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# BELSAY CASTLE, BELSAY, NORTHUMBERLAND
# SCIENTIFIC ANALYSIS AND HISTORIC INTERPRETATION OF DECORATED WINDOW GLASS BY HENRY GYLES OF YORK

## TECHNOLOGY REPORT

David Dungworth and Susan Harrison


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Research Department Report Series 97-2011

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## SUMMARY
The chemical composition of window glass from Belsay has been investigated using a portable x-ray fluorescence (pXRF) spectrometer. The analysis was undertaken to better understand the nature of the glass and its decoration, and to evaluate the effectiveness of pXRF as a method for analysing window glass. The Belsay window is likely to have been produced at the end of the 17th century and fitted in the early 18th century, based on historical evidence. The window has recently undergone conservation treatment at the University of York which has ensured that the glass is free from surface dirt — the glass is in the best possible condition for chemical analysis using pXRF. The glass includes 25 very pale green panes of high-lime low-alkali (HLLA) glass, a single pane of kelp (sea weed) glass and two panes of modern (post-1830) glass. The glass compositions are entirely consistent with window glass from the end of the 17th century. The metals (Mn, Fe, Co, Ni, etc) responsible for a range of colours in the decorated glass were also identified.

## ARCHIVE LOCATION
The Belsay window is stored at the English Heritage Helmsley Archaeology Store, North Yorkshire.

## DATE OF RESEARCH
2011

## ACKNOWLEDGEMENTS
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## COVER IMAGE:
The Belsay window viewed by transmissive light. Copyright. English Heritage/Bob Smith

# INTRODUCTION

Belsay Hall, Castle and gardens lie North West of Newcastle in Northumberland. Belsay Castle has been the seat of the Middleton of Belsay family for over 700 years; John Middleton built the existing tower house before his death in 1396, and this was extended into a manor house in the early 17th century. A further wing was constructed in the early 18th century. This 18th-century wing was largely demolished in the 19th century when the Castle was remodelled — it is now a ruin. Belsay Hall, a large neo-classical hall, was completed in 1817 by Sir Charles Monck.

Parts of the Belsay estate were taken into state guardianship in 1980 and are cared for by English Heritage. The *ex situ* window from Belsay Castle (ref 81071211) was first accessioned into the English Heritage collections following guardianship. It had been stored in a first floor room at Belsay Hall since at least the early 1990s and was removed to the English Heritage Helmsley Archaeology store in 2010 for assessment, research and conservation treatment.

This window is the only surviving painted window from Belsay, although several have been recorded. William Dugdale, Herald from the College of Arms, visited Belsay Castle and nearby St. Andrew's Church, Bolam on 31st August 1666[1]. He recorded the arms painted on the walls and windows at Belsay Castle. This included two representations of a wild man, the crest of the Middleton of Belsay arms. One was in a window in the Great Hall bearing an oak tree and showed the arms of Middleton as well as the arms of Middleton, Strivelyn and Lucy combined. The other, in a refectory window, showed a wild man bearing an oak tree and a shield.

The window is a painted armorial set in its original oak frame. (Figure 1) The window would have originally comprised nine panes of decorated glass surrounded by 24 small panes of amber glass and sixteen panes of undecorated colourless or pale green glass (Figure 1). The glass is crown glass of 1–2mm thickness. Some of the panes are slightly curved. The window is largely complete and in original condition with only the lower bearer of the frame and one painted pane, two amber panes and six colourless panes missing and a replaced glass panel and mending lead both in the outer border.[2] It has four horizontal iron square sectioned bars set into the frame; the leaded window is tied to these bars with copper alloy ties. Some of the ties are punched through the lead net as part of a later repair. The frame has layers of red paint and white paint on the inner face and a layer of white paint on the outer face. There is a single strip of modern pine (20mm deep) nailed to the top of the frame to provide support. This is probably of a mid 20th-

1 Dugdale's visitation 1666

2 New replacement panes were inserted during conservation undertaken by Alexandra Jung of the University of York in 2011. New leads were also inserted where missing. A full report on the work undertaken is available in the site archive.

century date. The original size of the window was 1117mm high, 915mm wide and 43mm deep.


*Figure 1. The complete window viewed by reflective light post-conservation 2011*

