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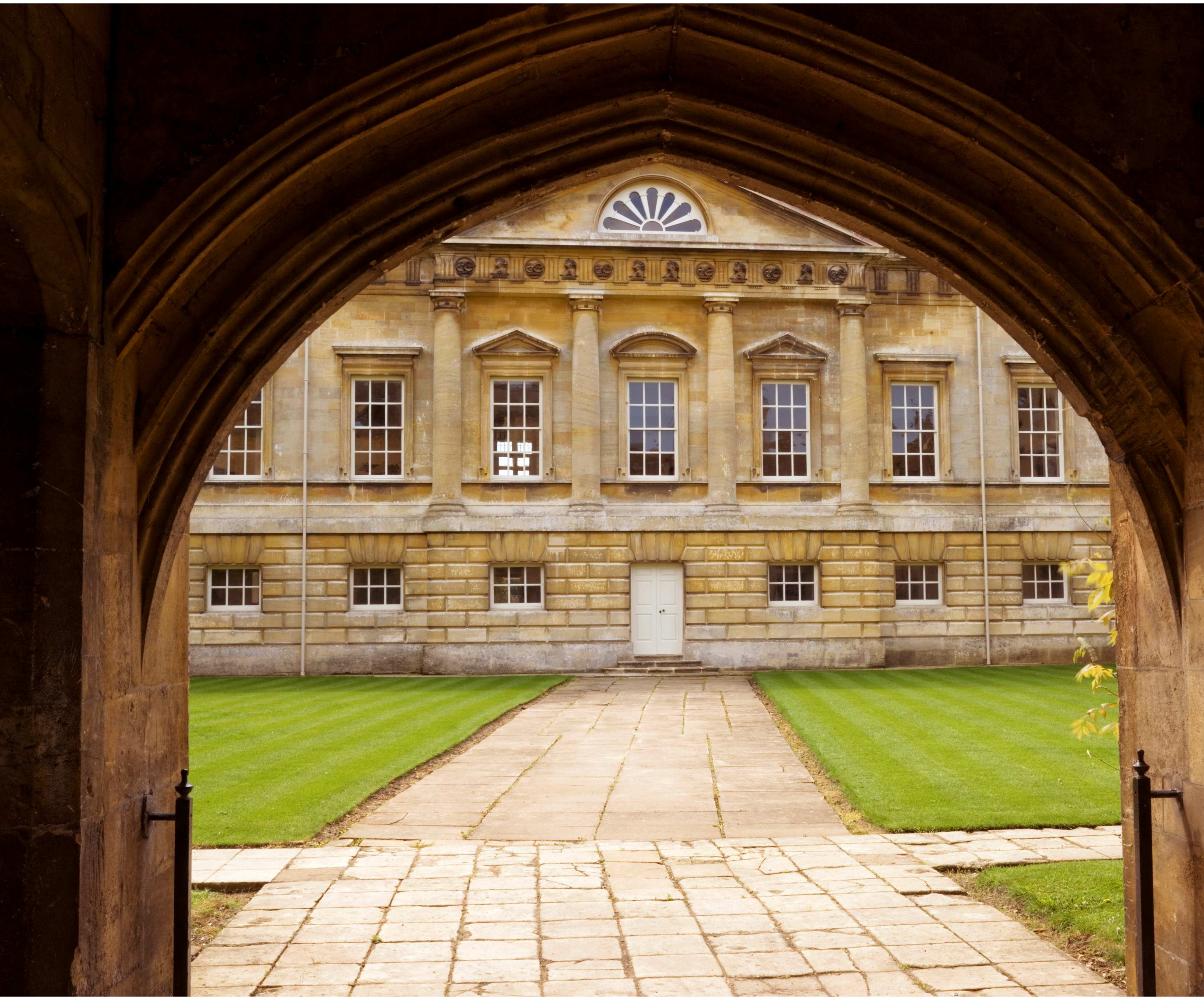
APETHORPE HALL, APETHORPE, NORTHAMPTONSHIRE
INVESTIGATION OF EXCAVATED WINDOW GLASS

TECHNOLOGY REPORT

Joanna Dunster



INTERVENTION AND ANALYSIS

ENGLISH HERITAGE

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Investigation of excavated window glass

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SUMMARY

Apethorpe Hall is a country house of huge cultural significance. It originated around 1470 and every later century has contributed significant additions and alterations. English Heritage has carried out a multi-faceted investigation using evidence gathered from documentary and visual research, dendrochronology, fabric analysis, geophysical survey, archaeological excavation and numerous other studies. A quantity of window glass was found during excavation of the Main and Service Courtyards by English Heritage in 2006. This assemblage was examined using XRF and SEM-EDS to attain quantified elemental composition including diagnostic minor and trace elements, in order to identify the types of glass present, and to interpret these according to a working chronology of the development of glass-making technology in England. Comparison with similar sites was made to discuss the typicality of the site against the wider context of historical glazing.

