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Summary

This report examines early eighteenth-century window glass recovered during the excavation of a seventeenth century glasshouse and eighteenth-century pottery. Two fragments of window glass are high-lime low-alkali glass while ten are mixed alkali glass with high strontium contents indicating that they were manufactured using seaweed (kelp).

Keywords

Glass
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Author's Address
David Dungworth: English Heritage, Fort Cumberland, Fort Cumberland Road, Eastney, Portsmouth, PO4 9LD. Telephone: 02392 856783. Email: david.dungworth@english-heritage.org.uk

Introduction

The manufacture of window glass became increasingly important in England during between the 17th and 19th centuries as more and more buildings came to be fitted with windows. The limited evidence for the nature of the glass manufactured suggests that there were several changes in fluxes and decolourisers used in window glass manufacture during this period. This report examines a small assemblage of window glass from the excavations at Silkstone to determined the composition of early 18th century window glass.

Sample Selection and Preparation

Figure 1. Window glass from Silkstone

The excavations at Silkstone revealed a well-stratified sequence of deposits associated with the manufacture of glass in the late 17th century and pottery in the 18th century (Dungworth 2003, Dungworth and Cromwell forthcoming). The glassworking phase produced evidence for the manufacture of tableware and bottles but none for the manufacture of windows. No certain examples of window glass were recovered from contexts associated with the glassworking phase. Twelve fragments of window glass were recovered from the overlying contexts associated with the manufacture of pottery in the early 18th century. Three fragments of window glass came from context [0007] and nine from context [0009] (Table 1). Clay pipes from [0007] suggest deposition *c.*1700-1750 and from [0009] suggest deposition *c.*1700-1730. The clay pipes provide information about when the window glass was deposited but not necessarily when it was manufactured. While the window glass

cannot have been manufactured after *c*.1750, some of it may have been made prior to *c*.1700. It is unlikely that any of the window glass was manufactured at Silkstone.

The glass fragments are generally of better quality than most 17th century glass which tends to be a strong green colour with abundant elongated air bubbles. The colour of the Silkstone window glass fragments varies from blue-green to pale green; two groups (the first comprising 4048, 4049 and 4052; the second 4050, 4051 and 4054) have sufficiently similar colours that they are likely to have been made at the same time and place.

Table 1. Samples of window glass from Silkstone

SF No.	Context	Min Thick	Max Thick	Colour	Comments
4015	0007	1.5	1.6	Pale green	One side with surface spots and blemishes
4019	0007	2.2	2.3	Pale blue-green	Good finish with surface streaks
4021	0007	1.3	1.4	Pale blue	Good finish
4040	0009	1.5	1.6	Pale blue-green	Good finish with a few surface spots
4041	0009	1.1	1.1	Pale green	One side with surface spots and blemishes
4048	0009	2.2	2.9	Blue-green	Good finish; cf. 4049 & 4052
4049	0009	2.9	3.5	Blue-green	Good finish; cf. 4048 & 4052
4050	0009	1.6	1.8	Pale green	Good finish with surface streaks and spots; joins 4051
4051	0009	1.6	1.8	Pale green	Good finish with surface streaks and spots; joins 4050
4052	0009	2	2.2	Blue-green	Good finish; cf. 4048 & 4049
4053	0009	1.8	1.9	Pale blue-green	Good finish
4054	0009	1.6	1.7	Pale green	Good finish with surface streaks and spots; cf. 4050 & 4051

Analytical Techniques

A sample was taken from each fragment of window glass using side-cutters. The samples, typically 1-3mm across (20-50mg), were then mounted in epoxy resin and ground and polished to a 3-micron finish. The samples were analysed using two techniques: an energy-dispersive spectrometer attached to a scanning electron microscope (SEM-EDS) and an energy dispersive X-ray fluorescence spectrometer (EDXRF). The SEM-EDS provides good levels of accuracy, precision and detection for low energy (<4kV) X-rays while EDXRF provides better results for higher energy (4-20kV) X-rays (Table 2). Both techniques provide an indication of concentration of different elements present but no information about the oxidation state of those elements. The results were calibrated against a range of reference materials of similar composition to the Silkstone samples (e.g. Corning, SGT, NBS and NIST).