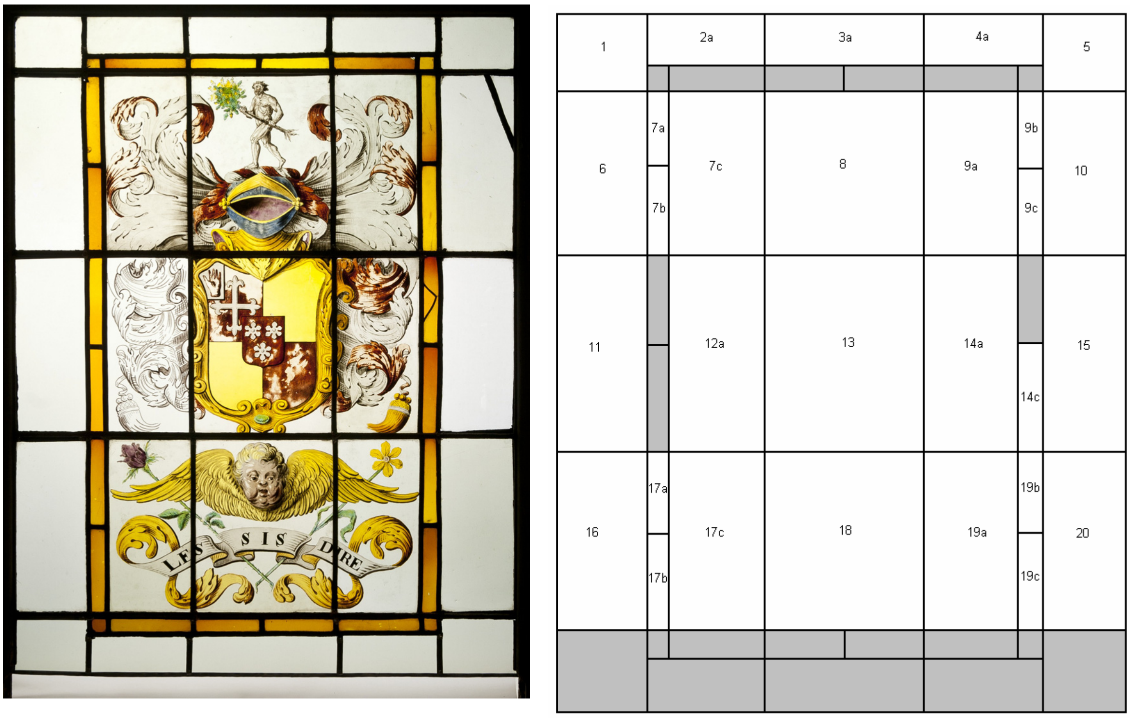


*Figure 2. The Belsay window and a schematic representation indicating the pane numbering used for this report (panes shaded grey were missing or not analysed)*

*Figure 3. Inner section of Edmond Gyles lead came*

*Figure 4. Inner section of EW lead came*

The glass panes are held together using an 8–8.5mm wide milled lead came of flat H-profile for the painted panes and the amber border including the surrounding lead of the latter. The leads of the outer plain border are of the same profile but slightly wider at 9–9.5mm. The cames are of different origins. The core of the lead cames of the inner section are impressed with the legend *EDMOND*GILES*OE*YORKE*1665*(Figure 3). This differs slightly on each side of the core. The came holding the colourless panes, including that inserted into the oak frame is impressed *EW*1697* (Figure 4) on one side of the core only, the other side bearing parallel milling marks. Although not all the leads are accessible it is possible to determine and map the different types by size.

The arms are: below a forward facing baronet's helm topped with a wild man holding an erased and fructed oak tree dexter is a central shield, quarterly, gules and or, in the first quarter a cross flory argent, with a sinister hand gules in canton. Centrally placed over that shield is a shield gules, three sexfoil argent. Below the main shield is a cherub head emerging from golden wings above the motto 'LES SIS DIRE' with a red rose and a yellow sexfoil narcissus both on long stalks crossed through the design.

The central shield of quartered red and gold with a cross flory in the upper left quadrant is that of the Middleton of Belsay arms. In addition a red left hand is placed in a square (canton) in the upper left quadrant to signify the status of Baronet. The central superimposed shield of three gold narcissi on a red background are the arms of Lambert of Calton, Yorkshire. The motto is that of the Middleton of Belsay family and means 'Let speak'. The crossed red rose and yellow narcissus are symbolic of the union of the two families of Middleton and Lambert. The arms are undoubtedly those of Sir John Middleton 2nd Baronet (1678–1717) who married Frances Lambert of Calton, Kirby Malham (grand daughter of General John Lambert) on 15th June 1699 at Kirby Malham.

The painting of the panel can most likely be assigned to Henry Gyles (1645–1709) a master glass painter and part of the Virtuosi group of the city of York in the 17th century. His father, Edmond Gyles (1611–76) was a glazier and a freeman of the city of York and of the guild of glaziers from 1634. Henry continued to use his father's mill throughout his life, despite at one point enquiring of a mill manufacturer in London in 1668 (Stowe 745, f.21). The use of this mill through two generations from 1665 to at least 1699 indicates that lead window came mills had a previously unrecognised longevity. Further examples of Edmond Gyles came used in Henry Gyles windows are known.[3]

The Belsay window does not exhibit a signature despite the fact that Gyles usually signed his work; however it is possible that he signed the pane which is now missing. Stylistically the window painting matches a number of Gyles' other works. Sundials and armorials were his speciality, although the advent of sash windows meant that fewer sundials were commissioned towards the end of his life. The cherub appears throughout his work and closely matches those painted on windows attributed to him at St John the Baptist's Church, Adel, Leeds and The Merchant Taylor's Hall, York. The dull red enamel and the now failing green enamel are also indicative of Gyles' work.

Further evidence linking Henry Gyles to this window is provided by his friendship with Frances Lambert's father, John Lambert. Lambert was an artist and part of the York

[3] There are strips of came from windows restored by Keith Barley of York in private hands.

Virtuosi who met at Gyles' house in York, correspondence between them also survives.[4] Similarly there is a connection between Gyles and John Middleton. In 1702 Gyles lent John Middleton his handwritten treatise on glass painting. Gyles inscribed 'Henry Gyles' book lent to Sr John Middleton June ye 7th 1702' inside the front cover.[5]

The original context for this window is unknown however it is surmised to be from one of the window apertures of the west wing extension at Belsay Castle completed by 1711(Figures 5 and 6)[6]. The window apertures on the 14th- and 17th-century building phases are too small and those at Belsay Hall too large. The lost Presbyterian chapel built by the non-conformist Middletons in the 17th century, abandoned in the early 19th century now underlying the front of Belsay Hall is unlikely to have had armorial windows.