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INTRODUCTION

Apethorpe Hall is a grade I listed country house arranged around three courtyards. The original building was erected around 1470 by Sir Guy Wolston and comprised a double courtyard house with a central Great Hall (Cattell *et al* 2006; Heward and Taylor 1996; Martin 2008a; 2008b; Morrison 2006; Waugh 2009). Wolston made additions to the house in the late 15th century, including a square battlemented stair turret, a parlour wing and additional lodgings. Sir Walter Mildmay became the owner of Apethorpe Hall in the middle of the 16th century and enlarged the house to reflect his status and ambition (he was Chancellor of the Exchequer). Most significantly, shortly before Queen Elizabeth visited the house in 1566, Mildmay built a new south range which contained a state apartment. In 1617 Apethorpe was inherited by Sir Francis Fane who, in 1622–24, enlarged and refurbished the state apartments and added a new east range at the behest of James I, who was a frequent visitor. The well-preserved plasterwork ceilings and carved stone fireplaces are some of the most important features of the building. The Fane family – who became the Earls of Westmorland in 1624 – retained ownership of Apethorpe until 1904. The 6th Earl made various alterations and additions in the early 18th century, including the installation of sash windows in the Old Dining Room, and the erection of the greenhouse (Orangery) on the south side of the Service Courtyard. In the 1740s, the 7th Earl began an ambitious rebuilding project, replacing the south elevation of the main courtyard, and reconstructing part of Wolston's north range as a new Library wing, all in a grandiose Palladian style. Extensive 'improvements' in the middle of the 19th century included the erection of a loggia and first-floor conservatory on the south front and the creation of a new front hall in the east range. In 1904 Apethorpe was bought by Leonard Brassey who carried out extensive restoration and modernisation of the house and gardens. In 1949 the house was sold to the Northamptonshire Diocesan Catholic Child Protection and Welfare Society who used it as an approved school until 1978, and as a community home until 1982. Various additions and alterations made at this time included the insertion of a dining hall into the Service Courtyard, the conversion of the greenhouse into ablution rooms and a sick bay, and the division and partitioning of numerous large rooms into dormitories (Martin 2008b). In 1982 the school closed and the house was sold to a Libyan businessman, who later became resident in Greece. It remained empty and neglected for the next twenty years. The failure to carry out Statutory Repair Notices led to Apethorpe being compulsorily purchased by DCMS in 2002.

The rescue acquisition of the property by English Heritage was followed by an extensive program of investigation, including landscape and geophysical survey (Linford and Martin 2006); fabric analysis (Martin 2008; Morrison 2006; Waugh 2009); sampling of roof timbers and wall-panelling for dendrochronology; documentary research into the heraldry and records of royal visits; and archaeological excavation of the Main and Service Courtyards (Cattell *et al* 2006).

The main aim of the archaeological excavation was to 'ground truth' geophysical results that appeared to show a potential earlier east range (Cromwell 2007). Additionally, a subterranean vault had been discovered in the Service Courtyard when the dining block was cleared, and a trench was positioned to investigate the sequence of this structure and its relationship to the nearby east face of the Main Hall range (*ibid*).

The excavation recorded foundations and rubble from the construction and demolition of small buildings and systems of drainage (Cromwell *personal communication*). Ceramics dated to the 12th–15th centuries were recovered, however, it could not conclusively be established whether this significantly pre-dated the construction of the house. Window glass was found in all excavation trenches, with the majority coming from the latest phases dated to the 19th and 20th centuries.

The aims of the current study are:

- to identify the glass types present, based on elemental composition
- to compare the elemental composition with the known chronology for English glass-making in order to date the manufacture of the glass
- to compare the glass with assemblages from sites of a similar type and contemporary date in order to consider typicality
- to re-assess the assigned sequence of deposition for the archaeological contexts based on likely date of glass

THE GLASS

The assemblage consists of 29 individual shards of glass, 26 of which were from the excavation of the Main and Service Courtyards (ape01–ape26). A working sequence of deposition is provided by the site stratigraphy, and certain of the contexts have been spot dated according to the ceramics they contained. Three further shards were provided from windows within the house which were *in situ* but broken (ape01a–ape03a).

The majority of the shards are transparent or semi-transparent with varying degrees of corrosion present, manifest in discolouration, iridescence and friability of the exposed surfaces (Newton and Davidson 1989). Of the 28 pieces in which the colour is discernable, 6 are tinged green including 2 with severe lamination which has caused the silicaceous layers to take on a friable metallic surface sheen, 13 are tinged blue, 4 are opaque and varying in shade between orange and yellow, and the remaining 5 are colourless. With the exception of one anomalous, heavily corroded shard, thickness varied between 0.6 to 2.8mm, with a mean of 1.37mm and a standard deviation of 0.56mm.

Two shards were determined to be vessel glass, and are not included in the present study. No shards showed any morphological evidence for the shape of window from which they might have come, and no joins were possible between fragments.

Table 1. Description of glass samples and their contexts

Sample	Context	Prior Date	Thickness	Description
Ape_01	1044	?	1.0mm	Colourless
Ape_02	4022	C19–C20	1.8mm	Green semi-opaque, surface corrosion
Ape_03	4000	C19–C20	0.6mm	Pale green, surface iridescence
Ape_04	4000	C19–C20	2.8mm	Colourless
Ape_05	2033	C16?	1.9mm	Heavily corroded
Ape_06	1026	C18?	1.8mm	Pale blue-green, heavy corrosion
Ape_07	1001	C18+	1.5mm	Pale blue-green
Ape_08	1001	C18+	2.0mm	Colourless
Ape_09	1001	C18+	2.6–3.1mm	Heavily corroded, black and iridescent
Ape_10	1056	?	1.5mm	Not window glass, not analysed
Ape_11	1056	?	0.6mm	Pale blue-green, corroded iridescent surface
Ape_12	1056	?	1.1mm	Pale blue-green, lightly corroded
Ape_13	4022	C19–C20	0.8–0.9mm	Colourless, corroded iridescent surface
Ape_14	4022	C19–C20	1.6mm	Pale green, lightly corroded
Ape_15	3000	?	0.9mm	Pale green, corroded surface
Ape_16	1057	C19–C20	1.0mm	Pale blue-green
Ape_17	2058	C18+	1.2mm	Amber, heavily corroded flaking surface
Ape_18	2058	C18+	1.5mm	Green
Ape_19	2059	C19	1.0–1.2mm	Amber, heavily corroded flaking surface
Ape_20	2059	C19	0.8mm	Amber, heavily corroded flaking surface
Ape_21	2059	C19	0.8mm	Green, corroded surface
Ape_22	2059	C19	0.9mm	Pale blue-green, lightly corroded
Ape_23	2059	C19	1.1mm	Pale blue-green, lightly corroded
Ape_24	2059	C19	1.6mm	Pale blue-green, lightly corroded
Ape_25	2008	C15–C17	5.6-6.3mm	Not window glass, not analysed
Ape_26	2037	C16	1.0mm	Colourless, highly corroded, iridescent
Ape_01a	Great Hall	late C17+	2.5mm	Colourless
Ape_02a	Great Chamber	1740+	1.2mm	Colourless
Ape_03a	Old Dining Room	1716/17+	1.0–1.2mm	Pale blue-green

METHODS

The shards were received pre-cleaned and packaged according to context. A macroscopic examination was carried out; measurement of thickness used a pair of precision callipers, which was calculated from the mean of three measurements at two edges and the middle of each shard. A sample of each shard was extracted and set in epoxy resin to expose a cross-section, in order that the uncorroded glass at the centre would be accessible for analysis. The resin blocks were polished using standard techniques and coated with carbon before being examined using the SEM.

