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Analysis of the Window Glass from Eynsham Abbey, Oxfordshire

Sarah Paynter[1] and Roger Doonan[2]

Summary

856 fragments of window glass, of which 132 were painted, were recovered during the excavation of Eynsham Abbey in Oxfordshire. 74 samples of the window glass were analysed using a scanning electron microscope (SEM) with an energy dispersive X-ray spectrometer (EDS) analytical facility. Four compositionally distinct varieties of glass were identified. Compositional group 1, comprising one fragment, is likely to date to the 12th century and to have been produced using a mineral alkali source, such as natron. Compositional groups 2 and 3 are forest glasses, produced using plant ashes, which are unlikely to post-date the 16th century. Group 4 is typical of the high-lime, low-alkali glasses (HLLA) introduced in the latter half of the 16th century, also produced using plant ashes.

Keywords

Glass
Medieval
Post Medieval
Technology

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Introduction

The foundation of Eynsham Abbey took place in the 11th century and the refoundation in the early 12th century. There are references to Lord Stanley living at the site following the 16th century dissolution of the Abbey, although there is little archaeological evidence for this period, and there was a further phase of demolition in the 17th century.

The largest quantities of glass came from two structures. 179 pieces came from structure 5220, which is described as a cellar or cesspit within a building to the west of the domestic range with a terminus ante quem of 1475. 113 fragments came from structure 5200, the west cloister range, which is attributed to the refoundation, although with later rebuilding (Cropper, 1997). The window glass specialist selected fragments that warranted special attention for analysis and phases 2A to 4B are represented. Phases 2A to 2F are pre-refoundation as is phase 3A (1066 to 1109). Later phases are 3B (1120 to 1200), 3C (1200 to 1330), 3D (1330 to 1450), 3E (1450 to 1539), 4A (1539 to 1660) and 4B (1660 to the present). Although the majority of the window glass is from phase 4A contexts, the fragments are largely of 13th century date (Cropper, 1997).

74 samples of the window glass were analysed using a scanning electron microscope (SEM) with an energy dispersive X-ray spectrometer (EDS) analytical facility. The glass was examined to determine if different compositional groups were present, and whether these were concentrated in particular areas or used for select applications (for example painted glass or glass of certain colours). The composition of glass can also be indicative of the date at which it was produced (Cropper, 1997).

Medieval Glass

Fluxes are compounds that, when reacted with silica, produce a melt of workable viscosity at temperatures of around 1000°C. The glasses discussed in this report are all fluxed by alkalis: potash and soda. Glasses generally have complex compositions and many other compounds, such as lime and magnesia, are found in addition to silica and the fluxes and are important constituents of the glass.

Roman and Anglo-Saxon soda-lime-silicate glasses are characterised by a low potash and magnesia content, which is indicative of a mineral source of alkali being used in their production, probably the evaporite known as natron. This type of glass is typical until about 1100AD when it is superseded by "forest glass", which is made from plant ashes. Glasses produced using plant ashes tend to have considerably higher magnesia and potash contents, although the relative amounts vary greatly depending on the type of plant, the region from which the plant derived, and even the time of year and the part of the plant used. For example, forest glass made from the ashes of forest plants such as beech and bracken typically contains quite high levels of potash, lime and magnesia but low levels of soda. However glass made from the ashes of desert plants or seaweed can contain high levels of soda and lower levels of potash and magnesia. In the latter half of the 16th century changes occurred in English glass technology with the arrival of glass workers from France. Although plant ashes were still used, the glass produced had a different composition, containing more lime and less potash. Consequently this glass is often referred to as high lime, low alkali (HLLA) glass.

Forest glass is far more susceptible to weathering than other types of glass, because of its composition. Thus natron glasses and HLLA medieval glasses can generally be easily distinguished from forest glass, as the former types of glass are more durable.

Results

On the basis of the analytical data, the glass fragments can be separated into four compositional groups as illustrated in figures 1 and 2. Therefore the analytical results have been grouped according to compositional type and are given in tables 1 to 4. Further analysis for elements present in very small quantities, using a technique with a lower detection limit, such as ICP, may allow subsets within each group to be identified.