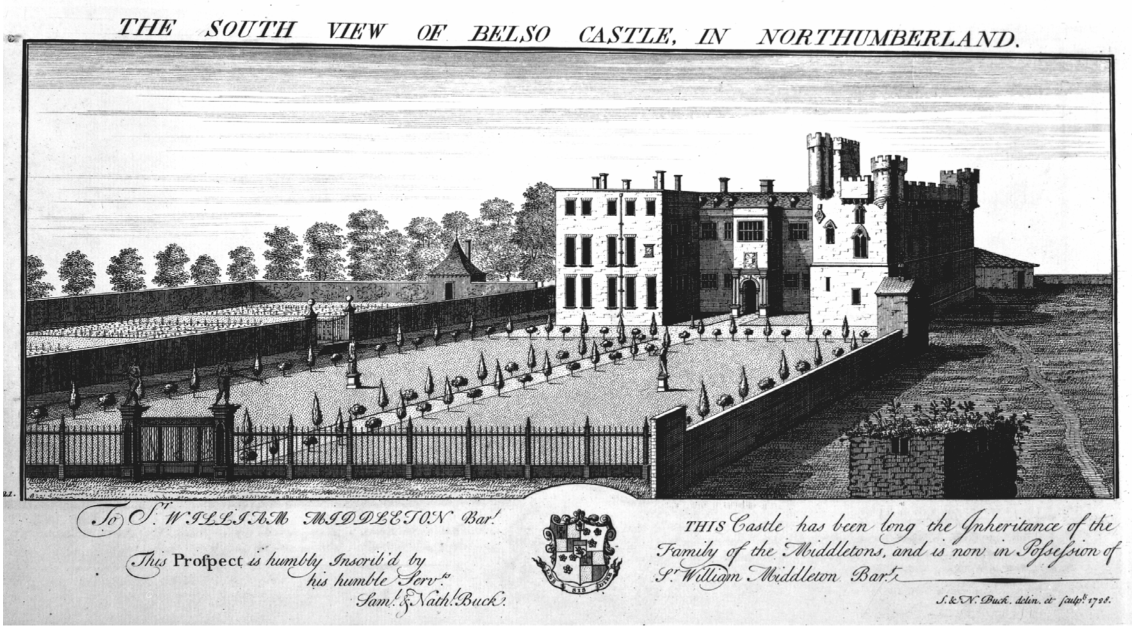


*Figure 5. The South view of Belsay Castle in Northumberland by Samuel and Nathaniel Buck 1728*

This window is probably the upper part of a fixed sash (Treve Rosoman personal communication) and its measurements fits the main series of windows fronting the new '1711' extension, of which one aperture remains complete today. This post-dates both the date surmised for the original manufacture of the window of 1699 and the death of the artist in 1709. Either the date of this extension is earlier than the date on the sundial

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4 Stowe 746, f34 and f37

5 Harl. 6376

6 Dated by a stone sundial shown on the building in a drawing by the Buck brothers in 1728. The sundial is now part of the fabric of West Bitchfield Tower, approx 1 mile south of Belsay Castle.

or the window was commissioned and stored or installed elsewhere and was subsequently installed at Belsay Castle.


*Figure 6. West Bitchfield Tower sundial 1711 (©Lightwave Studios 2010/Adam Lawrenson)*

John Middleton and his wife Frances occupied the Lambert seat of Calton Hall, Kirkby Malham, Yorkshire following the death of Frances Lambert's father in 1701. Calton Hall was eventually sold by their son Sir William Middleton 3rd baronet in 1727. The couple's first two children were baptised at Kirkby Malham, but by 1705 records show subsequent children were baptised and buried at Bolam church, Belsay (Hodgson 1827, 356) indicating that they may have moved to Belsay by then. Observations made during conservation on the solder joins between the outer 'Gyles' and the 'EW' cames show a very smooth surface with no trace of any already occurred lead oxidation at the time when they were soldered (Alexandra Jung personal communication). This means that if the plain border was added later on, it must have happened within a few years, after the painted panel had been leaded. However there are no signs on either the amber border or its surrounding leads, indicating any kind of preceding installation.

## AIMS AND OBJECTIVES

The Belsay window was analysed using a portable X-Ray Fluorescence (pXRF) to provide insights into the nature of the glass and to test the effectiveness of pXRF. It was hoped that the analysis of the Belsay window would provide a means of testing the recently published model for the chronological development of English window glass compositions (Table 1).The historic investigation suggests that the Belsay window was produced at the end of the 17th century; a period when window glass manufacturing technology was undergoing a transformation. From the late 16th century until the end of the 17th century almost all English windows made use of high-lime low-alkali (HLLA) glass. At the beginning of the 18th century kelp (sea weed) glass quickly came to dominate the flat glass market. Differences observed during examination of the window also suggested that although the central section of the window was undoubtedly painted to celebrate a marriage in 1699 it may have been fitted into its frame at a later date by another glazier or plumber using a different lead came and potentially a different source of glass.

*Table 1. Typical composition of different types of historic window glass (Dungworth 2011)*

| Phase | 1 | 2a | 2b | 3 | 4a | 4b | 5a | 5b |
|---|---|---|---|---|---|---|---|---|
| Start | | c1567 | c1600 | c1700 | c1835 | c1870 | c1930 | c1960 |
| End | c1567 | c1600 | c1700 | c1835 | c1870 | c1930 | c1960 | |
| $Na_2O$ | 2.5±0.3 | 1.4±0.7 | 2.4±1.4 | 7.9±0.7 | 12.7±0.9 | 12.9±2.1 | 13.9±0.5 | 13.3±0.4 |
| MgO | 7.3±0.7 | 3.4±0.5 | 3.0±0.7 | 5.3±0.3 | 0.2±0.1 | 0.2±0.2 | 2.8±0.2 | 3.8±0.2 |
| $Al_2O_3$ | 1.6±0.5 | 2.8±1.0 | 3.0±1.3 | 2.6±0.6 | 0.6±0.1 | 1.2±0.3 | 0.9±0.6 | 1.3±0.2 |
| $SiO_2$ | 55.8±2.5 | 60.4±1.8 | 60.9±2.0 | 66.5±1.4 | 70.8±1.2 | 71.9±0.4 | 72.2±0.7 | 72.2±0.5 |
| SO3 | 0.3±0.1 | 0.2±0.1 | 0.4±0.2 | 0.2±0.1 | 0.4±0.1 | 0.4±0.2 | 0.4±0.2 | 0.2±0.1 |
| Cl | 0.4±0.2 | 0.3±0.2 | 0.2±0.1 | 0.6±0.1 | 0.1±0.1 | <0.1 | <0.1 | <0.1 |
| $P_2O_5$ | 3.2±0.4 | 2.1±0.2 | 2.1±0.6 | 1.1±0.2 | <0.2 | <0.2 | <0.2 | <0.2 |
| $K_2O$ | 11.4±1.5 | 5.6±1.6 | 5.1±1.9 | 4.2±0.2 | 0.1±0.1 | 0.5±0.2 | 0.1±0.1 | 0.6±0.1 |
| CaO | 15.3±1.6 | 21.5±1.9 | 21.1±1.7 | 10.4±1.0 | 14.0±0.8 | 12.9±1.6 | 9.7±0.8 | 8.3±0.6 |
| MnO | 1.26±0.30 | 0.94±0.37 | 0.24±0.20 | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 |
| $Fe_2O3$ | 0.65±0.13 | 1.01±0.20 | 1.31±0.29 | 0.71±0.14 | 0.22±0.06 | 0.21±0.06 | 0.13±0.03 | 0.12±0.01 |
| $As_2O_3$ | <0.20 | <0.20 | <0.20 | <0.20 | 0.22±0.16 | <0.20 | <0.20 | <0.20 |
| SrO | 0.07±0.01 | 0.09±0.02 | 0.07±0.01 | 0.45±0.10 | 0.03±0.01 | 0.02±0.01 | 0.01±0.01 | 0.01±0.01 |