X-ray Fluorescence (XRF)

The XRF used was an Eagle II operated at 40kV, 1mA. Readings were taken for a 200-seconds run-time which enabled the full range of elements within range to be detected while economizing on the overall time available. Three readings were taken from different positions on each shard and a mean obtained. The spectra were deconvoluted using Vision32 software. Instrument calibration was carried out using an aluminium-copper reference material after every fifteen readings. The results were calibrated using Certified Reference Materials from Corning, the NIST and Pilkington.

Scanning Electron Microscope (SEM)

The SEM used was a FEI Inspect F operated at 25kV and 1nA. The back-scattered electron detector was used in order to identify the phase contrast between the lighter glass and darker corrosion layers. This imaging also allowed the microstructure of the glass corrosion to be viewed at a high level of magnification, revealing the laminar structure built up of layers of weathered glass crusts, which is responsible for the surface iridescence.

Readings were taken using an energy dispersive X-ray spectrometer (EDS) for a 100-seconds run-time. The means were obtained from three readings at different positions on each shard. The readings were aimed at the uncorroded core of the shard in each case, in order to obtain a result that was representative of the original composition of the glass. The spectra were deconvoluted using Oxford Instruments INCA software. Instrument calibration was carried out using a cobalt reference material after every fifteen readings. The results for Fe_2O_3 for each sherd were plotted against those from the XRF in order to determine the correspondence between the two instruments.

RESULTS

The SEM examination of the samples revealed that three were very corroded and no unweathered glass remained for analysis (09, 17, 20). The samples (Table 2) were divided into groups depending on the chemical composition of the glass (Figures 1–4).

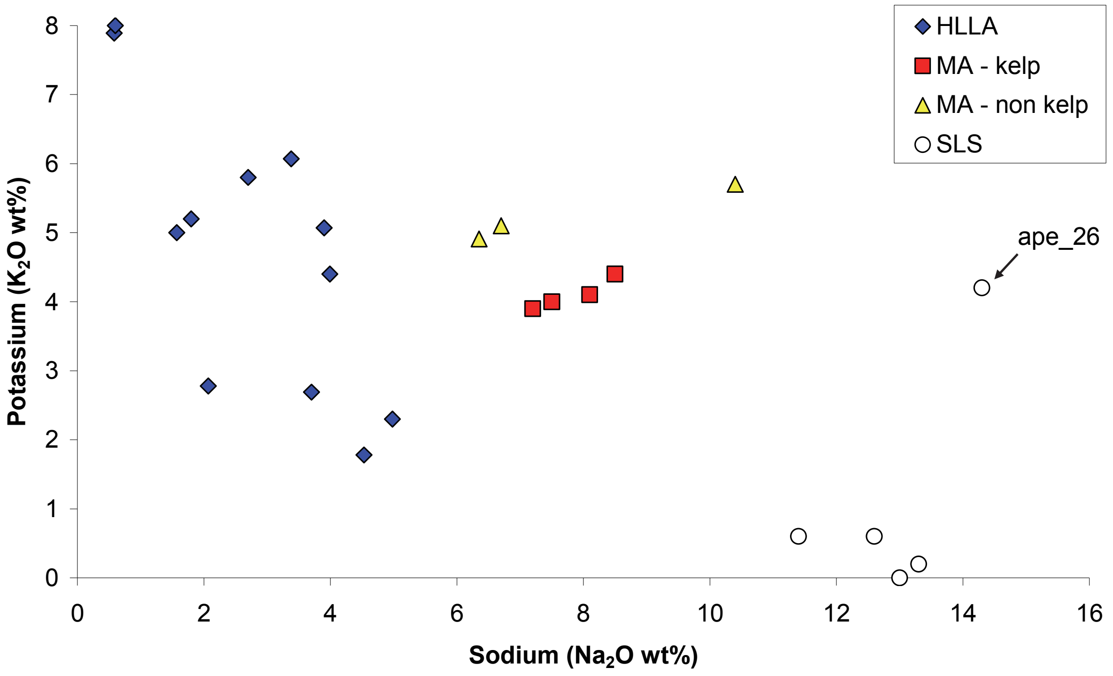

Figure 1. Sodium and potassium content of the Apethorpe window glass

Soda-Lime-Silica glasses

Four samples (01a, 04, 08 and 13) are soda-lime-silica (SLS) glasses with very low levels of P_2O_5. Three of these samples (01a, 08 and 13) contain little or no MgO and relatively high levels of CaO. This composition is typical of glass manufactured in the period *c*1835 to *c*1930 (*ie* from the introduction of synthetic soda to the introduction of sheet drawing). The fourth sample (04) contains levels of MgO and CaO that are consistent with manufacture during the period of drawn sheet manufacture but before the introduction of the float process (*ie* *c*1930 to *c*1960).

An additional sample (26) is a SLS glass but also contains small amounts of a range of elements not typically found in SLS glasses (Figures 1–4). This glass has a composition which is comparable with some *façon de venise* glasses (De Raedt *et al* 1998). This type of glass was developed in the Mediterranean in the medieval period and was produced in northern Europe from the 16th century (De Raedt *et al* 1998); but to date it has only been identified in vessel glass, not window glass. It was almost certainly manufactured before *c*1835.

