the corners of the already broken piece of the Virgin's drapery (Figure 82).



Sample 1	Green tinted glass with traceline paint on front face
Sample 2	Green tinted glass with traceline paint on front face

Figure 82: Diagram of Virgin and Child panel; sample locations and descriptions

Sample 1 was examined and analysed in the same manner as has been described previously for the Sherborne samples. Although the sample was badly damaged in the preparation process, the paint layer could be seen to be well preserved and quite homogeneous in appearance (Figure 83). In some areas the surface of the underlying glass was quite uneven but the paint layer remained securely attached (Figure 84).

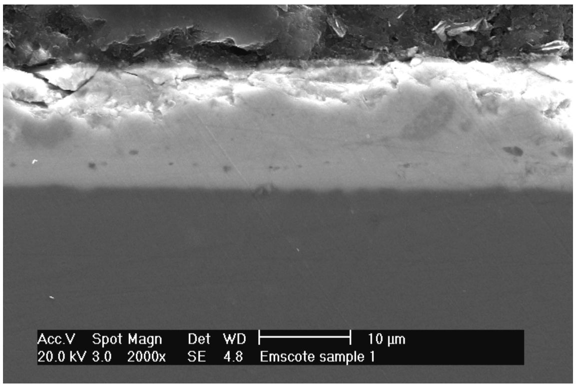


Figure 83: Relatively homogeneous paint layer of Emscote sample 1

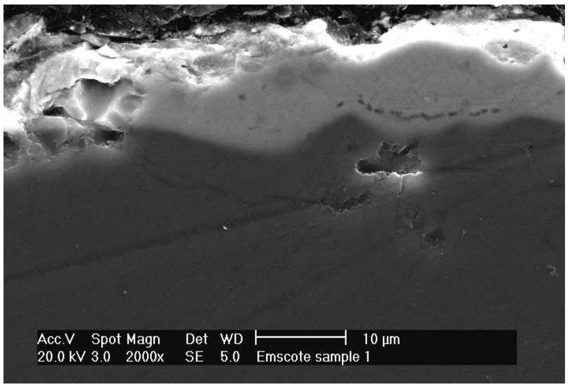


Figure 84: Uneven glass surface of Emscote sample 1

The average chemical compositions of the glass and paint of sample 1, as determined by EDS, are given in Tables 9 and 10 (original data in Appendix 3).

F	**Na_2O**	**Al_2O_3**	**SiO_2**	**Cl**	**K_2O**	**CaO**	**MnO**	**Fe_2O_3**	**MoO_3**
0.9	11.0	1.3	68.0	0.3	0.7	12.6	0.7	2.6	2.8

Table 9: Average composition of glass of Emscote sample 1

Na_2O	**SiO_2**	**CaO**	**Fe_2O_3**	**CoO**	**PbO**
2.7	24.3	1.2	32.8	5.1	33.8

Table 10: Average composition of paint of Emscote sample 1

Thus the glass of Emscote sample 1 is a soda-lime silicate of standard composition (very similar to that used at both Sherborne and Beverley), with manganese used to decolourise the iron present. The paint is a lead silicate coloured with a combination of iron oxide and cobalt oxide, with the total pigment loading around 38%. This corresponds to a pigment to flux ratio of around 1:2, comparable with that of the upper section of the Beverley West window; the use of a mixture of oxides giving a darker colour to the paint without increasing the pigment loading. The ratio of lead to silica in the flux is around 1.4:1, comparable to that used at Sherborne and Beverley.

