Wythenshawe Hall, Manchester. Assessment of Historic Window Glass

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SUMMARY
A survey of fire-damaged historic window glass at Wythenshawe Hall which included the *in situ* chemical analysis of 347 individual panes confirmed that much of the glass had been produced in the 17th century (or earlier) and was probably contemporary with the construction of the hall.

ACKNOWLEDGEMENTS
Thanks to Peter Barlow who initially suggested the survey and who provided numerous plans and photographs.

ARCHIVE LOCATION
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INTRODUCTION

Wythenshawe Hall is a grade II* listed Tudor timber-framed house built in 1540 for Robert Tatton. At the end of the 18th century, Lewis Wyatt partially rebuilt the hall and further alterations (possibly by Edward Blore) were made around 1840. In the 1920s the house and estate were sold to Manchester Corporation, and the house was for many years used as a museum and art gallery. In March 2016 the hall was damaged by fire. The fire damage completely destroyed one window (Figure 1) and damaged several others. The damaged window glass included numerous examples with decorated and heraldic glass. In order to inform the conservation of these windows, a survey was made of the affected windows. The aim was to identify the likely age of the extant glass in order to understand the significance of the windows and inform their future conservation. The survey included *in situ* measurements of chemical composition using portable X-ray fluorescence (pXRF) as well as laboratory-based chemical analysis using samples where these were available.

Figure 1. Wythenshawe Hall, window F9 showing extensive fire damage

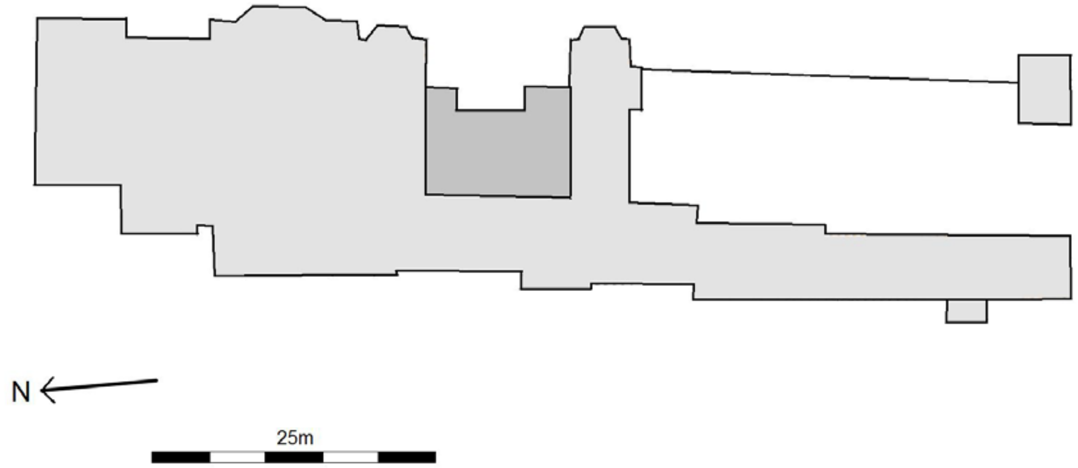

Figure 2. Plan of Wythenshawe Hall showing the historic core (darker grey)

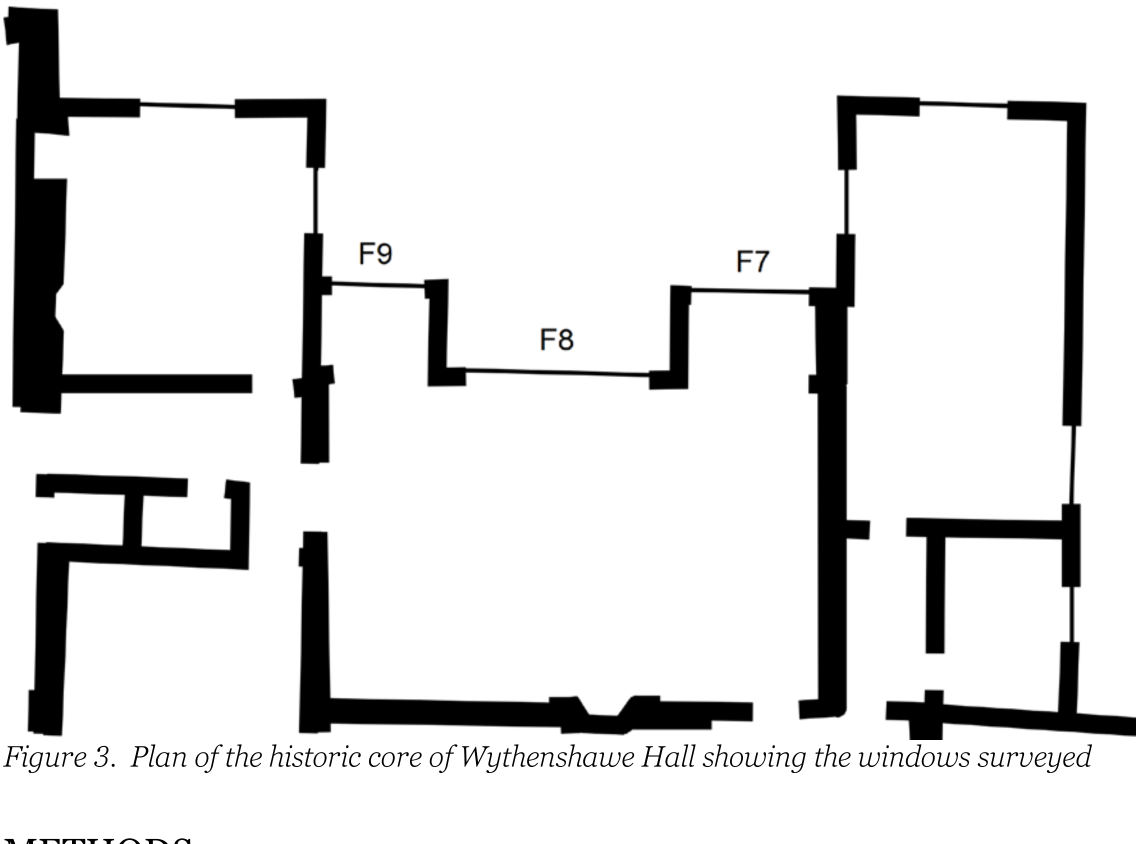

Figure 3. Plan of the historic core of Wythenshawe Hall showing the windows surveyed

METHODS

The main method used to complete the survey was portable X-ray fluorescence (pXRF) which was used to obtain information on the presence and concentration of a range of chemical elements in the glass. This technique has been successfully applied to the window glass in a number buildings (Dungworth 2012a; 2012b; 2014; Dungworth and Girbal 2011; Girbal and Dungworth 2011) and it has been shown that the chemical composition of the glass usually falls into one of several groups that can be assigned to particular periods (Table 1).

Table 1. Composition of historic window glass of different periods

Type	Date	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	MnO	Fe_2O_3	As_2O_3	SrO
Forest	<1567	2.5	7.3	1.6	55.8	3.2	11.4	15.3	1.26	0.65	<0.05	0.07
		±0.3	±0.7	±0.5	±2.5	±0.4	±1.5	±1.6	±0.30	±0.13		±0.01
HLLA	1567–1700	2.0	3.1	2.9	60.7	2.1	5.3	21.2	0.52	1.19	<0.05	0.08
		±1.3	±0.6	±1.1	±1.9	±0.5	±1.8	±1.7	±0.45	±0.29		±0.02
Kelp	1700–1835	7.8	5.3	2.8	66.6	1.1	4.2	10.1	<0.05	0.75	<0.05	0.43
		0.7	0.3	0.6	1.4	0.2	0.2	0.9		0.17		0.08
LeBlanc	1835–1930	12.4	0.2	0.9	71.0	<0.2	0.3	13.9	0.17	0.26	0.16	0.02
		±1.1	±0.1	±0.3	±1.3		±0.2	±1.1	±0.37	±0.06	±0.18	±0.01
Drawn	1930–1960	14.5	2.4	0.8	72.2	<0.2	0.1	9.6	<0.05	0.13	<0.05	0.01
		±1.2	±1.0	±0.5	±0.6		±0.1	±0.7		±0.03		±0.01
Float	1960>	13.9	3.5	1.1	72.3	<0.2	0.4	8.3	<0.05	0.15	<0.05	0.01
		±1.2	±0.5	±0.2	±0.5		±0.3	±0.5		±0.03		±0.01

While laboratory-based chemical analysis can provide a full and quantitative analysis of historic window glass, pXRF analysis is always partial (*eg* sodium is not detected) and there are often systematic and random errors (*eg* surface corrosion and variable glass thickness) which render the results semi-quantitative. The detection and quantification of some light elements (such as magnesium and phosphorus) can become unreliable (Dungworth *et al* 2011). Nevertheless, the pXRF results are often best for relatively heavy elements, such as strontium, which can be extremely useful for determining the period of manufacture.