The pXRF analysis of the Belsay window was also undertaken to help test this method for the analysis of *in situ* window glass. There are two aspects of this window that provide ideal conditions for pXRF, especially when compared to other recent and ongoing programmes of analysis. The fact that the window is detached from the castle means that access was very straight forward. This contrasts with the analysis of some *in situ* windows located more than 1m above floor height (Dungworth and Girbal 2011). Where access to a window is difficult and/or uncomfortable, it is more likely for instrumental errors to affect the results — primarily because of difficulties in maintaining the instrument in contact with the glass throughout the analysis. The recent conservation treatment of this window at the University of York (the glass is now almost completely free of any surface deterioration or adhering dirt) has resulted in surfaces that are as clean as could ever be expected for historic window glass. This contrasts with some windows analysed recently which have had chemically weathered surfaces that were also covered in a thin film of dirt; both of these phenomena are likely to have a significant impact on pXRF data quality (Dungworth *et al* 2011).

## METHODS

The pXRF instrument used was a Niton XL3t which was operated following procedures developed during the *in situ* analysis of historic window glass at Walmer Castle (see Dungworth and Girbal 2011 for further details). The Niton XL3t is not capable of reporting the sodium content of any analysed material. The detection limits for light elements (Z = 12–17) was improved by flushing the instrument with helium. It is anticipated that the results for light elements (Z = 12–22) will be affected to some degree by surface corrosion or contamination (cf Dungworth and Girbal 2011). Development testing of the Niton XL3t on window glass (Dungworth and Girbal 2011) has established that where the glass thickness was less than the effective X-Ray penetration, light elements were consistently overestimated.

During the conservation treatment undertaken at the University of York, a small fragment of pane 6 was detached and made available for laboratory-based analysis. This was prepared using standard techniques and analysed using SEM-EDS for elements up to iron and using EDXRF for heavier elements (the techniques are described in more detail in Dungworth 2009).

## RESULTS

The comparison of the data obtained on the chemical composition of pane 6 using SEM-EDS/EDXRF and pXRF suggests that latter technique has consistently underestimated the concentration of light elements (Table 2). The analytical total (the sum of all elements detected) falls significantly short of 100wt% — in the case of pane 6 the pXRF analytical total is less than 80wt%. While a small proportion of this short-fall can be explained by the presence of sodium, which cannot be detected using the Niton XL3t, this cannot explain all of the deficit. The consistent underestimation is the opposite effect that would be expected if the glass were thinner than the effective X-Ray penetration, however, the correlation between element atomic number and pXRF underestimation (Figure 7) suggests that this phenomenon is an instrumental error rather than a reflection of the nature of the glass. The reasons for this error are unclear — the glass showed no visible signs of deterioration, corrosion or adhering dirt which might affect the analytical results.

*Table 2. Chemical composition of pane 6 as determined by SEM-EDS/EDXRF and pXRF*

| | SEM-EDS | pXRF |
|---|---|---|
| $Na_2O$ | 3.00 | NA |
| MgO | 2.86 | 0.90 |
| $Al_2O_3$ | 2.42 | 1.22 |
| $SiO_2$ | 59.69 | 43.31 |
| $P_2O_5$ | 2.24 | 1.40 |
| $SO_3$ | 0.56 | 0.61 |
| Cl | 0.47 | 0.33 |
| $K_2O$ | 4.06 | 3.27 |
| CaO | 23.17 | 26.18 |
| $TiO_2$ | 0.19 | 0.18 |
| MnO | 0.17 | 0.16 |
| $Fe_2O_3$ | 1.20 | 1.21 |
| $Rb_2O$ | 0.003 | 0.003 |
| SrO | 0.127 | 0.130 |
| $ZrO_2$ | 0.016 | 0.017 |