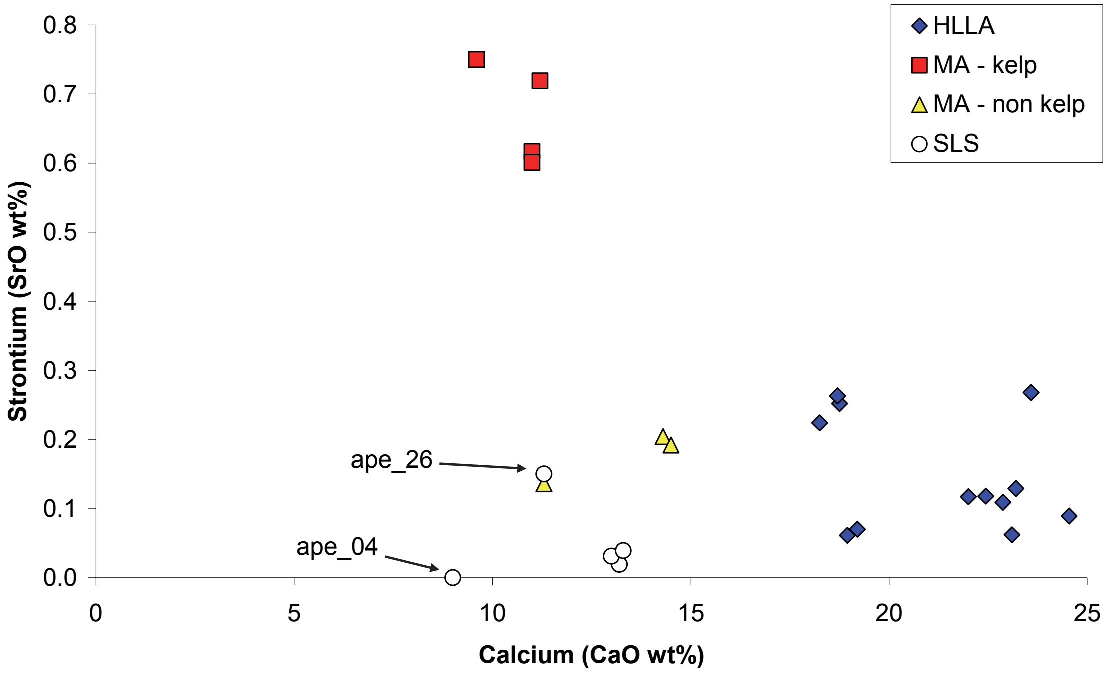

Figure 2. Calcium and strontium content of the Apethorpe window glass

High-Lime Low-Alkali glasses

Twelve samples (02, 03, 05, 06, 07, 11, 12, 14, 15, 18, 19 and 21) contain high levels of CaO and low levels of the two alkalis (Na_2O and K_2O). These are High-Lime Low-Alkali (HLLA) glasses which were used in the manufacture of window glass in England from the late 16th century to the end of the 17th century. It is possible that some of this window glass is earlier than this as HLLA glass was produced before the end of the 16th century in France and Germany. Typically these glasses contain relatively high Fe_2O_3 (>0.7wt%) and P_2O_5 (>1wt%). Five of the samples show unusually low levels of CaO, one has very low P_2O_5 and four have elevated SrO.

Mixed Alkali glasses

There are seven samples (02a, 03a, 01, 16, 22–24) which contain higher levels of Na_2O (6–11wt%) than would be expected for HLLA glasses, but lower than would be normal for SLS glasses. They contain less CaO than would be normal for HLLA glass but more P_2O_5 and SrO than would be usual for SLS glass. This is a mixed alkali type glass which can be divided into two groups based on SrO: the samples (16, 22–24) with elevated SrO (0.6–0.8wt%) would have been made using kelp (seaweed ash), the remaining samples contain low levels of SrO (0.1–0.2wt%) and were made using little or no kelp. Mixed alkali kelp glasses were used for the manufacture of window glass from the beginning of the 18th century to *c*1835. Some non-kelp mixed alkali glasses were used in the manufacture of *façon de venise* tablewares (De Raedt *et al* 1998; Dungworth and

Brain 2009; Dungworth and Cromwell 2006) but evidence for their use in windows is slim (Dungworth 2006).