The pXRF instrument chosen to undertake the *in situ* non-destructive analysis of historic window glass was a Niton XL3t (Cu/Zn Mining Mode) which allowed the simultaneous determination of the concentration of over 20 elements (including many of those determined using laboratory-based techniques). In order to complete the survey in the quickest possible time, the instrument was set to acquire data for 40 seconds for each analysis. It was anticipated that the lighter element data would be somewhat unreliable and most interpretations have been based on the data from heavier elements (cf Dungworth *et al* 2011). Given the anticipated problems with surface corrosion (and glass thickness) affecting the quality of results, no attempt has been made to calibrate the raw results against certified reference materials.

The fire damage at Wythenshawe Hall (Figure 1) provided the opportunity to collect small samples of broken glass which could be analysed using pXRF (Table 2) and using laboratory-based techniques (Table 3). These samples were analysed using a Bruker Tornado EDXRF and an Oxford Instruments X-ray detector attached to a scanning electron microscope (SEM-EDS). These samples were prepared and analysed using methods described in numerous other reports (*eg* Dungworth 2009). The sixteen samples included one medieval forest glass (sample WH14), six high-lime, low-alkali (HLLA) glass and nine Leblanc soda glasses. The nine Leblanc soda glass included only two examples with the low levels of iron (0.2–0.3wt% Fe_2O_3) usually associated with plain ('white') glass of this period. In others panes the iron levels were considerably higher (~1wt% Fe_2O_3) and this yielded a distinct greenish tint to the glass. It is likely that this glass was deliberately formulated the purpose of repairing/replacing historic window glass (cf Girbal and Dungworth 2011).

Table 2. pXRF analysis of selected fragments of glass from Wythenshawe Hall

Sample	Window	P	K	Ca	Mn	Fe	As	Sr
WH01	F9*01	<0.2	0.2	6.5	<0.01	0.76	0.09	0.004
WH02	F9*02	1.0	4.0	17.3	0.37	0.77	0.05	0.045
WH03	F9*03	1.1	3.2	16.8	0.29	0.65	0.05	0.041
WH04	F9*04	<0.2	0.2	10.6	<0.01	0.13	0.02	0.013
WH05	F9*05	1.1	3.6	16.5	0.38	0.64	0.05	0.042
WH06	F9*06	<0.2	0.2	6.5	<0.01	0.75	0.11	0.004
WH07	F9*07	<0.2	0.1	6.7	0.54	1.02	0.14	0.004
WH08	F9*08	0.2	0.2	7.1	<0.01	0.87	0.12	0.005
WH09	F9*09	1.3	4.8	14.6	<0.01	1.29	<0.01	0.043
WH10	F9*10	<0.2	0.2	6.5	<0.01	0.72	0.10	0.003
WH11	F9*11	1.41	3.8	16.0	0.46	0.67	0.04	0.046
WH12	F9*12	<0.2	0.2	6.6	0.51	1.02	0.12	0.004
WH13	F9*13	<0.2	0.2	9.4	0.27	0.97	0.08	0.006
WH14	F9*14	1.4	7.9	9.7	0.65	0.61	<0.01	0.037
WH15	F9*15	1.1	3.6	16.3	0.39	0.66	0.05	0.041
WH16	F8L8P9	<0.2	0.1	10.2	0.26	0.21	0.58	0.015

Table 3. Laboratory-based analysis (SEM-EDS and EDXRF combined) of selected fragments of glass from Wythenshawe Hall

Sample	Window	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	MnO	Fe_2O_3	As_2O_3	SrO
WH01	F9*01	16.7	1.0	0.8	70.7	<0.2	0.2	9.7	0.05	1.13	0.09	0.010
WH02	F9*02	1.1	2.2	1.5	60.5	2.3	5.2	24.5	0.57	1.09	0.03	0.062
WH03	F9*03	1.4	2.1	1.3	62.5	2.1	4.3	23.8	0.42	0.94	0.03	0.061
WH04	F9*04	13.0	0.5	0.6	70.7	<0.2	0.2	14.7	<0.02	0.23	0.01	0.026
WH05	F9*05	1.2	2.3	1.4	61.4	2.6	4.7	23.7	0.62	0.96	0.03	0.060
WH06	F9*06	16.8	0.9	0.8	70.6	<0.2	0.2	9.6	0.07	1.14	0.09	0.009
WH07	F9*07	17.2	0.5	0.7	69.6	<0.2	0.2	9.6	0.76	1.33	0.12	0.012
WH08	F9*08	16.0	0.9	0.8	70.4	<0.2	0.2	10.3	0.12	1.23	0.10	0.008
WH09	F9*09	3.0	2.8	4.4	55.7	2.7	6.4	21.4	0.12	1.89	<0.01	0.059
WH10	F9*10	16.9	1.0	0.7	70.6	<0.2	0.2	9.6	0.06	1.08	0.09	0.010
WH11	F9*11	1.2	2.4	1.3	60.4	2.6	5.2	23.7	0.67	1.02	0.02	0.066
WH12	F9*12	17.1	0.5	0.7	69.8	<0.2	0.2	9.5	0.76	1.38	0.12	0.011
WH13	F9*13	14.9	0.6	0.8	68.5	<0.2	0.1	13.5	0.43	1.23	0.07	0.011
WH14	F9*14	2.4	5.3	1.7	57.7	3.1	11.0	15.0	0.93	0.97	<0.01	0.072
WH15	F9*15	1.2	2.3	1.4	61.0	2.4	4.8	24.0	0.63	1.00	0.03	0.062
WH16	F8L8P9	13.8	0.3	0.7	69.8	<0.2	0.2	14.0	0.40	0.33	0.36	0.036

The results of the pXRF and laboratory-based analyses show a good correspondence between the two methods (Figures 4–7). In most of the cases where no phosphorus was detected using pXRF, this element could not be detected using the laboratory-based instruments (sample WH08 is the sole exception — a soda-lime-silica glass with little or no phosphorus but the pXRF result indicated the presence of 0.2wt% phosphorus). The comparison of pXRF and laboratory-based results suggests that the pXRF samples with high levels of arsenic are probably slightly over estimated.

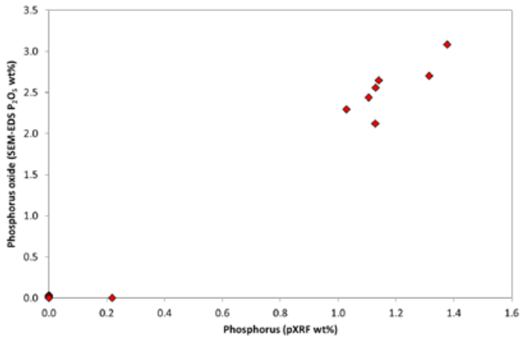

Figure 4. Plot of pXRF and laboratory-based analytical data (phosphorus) for Wythenshawe window glass

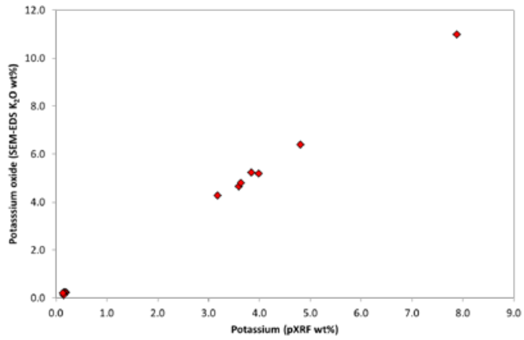

Figure 5. Plot of pXRF and laboratory-based analytical data (potassium) for Wythenshawe window glass