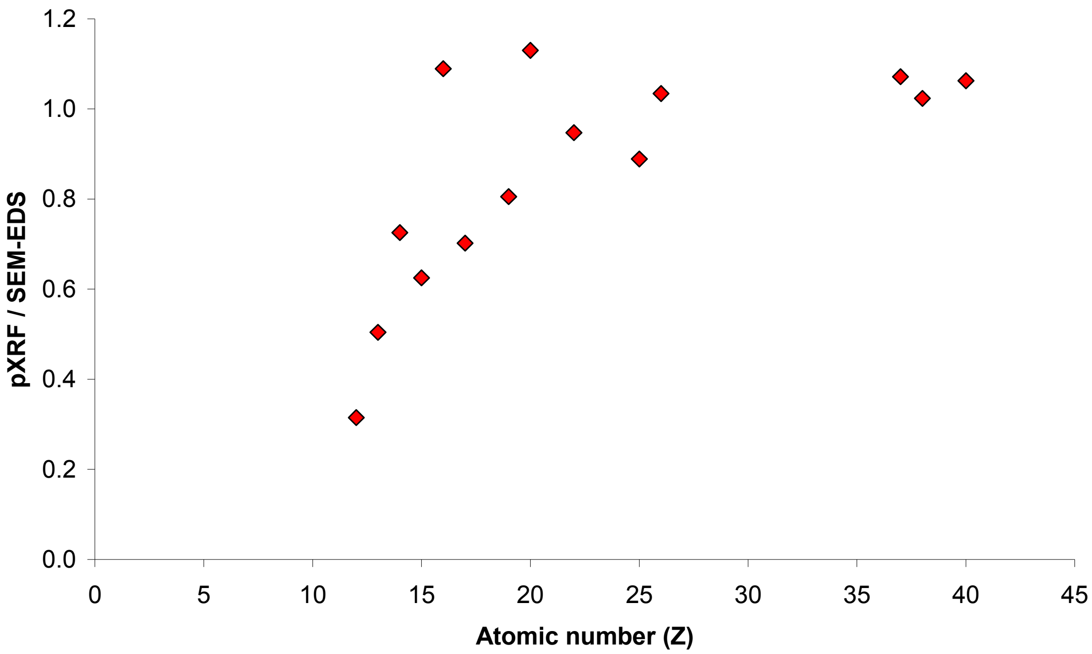


*Figure 7. pXRF underestimation versus atomic number for pane 6*

The comparison between SEM-EDS/EDXRF results and those obtained using pXRF on pane 6 suggest that pXRF will have underestimated elements up to potassium but that heavier elements will be largely unaffected. Even though light elements are likely to have been underestimated using pXRF, it is still possible to assign all of the analysed glass to one of the major categories of historic window glass (cf Table 1). Most of the panes are HLLA glass but there is a single pane of kelp glass and two modern[7] replacement panes.

Panes 11 and 12c are made of a glass which contains very low levels of minor elements. The absence of phosphorus suggests that this glass was made using synthetic soda (eg Leblanc soda) rather than alkali derived from any plant ash (Figure 8). This indicates that these panes were manufactured after the introduction of synthetic soda manufacturing technology (c1830). Pane 15 contains a sufficient range of minor elements including phosphorus to indicate that it was manufactured using alkali derived from a plant. The very high levels of strontium (Figure 9) allow the plant used to be identified as kelp (sea weed), which shows that the pane was probably between c1700 and c1830. A small amount of vessel glass was manufactured using kelp during the last few decades of the 17th century (Dungworth and Cromwell 2006) but it does not appear to have been used for window glass until the beginning of the 18th century. Given the likely date of manufacture of the Belsay window, pane 15 could be original; however, if it is a later repair or replacement, this is likely to have taken place before c1830.

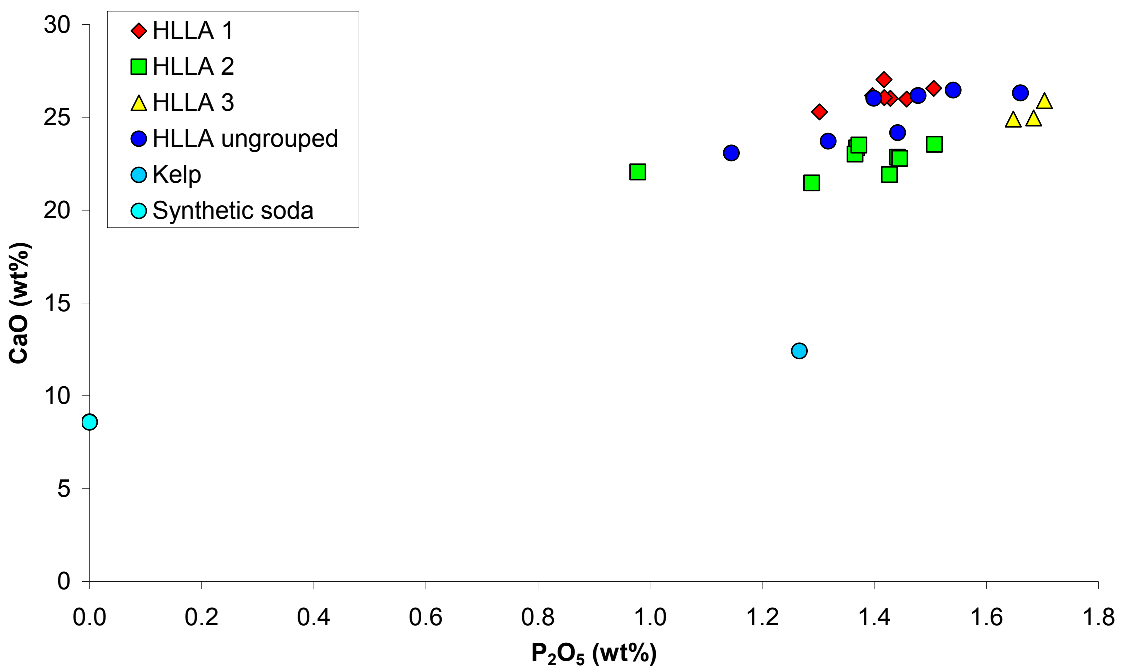


*Figure 8. CaO and $P_2O_5$ concentrations showing different glass types and groups*