Table 1: Normalised compositional data for glasses in compositional group 1

Structure	Phase	SFNo	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	K_2O	CaO	TiO_2	MnO	Fe_2O_3	CuO
XX	2A	7	13.57	1.10	2.26	71.51	0.41	0.59	0.97	7.27	0.17	0.77	1.07	0.33

Table 2: Normalised compositional data for glasses in compositional group 2

Structure	Phase	SFNo	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	K_2O	CaO	TiO_2	MnO	Fe_2O_3	CuO
5246	4A	265	2.83	8.20	1.17	55.14	3.83	0.22	10.66	15.51	0.27	1.42	0.67	0.09
5246	4A	318	2.28	6.98	1.57	56.27	3.86	0.28	14.19	12.73	0.27	0.96	0.60	0.03
5246	4A	344	2.77	6.86	0.79	57.23	4.00	0.10	14.37	12.25	0.15	0.91	0.59	0.00
5246	4A	247	2.47	6.53	1.33	60.35	2.96	0.23	11.60	12.00	0.34	1.37	0.81	0.02
5243	4A	1549	1.96	6.70	1.12	48.03	5.28	0.41	17.98	15.57	0.18	1.88	0.66	0.24
5243	4A	1549	1.85	6.64	1.28	47.62	5.25	0.49	17.77	15.85	0.27	1.94	0.81	0.22
5241	3E	1512	3.04	7.15	0.86	57.66	3.98	0.19	13.86	11.49	0.22	0.97	0.57	0.00
5241	3E	1511	1.88	7.14	1.44	55.02	3.79	0.18	15.00	13.70	0.20	1.04	0.60	0.00
5241	3E	1511	2.01	7.01	1.29	55.07	3.99	0.31	14.89	13.44	0.20	0.95	0.72	0.11
5241	3E	1511	2.12	7.00	1.44	57.01	3.53	0.36	9.98	16.76	0.13	1.28	0.40	0.00
5235	3D	173	2.66	6.76	1.18	55.75	4.55	0.19	14.92	11.85	0.36	1.02	0.72	0.04
5228	3C	172	1.62	6.52	1.26	60.00	2.84	0.37	9.91	15.09	0.36	1.27	0.57	0.18
5227	4A	1459	2.73	8.49	0.80	55.50	4.49	0.12	10.50	15.47	0.36	1.05	0.47	0.00
5227	4A	1459	2.21	7.48	0.30	56.33	3.96	0.41	13.23	14.33	0.17	1.29	0.29	0.00
5227	4A	1428	2.45	6.73	0.26	54.08	4.28	0.43	16.70	11.27	0.03	0.64	0.73	2.41
5220	4A	323	2.91	8.26	1.24	55.03	3.89	0.38	10.64	15.44	0.18	1.42	0.59	0.02
5220	4A	356	2.31	7.90	0.99	55.88	3.26	0.47	12.55	14.77	0.13	1.24	0.48	0.02
5220	4A	211	2.06	7.86	0.93	55.91	3.24	0.53	12.47	15.01	0.21	1.25	0.47	0.05
5220	4A	211	2.30	7.70	1.08	56.35	3.53	0.35	12.38	14.48	0.10	1.12	0.61	0.00
5220	4A	319	2.14	7.65	0.97	55.57	3.40	0.50	12.52	15.18	0.21	1.31	0.55	0.00
5220	4A	368	2.33	7.60	0.82	55.41	3.95	0.54	10.92	16.43	0.12	1.29	0.59	0.00
5220	4A	368	2.26	7.55	1.27	57.55	3.85	0.35	11.74	13.04	0.30	1.38	0.72	0.00
5220	4A	437	1.56	7.55	1.03	58.29	2.93	0.46	10.85	15.14	0.33	1.29	0.54	0.02
5220	4A	319	2.49	7.32	1.42	55.86	3.48	0.29	9.87	17.15	0.26	1.26	0.54	0.04
5220	4A	368	2.26	7.10	1.39	57.36	3.16	0.36	12.17	14.05	0.26	1.28	0.59	0.02
5220	4A	507	4.30	6.75	2.50	58.60	3.25	0.20	10.64	11.66	0.34	1.07	0.66	0.04
5220	4A	320	1.97	6.63	1.41	53.44	4.74	0.36	14.98	14.25	0.25	0.97	0.84	0.15
5216	4A	1152	2.24	7.78	0.97	57.58	3.93	0.09	11.51	14.21	0.01	1.46	0.23	0.00
5216	4A	1098	2.13	7.09	1.20	52.24	5.14	0.31	15.21	14.40	0.30	1.10	0.70	0.19
5212	4A	178	2.80	7.98	1.25	52.70	4.71	0.27	15.46	12.84	0.27	1.06	0.64	0.03
5208	3E	605	2.89	7.12	1.10	57.22	4.03	0.20	14.11	11.40	0.15	1.04	0.64	0.09
5208	3E	98	2.95	7.08	2.13	55.70	3.62	0.11	11.52	14.70	0.23	1.22	0.60	0.14
5208	3E	157	2.86	6.51	1.07	53.00	3.92	0.36	14.73	11.64	0.28	1.36	0.72	3.55
5207	4A	838	2.48	7.70	1.04	57.16	3.21	0.29	12.46	13.63	0.25	1.21	0.58	0.00
5200	4B	440(1)	2.33	7.82	0.77	54.56	4.24	0.17	14.76	13.61	0.22	1.08	0.43	0.00
5200	4B	440	2.22	7.75	0.92	55.91	3.04	0.09	13.04	15.12	0.19	1.50	0.23	0.00
5200	4B	747	2.50	7.69	0.50	56.20	3.88	0.39	12.57	14.72	0.00	1.17	0.38	0.00
5200	4B	440(4)	2.30	7.54	1.30	55.23	4.06	0.28	14.04	13.07	0.12	1.16	0.90	0.00
5200	4B	635	2.15	7.55	1.06	53.84	4.94	0.17	13.32	14.66	0.12	1.36	0.68	0.17
5200	4B	747	1.71	7.17	1.48	57.56	3.24	0.15	13.09	13.24	0.44	0.92	1.00	0.00
5200	4B	747(1)	2.45	6.44	0.89	58.26	3.64	0.32	12.23	13.63	0.31	1.03	0.80	0.00
5200	4B	747(2)	3.05	6.26	1.21	58.08	3.42	0.24	12.28	12.90	0.31	1.54	0.66	0.05
5192	3B	1526	2.45	6.34	1.06	55.44	4.54	0.28	15.05	12.81	0.29	1.03	0.72	0.00
5186	3A	239	2.87	6.86	1.01	52.17	5.03	0.39	13.85	15.72	0.23	1.30	0.46	0.10
Average			**2.41**	**7.24**	**1.14**	**55.66**	**3.91**	**0.30**	**13.10**	**14.00**	**0.23**	**1.21**	**0.61**	**0.18**