Table 2. Minimum Detection limits (MDL) and analytical errors for each oxide

	SEM-EDS			EDXRF	
	MDL	Error		MDL	Error
Na_2O	0.1	0.1	**V_2O_5**	0.02	0.03
MgO	0.1	0.1	**Cr_2O_3**	0.02	0.03
Al_2O_3	0.1	0.1	**NiO**	0.02	0.03
SiO_2	0.5	0.2	**MnO**	0.02	0.03
P_2O_5	0.2	0.1	**Fe_2O_3**	0.02	0.03
SO_3	0.2	0.1	**CoO**	0.02	0.02
Cl	0.1	0.1	**CuO**	0.02	0.03
K_2O	0.1	0.1	**ZnO**	0.01	0.01
CaO	0.1	0.1	**As_2O_3**	0.15	0.05
TiO_2	0.1	0.1	**SnO_2**	0.10	0.05
BaO	0.2	0.1	**Sb_2O_5**	0.15	0.07
			SrO	0.01	0.01
			ZrO_2	0.02	0.01
			PbO	0.05	0.05

Results

The chemical analysis of the 12 fragments of window glass from Silkstone shows that 2 are HLLA glasses (sf 4015 and 4041) and 10 are mixed alkali glasses (see appendix).

The HLLA glass fragments have compositions which are distinct from those of the HLLA glass produced at Silkstone for the manufacture of bottles (Dungworth 2003). HLLA glass was introduced to England in the late 16th century (Dungworth and Clark 2004) and was used for the manufacture of windows until at least the late 17th century. HLLA window glass has been recognised from post-Dissolution contexts at Eynsham Abbey (Paynter and Doonan 2003), the early 17th-century Chastleton House (Mortimer 1993) and at the late 17th-century Palace House Mansion, Newmarket, Suffolk (Bayley *et al*. forthcoming).

The 10 fragments of mixed alkali glass include two groups (4048, 4049 & 4052, and 4050, 4051 & 4054) that are visually very similar; these have chemical compositions which are identical (within the limits of accuracy of the techniques used) and were certainly produced from the same batch of ingredients. The compositions are so close to each other that the two groups probably come from two panes of glass.

Table 3. Average composition of the mixed alkali window glass fragments from Silkstone

	Na_2O	**MgO**	**Al_2O_3**	**SiO_2**	**P_2O_5**	**Cl**	**K_2O**	**CaO**	**TiO_2**	**MnO**	**Fe_2O_3**	**SrO**	**ZrO_2**	**PbO**
mean	7.8	5.6	2.1	63.9	1.4	0.8	4.4	10.7	0.13	0.09	1.02	0.37	0.05	1.1
sd	0.3	0.3	0.4	2.2	0.4	0.1	0.4	0.8	0.04	0.03	0.18	0.05	0.00	1.1

The mixed alkali window glass from Silkstone has an average composition (Table 3) which is similar the mixed alkali glass production waste from Silkstone (Dungworth 2003) and Cheese Lane, Bristol (Dungworth and Mortimer 2005, Mortimer and

Dungworth 2005). Nevertheless, the slight differences in composition show that the early 18th-century window glass at Silkstone was not made at Silkstone.

The strontium content of the Silkstone window glass (and many other mixed alkali glasses) is substantially higher than that of most other types of glass. The strontium oxide contents of mixed alkali glasses are usually in the range 3000 to 5000ppm compared to 200 to 1000ppm in HLLA glass (Dungworth 2003) and less than 200ppm in lead crystal (Dungworth and Brain 2005). There are few sources of glassmaking materials that are rich in strontium: most terrestrial plant ashes contain low levels of strontium (Jackson *et al*. 2005). One raw material that was used in the early 18th century which is rich in strontium is seaweed. A 1766 notice in a Bristol newspaper advertising the sale of a glasshouse in Cheese Lane, Bristol (Buckley 2003: 91-92) lists various ingredients used in making crown window glass, including kelp (seaweed). Analysis of glassworking debris from Cheese Lane (Mortimer and Dungworth 2005) showed that this was a mixed alkali glass with high levels of strontium oxide. Kelp was exploited on a small scale in coastal districts before the 18th century (Godfrey 1975, 159) but it became a significant industry during the 18th and early 19th century, especially in Wales, Ireland and Scotland (Gray 1951). The kelp industry collapsed in the 1830s when the LeBlanc process, which allowed the conversion of salt into sodium carbonate, was adopted in Britain (Muspratt 1863, 202-3).