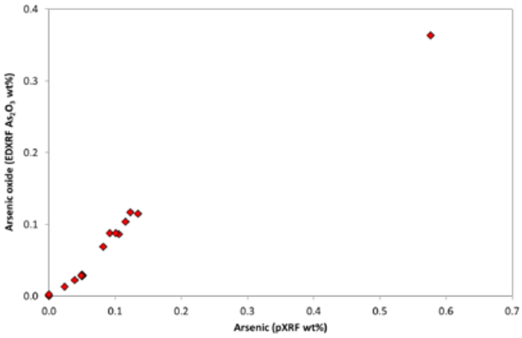

Figure 6. Plot of pXRF and laboratory-based analytical data (arsenic) for Wythenshawe window glass

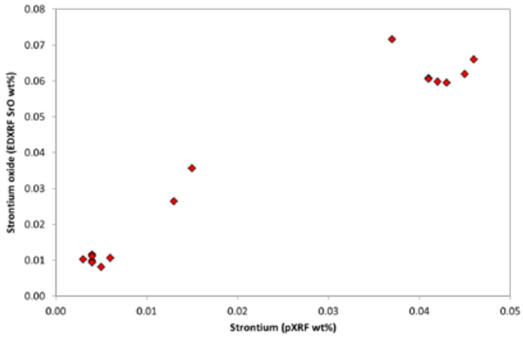

Figure 7. Plot of pXRF and laboratory-based analytical data (strontium) for Wythenshawe window glass

RESULTS

The analysis of 347 panes (undertaken over three days) allowed the identification of several different types of glass based on the concentration of selected elements. The quality of the analyses of many lighter elements was clearly affected by surface corrosion, dirt and the fact that some of the glass did not present a smooth and flat surface for analysis (cf Dungworth *et al* 2013; Girbal and Dungworth 2011).

While the levels of sulphur detected (Figure 8) in most panes are typical for historic window glass (*ie* <1wt%) a significant number of analysed panes yielded sulphur concentrations in the range of 1–17wt%. The levels of sulphur detected in these panes reflect the corrosion of the glass rather than the original composition of the glass as manufactured.

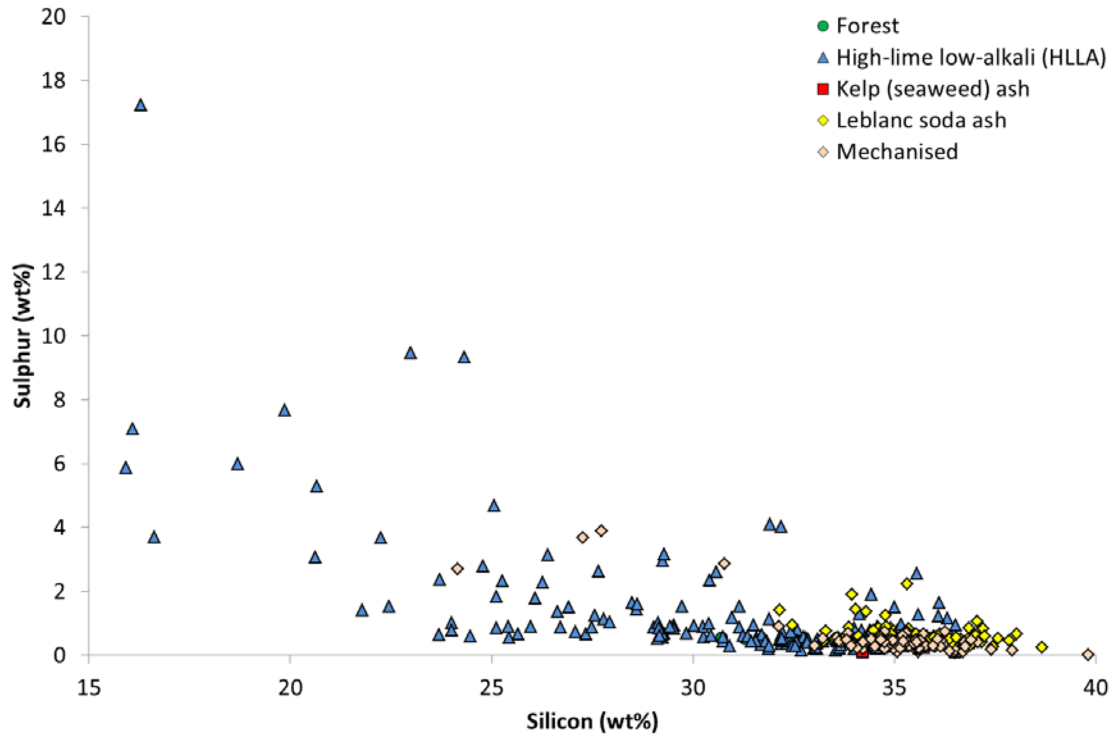

Figure 8. Silicon and sulphur content of the analysed window glass (pXRF)

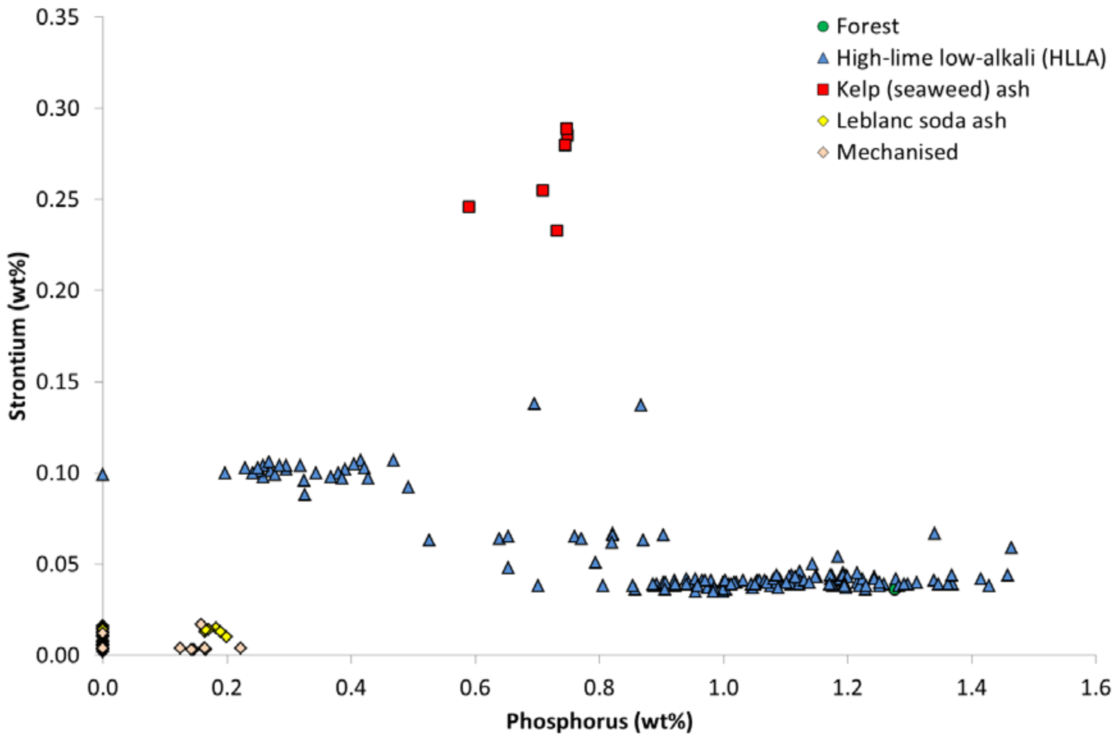

Figure 9. Phosphorus and strontium content of the analysed window glass (pXRF)

The levels of phosphorus and strontium often provided the best indication of the original nature of the glass (Figure 9). Glasses made prior to *c*1835 using plant ashes usually contain easily detectable concentrations of phosphorus (0.2–1.5wt%), although phosphorus was not detected in one sample of what would appear to be a

HLLA glass and several apparently post-1835 panes appeared to contain small amounts of phosphorus. These exceptions from the model are most likely to result from the limitations of *in situ* pXRF analysis of corroded historic glass. The levels of strontium provided an excellent indication of the original nature of the glass and proved to be the most useful element in determining the date of manufacture. The seaweed (kelp) ash glass consistently contains more strontium than any other type of glass. In addition, the glasses made using terrestrial plant ash (forest and HLLA) could easily be distinguished from those made using industrial soda (Leblanc soda ash and mechanised); the former contained 0.03–0.15wt% strontium while the latter contained <0.02wt%.