Table 3: Normalised compositional data for glasses in compositional group 3

Structure	Phase	SFNo	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	K_2O	CaO	TiO_2	MnO	Fe_2O_3	CuO
5241	3E	1503	1.47	5.20	1.88	55.84	4.85	0.02	15.18	13.99	0.24	0.50	0.81	0.01
5227	4A	11859	1.34	5.26	3.65	47.15	5.28	0.31	10.14	24.73	0.42	0.82	0.89	0.00
5220	4A	475	0.75	5.75	0.98	46.90	5.64	0.24	18.42	19.14	0.15	1.43	0.53	0.07
5216	4A	1091	1.97	5.57	1.78	57.94	3.68	0.31	12.28	14.76	0.21	1.05	0.45	0.00
5212	3C	426	0.85	5.46	1.68	50.14	5.03	0.35	17.20	17.35	0.31	0.91	0.68	0.04
5208	4A	757	0.51	4.45	2.84	47.15	4.52	0.36	15.39	22.81	0.32	0.73	0.77	0.14
5201	3C	913	0.70	5.26	1.61	50.96	4.97	0.20	17.21	17.24	0.30	0.68	0.80	0.06
5200	4B	635	1.90	4.91	1.93	57.63	3.55	0.06	13.26	15.10	0.09	0.84	0.73	0.00
5192	3B	427	1.32	5.76	1.43	53.49	3.89	0.17	16.77	15.55	0.29	0.81	0.45	0.08
5192	3B	1271	1.23	5.62	0.82	53.32	4.14	0.15	19.34	11.67	0.21	0.75	0.31	2.43
5186	3A	238	1.95	6.17	1.12	54.07	5.32	0.16	17.73	12.14	0.17	0.87	0.27	0.03
Average			**1.27**	**5.40**	**1.79**	**52.24**	**4.62**	**0.21**	**15.72**	**16.77**	**0.25**	**0.85**	**0.61**	**0.26**