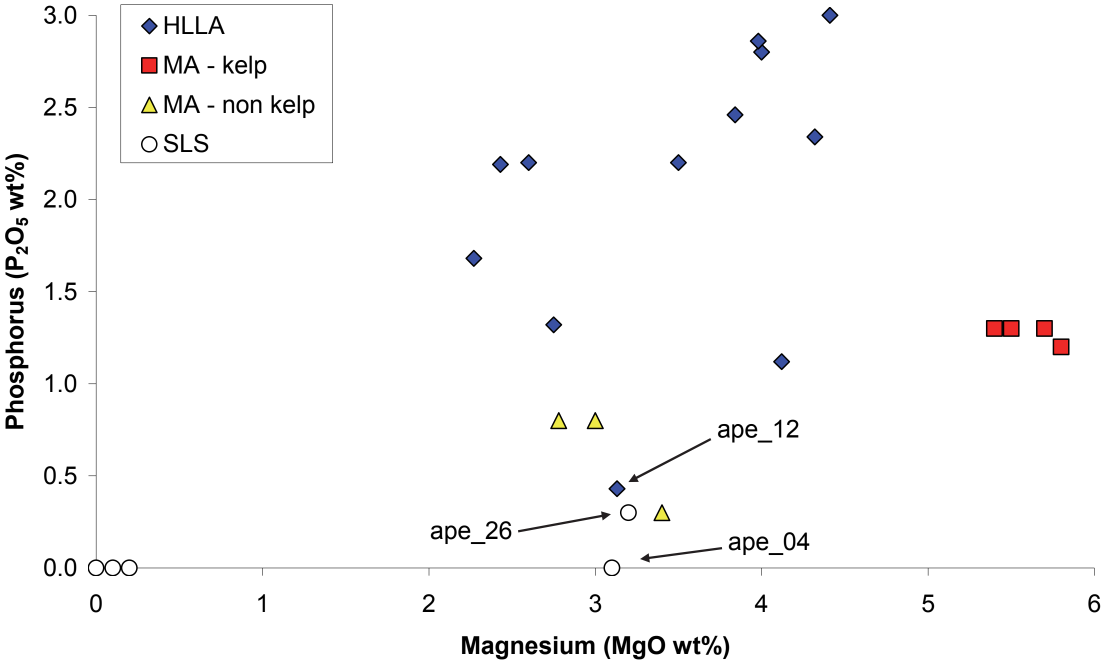

Figure 3. Magnesium and phosphorus content of the Apethorpe window glass

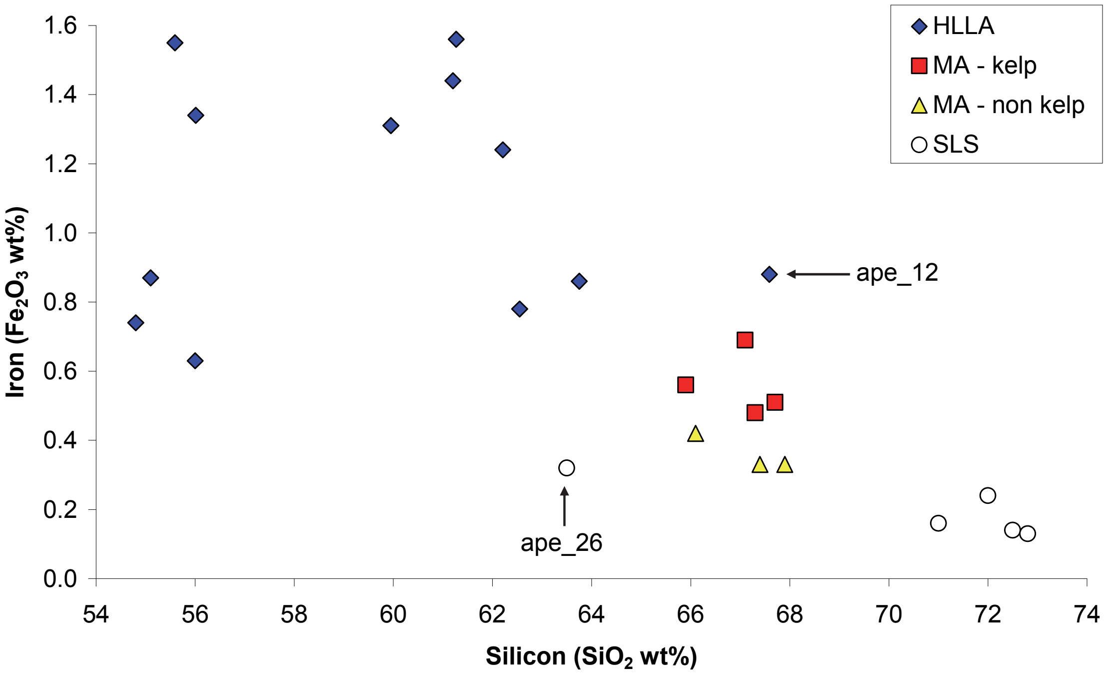

Figure 4. Silicon and iron content of the Apethorpe window glass

Table 2. Chemical composition of Apethorpe window glass (SEM-EDS and EDXRF)