The distinction between most glass types is further reinforced by an examination of the potassium and calcium concentrations (Figure 10). The low values for these two elements for some of the HLLA glass generally correlates with the high levels of sulphur detected and illustrates the effects of corrosion on pXRF analysis. Two samples gave levels of potassium that were significantly higher than any of the other glass. It is likely that these two panes are medieval forest glass.

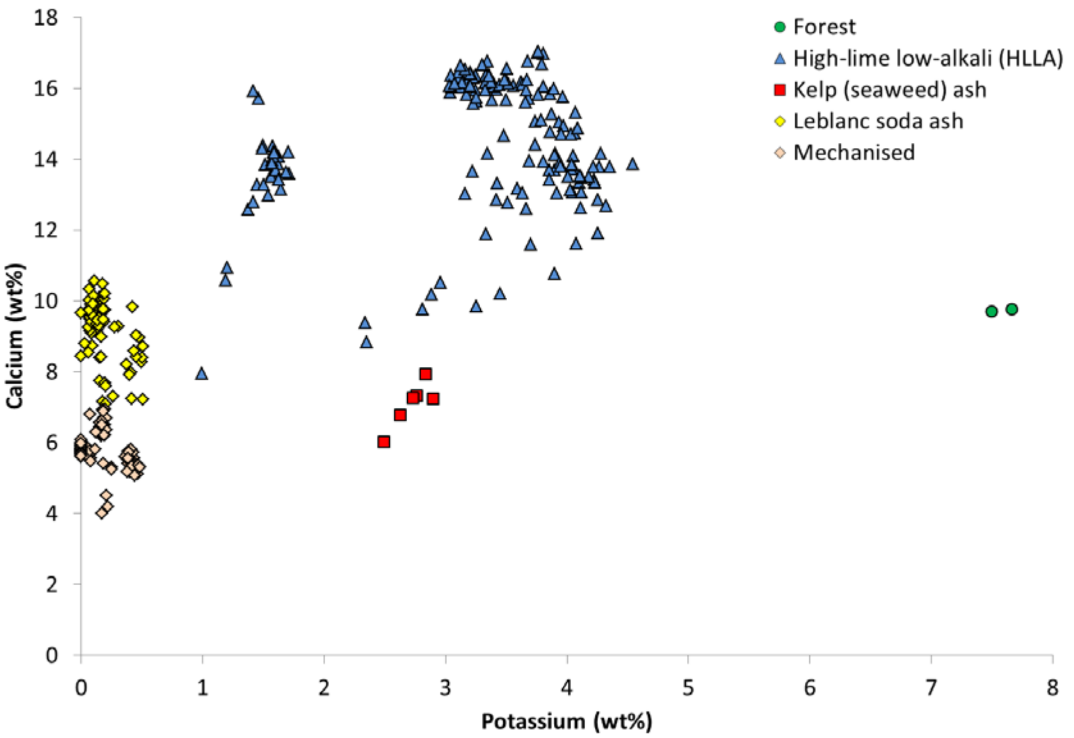

Figure 10. Potassium and calcium content of the analysed window glass (pXRF)

The levels of iron detected using *in situ* pXRF varied considerably (Figure 11). In some cases the concentrations of iron matched contemporary plain window glass (cf Table 1); however, in some cases the levels of iron detected were much higher than would be expected. Some later glasses were deliberately produced with elevated levels of iron in order to produce 'antique' glass. The unpainted, plain window glass in F7 (see Figures 12–14) includes 55 panes of Leblanc soda ash and mechanised glass: of which 14 contain low levels of iron (0.15–0.35wt%) but 41 have much higher iron concentrations (0.7–1.6wt%).

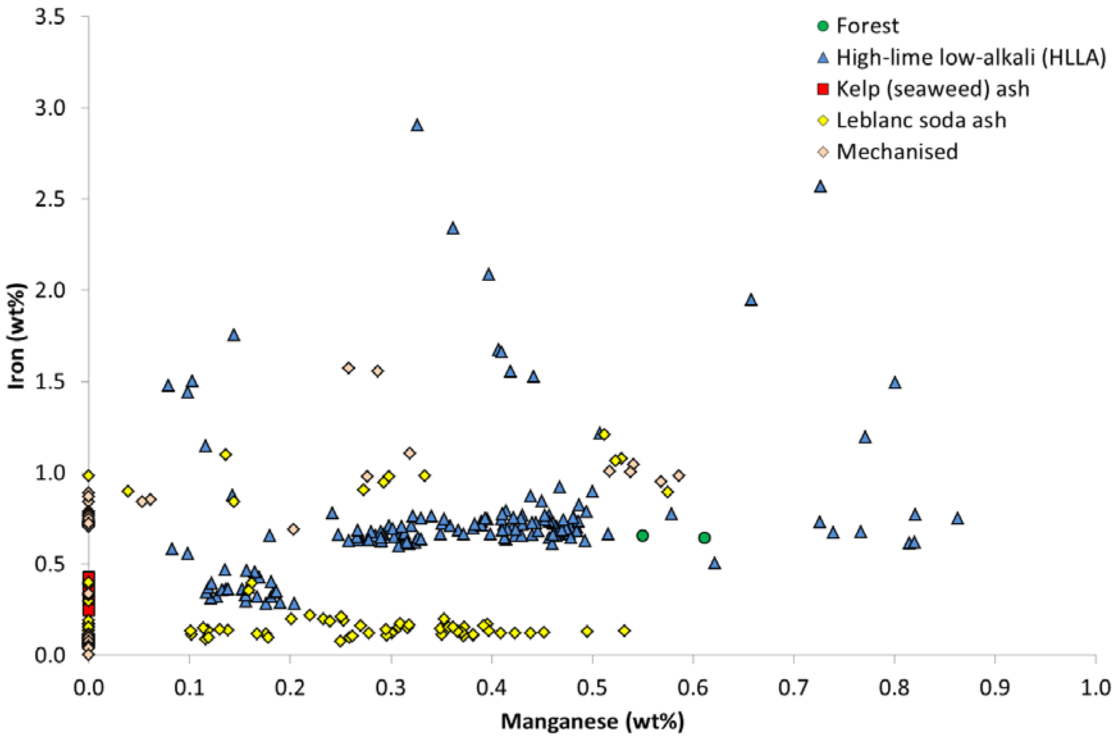

Figure 11. Iron and manganese content of the analysed window glass (pXRF)

While the data has been divided into five major types (each of chronological significance) it is also possible to recognise a number of sub-types based on a suite of elements. Thus the HLLA can be divided into four sub-types, A–D (Table 4).

Table 4. Composition of HLLA sub-types (selected elements, pXRF analysis)

	P	K	Ca	Mn	Fe	Zn	As	Sr	Zr
A	0.31	1.57	13.7	0.16	0.36	0.012	<0.01	0.102	0.007
	±0.09	±0.08	±0.5	±0.03	±0.08	±0.004		±0.003	±0.001
B	1.04	3.39	16.2	0.35	0.67	0.018	0.049	0.040	0.020
	±0.10	±0.25	±0.3	±0.07	±0.04	±0.003	±0.006	±0.002	±0.002
C	1.18	3.85	13.4	0.43	0.89	0.028	0.026	0.040	0.010
	±0.16	±0.39	±1.2	±0.09	±0.37	±0.009	±0.019	±0.003	±0.001
D	0.82	3.80	13.4	0.77	1.10	0.013	0.057	0.064	0.029
	±0.24	±0.41	±1.9	±0.06	±0.65	±0.003	±0.040	±0.002	±0.001

The spatial distribution of these HLLA sub-types probably reflects different periods of glazing and/or different workshops (Table 5). The six heraldic lights in F8 (L1–L6) show variable use of the sub-types: A is mostly found in L1 and L6, while the other types were mostly used in L2–5 (especially sub-type C). Sub-type B is used extensively in window F7 with only two panes of sub-type C (and none of sub-types A or D).