Table 4: Normalised compositional data for glasses in compositional group 4

Structure	Phase	SF No	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	K_2O	CaO	TiO_2	MnO	Fe_2O_3	CuO
XX	2F	864	1.11	2.95	4.88	58.55	2.49	0.19	8.40	19.31	0.30	0.36	1.47	0.00
XX	2F	868	1.25	2.86	2.65	62.97	2.00	0.27	4.97	20.34	0.40	1.13	1.16	0.00
5247	4A	1065	2.61	2.78	2.27	59.53	3.12	0.15	4.58	23.53	0.22	0.68	0.41	0.11
5247	4A	1061	2.41	2.00	2.54	64.68	2.13	-0.04	6.44	18.08	0.27	0.13	1.37	0.00
5220	4A	243	1.79	3.40	4.03	54.64	3.55	0.11	6.83	22.98	0.35	1.74	0.57	0.00
5216	3D	1223	1.86	4.10	2.66	57.45	3.44	0.26	9.67	18.81	0.27	0.82	0.66	0.00
5216	3D	1123	2.53	3.30	2.65	58.99	2.18	0.21	4.39	22.87	0.53	1.08	1.28	0.00
5216	4A	1073	4.49	4.01	5.10	59.44	2.74	0.36	4.42	17.61	0.28	0.44	1.11	0.00
5216	4A	1106	3.06	3.73	3.68	58.75	2.43	0.16	7.46	19.17	0.30	0.26	1.00	0.00
5216	4A	1106	3.96	2.34	2.79	64.41	2.03	0.06	6.40	16.09	0.25	0.12	1.55	0.00
5208	3E	156	1.52	4.09	4.09	52.87	3.79	0.27	8.33	22.01	0.42	1.56	1.02	0.04
5207	4A	839	2.28	3.76	4.56	56.09	2.57	0.23	8.75	19.73	0.33	0.31	1.38	0.00
5207	4A	839	0.64	2.99	1.90	64.46	1.81	0.24	5.09	20.49	0.37	1.04	0.82	0.14
5207	4A	839	1.39	2.90	2.70	62.58	2.00	0.30	4.67	20.77	0.39	1.16	1.03	0.12
5206	4A	815	2.32	1.97	3.06	64.46	2.03	0.26	6.25	17.35	0.41	0.23	1.65	0.00
5201	3C	932	1.56	2.80	2.59	61.49	2.56	0.36	4.70	21.10	0.42	0.92	1.47	0.03
5200	4B	747	2.32	3.14	2.34	60.95	2.99	0.26	4.46	22.13	0.30	0.38	0.73	0.00
5200	4B	747(3)	2.57	3.09	2.92	60.16	2.91	0.41	4.43	21.96	0.40	0.71	0.43	0.00
5200	4B	747	2.15	2.66	3.60	61.49	2.69	0.27	5.02	20.49	0.38	0.52	0.66	0.08
Average			**2.20**	**3.10**	**3.21**	**60.21**	**2.60**	**0.23**	**6.07**	**20.25**	**0.35**	**0.71**	**1.04**	**0.03**