#	colour	type	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	Cl	K_2O	CaO	TiO_2	MnO	Fe_2O_3	ZnO	As_2O_3	SrO	ZrO_2	BaO	PbO
ape_01	clls	MA	6.4	2.8	1.0	67.9	0.8	0.2	1.0	4.9	14.5	0.10	0.20	0.33	<0.01	0.09	0.19	0.012	<0.2	<0.05
ape_02	gr	HLLA	3.3	3.8	5.7	54.3	3.0	<0.1	0.9	6.4	19.9	0.3	0.39	1.48	0.03	<0.05	0.07	0.024	<0.2	0.10
ape_03	gr	HLLA	1.7	1.8	2.6	67.3	1.4	0.3	0.3	2.7	20.1	0.24	0.16	1.33	0.02	<0.05	0.09	0.019	<0.2	0.10
ape_04	clls	SLS	12.6	3.1	1.2	72.8	<0.2	0.2	0.1	0.6	9.0	<0.05	<0.02	0.13	<0.01	<0.05	<0.005	0.010	<0.2	<0.05
ape_05	?	HLLA	0.6	3.8	2.7	56.0	2.5	0.4	<0.1	7.9	22.9	0.16	2.01	0.63	0.02	<0.05	0.11	0.023	0.5	<0.05
ape_06	bl	HLLA	2.7	4.0	3.6	54.8	2.8	0.2	0.7	5.8	23.2	0.16	1.04	0.74	0.03	<0.05	0.13	0.018	0.30	<0.05
ape_07	bl	HLLA	4.1	3.5	3.2	61.1	1.0	0.4	0.5	2.8	22.1	0.17	0.09	1.04	0.01	<0.05	0.26	0.017	<0.2	<0.05
ape_08	clls	SLS	13.0	<0.1	0.6	72.0	<0.2	0.4	0.2	0.0	13.0	<0.05	0.49	0.24	<0.01	0.11	0.03	0.009	<0.2	<0.05
ape_11	bl	HLLA	4.0	2.8	2.3	62.3	1.4	0.6	0.7	2.9	22.2	0.10	0.13	0.63	<0.01	<0.05	0.27	0.017	<0.2	<0.05
ape_12	bl	HLLA	3.9	2.9	2.7	68.2	0.4	0.2	0.6	1.9	18.3	0.18	0.05	0.74	0.03	<0.05	0.22	0.022	<0.2	<0.05
ape_13	clls	SLS	13.3	0.2	0.6	71.0	<0.2	0.4	0.3	0.2	13.3	<0.05	0.66	0.16	<0.01	0.13	0.04	0.009	<0.2	<0.05
ape_14	gr	HLLA	3.9	4.2	5.5	55.1	3.0	<0.1	0.9	5.5	19.8	0.17	0.49	1.29	0.06	<0.05	0.06	0.014	<0.2	0.11
ape_15	gr	HLLA	3.8	4.1	3.7	59.0	2.2	0.4	0.5	4.9	19.7	0.24	0.11	1.26	0.08	<0.05	0.25	0.034	<0.2	0.14
ape_16	bl	kelp	8.5	5.7	1.8	67.1	1.3	0.1	0.6	4.4	9.6	0.09	0.07	0.69	<0.01	<0.05	0.75	0.018	<0.2	<0.05
ape_18	gr	HLLA	1.8	2.6	2.6	61.2	2.2	0.4	0.2	5.2	22.0	0.22	0.22	1.44	0.02	<0.05	0.12	0.024	<0.2	<0.05
ape_19	y	HLLA	0.6	3.5	4.8	55.1	2.2	0.2	0.2	8.0	23.1	0.28	0.93	0.87	0.02	<0.05	0.06	0.024	0.39	<0.05
ape_21	y	HLLA	1.6	2.5	2.7	61.1	2.2	0.4	0.2	5.2	22.1	0.20	0.23	1.51	0.03	<0.05	0.12	0.024	<0.2	<0.05
ape_22	bl	kelp	7.5	5.5	2.1	67.3	1.3	0.3	0.6	4.0	11.0	0.09	0.05	0.48	<0.01	<0.05	0.62	0.030	<0.2	<0.05
ape_23	bl	kelp	8.1	5.8	2.1	65.9	1.2	0.3	0.7	4.1	11.2	0.11	0.06	0.56	<0.01	<0.05	0.72	0.03	<0.2	<0.05
ape_24	bl	kelp	7.2	5.4	2.0	67.7	1.3	0.3	0.6	3.9	11.0	0.07	0.05	0.51	<0.01	<0.05	0.60	0.028	<0.2	<0.05
ape_26	clls	SLS	14.3	3.2	1.0	63.5	0.3	0.2	1.4	4.2	11.3	0.09	0.42	0.32	<0.01	<0.05	0.15	0.017	<0.2	<0.05
ape_01a	clls	SLS	11.4	0.1	1.6	72.5	<0.2	0.3	0.0	0.6	13.2	0.07	<0.02	0.14	<0.01	<0.05	0.02	0.009	<0.2	<0.05
ape_02a	clls	MA	6.7	3.0	1.0	67.4	0.8	0.2	0.9	5.1	14.3	0.08	0.21	0.33	<0.01	0.08	0.20	0.016	<0.2	0.05
ape_03a	clls	MA	10.4	3.4	1.3	66.1	0.3	0.2	0.8	5.7	11.3	0.13	0.03	0.42	<0.01	<0.05	0.14	0.017	<0.2	<0.05

DISCUSSION

The Apethorpe assemblage of window glass has been divided into groups based on their chemical compositions (see Figures 1–4). The groups are useful for categorizing the glass, giving a chronology to their production and use, if not deposition.

Soda-Lime-Silica glass

The SLS glass is all colourless and transparent, with little or no corrosion. Four samples were made using synthetic soda (*ie* after *c*1835) and a fifth appears to have been made using soda-rich plant ashes similar to those used for the manufacture of *façon de venise* tableware (Table 2).

The *façon de venise* type window glass sample (26) was recovered from a context (2037, Trench B) which was spot dated using ceramics to the 16th century (2 Cistercian ware sherds). This type of glass was manufactured in London and the Low Countries (as well as Italy and other countries) at this time (De Raedt *et al* 1998) but so far evidence has only been found for its use in the manufacture of tablewares. The apparent use of *façon de venise* glass for window glazing at Apethorpe in the 16th century may possibly be associated with improvements made to the house in the 1560s for the visit of Elizabeth I. The use of this glass in this context would represent conspicuous consumption of a rare and expensive material and contrasts with practice at the contemporary Basing House which employed medieval forest glass and HLLA glass in its windows (Dungworth 2009b). The composition of sample 26 is similar to the *vitrum blanchum* glass manufactured in Venice and Antwerp (De Raedt *et al* 1998), although it contains rather more SrO and ZrO_2 than would be expected for these manufacturers. The composition does not match the soda-rich *façon de venise* glass produced in the 16th and early 17th centuries in London (Aldgate and Broad Street, De Raedt *et al* 1998). The exact source, therefore, of this remains uncertain at this time.

The remaining SLS glass samples all have compositions which are consistent with manufacture after the introduction of synthetic soda *c*1835. Samples 08 and 13 may be the earliest within this group: they contain little or no MgO which is typical of synthetic soda glass manufactured up to the introduction of drawing techniques in the 1930s. In addition, they contain small amounts of As_2O_3 which appears to have been a popular decolouriser in window glass manufacture between *c*1835 and *c*1870 (although the Apethorpe samples contain slightly less arsenic than most of the glass of this period and small amounts of arsenic were occasionally used in window glass manufacture up to the middle of the 20th century). Sample 08 was recovered from a context (1001, Trench A) which was spot dated to the 18th century and onwards. The presence of this glass suggests that the context must have formed after *c*1835 and that the ceramics are residual. Sample 13 was recovered from a context (4022) which was spot dated to the

19th to 20th centuries which is entirely consistent with the glass. Sample 01a has a composition which is most closely paralleled among window glass of the period from *c*1870 to *c*1930. It was recovered from a window of the Great Hall on the north-west side of the courtyard. These windows were originally installed in the 17th century, but this particular pane must have been inserted (a repair?), possibly during the works undertaken for Leonard Brassey. Sample 04 has a composition which indicates that it was manufactured between *c*1930 and *c*1960. It was recovered from a context (4000) which is dated to the 19th to 20th centuries — this sherd probably represents alterations or repairs undertaken during the period when Apethorpe was an Approved School.