Table 5. Spatial distribution of HLLA sub-types (omits nine panes which did not conform to any of the four sub-types)

Window Light	F7 L5	F7 L6	F7 L7	F7 L8	F8 L1	F8 L2	F8 L3	F8 L4	F8 L5	F8 L6	All
A	0	0	0	0	8	1	0	2	0	15	26
B	13	15	10	16	0	4	2	3	1	0	64
C	1	0	0	1	0	9	13	15	10	2	51
D	0	0	0	0	0	3	4	2	0	2	11
All	14	15	10	17	8	17	19	22	11	19	152

Window F7

Window F7 comprises eight lights each formed of diamond-shaped panes of white (*ie* nominally colourless) glass with borders of red- and blue-coloured glass (Figure 12). The pXRF survey included each of the whole (or near whole) white panes in the four lower lights (L5–L8 from left to right). Access to the upper four lights was not possible and the coloured panes were too small to allow reliable pXRF analysis.

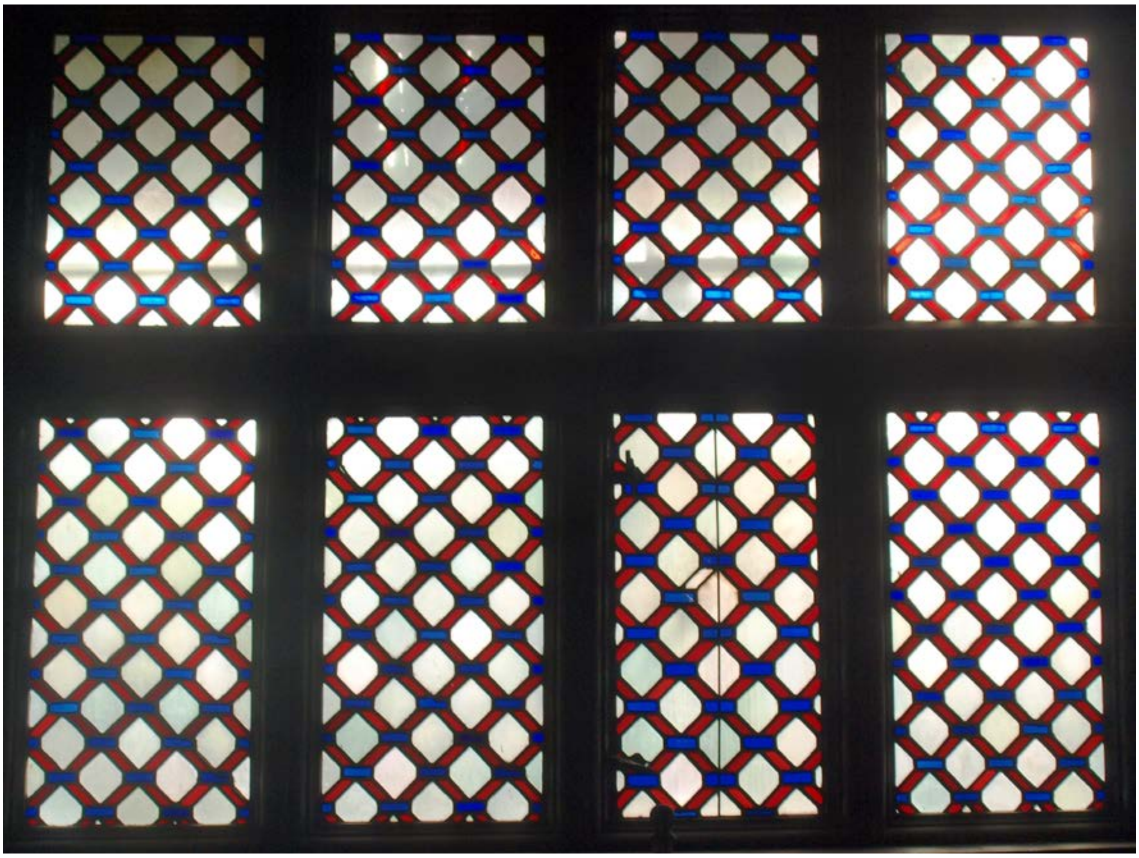

Figure 12. Wythenshawe Hall Window F7

The analysis of 117 panes from Lights L5–L8 showed that one was Perspex while all the rest were made of glass. Two panes are tentatively identified as forest glass, approximately half of the glass panes could be identified as HLLA glass, and the remaining glass included five panes of kelp glass, 16 of Leblanc soda ash glass and 35 of mechanised glass. The high proportion of HLLA panes suggests that the surviving window was probably constructed before the beginning of the 18th century. The presence of two panes of forest glass suggests that these panes were manufactured prior to the late 16th century. These two panes could have formed part of a glazing scheme installed during the original construction of the Tudor hall in 1540. It is also possible that the two panes of forest glass were re-used in a slightly later window. HLLA glass does not seem to have been produced in Britain prior to the late 16th century (Dungworth and Clark 2004); however, it was produced earlier on the continent and was imported for some glazing projects. Some of the coloured late medieval window glass in England does seem to be HLLA and was imported (Dungworth *et al* 2011). The HLLA in window F7 is all plain or 'white' glass and is perhaps slightly more likely to have been produced in England. If this tentative suggestion is accepted, then this glass would have been produced (and installed) no earlier than the late 16th century. The presence of five panes of kelp glass shows that repairs were carried out at some stage during the 18th century (or early 19th century). Similarly the Leblanc soda ash and mechanised panes attest to repair later in the 19th century and/or 20th century.

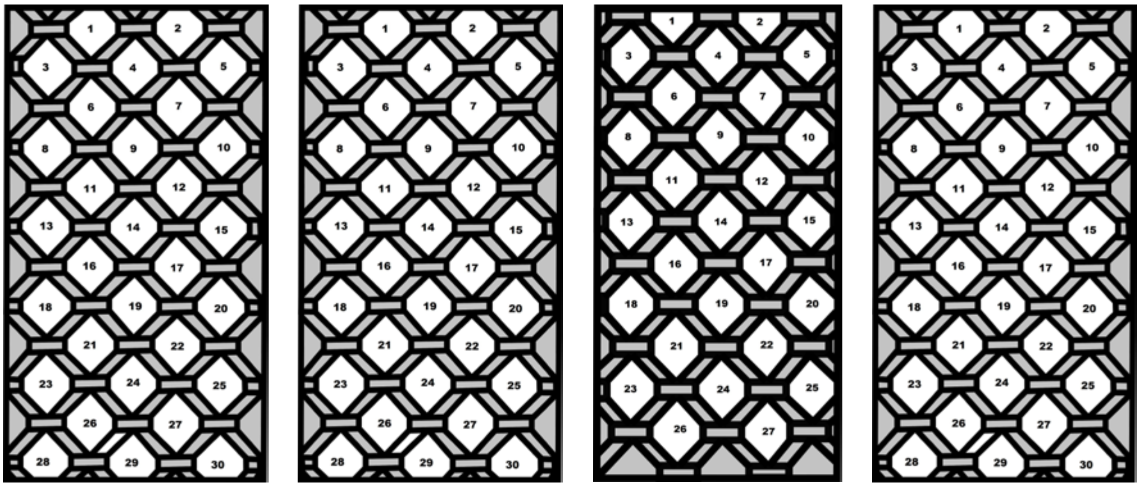

Figure 13. Wythenshawe Hall Window F7 showing the numbering for the analysed panes in the lower four lights (lights L5–L8)