Lead oxide is present in all of the mixed alkali window glass samples from Silkstone in variable but small amounts. Similar levels of lead oxide are seen in the mixed alkali glass produced at Silkstone in the 1660s but it is absent from that produced in the 1670s (Dungworth 2003). Lead oxide was not detected in the 18th-century mixed alkali glass produced at Cheese Lane (Dungworth and Mortimer 2005). It is not certain if the lead was deliberately added, and it is doubtful whether such low amounts of lead oxide would have had a significant impact on the physical properties of the glass (e.g. melting temperature, viscosity, etc).

Conclusion

Most of the early 18th century window glass fragments from Silkstone are mixed alkali glasses. The high levels of strontium in these mixed alkali glasses point to the use of seaweed ash (kelp) as a flux. Documentary evidence suggests that kelp may have been used on a limited scale in glassmaking by the early 17th century but that its use greatly expanded from the beginning of the 18th century. The remaining 2 samples of window glass from Silkstone are high-lime low-alkali (HLLA) glasses. HLLA glass was widely used for window glass manufacture from the late 16th century and was still being used until at least the end of the 17th century. It is possible that the HLLA window glass from early 18th century contexts at Silkstone was produced during the early years of the 18th century. Alternatively, the HLLA window glass might be residual in the contexts in which it was found.

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Appendix: Table 4. Chemical composition of the window glass from Silkstone

Sample	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	Cl	K_2O	CaO	TiO_2	MnO	Fe_2O_3	ZnO	SrO	PbO	Total
4015	0.8	1.9	1.8	60.5	2.0	0.34	0.13	6.2	24.3	0.12	0.07	0.72	0.02	0.05	<0.05	98.84
4019	7.9	5.5	2.5	64.7	1.1	<0.2	0.59	4.5	11.0	0.16	0.10	1.21	<0.01	0.38	0.09	99.77
4021	7.4	5.6	1.4	65.6	1.4	<0.2	0.83	3.7	12.1	<0.1	0.05	0.58	<0.01	0.46	0.30	99.41
4040	8.1	6.0	1.8	63.2	1.5	<0.2	1.02	3.9	10.0	0.12	0.10	0.93	<0.01	0.28	2.56	99.46
4041	2.7	2.9	2.4	58.8	2.3	0.39	0.52	4.1	22.3	0.18	0.18	1.04	0.02	0.10	0.06	97.99
4048	8.1	6.0	2.1	61.1	1.8	<0.2	0.89	4.8	11.3	0.15	0.13	1.05	0.01	0.40	1.41	99.30
4049	8.0	5.8	2.0	60.3	1.9	<0.2	0.87	4.8	11.1	0.15	0.12	1.01	<0.01	0.39	1.42	97.77
4050	7.7	5.4	2.5	65.9	0.9	<0.2	0.65	4.3	10.0	0.16	0.07	1.15	<0.01	0.37	0.35	99.58
4051	7.6	5.5	2.5	66.3	0.9	<0.2	0.72	4.3	10.0	0.17	0.07	1.15	<0.01	0.37	0.31	99.90
4052	8.3	6.1	2.1	61.8	1.8	<0.2	0.90	4.9	11.4	<0.1	0.12	1.03	<0.01	0.39	1.42	100.29
4053	7.2	5.2	1.7	64.5	1.5	<0.2	0.90	4.1	9.7	<0.1	0.10	0.95	<0.01	0.28	3.17	99.28
4054	7.6	5.4	2.6	65.6	1.0	<0.2	0.65	4.3	9.9	0.18	0.06	1.15	<0.01	0.36	0.37	99.38

V_2O_5, Cr_2O_3, CoO, NiO, CuO, As_2O_3, SnO_2, Sb_2O_5 and BaO were not detected in any of the samples