Discussion

The foregoing technical study has shown that there are many similarities between the three case studies described. The glasses used to create the windows are composed of both soda-lime and lead silicates, mostly of standard compositions. The glass paints used are composed of lead silicate glasses coloured with metal oxide pigments, primarily iron oxide with the addition of other metal oxides, notably cobalt, in the later windows (the lower part of the Beverley West window and the Emscote panel). The Sherborne window has the highest pigment loading (around 50% of the paint) and the lower part of the Beverley window the lowest pigment loading (around 15% of the paint) with the upper part of the Beverley window and the Emscote panel falling in between (around 25 – 40%). Many of the paint layers appear to be granular, with individual pigment particles clearly visible. Although the composition of the flux component varies between samples, on average it is quite consistent between the various windows, with the ratio of lead to silica varying between around 1:1 and 1.5:1 (in other words, lead and silica were mixed in approximate proportions between 1:1 and 3:2). This suggests the use of a flux recipe similar to that given in Porter's *Treatise*, composed mainly of flint glass (3 parts silica to 2 parts lead oxide)[2] with the addition of lead oxide to soften the flux.[3] Porter also suggested the use of equal weights of pigment and flux,[4] as used at Sherborne. There is no evidence for the presence of borax in these formulations; however, its use cannot be ruled out by this analysis. It is

[2] Pellatt, 1849: 34.
[3] Porter, 1832: 294.
[4] Porter, 1832: 296.

interesting that there is relatively little difference in the paints used by Hardmans for these three windows, over a period of nearly forty years.

The use of lead silicate glasses in both the Sherborne and Beverley windows suggests that the paint applied to these glasses must have been fired at a relatively low temperature; the softening point of lead silicate glasses is significantly less than that of soda-lime silicate glasses[5] and the base glass should not deform during the firing process. If all the pieces of each window were fired together, at a similar temperature, then the paint on the soda-lime silicate pieces would have been left under-fired compared to that on the softer lead silicate pieces. In combination with the relatively coarse pigment particles and high pigment loading seen in some of the case study examples, this would have resulted in a fired paint layer that appeared to be well fixed but was vulnerable to future deterioration. In addition, the paint would have been attached more firmly to the softer lead silicate glasses; it is notable that the colourless glasses used for the flesh areas (which show the worst deterioration at both Sherborne and Beverley) have the harder soda-lime silicate composition.

The analysis carried out on samples from the Beverley Minster West window shows that corrosion of the glassy phase of the paint has occurred. Atmospheric moisture has leached alkali metals (and also lead, especially if the moisture was slightly acidic)[6] from the paint, creating an alkaline solution on the surface of the paint which is then able to attack the silicate matrix. Cracks and pinholes in the paint layer, as seen in the Sherborne samples, would also encourage water to enter, and be held in, the paint layer, causing further

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[5] Schalm, 2000: 286.
[6] Eppler, 1992: 382; Paul, 1990: 207.

deterioration. The gradual breakdown of the paint structure would lead to loss of surface material, causing the paint layer to become thinner over time and resulting in the visual fading effect.

The involvement of water in the deterioration process suggests that the environment of the window may also be important. Both leakage of rainwater and the formation of condensation can lead to the inside (painted) face of the window being damp for long periods of time (as noted by the Rev Harston in his complaint to Hardmans regarding the north aisle windows at Sherborne), thus encouraging the corrosion process. The outside face of the window is certain to be exposed to the weather, however, this is a different environmental cycle as the glass is washed clean by rainwater and then dries until the next rainfall. The inside face, by contrast, becomes damp by condensation (allowing the corrosion process to begin) and then dries by evaporation, leaving corrosion products on the surface which will continue the process as soon as condensation recurs (most likely on a daily cycle). It has also recently been suggested that the use of coke-fired heating systems in such buildings could affect the deterioration process, as combustion products combine with condensation to produce acidic conditions at the paint surface.[7] As there is no significant difference between the chemical composition of the paints used on the inside and outside faces of the Sherborne glass, it seems likely that these different inside and outside environments, in combination with the different base glass compositions, are responsible for their different levels of deterioration.

[7] Clare, 2009: 4-5.

CHAPTER 4

Conservation discussion

An important aspect of the phenomenon of severe paint loss is to consider how windows suffering from such loss can be conserved for the future; understanding the mechanism of deterioration is critical to making informed decisions relating to this conservation. The decision-making process is supported by the *Guidelines for the Conservation and Restoration of Stained Glass* developed by the Corpus Vitrearum Medii Aevi (CVMA) and also by more general conservation principles, such as those embodied in the *Venice Charter*, adopted by ICOMOS in 1965, and English Heritage's *Conservation Principles* of 2008.