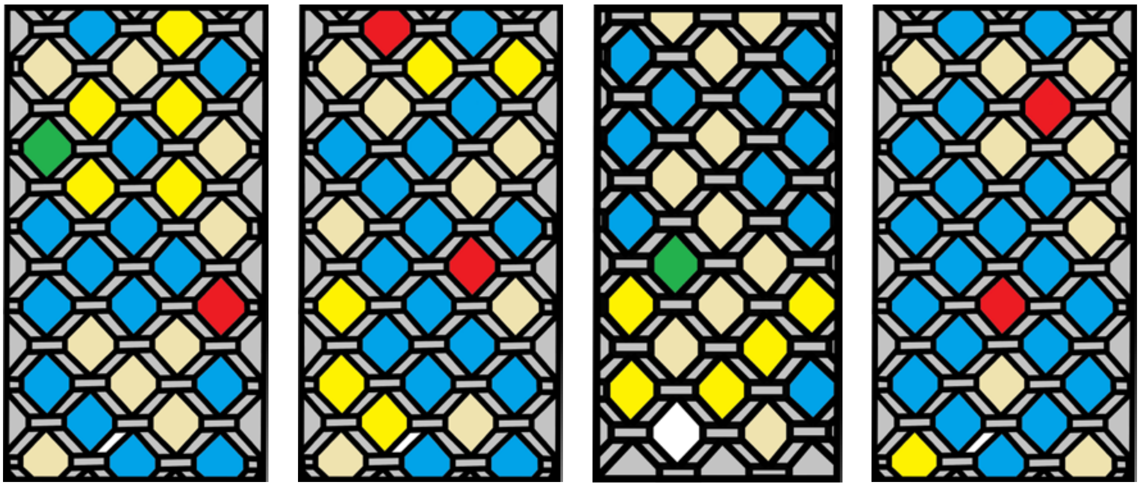

Figure 14. Wythenshawe Hall Window F7 (L5–L8) showing the panes coloured to indicate the type of glass (green = forest; blue = HLLA; red = kelp; yellow = Leblanc soda ash; beige = mechanised; white = miscellaneous (Perspex); grey = not analysed)

Window F8

Window F8 comprises twelve lights arranged in two rows (Figure 15). The upper six lights (L1–L6) contain coloured and painted heraldic glass in lead cames. The most common motif in the heraldic glass is four crescent moons (signifying the Tatton family). The lower six lights (L7–L12) are all plain glass with ferrous metal glazing bars.

Figure 15. Wythenshawe Hall Window F8

The six upper lights of heraldic glass each show a heraldic shield at the centre with a border composed of decorative scroll elements (in blue and yellow-orange) on a background of diamond panes with rectangular borders (in a similar arrangement to Window F7, but entirely in 'white' glass'). The decoration uses a wide range of glass painting techniques. Some panes are composed of glass coloured (*eg* blue) throughout by the use of metal oxides ('pot metal'), while some are coloured (*eg* red) just on one surface by the application of a thin layer of intensely coloured glass ('flashed glass'). In several instances the flashed layer has been selectively abraded to produce regions of red and white colour in the same pane of glass (*eg* the *croissants de lune* in light L4, see Figure 25). Other panes contain an additional colour by the use of enamel or glass paint (examples include both blue and red). The use of coloured enamels in decorated glass in England dates from the 16th century onwards. The scroll borders show extensive use of silver stain to produce regions of yellow-orange colour. The final technique used to decorate the glass is the application of *grisaille* or black glass paint; this was used to provide thin outlines for figurative designs as well as patterned backgrounds.

The analysed glass in the six upper lights of heraldic glass (Figures 16–33) is mostly HLLA glass. While some of this glass could have been produced in mainland Europe and imported before the late 16th century, it seems slightly more likely that much of it was manufactured in Britain after the arrival of French glassmakers from *c*1567. All of these lights show at least some later repairs, with the composition of the glass indicating repairs in the 18th, 19th and 20th centuries.

Light 1 (Figures 16–19) shows extensive repair and replacement of the original glass: eight out of the fourteen analysed panes are HLLA glass but the other six are later (18th and 19th centuries). The two panes of *croissants de lune* with white moons on a red background (P11 P12) are Leblanc soda glass (*c*1835–*c*1930). In this instance the red areas have been produced by painting red enamel and leaving the crescent moon unpainted (with a black *grisaille* outline). This contrasts with many other lights in this window where red flashed glass was selectively abraded. A similar technique (*ie* the use of enamel rather than abrading flashed glass) has been employed on P14 to produce the rampant lion. The composition of this pane suggests that it was made sometime after *c*1930.

Figure 16. Window F8L1

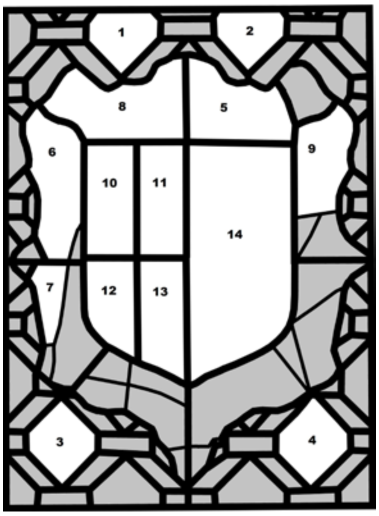

Figure 17. Window F8L1, panes analysed

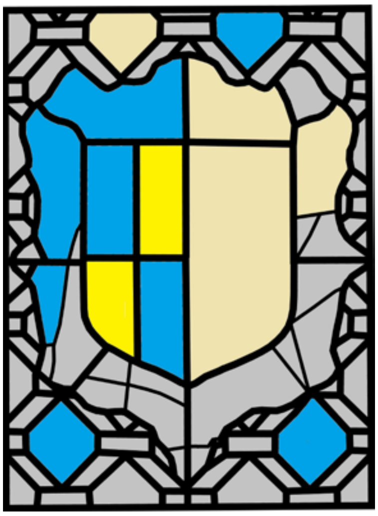

Figure 18. Window F8L1, colour-coded by type of glass (see caption for Figure 14)

Figure 19. Window F8L1, panes P5 (right) and P8 (left) showing the later repair on the right executed using black rather than blue enamel

Two of the panes of border scrollwork in this light (P5 and P9) are later repairs. A close examination of the execution of the decoration on these panes shows differences with the original HLLA panes (P6–8). The original panes are decorated by outlining features with grisaille and filling in selected areas with silver stain (yellow-orange) or blue enamel. The later repairs have been painted by a less skilled artist who has been unable to colour selected areas with a blue enamel and has instead coloured these areas black (Figure 19).

Light L2 (Figures 20–22) is composed almost entirely of HLLA glass and pXRF analysis showed a limited repair (*c*1835–*c*1930) to three panes on the right half of the shield (P14–16). The two panes of *croissants de lune* with white moons on a red background (P11 P18) have been produced by selectively abrading areas of red flashed glass (in contrast with the enamel painting of light L1).

Figure 20. Window F8L2

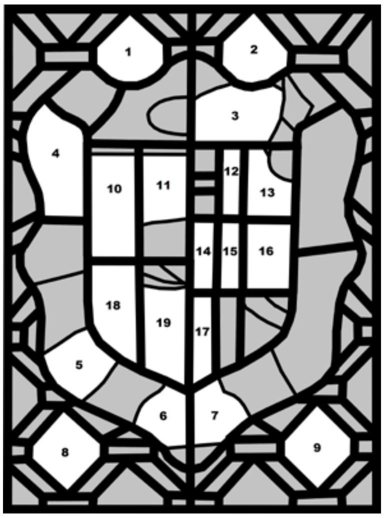

Figure 21. Window F8L2, panes analysed

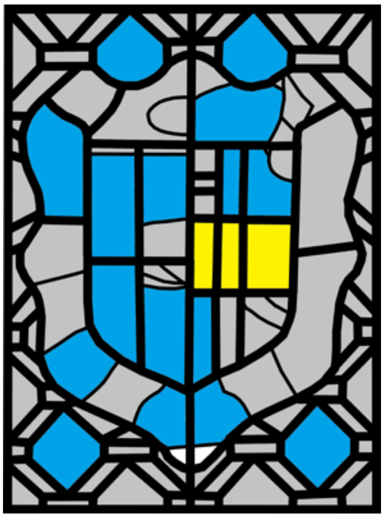

Figure 22. Window F8L2, colour-coded by type of glass (see caption for Figure 14)

Light 3 (Figures 23–25) is contains a large proportion of HLLA glass with the only identified repairs being two of the plain diamond panes at the top. One of these was replaced *c*1835–*c*1930 (P2) and the other after *c*1930 (P1).