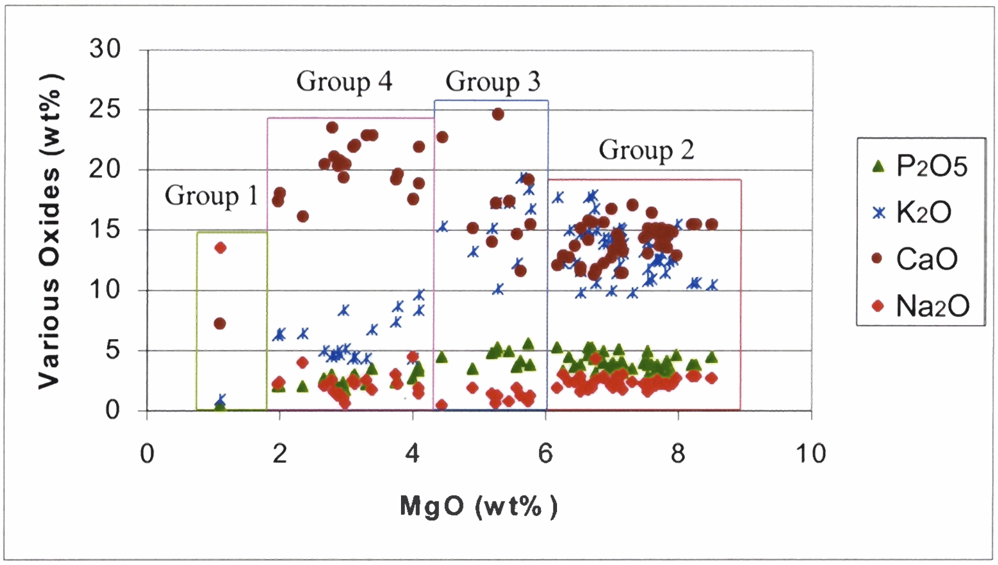

Figure 1: Plot of sodium, calcium, phosphorous and potassium oxides (wt%) against magnesium oxide (wt%) for compositional groups 1, 2, 3 and 4 from Eynsham

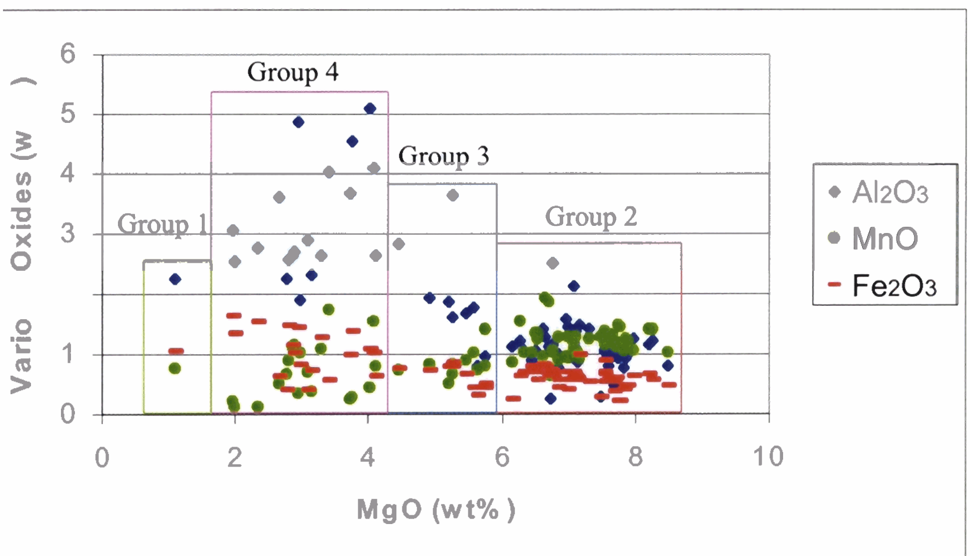

Figure 2: Plot of iron, aluminium and manganese oxides (wt%) against magnesium oxide (wt%) for compositional groups 1, 2, 3 and 4 from Eynsham

Group 1

Only one fragment, SF 7, falls into this compositional category, characterised by a high soda (Na_2O) content, medium lime (CaO) content but low magnesia (MgO) and potash (K_2O) content. This composition is similar to that of Roman and later Anglo-Saxon soda-lime-silicate glasses, which were probably produced using a mineral source of alkalis, such as natron.

Although fragment SF 7 derives from a pre-refoundation context (phase 2A), as do fragments SF 868 and SF 864 (both compositional group 4), these fragments are thought to be intrusive to the contexts from which they were retrieved. On the basis of the appearance of the fragments, SF 7 has been assigned to the early medieval period, possibly the early 12th century, whilst the other two fragments are thought to be late medieval / transitional in date (SF 868 possibly dates to the 16th century). The blue colour of SF 7 is predominantly due to the presence of 0.12wt % cobalt oxide, which is a very strong glass colourant, although 0.3wt % copper oxide was also detected. Durable blue glass has been found at Winchester, York Minster, Chartres Cathedral and the Abbey church of St Denis (Ile-de-France). The glass from these sites, which has been analysed, is compositionally similar to the fragment from Eynsham. The fragments from York are 11th century and this type of glass is also known from 12th century contexts (Cox and Gillies, 1986). Therefore the assignment of this fragment to the 12th century is likely to be accurate and this is the earliest piece of glass analysed.

The origins of this distinctive glass type are unknown although speculation has surrounded a description by Theophilus of the production of a type of expensive blue glass in France for use in windows, using ancient glass as a component. The collection of "different kinds of glass... found in mosaic work in ancient pagan buildings" and also " various small vessels" by the French is described. This is followed by "They even melt the blue in their furnaces, adding a little of the clear white to it, and they make from it blue glass sheets which are costly and very useful in windows" (Hawthorne and Smith, 1979).