Preventive conservation

Since the time of the *Venice Charter* it has been generally agreed that preventive conservation, in terms of the maintenance and preservation of historic objects and places, is essential in order to safeguard and sustain their cultural value and significance.[1] The CVMA *Guidelines* state that "Preventive conservation is fundamental to the preservation of stained glass".[2] Thus, in the case of windows suffering from paint loss, the first priority is to adopt some way of slowing, or halting completely, any further deterioration of the paint.

The analysis and discussion in Chapter 3: Technical Study has established that the deterioration mechanism in these case studies is the corrosion of the glassy phase of the vulnerable glass paint. Glass corrosion is fundamentally linked to the presence of moisture, and so it follows that any preventive conservation

[1] ICOMOS, 1965: Art. 4; English Heritage, 2008: 22.
[2] CVMA, 2004: para 3.1.

measure taken must have the aim of reducing or removing any moisture present on the painted glass. It is generally accepted that the best way to achieve this aim in the architectural context is through the installation of an external protective glazing system.[3]

Protective glazing

The use of external protective glazing systems has a long history, with early examples including sheets of plate glass installed over the Five Sisters and Great East Windows of York Minster in 1861-2.[4] These early installations were probably more concerned with insulating the building rather than protecting the glass; however, more recent studies have clearly demonstrated the protection afforded to the original glass by protective glazing. The glass is protected in several ways; firstly, by removing its function as the external ‘skin’ of the building, so that it is no longer exposed to wind and rain; secondly, by reducing (or removing) the likelihood of condensation forming on its inner face; and thirdly, by reducing the thermal stress of the daily temperature cycle.[5]

An external protective glazing system, in essence, consists of a second glazed panel placed outside of the original glazing. This can be achieved either by leaving the original glazing in place and mounting the protective glazing to the exterior, or by moving the original glazing towards the interior and installing the protective glazing in its place.[6] The space between the two panels can be vented (internally or externally) or unvented, although it is generally agreed that vented systems are more effective.[7] Internally ventilated systems (often known as isothermal glazing, as the intention is to keep both faces of the original glass

[3] CVMA, 2004: para 3.2.1.
[4] Barley, 2009: 111; Newton and Davison, 1989: 267.
[5] Rauch, 2004; Bernardi et al, 2006: 76; Becherini et al, 2009: 248.
[6] Oidtmann et al, 2000.
[7] Rauch, 2004.

at the same temperature) are often preferred, as circulation of the warmer internal air through the interspace reduces the likelihood of condensation forming on the original glass.[6] As the aim of installing protective glazing for windows suffering from deterioration of the paint is to reduce contact with moisture, then an internally ventilated system is to be preferred. It is important, however, that the system is carefully designed for the particular situation, ensuring that the ventilation causes sufficient air movement in the interspace.[8] A well-designed protective glazing system has been likened to bringing historic glass into 'museum conditions', whilst enabling it to remain in its architectural context.[6]

The criticism most often levelled at the use of protective glazing systems relates to the intervention involved to the fabric of the building (the surrounding masonry) and to the change in the external aesthetic of the building. Much effort has been made to address this second criticism, such as the use of leaded or kiln-formed glazing for the outer protective layer;[7] external wire grilles, often used for mechanical protection, also offer a useful disguise.[9] However, as the protection afforded to the glass and its paintwork has now been demonstrated in many studies, the benefits of protective glazing have generally been agreed to outweigh the disadvantages, thus justifying the intervention. Indeed, the CVMA *Guidelines* state that "The installation of a protective glazing system is a crucial part of the preventive conservation of architectural stained glass".[3]

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[8] Oidtmann et al, 2000; Barley, 2009: 112.
[9] Rauch, 2004; Barley, 2009: 114.