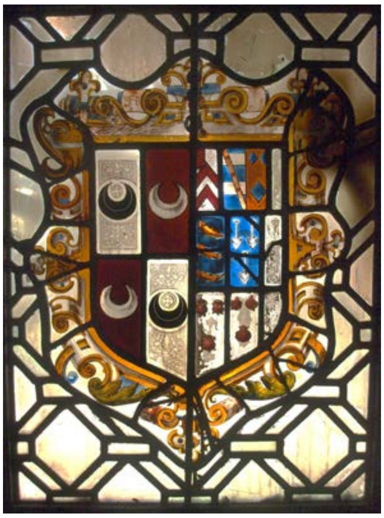

Figure 23. Window F8L3

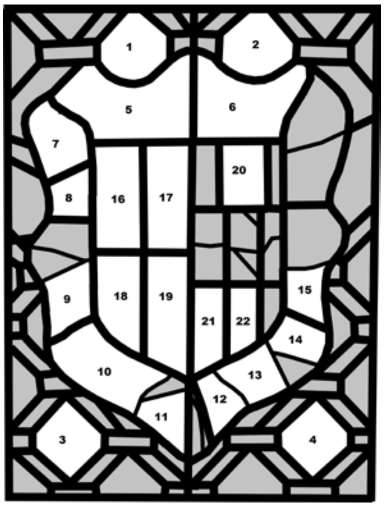

Figure 24. Window F8L3, panes analysed

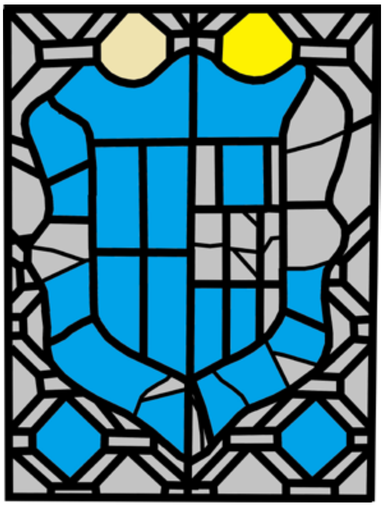

Figure 25. Window F8L3, colour-coded by type of glass (see caption for Figure 14)

The use of pXRF analysis on Light 4 (Figures 26–29) indicates a similar history with a single repair to a plain diamond pane in the bottom right corner (P4).

Figure 26. Window F8L4

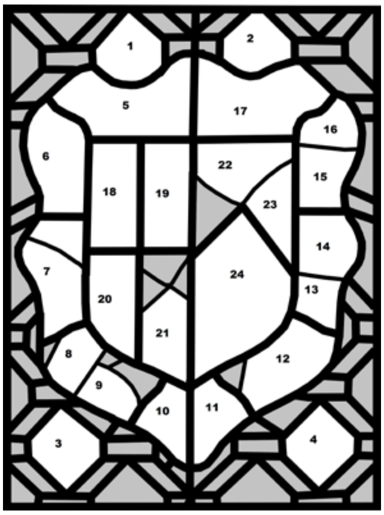

Figure 27. Window F8L4, panes analysed

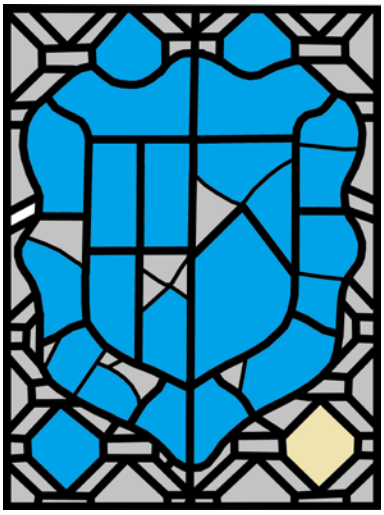

Figure 28. Window F8L4, colour-coded by type of glass (see caption for Figure 14)

A close examination of the right half of the heraldic shield (Figure 29) shows that this has been repaired (and the paint for the bottom half of the top right cross has been executed rather amateurishly); however, this glass is a HLLA glass and so the repair was probably effected before the end of the 17th century.

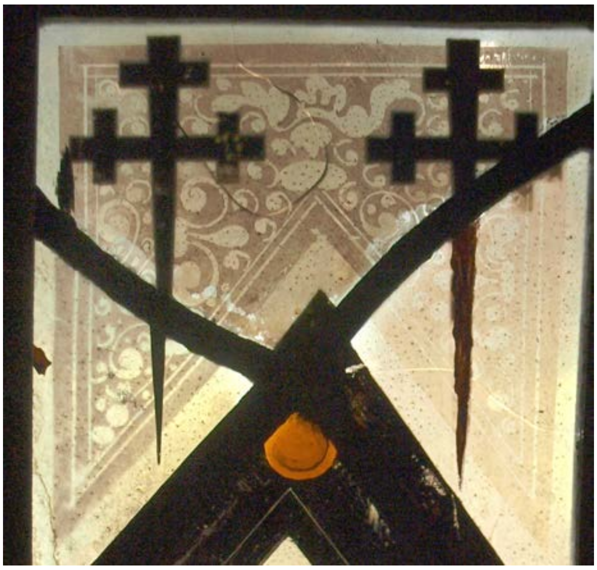

Figure 29. Detail of F8L4P22–23 showing a repair which probably took place before the end of the 17th century

Figure 30. Window F8L5

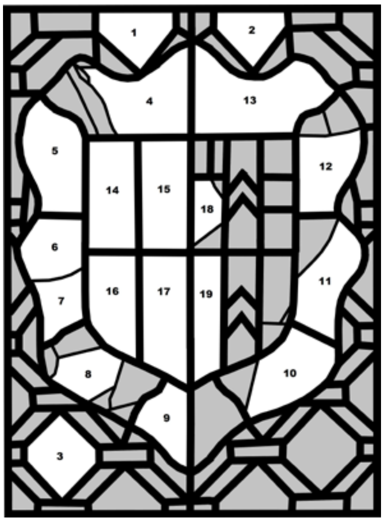

Figure 31. Window F8L5, panes analysed

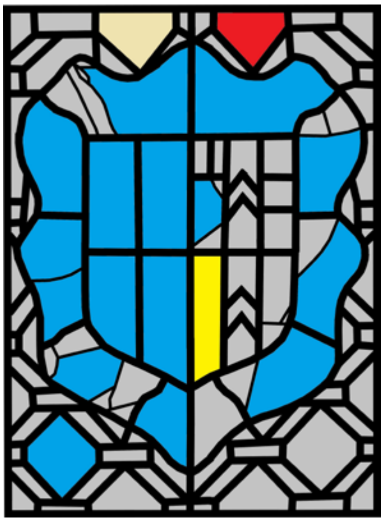

Figure 32. Window F8L5, colour-coded by type of glass (see caption for Figure 14)

Light L5 (Figures 30–32) is composed largely of HLLA glass and pXRF analysis showed limited repair to three panes but each was likely to have been carried out at a different time. A plain diamond pane at the top right (P2) is a kelp glass and would have been inserted *c*1700–*c*1835; while that on the top left (P1) was inserted after *c*1930. The repair to part of the heraldic shield (P19) was carried out *c*1835–*c*1930.