Mixed Alkali – Kelp glass

The mixed alkali kelp glasses from Apethorpe compare well with similar glass from Shortlands Lane, Devon (Girbal and Ford 2010), Shaw House, Berkshire (Dungworth and Loaring 2010), Cheese Lane, Bristol (Jackson 2005), St Thomas St, Bristol (Dungworth 2007) and Margam Castle, Glamorgan, Wales (Dungworth and Adams 2010). Samples 22 and 24 have chemical compositions which differ by less than the analytical precision and so may have been produced at the same time and place, and may even be two fragments from the same pane of glass (both were recovered from the same context). The other two samples (16 and 23) have compositions which differ by more than the analytical precision and so must belong to other batches of glass. The kelp glasses were all recovered from contexts which have been spot dated to the 19th or 20th centuries, and so they are likely to be residual.

Kelp-based mixed alkali glasses are first detected in the archaeological record in the late 17th century (Dungworth and Cromwell 2006) but their use for the manufacture of window glass appears to date only from the beginning of the 18th century (Dungworth 2011). This type of glass continued in use throughout the 18th century and into the early 19th century. During the 1830s the introduction of synthetic soda rapidly supplanted the use of kelp and no kelp-based glasses are known to have been manufactured after *c*1835 (Dungworth 2009a; Dungworth and Adams 2010). Within this period (*c*1700 to *c*1835) there are no apparent changes in the nature of kelp based mixed alkali glass which would help refine the dating of manufacture. It is tempting to associate the kelp glass with the alterations made to Apethorpe during the early 18th century.

Mixed Alkali – non kelp glass

The mixed alkali glasses (samples 07, 11, 12 and 15) with the low SrO content have compositions which are otherwise quite similar to the kelp glasses, nevertheless, the low SrO content indicates that little or no kelp was used. Two of these samples (01 and 02a) have compositions which differ by less than the analytical precision and so may have been produced at the same time and place. As one was recovered from a (broken) window in the Great Chamber and the other from an archaeological context, it is unlikely they were from the same pane of glass. The third sample (03a) has a sufficiently different chemical composition to indicate production at a different time/place. This sample has a composition which is very close to that produced at Broad Street in the early 17th century (De Raedt *et al* 1998), although glass from that site has usually been described as *façon de venise* rather than mixed alkali. There is no widely agreed criteria for distinguishing mixed alkali glass and *façon de venise* glass.

These mixed alkali glasses were probably made using plant ash(es) which provided a range of elements (Na_2O, MgO, P_2O_5, K_2O, CaO and more besides) but the exact type of plant(s) used remains uncertain. There are relatively few published analyses of post-medieval mixed alkali glasses with which these samples can be compared: the glass from Silkstone contains much less CaO and more Fe_2O_3 (Dungworth and Cromwell 2006), the Antwerp glass contains more Na_2O and less CaO (De Raedt *et al* 1998) and the Lincoln glass contains more K_2O and less CaO.

Non-kelp mixed alkali glasses were produced in England from at least the later 17th century (and possibly even earlier) but there is little published evidence for their continued production after the end of the 17th century. It is most unlikely that there would have been any production after the introduction of synthetic soda *c*1835.

High-Lime Low-Alkali glass

The HLLA glasses are the most numerous (half of all analysed window glass samples are HLLA glass) and also show the greatest variety in composition (Figures 1–4). None of the samples have compositions which differs from each other by less than the analytical precision and so they can all be regarded as having been made at different times and/or places. While most of the HLLA samples have compositions which compare broadly with most English HLLA window glass (Dungworth 2011) there are some with minor differences which are difficult to explain. The main group (comprising samples 02, 03, 05, 06, 14, 18, 19 and 21) shows the most similarity with other HLLA window glass. Within this group there is a positive correlation between MnO and BaO. It is unlikely that either of these elements were deliberately added to these glasses; it is more likely that both elements were naturally present in the plant ash that was used as a flux (both also correlate with K_2O). The low BaO group also contains less MgO and Al_2O_3 but more SiO_2. HLLA glass was manufactured in Europe for use in windows from the medieval period to the 18th century (and perhaps even later). The manufacture of this glass type in England began in the late 16th century and appears to have ended at the beginning of the 18th century. One sample (05) from this group comes from a context (Trench B, 2023) which was tentatively dated to the mid 15th century to the mid 16th century. HLLA glass was produced in continental Europe during this period (but not England). The other samples come from contexts which were spot dated to the 18th century or later. As HLLA window glass production appears to have ceased in England by the beginning of the 18th century, the glass in these contexts is likely to be residual.

The remaining four samples (07, 11, 12 and 15) have compositions which show significant differences with most English HLLA window glass. These samples contain high levels of Na_2O that are only paralleled among some of the window glass from Chastelton House (Mortimer 1993) and Palace House Mansion, Newmarket, Suffolk (Bayley *et al* 2009). The SrO content of this glass is very high compared to HLLA glass, except for glass from Cullompton, Devon (Girbal and Ford 2010). The relatively high strontium content of this glass suggests that at least a proportion of kelp was used. The date at which this glass was manufactured is at present uncertain but is likely to be within the 17th century (or possibly very early in the 18th century). The samples of this glass come mostly from Trench A (with a single sample from Trench C) but it has not been possible to establish spot dates for most of these contexts (one sample [07] is from trench A context 1001 which was spot dated to the 18th century or later.