Paint consolidation

Various attempts have been made in the past to consolidate loose paint. Early in the twentieth century attempts were made to re-fire loose paint, either with the addition of flux to the paintwork or with a coating of a low-melting glass over the entire surface (known as the Zettler process or Schmitz's process).[10] This process required preparatory cleaning to ensure adhesion (likely to damage fragile paintwork) and risked discolouration of, or damage to, the original glass in the firing process; glasses treated in this manner have since deteriorated markedly, and the treatment has proved impossible to reverse.[11] This type of intervention is therefore no longer considered acceptable.

More recently, synthetic adhesives have been used for paint consolidation, for example the use of Viacryl (an acrylate resin, hardened with the isocyanate Desmodur)[12] on the west windows of Chartres Cathedral.[13] The acrylic resin Paraloid B-72 has become the most widely used consolidant, as it is generally agreed to have good durability and also to be reversible (due to its solubility in medium polarity solvents, retained even after ageing).[11] However, Paraloid B-72 has limited water resistance and may allow water vapour to penetrate through to the object surface, thus protection from weathering is required.[14] The application must be carefully controlled to ensure good penetration and adhesion, and may result in darkening of the surface as well as increased gloss.[15]

[10] Newton, 1982: 35; Newton, 1974: 19.
[11] Jägers et al, 2000.
[12] Newton, 1982: 11-12.
[13] Newton, 1982: xxviii.
[14] Chapman and Mason, 2003: 385.
[15] Chapman and Mason, 2003: 386.

Further synthetic resins, as well as inorganic materials, are continually being developed and tested for use as consolidants for artworks such as stained glass. However, it must be remembered that any such treatment risks damage to the fragile paint. In particular, although treatments with Paraloid B-72 are theoretically reversible, any later removal of the consolidant would be likely to cause further damage to the underlying paint layer. For these reasons, the CVMA *Guidelines* state that “Paint consolidation is only recommended when paint is in imminent danger of loss. In the case of unstable – but not flaking – paint, preventive conservation methods are preferred.”[16] Thus, for the type of paint loss seen in this study, preventive conservation would be preferred over the use of consolidants.

Preventive conservation can be both necessary and effective for the preservation of stained glass suffering from paint loss; in particular, the installation of a well-designed, internally ventilated protective glazing system can be expected to slow down, or even halt, further deterioration. However, it will not improve the faded appearance; to achieve this requires the greater intervention of restoration.

Restoration

The restoration of lost or faded detail of stained glass windows is a much more difficult and controversial problem than that of conservation of the surviving material. The ethical issues surrounding restoration (“to return a place to a known earlier state”)[17] are particularly intractable when considering figurative painted glass, as although the great majority of the original material (the glass and lead matrix) may be in good condition, the loss of a relatively small amount

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[16] CVMA, 2004: para 4.3.2.
[17] English Heritage, 2008: 72.

of painted detail can be of great detriment to the perceived value and significance of the window. In the case of the Sherborne Abbey West window, for example, it was successfully argued in the Consistory Court that the loss of detail from the faces and inscriptions, in particular, had resulted in a window with “no inspiration or message which will advance the worship and mission of the church by preaching or teaching”.[18]

The CVMA *Guidelines* state that “the insertion of infills, inpainting and restoration of missing paint ... should only be undertaken when fully justifiable based on thorough art-historical and technical research”.[19] The *Venice Charter* goes further, arguing that restoration must be “based on respect for original material and authentic documents. It must stop at the point where conjecture begins”;[20] in other words, restoration can only be carried out if complete and incontrovertible evidence for the previous state of the object exists, either in the object itself or in related documentation. However, in most cases it is practically impossible for the conservator to have complete evidence of the original state of the object; in the case of a stained glass window, it might be clear from the surviving material that painted detail, such as a face or an inscription, was originally present, but not the exact original appearance of that detail. Methods for improving the visibility of the lost or ‘ghosted’ detail have been suggested.[21] However, even if the original full-scale drawing (cartoon) of the window survives, the strength of the original painted line is unknown; thus the restoration can only ever be “an inaccurate approximation” of the original.[22] This argument therefore allows for no restoration, and effectively consigns to

[18] All England Law Reports, 1996: 779.
[19] CVMA, 2004: para 4.4.1.
[20] ICOMOS, 1965: Art. 9.
[21] Newton and Davison, 1989: 256.
[22] Fisher, 1994: 3.

removal and replacement those windows whose meaning is deemed to have been irretrievably lost.