[7] Two modern panes inserted during conservation in 2011

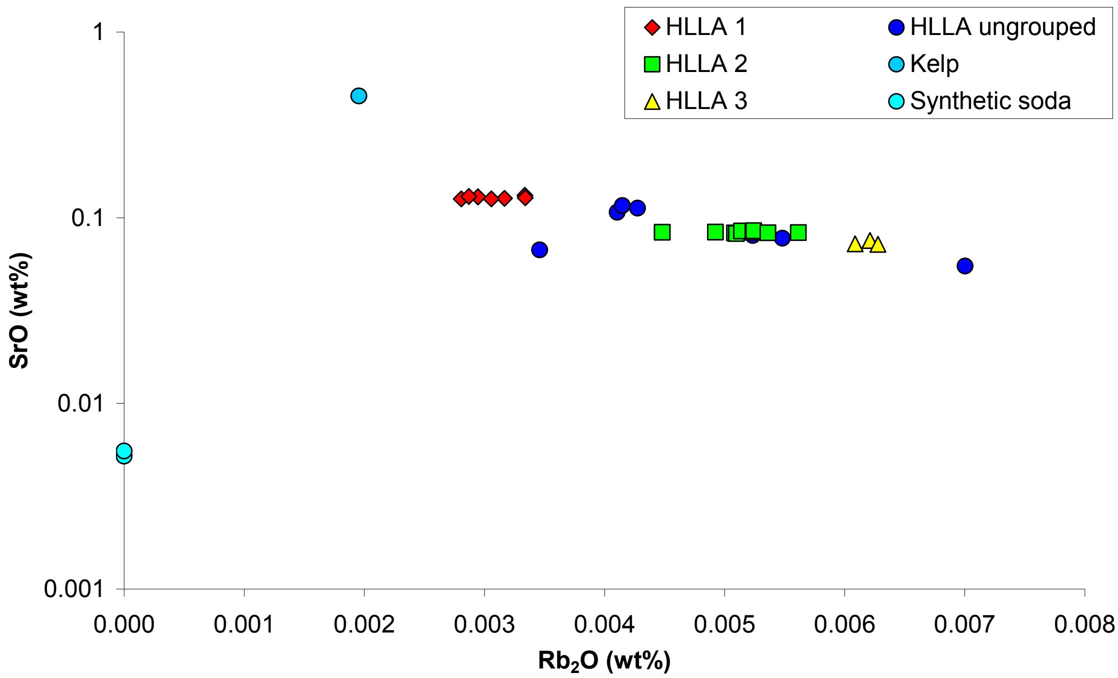


*Figure 9. SrO and $Rb_2O$ concentrations showing different glass types and groups*

All of the remaining panes contain sufficient phosphorus to indicate that they were manufactured using a plant ash. The relatively low strontium content of these panes shows that this was a terrestrial plant ash. The high calcium content of this glass confirms that it is a HLLA type. HLLA glass was produced in England from the late 16th century and was widely used for windows until the beginning of the 18th century.

*Table 3. Average composition of HLLA glass groups (pXRF)*

| | MgO | $Al_2O_3$ | $SiO_2$ | $P_2O_5$ | $K_2O$ | CaO | $TiO_2$ | MnO | $Fe_2O_3$ | $Rb_2O$ | SrO | $ZrO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.9 | 1.1 | 42.9 | 1.4 | 3.3 | 26.2 | 0.18 | 0.16 | 1.2 | 0.003 | 0.13 | 0.017 |
| 2 | 0.7 | 1.1 | 42.9 | 1.4 | 3.9 | 22.7 | 0.16 | 0.18 | 1.2 | 0.005 | 0.08 | 0.015 |
| 3 | 0.9 | 1.4 | 43.6 | 1.7 | 4.5 | 25.3 | 0.20 | 0.22 | 1.4 | 0.006 | 0.07 | 0.018 |

The HLLA glass comprises several compositional groups (Figure 4, Table 3) which can be defined partly through major and minor elements (Figure 3), although the groupings are even more clearly seen when trace elements are considered (Figure 4). The existence of several HLLA compositional groups probably reflects the use of glass from more than one source. HLLA 1 glass is found exclusively in the plain border around the window, while HLLA 2 and HLLA 3 are used for the central decorated panes and some HLLA 2 is used for the thin amber border (Figure 10).

The differences in chemical composition between the HLLA 1 glass used for the border and the HLLA 2 and HLLA 3 glasses used for the central decorated panes may provide some clues about how the window as a whole was produced. The border glass and the decorated glass were not obtained from the same source and this division hints at craft-based choices in the materials used. It is possible that the glass used for the decorated panes was deliberately selected because it was in some way better suited for painting (or perhaps just *perceived* as better for painting). Alternatively, the division may be between different artisans: the decorated glass panel may have been produced by one artisan and then supplied to another who assembled the decorated and plain glass into the finished window. This seems most likely given that Gyles seemed to assemble, or be responsible for assembling his own panes using came of his own manufacture but was largely confined to York in the later part of his life. In addition there may have been a time lag between original manufacture and final fitting.