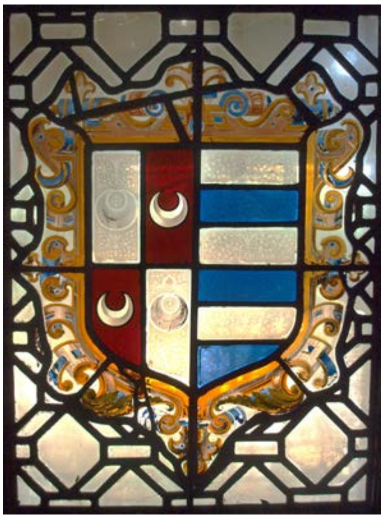

Figure 33. Window F8L6

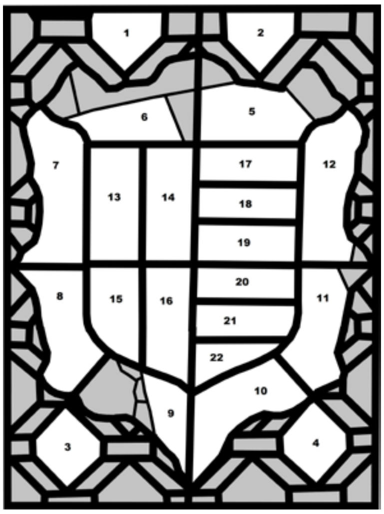

Figure 34. Window F8L6, panes analysed

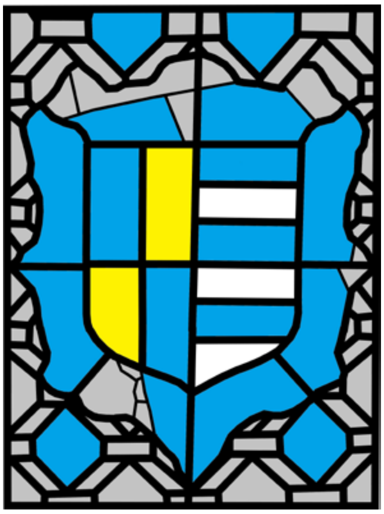

Figure 35. Window F8L6, colour-coded by type of glass (see caption for Figure 14, the white-coded panes are flint glass)

Light L6 (Figures 33–35) is composed largely of HLLA glass with three panes of flint glass and two later repairs. The two panes of *croissants de lune* with white moons on a red background (P14 and P15) are Leblanc soda glass (*c*1835–*c*1930). In this instance the red areas have been produced by painting red enamel and leaving the crescent moon unpainted (with a black *grisaille* outline). This contrasts with many other lights in this window where red flashed glass was selectively abraded. The three horizontal stripes of blue glass on the right of the heraldic shield are all composed of flint glass (potassium-lead-silicate). This type of glass was developed in the late 17th century (Dungworth and Brain 2009) but was usually used for the production of colourless tableware. The analysis of 19th-century window glass (and contemporary texts) suggests that flint glass was often used for the manufacture of coloured glass especially for Gothic Revival projects (Dungworth and Adams 2011; Dungworth *et al* 2011). It is likely that these three panes were manufactured in the 19th century (or possibly later) and represent later repairs. The analysis of the top two blue flint glass panes (P18 and P20) detected small quantities of cobalt which would be responsible for the blue colour; however, no cobalt was detected in the third pane (P22). Close examination of these panes shows that the top two share the same tint while the third is somewhat paler. It is possible that the third pane is a flashed glass (*ie* a thin layer of intensely blue glass on a colourless base) with the flashed layer on the outside (*ie* opposite side to that analysed).

The lower lights in window F8 are all of plain (colourless) glass (Figure 36). The glass is held in ferrous metal glazing bars and so the entire scheme is likely to date to the late 18th century or later. The pXRF analysis (Figure 37) showed that all of the glass is Leblanc soda ash (*c*1835–*c*1930) or mechanised glass (*c*1930 onwards). It is likely that the window was first produced in the period *c*1835–*c*1930 and the mechanised glass represents later repairs. There are variations in the composition of the Leblanc soda ash glass and the mechanised glass which suggest several periods of repair and replacement. Most of the Leblanc soda ash glass contains levels of arsenic which would indicate manufacture in the middle of the 19th century (*c*1835–*c*1870); it is likely that this represents the original glass in this window. All of the analysed glass in these lights contains low levels of iron that are typical of plain glass of the 19th and 20th centuries; this contrasts with the extensive use of ‘antique’ glass in window F7 (see above).

Figure 36. Wythenshawe Hall Window F8 lower lights (L8–L12). NB light L7 (to the left) has been omitted as it was too damaged (and obscured by wire mesh) to analyse

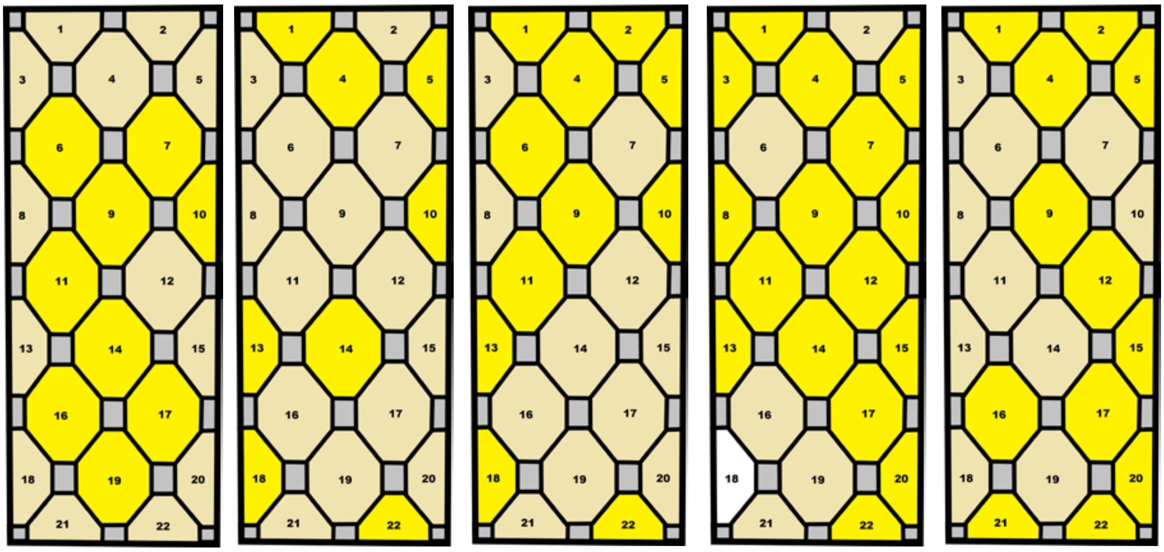

Figure 37. Wythenshawe Hall Window F8 showing the panes coloured to indicate the type of glass (yellow = Leblanc soda ash; beige = mechanised; white = miscellaneous (Perspex); grey = not analysed)

CONCLUSION

The use of portable X-ray fluorescence (pXRF) analysis enabled the chemical analysis of 347 panes of glass (over a period of three days) from the historic core of Wythenshawe Hall. The chemical composition of the glass indicates the period of manufacture and so provides information on the original date of the windows and the degree to which the glass has been subsequently repaired and replaced.

The six heraldic lights in window F8 are largely composed of high-lime, low-alkali (HLLA) glass and were probably made in England between *c*1567 and *c*1700 (Figure 38). This type of glass was manufactured on the continent at an earlier period and it is possible that the window was produced before *c*1567 using imported glass. In addition, the pXRF analysis detected several panes of medieval forest glass (produced between *c*1300 and *c*1567) in F7 and F9 which could have formed part of an earlier glazing of the Hall. It is possible that small amounts of this medieval glass were re-used and incorporated into slightly later windows. Nevertheless, it is also possible that this glass was provided during a period of window glass restoration using a completely different source (cf Dungworth and Girbal 2011). The pXRF analysis of these lights shows that there has been some later repair to each light and that this took place in the 17th, 18th, 19th and 20th centuries (Figure 38).

Figure 38. Wythenshawe Hall Window F8 (L1–L6) showing images of the windows and schematic colour-coded representations to indicate the type of glass (blue = HLLA; red = kelp; yellow = Leblanc soda ash; beige = mechanised; white = miscellaneous (flint glass); grey = not analysed)

The six lower, plain lights in F8 contain only 19th- and 20th-century glass this glazing was probably designed and installed in the middle of the 19th century.

Window F7 contains a high proportion of HLLA glass and is probably broadly contemporary with the heraldic glass in F8; however, it also contains numerous later repairs and replacements.

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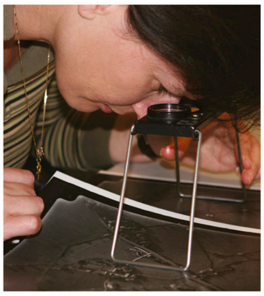


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