Fortunately, more recent guidelines offer more opportunity for the justification of restoration. English Heritage's *Conservation Principles* state that restoration can be acceptable if based on "compelling" evidence and resulting in an increase in the overall cultural significance, derived from a range of values (evidential, historical, aesthetic and communal). Thus, if any value lost (such as the evidential value of the current state of the object) is outweighed by some other value gained (such as the aesthetic or communal value of the restored state) then restoration can be justified.[23] Mitigation of any lost value can be achieved by detailed recording of the initial and final state of the object, as well as the restoration process undertaken;[23] such recording would be expected in any case for conservation work.[24] Following these principles (which are reflected in the CVMA *Guidelines)*, it becomes possible to justify the restoration or enhancement of lost detail based on three criteria: sufficient evidence of the previous appearance, sufficient improvement in the overall significance of the object, and appropriate documentation of the intervention. The justification must then be made based on the particular values and circumstances of any given case; however, an important element of this justification could be the increase in the communal (social or spiritual) value, as well as aesthetic value,[25] of the window as achieved through the restoration of its meaning and message.

A further objection which has been made to restoration work is that of falsification of the historical record, in other words, that the restoration makes

[23] English Heritage, 2008: 55.
[24] CVMA, 2004: para 2.2.
[25] English Heritage, 2008: 30, 32.

the object appear to be in a better state of preservation than it actually is.[21] The CVMA *Guidelines* state that any new glass inserted must be permanently identified as such,[19] but it might be rather more difficult to achieve this in the case of restored paint. Again, careful documentation of the previous condition and the restoration can be used to mitigate this issue. Equally, any restoration "must be guided by the principles of minimum intervention and reversibility";[19] thus, if required, it should be possible to return the object to its unrestored state in order to recover this historical evidence.

Possible restoration approaches

If it is accepted that restoration of painted detail can, in certain circumstances, be justifiable, then possible methods to achieve such restoration should be considered. It is a central tenet of conservation philosophy that any intervention should, as far as possible, be reversible,[26] and this has led to certain practices which were used in the past being deemed unacceptable by current standards. For example, the repainting and refiring of lost painted detail is both irreversible and may be dangerous to the original glass, and so is not considered acceptable by the CVMA.[16] Other options available include replacement, back-plating, and cold painting.

The replacement of individual pieces of painted glass has been a common occurrence in the history of stained glass conservation, and is still done today when deemed necessary (for example, if the original piece is lost or too badly damaged to be returned to the window). As mentioned previously, any inserted piece "must be identified in a permanent manner with a date and signature or other identifying symbols".[19] However, where the original glass is still in good

[26] English Heritage, 2008: 46.

condition but the paint has been lost or faded, it would be much more difficult to justify replacement of glass pieces, particularly if the paint loss occurs across most or all of the painted pieces within the window. If replacement was to be carried out, there would be a danger of creating an entire copy window to replace the original one; although this has occurred in the past,[27] it would not be acceptable today. Any replacement of the entire window would constitute new work, which should "aspire to a high quality of design and execution"[28] and "bear a contemporary stamp".[20] It could be argued that this is what has occurred in the case of the Sherborne West window.