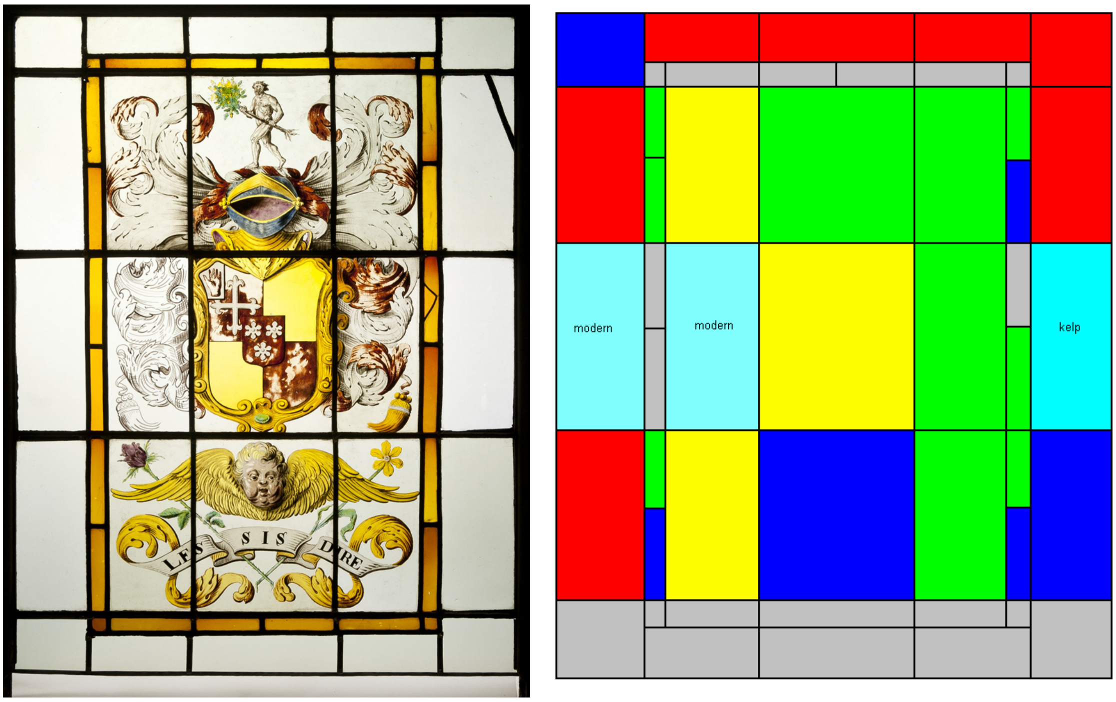


*Figure 10. The Belsay window and a schematic representation indicating the chemical type and groups of the analysed panes (the colours indicate glass type and group and correspond to those used in Figures 3 and 4; panes shaded grey were missing or not analysed)*

The glass in pane 10, which shows a leaded repair, is contemporary with the majority of the other outer panes. The mending lead is not soldered to the lead net. The pane below it (number 15) may be interpreted as a later insertion and may have been part of the same repair. It has not been possible to examine the core of the leads above, below and between panes 10 and 15 but they match the width of the 'EW' came, as does the width of the repair lead. Given the possible date range of the manufacture of pane 15 and the lack of oxidation on the cames and the matching cames the repair is likely to have taken place within a few years or even at the original fitting of the window. Additionally there is a strip of 'EW' came between panes 8 and 13 which may be a contemporary repair when the undecorated colourless border glass was fitted.

## CONCLUSIONS

The pXRF analysis of the detached window from Belsay Castle (ref 81071211) has succeeded in characterising the nature of the glass used. It was possible to obtain information on the chemical composition of 29 separate panes of glass in less than two hours. To have attempted to obtain comparable information using laboratory-based instruments would have taken several days. The speed and ease with which pXRF data can be obtained (to say nothing of the fact that no damage is done in the process) makes this a valuable tool for the conservation of historic materials such as window glass.

The recent conservation treatment of the window and the fact that it was easily accessible in an archaeological store, rather than being *in situ* in a building, provided ideal conditions for pXRF analysis. Nevertheless, the results obtained do not appear to provide a fully accurate quantitative indication of the glass composition. The sum of all the elements detected falls considerably short of 100wt%. A comparison between the pXRF and the laboratory-based analysis of pane 6 suggests that the concentration of light elements has been consistently underestimated by pXRF.

The scientific dating of the glass corroborates the historic investigation evidence in dating the initial production of the window to 1699 and subsequent fitting and repair in the early 18th century. Together the evidence confirms the significance of the central panel as an important example of late Gyles' work and the unusual survival of an original unrestored early 18th-century window.

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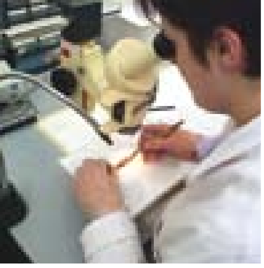
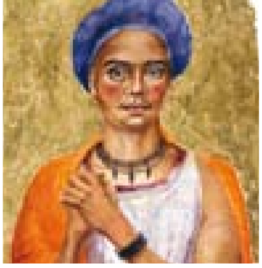
## APPENDIX 1. PXRF RESULTS