Group 2

The group 2 glasses are forest glasses, characterised by high potash, magnesia and lime values. They are distinguished from the glasses in other groups predominantly by having higher magnesia contents. This compositional group is the largest of the assemblage and includes fragments of grisaille, painted, plain and tinted glass. All of the crown glass analysed was compositionally group 2. The majority of the fragments are thought, on the basis of their appearance, to date to the 13th/14th centuries. However the group also includes some fragments thought to be of later date (Cropper, 1997), such as the crown glass pieces (including SF 368), SF 1152, SF 437 (painted with angels) and SF 1549 (with a green tint). Fragments from structures 5220, 5227, 5246, 5212, 5207, 5200, 5241, 5208, 5216, 5186, 5235, 5243, 5228, 5192 form part of this group, and derive from phase 3B to 4B contexts.

The group 2 glass composition is very similar to that of other forest glasses produced in England from the 12th century, largely in the Weald and Staffordshire, until the latter half of the 16th century. (This is discussed further in the conclusions of this report). This is consistent with the fact that the majority of the glass of group 2 composition appears to date from the 13th to the 14th centuries, with some fragments thought to be of later date. However fragments of group 2 composition are unlikely to be later than 16th century in date.

Group 3

These glasses are also forest glasses but can be distinguished from those of other compositional groups as they contain more magnesia than group 4 but less than group 2. They also contain relatively high levels of phosphorous oxide, more than group 4 glasses, and slightly less soda than either group 2 or 4 glasses. Again these fragments have been assigned largely to the 13th and 14th centuries and the group includes fragments that are painted, tinted and plain. Fragments have derived from structures 5186, 5192, 5220, 5216, 5212, 5201, 5241, 5227, 5200 and 5208 and from phase 3A to 4B contexts. Again this compositional group is typical of the forest glass produced between the 12th century and the latter half of the 16th century (see the conclusions section of this report).

Group 4

The final group, group 4, can be distinguished from the other glasses because they contain less magnesia, considerably less potash and considerably more lime than the other glasses. These glasses are typical of the high-lime, low-alkali glasses (HLLA) previously noted in late-medieval and post-medieval contexts (Mortimer, 1991; Kenyon, 1967). Although this group includes fragments from phase 2F to 4B contexts, their appearance is characteristic of later date and these fragments are likely to be intrusive to the contexts from which they were retrieved. Fragments SF 932, 156, 1704, 1065 are described as late, fragments SF 868 and 864 are thought to date to the 16th century, fragments SF 1223 and 1166 are thought to date to the 17th century and fragments 1223 and 1073 are described as post-medieval. The fragments derive from structures 5216, 5208, 5207, 5220, 5200, 5201, 5247 and 5206. The group includes painted and plain glass and the style of the painting is also typical of a later date (Cropper, 1997). HLLA glasses become more common in the latter half of the 16th century (Mortimer, 1997) and so the glasses of this group are likely to post-date the mid-16th century.

Conclusions

Use and Distribution of Different Compositional Glass Types

Four compositional categories of glass were noted amongst the window glass from Eynsham. No correlation was observed between the types of glass, for example painted, tinted or plain, and their compositions with the exception that glass of group 1 composition was used only for dark blue window glass and all of the crown glass analysed was of compositional group 2. The composition of the paint used for the glass was not analysed in this study.

Although the glasses were examined by phase, the phasing was not always consistent with the suspected dates of the fragments in terms of either their style or composition, indicating that many fragments were intrusive in the contexts from which they were retrieved. Similarly more than one composition of glass was represented for most structures. However examination of the relative proportions of the different glass groups present by context may provide some indication of the dates of glazing or glazing repair for different structures. This has not been rigorously attempted in this report, since only a selection of the fragments recovered from each structure were analysed. However the compositional data agree with the dates previously suggested on the basis of the condition, form and decorative style of the fragments (Cropper, 1997). In particular the group 4 glass is likely to be considerably less weathered than glass of group 2 or 3 composition.

Figure 3 shows a plot of the type of glass utilised versus structure for the analysed subset only. From the plot it can be seen that a larger proportion of HLLA glass (group 4) was identified for certain structures. The HLLA glass is likely to post-date the mid-16th century and so be associated with the post-dissolution occupation of the site. Although the archaeological evidence for this period of occupation is poor the kitchen, structure 5216, was certainly still in use and the largest number of HLLA group 4 fragments, of those analysed, derive from this structure. Structures 5200 (the west cloister range), 5207 and 5247 also yielded several fragments.