The use of back-plates, thin glasses carrying painted detail and fixed behind the original glass,[29] constitutes an ethically satisfying approach to the restoration of painted detail. The restored detail is fired onto the back-plate and so is permanent, however, the back-plate is not permanently fixed to the original glass and so the intervention is reversible. The back-plate is often contoured by 'slumping' in a kiln to fit the original glass and the edges sealed using silicon adhesive,[30] thus the painted detail is close enough to the original glass surface to avoid any problems with parallax.[31] The original glass or painted surface should not be affected (except by the silicon adhesive, which is mechanically removable) and remains separate from the restoration painting, which can be therefore be fully documented. However, there can be technical problems with back-plates; if the seal between the original glass and the plate is broken then moisture can penetrate and become trapped, causing damage to the original

[27] Barley, 1997: 118-9; Le Couteur, 1920: 70-71.
[28] English Heritage, 2008: 58.
[29] Newton and Davison, 1989: 256; Barley, 1997: 133-5.
[30] Barley, 1997: 133-5.
[31] Newton, 1982: xxvi.

glass.[32] It has been suggested that the weight of the back-plates may cause problems if applied to large areas of a window,[33] however the use of very thin (1 mm) glass for the back-plates should ensure that the additional weight is relatively small. Back-plating is not generally suitable for areas of coloured glass;[34] front-plating has been suggested for these cases,[35] although attaching plates over a painted surface may endanger the already fragile paint (this issue would also call into question the attachment of back-plates over original back-painting). Finally, the addition of the back-plate generally requires the use of a wider lead calme to accommodate the extra glass thickness,[31] and this may in turn require the window to be re-leaded; a procedure which is not reversible, and which may not otherwise have been necessary. An alternative to re-leading might be to individually lead the back-plates and solder them to the original lead matrix; in this case, the additional weight of glass and lead could be considerable, and so it would be necessary to ensure that the original lead matrix retained sufficient strength and support. As the ensemble would not be sealed, it would be necessary to ensure that no moisture could become trapped between the original glass and the back-plate, most likely by the installation of a protective glazing system. Image parallax could also be an issue with the plate being situated several millimetres from the original glass.

Finally, it is possible to use cold painting (that is, paint that will not be fired) to restore painted detail. This is a simple application of either normal glass paints, mixed with water and gum arabic, or alternatively acrylic-based paints.[36] No additional weight is placed on the lead matrix and large areas can be treated,

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[32] Holden, 1995: 6.
[33] Fisher, 1994: 4; Holden, 1995: 6.
[34] Fisher, 1994: 4; Holden, 1995: 5.
[35] Terry, 2009: 70.
[36] Barley, 2009: 114.

whilst keeping the physical intervention to a minimum. As the paint is unfired, it will remain soluble and thus could be removed at a later date; however, in the meantime the window must be kept dry, for example by the installation of a protective glazing system. If the cold paint were applied over areas of deteriorated and fragile paint, this original paint might be damaged in the application process, and would almost certainly be damaged in any removal process; thus the technique is not, strictly speaking, reversible. The use of cold painting should therefore be restricted to areas where no surface detail has been applied previously (for example the reverse face of the glass, although care must be taken to avoid any areas of original back-painting) and where the glass surface shows no sign of damage or deterioration. A further issue with the use of cold painting is that of documenting the intervention; as the restoration painting is carried out on the original glass, it is not possible to create a record of the painting itself, only of the glass before and after restoration. Finally, the longevity of cold painting is unproven; one estimate is that it should last “between forty and fifty years”.[37]

It is clear from the discussion above that there is not one single, ideal technique for the restoration of missing or faded paintwork; each of the restoration techniques discussed has its own advantages and drawbacks, and so the most appropriate technique should be selected according to the particular circumstances. Those circumstances include both the current state of the window and the context: a monumental window in its architectural surroundings, naturally viewed from some distance away, is likely to retain legibility with less detail than a panel viewed at close quarters in a museum setting. Also, as the CVMA *Guidelines* state, any treatment “should not be carried out

[37] Terry, 2009: 52.

indiscriminately on the whole panel";[38] it may be more appropriate to restore only certain details, or to restore different areas using different techniques. In the case of figurative windows, it has often been suggested that restoring detail only to heads (or 'flesh areas' such as faces and hands) and inscriptions will have the effect of improving the 'readability' of the entire window;[39] however, this must be done with care as it runs the risk of drawing attention to the worse state of the remaining unrestored areas.[40] Whatever restoration is carried out, it is of paramount importance that the intervention is fully documented so that the restored detail can be distinguished from the surviving original material.