| | MgO | $Al_2O_3$ | $SiO_2$ | $P_2O_5$ | $SO_3$ | Cl | $K_2O$ | CaO | $TiO_2$ | MnO | $Fe_2O_3$ | CuO | ZnO | $As_2O_3$ | $Rb_2O$ | SrO | $ZrO_2$ | Type |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 01 | 0.6 | 1.0 | 41.6 | 1.1 | 0.5 | 0.2 | 4.0 | 23.1 | 0.19 | 0.21 | 1.21 | <0.01 | 0.02 | <0.01 | 0.004 | 0.116 | 0.015 | HLLA? |
| 02 | 0.9 | 1.1 | 41.8 | 1.4 | 0.6 | 0.3 | 3.3 | 26.0 | 0.17 | 0.16 | 1.18 | <0.01 | 0.02 | <0.01 | 0.003 | 0.127 | 0.017 | HLLA1 |
| 03 | 0.8 | 1.2 | 43.1 | 1.4 | 0.5 | 0.3 | 3.5 | 27.0 | 0.18 | 0.17 | 1.23 | <0.01 | 0.02 | <0.01 | 0.003 | 0.132 | 0.017 | HLLA1 |
| 04 | 0.9 | 1.2 | 43.3 | 1.4 | 0.6 | 0.3 | 3.3 | 26.2 | 0.18 | 0.16 | 1.21 | <0.01 | 0.02 | <0.01 | 0.003 | 0.130 | 0.017 | HLLA1 |
| 05 | 0.9 | 1.0 | 42.4 | 1.4 | 0.4 | 0.3 | 3.3 | 26.1 | 0.18 | 0.16 | 1.17 | <0.01 | 0.02 | <0.01 | 0.003 | 0.128 | 0.017 | HLLA1 |
| 06 | 0.8 | 1.0 | 40.4 | 1.3 | 0.4 | 0.3 | 3.2 | 25.3 | 0.17 | 0.15 | 1.19 | <0.01 | 0.02 | <0.01 | 0.003 | 0.126 | 0.017 | HLLA1 |
| 07a | 0.7 | 1.2 | 44.7 | 1.5 | 0.7 | 0.3 | 4.2 | 23.5 | 0.16 | 0.18 | 1.23 | 0.01 | 0.02 | <0.01 | 0.005 | 0.085 | 0.015 | HLLA2 |
| 07b | 0.8 | 1.1 | 44.8 | 1.3 | 0.3 | 0.3 | 3.5 | 21.5 | 0.15 | 0.17 | 1.16 | 0.06 | 0.02 | <0.01 | 0.005 | 0.083 | 0.014 | HLLA2 |
| 07c | 0.9 | 1.4 | 42.8 | 1.7 | 1.4 | 0.3 | 4.6 | 25.0 | 0.20 | 0.23 | 1.41 | 0.01 | 0.03 | 0.01 | 0.006 | 0.072 | 0.019 | HLLA3 |
| 08 | 0.7 | 1.1 | 42.3 | 1.4 | 1.1 | 0.3 | 4.0 | 23.0 | 0.16 | 0.19 | 1.26 | 0.01 | 0.02 | 0.02 | 0.005 | 0.082 | 0.015 | HLLA2 |
| 09a | 0.7 | 1.1 | 42.5 | 1.4 | 1.3 | 0.3 | 4.1 | 22.8 | 0.16 | 0.18 | 1.22 | 0.01 | 0.02 | 0.03 | 0.006 | 0.083 | 0.014 | HLLA2 |
| 09b | 0.9 | 1.2 | 45.6 | 1.4 | 0.4 | 0.3 | 3.5 | 21.9 | 0.15 | 0.20 | 1.17 | 0.09 | 0.02 | <0.01 | 0.005 | 0.083 | 0.015 | HLLA2 |
| 09c | 0.5 | 0.9 | 41.4 | 1.3 | 0.6 | 0.1 | 4.1 | 23.7 | 0.14 | 0.10 | 1.17 | 0.19 | 0.02 | <0.01 | 0.007 | 0.055 | 0.015 | HLLA? |
| 10 | 1.0 | 1.2 | 43.3 | 1.5 | 0.5 | 0.3 | 3.4 | 26.0 | 0.18 | 0.17 | 1.19 | <0.01 | 0.02 | <0.01 | 0.003 | 0.126 | 0.018 | HLLA1 |
| 11 | <0.5 | <0.2 | 52.1 | <0.5 | 0.1 | 0.4 | 3.1 | 8.6 | 0.54 | <0.01 | <0.01 | 0.01 | <0.01 | <0.01 | <0.001 | 0.005 | 0.004 | Modern |
| 12c | <0.5 | <0.2 | 51.4 | <0.5 | 0.1 | 0.4 | 3.1 | 8.6 | 0.54 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.001 | 0.006 | 0.004 | Modern |
| 13 | 1.0 | 1.5 | 44.6 | 1.7 | 2.0 | 0.2 | 4.6 | 25.9 | 0.21 | 0.21 | 1.45 | 0.01 | 0.02 | 0.04 | 0.006 | 0.075 | 0.018 | HLLA3 |
| 14a | 0.7 | 1.2 | 39.9 | 1.7 | 1.0 | 0.2 | 3.7 | 26.3 | 0.17 | 0.18 | 1.43 | 0.01 | 0.02 | 0.01 | 0.005 | 0.078 | 0.016 | HLLA? |
| 14c | 0.8 | 1.3 | 46.7 | 1.4 | 0.6 | 0.3 | 3.7 | 22.9 | 0.16 | 0.17 | 1.22 | 0.04 | 0.02 | <0.01 | 0.005 | 0.085 | 0.015 | HLLA2 |
| 15 | 2.4 | 0.8 | 53.1 | 1.3 | 0.0 | 0.5 | 3.7 | 12.4 | 0.11 | <0.01 | 0.57 | <0.01 | <0.01 | 0.01 | 0.002 | 0.454 | 0.006 | Kelp |
| 16 | 1.1 | 1.3 | 45.7 | 1.5 | 0.5 | 0.3 | 3.3 | 26.6 | 0.18 | 0.15 | 1.22 | <0.01 | 0.02 | <0.01 | 0.003 | 0.130 | 0.017 | HLLA1 |
| 17a | 0.9 | 1.3 | 45.7 | 1.4 | 0.3 | 0.3 | 4.1 | 23.5 | 0.17 | 0.19 | 1.24 | 0.01 | 0.02 | <0.01 | 0.005 | 0.083 | 0.015 | HLLA2 |
| 17b | 0.7 | 0.8 | 41.7 | 1.5 | 0.8 | 0.2 | 3.5 | 26.2 | 0.16 | 0.25 | 1.06 | 0.01 | 0.02 | 0.01 | 0.004 | 0.107 | 0.015 | HLLA? |
| 17c | 0.8 | 1.4 | 43.4 | 1.6 | 0.7 | 0.2 | 4.5 | 24.9 | 0.19 | 0.22 | 1.44 | 0.01 | 0.02 | <0.01 | 0.006 | 0.072 | 0.018 | HLLA3 |
| 18 | 0.7 | 1.1 | 38.1 | 1.5 | 0.6 | 0.2 | 3.5 | 26.5 | 0.18 | 0.18 | 1.40 | 0.01 | 0.02 | <0.01 | 0.005 | 0.080 | 0.017 | HLLA? |
| 19a | 1.0 | 1.1 | 44.5 | 1.4 | 0.5 | 0.3 | 4.0 | 23.4 | 0.16 | 0.18 | 1.23 | <0.01 | 0.02 | <0.01 | 0.004 | 0.084 | 0.014 | HLLA2 |
| 19b | 0.0 | 0.4 | 29.5 | 1.0 | 1.0 | 0.2 | 3.8 | 22.1 | 0.16 | 0.18 | 1.27 | 0.01 | 0.02 | 0.02 | 0.005 | 0.084 | 0.015 | HLLA2 |
| 19c | 1.0 | 1.7 | 42.2 | 1.4 | 0.5 | 0.6 | 1.9 | 26.0 | 0.22 | 0.51 | 0.75 | <0.01 | 0.03 | <0.01 | 0.003 | 0.067 | 0.015 | HLLA? |
| 20 | 1.3 | 1.4 | 47.0 | 1.4 | 0.3 | 0.3 | 4.4 | 24.2 | 0.17 | 0.12 | 1.36 | <0.01 | 0.02 | <0.01 | 0.004 | 0.113 | 0.017 | HLLA? |

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