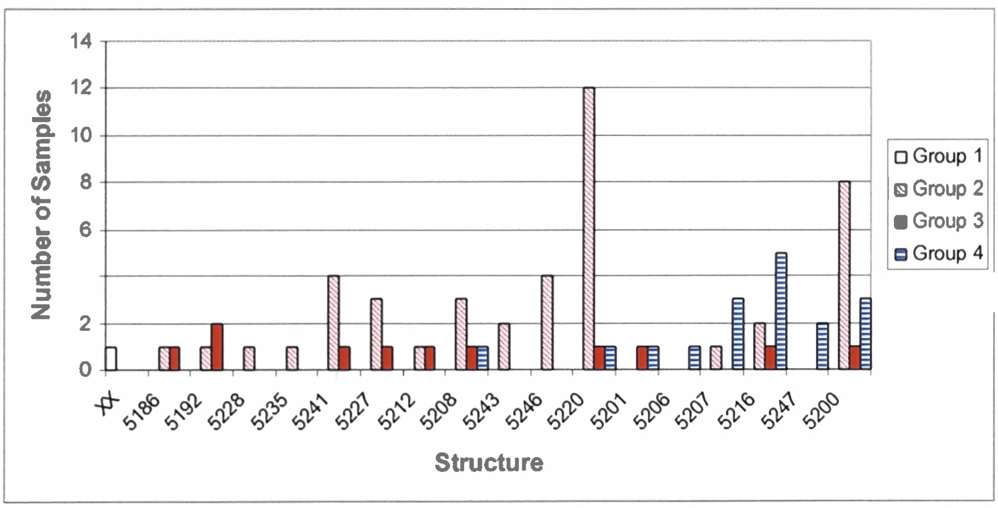

Figure 3: Distribution of glass compositional groups (analysed fragments only) by structure.

Weathering

The poor condition of the forest glasses (compositional groups 2 and 3) relative to the soda-lime-silicate glass (group 1) and the HLLA glass (group 4) was noted (Cropper, 1997). The HLLA glass often appears both harder and brighter than the forest glass and the blue group 1 glass is described as more durable. This is a result of the compositional differences between the glasses. The forest glasses are far more susceptible to attack by water by virtue of their composition (Pollard and Heron, 1996). As a result forest glass fragments can be distinguished from other glasses as they are generally pitted and severely weathered.

The Origins of the Eynsham Window Glass

Forest and HLLA glasses were produced using ashes from plants, which have variable compositions dependent on such things as the species of plant, the region where the plant grew and the part of the plant selected. The plant ashes are the main source of potash, magnesia and lime in the glass. The other major component of these glasses is silica, and this derives from sand or possibly quartz pebbles. The silica source can contribute compounds such as alumina, iron oxide and also some lime to the glass composition. It is sometimes possible to distinguish between glasses produced in different regions because the differing composition of the raw materials used, particularly the plant ashes, can result in a characteristic glass composition that is diagnostic. However glass workers in the same area, and utilising ashes from the same plant species, might produce products with very similar compositions, even though they are working at different furnace sites. Alternatively, as the raw materials used to produce the glasses were themselves variable, a range of compositions might have been produced at one site. Glass workers also collected waste glass, known as cullet, to add to their glass batches. Although this glass was probably carefully selected it would have been of variable composition and is therefore another factor to consider when interpreting the composition of the glass produced. Other variables, such as the temperature and duration of firing, and the types of additional stages involved in glass production, such as fritting and refining, may also have affected the composition of the glass produced. For example the low alkali content of the HLLA glasses suggests that these probably required firing at higher temperatures than the forest glasses, which had a higher alkali content.

Evidence for medieval glass working is rare outside the Weald, until the 16^{th} century. However Staffordshire is one of a small number of areas that are known to have had glass workers during the late 13^{th} to early 17^{th} century, when it was home to a glass industry producing mostly window glass for a national market (Welch, 1997). Early in the 17^{th} century the glass industry switched from wood to coal as the source of fuel for glass-making furnaces, and the industry became concentrated in the coal districts of the Midlands and Tyneside. Glass has been analysed from furnace sites in Staffordshire and the Weald, although a larger number of analyses are required to build a representative database. The glass from both regions falls into two compositional categories, forest glass and HLLA glass. The Eynsham compositional groups 2 and 3 are forest glasses, whereas group 4 is made up of the later HLLA glass.