Proposed conservation and restoration strategies for case study windows

Having considered the available techniques, possible strategies for the conservation and restoration of the windows examined in this study can be proposed.

In the case of the previous West window of Sherborne Abbey, the paint loss is so severe that the window is unlikely to have any future use unless some restoration is carried out (indeed, having been removed from its original location, it is unclear whether the window will have any future use other than as a research object). Were the window to be re-installed in an architectural context (problematic, given its very large size), the provision of protective glazing would be essential to preserve the little original paint that has survived; such an installation would also allow the preservation of the majority of the original lead-work, as the window would not have to provide the weather shield for the building. The survival of some fragile paint on both surfaces of the glass

[38] CVMA, 2004: para 4.1.
[39] Newton, 1982: xxvi; CCC, 1994: 2; Lawrence, 1995: 8.
[40] Holden, 1995: 5.

indicates that cold painting on either surface is not possible; therefore the only remaining option is to provide restoration detail on back-plates. If the window is not to be re-leaded, it might be possible to attach leaded back-plates to the original lead in particular areas, such as the ‘flesh areas’ of hands and faces, as well as inscriptions. The restoration should be done with some subtlety, to restore legibility without causing the restored areas to ‘stand out’ from the remaining, unrestored areas. Replacement of badly damaged heads (such as that of Joshua, panel 2e) might also be considered. Unfortunately it is unlikely that the original cartoons from this window have survived (the collection in Birmingham Museum and Art Gallery only dates back to 1866) and so any restoration painting would have to be created based on the (little) surviving evidence in the window (such as the flesh tone painting on the reverse of the glass) and possibly comparison with other Hardman windows of the period. The skill of the glass-painter in capturing the style would be an important factor in achieving a satisfactory result; however, some experimentation would be worthwhile in an attempt to return some legibility, and therefore communal or social value, and so increase the overall cultural significance of this historically important window.

In the case of the West window of Beverley Minster, the paint loss is much less severe, and the window is still legible in its current state; however, corrosion of the glass paint will continue unless preventive conservation is carried out in order to prevent attack by moisture. The installation of a protective glazing system is therefore the highest priority, in order to preserve the paintwork from further loss. As this would most likely involve the de-installation of the window, the opportunity to fully document and photograph the window should be taken, to create a detailed record of its current condition in case of further deterioration in the future. Again, it is unlikely that the cartoons for this window survive in the Hardman archive (although the original small-scale design is held at the Minster), and so any future restoration that was deemed necessary would have to be based on the current condition of the window. As with the Sherborne window, the most appropriate restoration technique would be the attachment of back-plates carrying reinforcing detail for the worst-affected flesh areas.

The Emscote panels are in relatively good condition, retaining the majority of their original paint, and so neither preventive conservation nor restoration of the painted detail is currently necessary. However, there are some signs of paint vulnerability, and so if the panels were to be re-installed into an architectural context, it would be prudent to install them with protective glazing, in order to prevent any future deterioration. Full documentation and photography of all panels should be carried out as part of the installation, although it is likely that the original cartoons for these windows survive in the Hardman archive.

CHAPTER 5

Conclusions

John Hardman and Company began producing stained glass in 1845 at the behest of architect AWN Pugin, and quickly became a prolific producer of stained glass windows. Pugin was the firm’s first chief designer, followed after his death in 1852 by his pupil John Hardman Powell, who continued Pugin’s adherence to medieval design principles. By 1850 James Hartley of Sunderland had become Hardmans’ major glass supplier, and Francis Emery of Cobridge supplied glass paints. Hancocks of Worcester also supplied glass paints, from around 1870 onwards.

The six windows commissioned for Sherborne Abbey and installed in 1851–52 represent early examples of Hardmans’ output, and show severe problems with the durability of the painted detail. By the time of installation of the Beverley Minster West window in 1859 and 1865, the durability had improved but there remain significant issues of paint loss. Later windows at Beverley and at All Saints’ Church Emscote show that the problem had largely been resolved by around 1880.