CONCLUSIONS

The assemblage from Apethorpe incorporates samples of glass types from every period of post-medieval glass-making (Dungworth 2011). The earliest type of glass found is the HLLA which is also the most abundant (although no samples of this glass type have yet been identified *in situ* in extant windows). HLLA glass was produced in Germany from the 14th century (Wedepohl 1997) and in France from the 16th century (Barrera and Velde 1989), however, it was not produced in England until the late 16th century (Dungworth and Clark 2004). If it is assumed that the Apethorpe HLLA glass was manufactured in England then this glass can only have been installed after *c*1567 (Dungworth and Clark 2004) and could represent Sir Francis Fane's works in the early 17th century. If the HLLA glass was produced in England then none of the glass predates c1567 and so none of the earliest windows (Wolston or Mildmay) would be represented. It is possible that the earlier windows were glazed using 'forest glass' which is notoriously prone to corrosion. Indeed several samples of window glass were so corroded that no analysis was possible. If it is assumed that at least some of the HLLA glass was imported from continental Europe then the Wolston and Mildmay phases may be represented in the analysed window glass. It is known that for some high status late medieval building projects imported window glass was specified. A 15th-century contract for the glazing of the Countess of Warwick's chapel specified that the glazier 'use no glass of England, but glass from beyond seas' (Marks 1993). The HLLA glass with the high SrO content has a parallel with only one other site and for the moment it is unclear when (or where) this type of glass was manufactured.

The analysis of the other glasses has highlighted the problem of distinguishing some soda-rich and mixed alkali glasses made using plant ashes. While other groups (synthetic soda SLS glass, 'forest' glass and HLLA glass) can be differentiated quite easily there are no commonly agreed criteria for separating mixed alkali glasses from soda-rich glasses. The problem is that while the soda-rich glasses usually contain more sodium than the mixed alkali glasses, there is a continuum from the most soda-rich glasses to the mixed alkali glasses. In addition all soda-rich glasses made using plant ashes (including the finest Venetian cristallo) contain at least some potassium. De Raedt *et al* (1998) separated their Antwerp samples into façon *de venise* and mixed alkalis glasses but they classed all the contemporary London production (Aldgate and Broad St) as *façon de venise* although the Aldgate glass contains less sodium and more potassium than the Antwerp mixed alkali glass (Figure 5). While Apethorpe sample 26 has a composition which lies within the Venetian and best of the façon de venise glasses, and samples 01 and 02a are clearly mixed alkali glasses, the status of sample 03a is less clear (Figure 5).

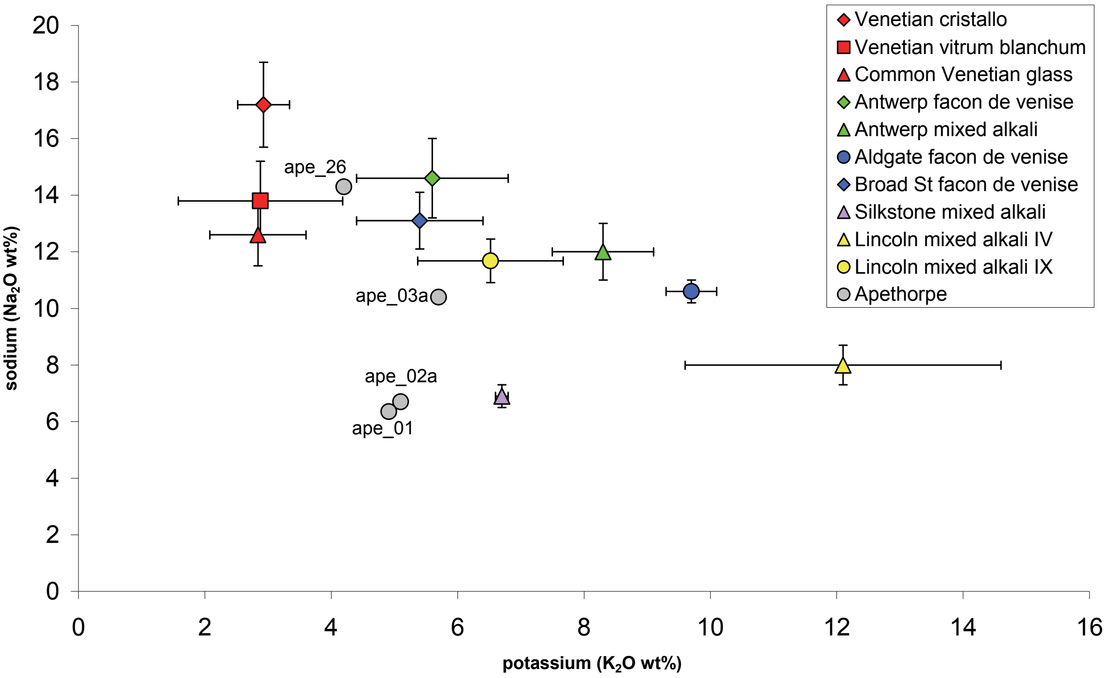

Figure 5. Sodium and potassium content of Venetian, façon de venise and mixed alkali glass

Leaving aside the problems of categorising these types of glass (something which may be more of an issue for those analysing historic glass than for those who made it in the first place), the fact that such high status glass was used for glazing is unusual. The analysis of thousands of samples of historic window glass (Dungworth 2011; 2012a; 2012b) has not previously identified the use of this glass type in an architectural context. Glass vessels of this type were imported but were generally only available to the very wealthy. Of the Apethorpe samples one (sample 26) was recovered from a 16th-century context and so was presumably installed in a window then or slightly earlier. The use of venetian (or façon de venise) glass in this way would represent conspicuous consumption but one which would not perhaps be out of place in the country house of a member of the political elite who hoped to impress royalty. This sort of behaviour may be paralleled at Walmer Castle (Dungworth and Girbal 2011) where non-destructive analysis identified the use of a different glass which had not previously been noted. That glass probably belonged to the early 19th century and was imported from Bohemia.

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