Both forest glass and HLLA glass has been found at Staffordshire furnace sites, such as those at Bagot's Park, near Cattail Pool (Mortimer, 1991) and at Little Birches, Wolseley. It appears that in the vicinity of Cattail Pool there may be waste from more than one furnace as crucibles of early and late types and both forest glass and HLLA glass have been identified. The forest glass may have been used to produce windows whilst the HLLA glass may have been used to make vessels (Welch, 1997). Both forest glass and HLLA glass has been identified from Bagot's Park, although the majority is of the forest glass type, which is consistent with the proposed 1530s date of this furnace. At Little Birches two furnaces were discovered. The majority of the glass analysed from the site came from the later furnace and only forest glass was identified. HLLA and forest glass types have been identified at various medieval Wealden glass sites (Kenyon, 1967), for example analyses of glass from furnace sites at Knighton and Blunden's Wood (Surrey) have shown that forest glass was produced there.

The forest glass from Little Birches, Staffordshire, is a very good match for the Eynsham window glass compositional group 2 (Mortimer, 1997). Crown glass windows were the principal, or only, products of the two furnaces at Little Birches. The earliest furnace was dated to the first half of the 14th century and the other to the mid-16th century. However all of the forest glass from the sites listed in table 5 has a similar composition, and this is also true for the HLLA glass, despite having been produced in a variety of locations, from the Weald to Staffordshire. Thus it is likely that other furnace sites may exist that also produced glass compositionally similar to the Eynsham glass. Although it is not possible to determine conclusively the origins of the Eynsham glass using these data, other analytical techniques, such as ICP analysis, could be used to obtain a more specific chemical finger print of glasses from furnace sites in Staffordshire and the Weald. With ICP analysis, elements present in very small amounts can be detected and, by comparing the concentrations of these elements, the products of the two regions, and even different furnace sites within the regions, might be distinguishable. The results could then be compared to glass from Eynsham and other medieval sites where glass was utilised.

Table 5: Comparison of medieval forest glass and HLLA glass from different sources with the glass from Eynsham. Wealden glass analyses from Kenyon, 1967. Staffordshire glass analyses from Mortimer, 1993 and 1997.

Date	Source	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	K_2O	CaO	TiO_2	MnO	Fe_2O_3
11th / 12th	Eynsham Group 1	13.57	1.10	2.26	71.51	0.41	0.59	0.97	7.27	0.17	0.77	1.07
12th to second half of 16th	Eynsham Group 2	2.41	7.24	1.14	55.66	3.91	0.30	13.10	14.00	0.23	1.21	0.61
	Little Birches (av)	2.34	7.72	1.27		3.47		12.53	13.66			
	Bagot's Park Group 1 (av)	2.60	7.84	1.43	59.87	3.65	0.23	11.24	10.69	0.20	1.70	0.55
	Cattail Park Group 1	2.50	8.39	1.30	57.64	3.40	0.40	11.19	12.89	0.20	1.60	0.50
	Knighton (av)	1.80	6.70	2.40	56.47	3.70	0.25	10.09	16.14	0.30	1.15	1.00
	Early Weald Sample A	2.3	6.7	-	56	-	-	11.1	15	-	-	0.5
	Eynsham Group 3 (av)	1.27	5.40	1.79	52.24	4.62	0.21	15.72	16.77	0.25	0.85	0.61
Mid-16th +	Eynsham Group 4 (av)	2.20	3.10	3.21	60.21	2.60	0.23	6.07	20.25	0.35	0.71	1.04
	London, Mortimer (1991)	2.99	3.68	3.31		3.19		4.62	20.7			
	Cattail Park Group 2 (av)	4.53	3.73	3.53	60.40	2.82	0.17	4.34	18.43	0.34	0.61	1.11
	Bagot's Park Group 2 (av)	3.26	4.10	3.76	59.32	2.62	0.29	6.42	17.86	0.35	0.64	1.38
	Late Weald Sample A	0.4	2.6	-	64.7	-	-	4.7	20.8	-	-	0.7
	Late Weald Sample B	1.2	2.7	-	59.5	-	-	4.4	24.9	-	-	0.96

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