Examination of published nineteenth-century glass paint recipes shows the results of considerable experimentation with the composition of glass paints, with pearl-ashes, common salt, borax and arsenic all being added to the long-established lead glass composition, presumably to achieve lower firing temperatures; at least one commentator noted problems resulting from the addition of borax. Problems in firing were also noted, especially relating to the firing temperature and the fuel used in the kiln. The wide range of glass paints available, combined with rather basic control of the firing process, must have meant that achieving a satisfactory result was largely due to experience gained through trial and error; thus many possible reasons for failure can be suggested.

Technical study of panels from Sherborne, Beverley and Emscote has demonstrated that the glass paints used approximate those suggested in Porter's 1832 *Treatise on the Origin, Progressive Improvement and Present State of the Manufacture of Porcelain and Glass*. Although there appears to be no obvious chemical reason for their failure, examination using a scanning electron microscope shows the Sherborne paints to be over-pigmented and to contain relatively coarsely ground pigment; the most deteriorated samples also have numerous vertical micro-cracks through the painted layer. The use of lead silicate as well as soda-lime silicate as substrate glasses at both Sherborne and Beverley suggests that a relatively low firing temperature may have been used, leaving the paints under-fired. This would have left the paint layers vulnerable to environmental attack, resulting in the corrosion and breakdown seen in the Beverley samples. It is interesting to note that the paints used in all three case studies are reasonably similar to each other; no significant chemical differences can be seen which might explain the differences in later deterioration. It seems likely, therefore, that these differences are due to the physical structure of the paint layer, and therefore to the base glass used and the firing process, as well as to differences in the surrounding architectural environment.

Understanding the mechanism of deterioration is vital if appropriate conservation techniques are to be developed for the treatment of windows suffering from severe paint loss. The most important are methods of preventive conservation, particularly the installation of external protective glazing, which should slow down or even halt the deterioration by reducing contact with moisture. It is important that action is taken as soon as possible, as continued deterioration will lead to progressive loss of paint material, resulting in the fading effect seen at Sherborne and Beverley, and ultimately loss of evidence of the original appearance.

Restoration of lost painted detail is both difficult and controversial, with substantive arguments being made both for restoration to improve legibility and against restoration as falsifying the historical record. In every case a balanced judgement must be made as to the effect of restoration on the values and overall cultural significance of the window before proceeding. If the decision is made to restore detail, then several practical techniques, such as back-plating and cold painting, are available, each with advantages and drawbacks; again careful consideration is required in order to select the most appropriate technique for the particular circumstances.

Suggestions for further work

This study represents an initial approach to the problem of severe paint loss from nineteenth-century windows. Only one type of paint loss, experienced by windows created by one firm, has been examined; many opportunities therefore follow for expanding the scope of the study in both art-historical and technical directions.

Scanning electron microscopy coupled with energy dispersive x-ray spectrometry has proved to be a useful tool for examination of historic paint layers; however, the inability of this technique to detect boron (and hence confirm the presence, or absence, of borax) is frustrating. The identification of a suitable technique to both detect and quantify boron would be a very useful feature of any future study of nineteenth-century glass paints, allowing insight into what might actually constitute the ‘borax problem’.

Further investigation into the combined effects of glass paint composition, firing process and in-use environment would be extremely useful in order to identify the most important causes of paint deterioration. A number of paint, flux and pigment samples have been collected as part of this study (EDS analyses of selected samples are given in Appendix 3) which might form a useful basis for further work, for example, by subjecting a range of fired paint samples to controlled environmental changes in order to assess the resulting deterioration.

Finally, given the number of nineteenth-century windows currently suffering from loss of painted detail, further discussion and evaluation of appropriate conservation and restoration techniques would be very valuable to the conservation profession. In particular, the installation of protective glazing systems (now generally accepted for the preservation of medieval glass), as a method of protecting vulnerable paint surfaces from further deterioration, would be an important step forward in the treatment of these windows.