RESEARCH REPORT SERIES no. 4-2013

BARMOOR CASTLE, LOWICK, BERWICK-UPON-TWEED, NORTHUMBERLAND
CHEMICAL ANALYSIS OF WINDOW GLASS

TECHNOLOGY REPORT

Vanessa Castagnino

INTERVENTION
AND ANALYSIS

ENGLISH HERITAGE

Barmoor Castle, Lowick, Berwick-upon-Tweed, Northumberland

Chemical Analysis of Window Glass

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NGR: NT 9974 3988

ISSN 2046-9799 (Print)
ISSN 2046-9802 (Online)

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SUMMARY

During an investigation of Barmoor Castle, Lowick, Northumbria (NT 99736 39879), the construction date for the tower need to be established for an English Heritage 'Building at Risk' grant and repair programme. The tower was either constructed in 1801 with the main house or with the extension to the building in 1892. The possibility of original window glass, situated behind a boarded window in the tower, was considered and the glass was submitted for chemical analysis in the hope that a fixed date for the construction could be ascertained. At these two dates manufacture window glass are different both optically and chemically.

ACKNOWLEDGEMENTS
Thank you to Chris Baglee of Spence and Dower for the window glass samples and site information. Thanks to David Dungworth for the wealth of information on window glass composition and analytical techniques, and for his support.

ARCHIVE LOCATION
Fort Cumberland, Fort Cumberland Road, Eastney, Portsmouth PO4 9LD

DATE OF RESEARCH
2012

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INTRODUCTION

Barmoor Castle, Lowick, Northumbria (NT 99736 39879) is a substantial neo-classical country house constructed in 1801 that incorporates earlier masonry in its structure (Pevsner and Richmond 1992, 158) The building received a grant from English Heritage in 1986, but despite subsequent repairs being made it has deteriorated further. English Heritage, as part of its 'Building at Risk' remit offered a grant towards a package of project development work which will inform a further repair programme in the future.

During the investigation, a chance discovery of a sash window that had been boarded over with shelving was noted. When this took place is unknown. The window in the tower was either constructed in 1801 with the main house, or in 1892 with the extension nearby. Chemical analysis of the window glass might determine the date of the glass and also that of the tower. At these two dates manufacture window glass are very distinct and different both optically and chemically.

From the early 1700s until the mid-1830s the majority of standard window glass had seaweed ash as a flux (Dungworth 2011, 28). This gives a distinct chemical composition to the glass: high levels of phosphorous indicate plant ash was utilised as a flux, and high levels of strontium denote that plant ash was marine based (Dungworth 2011, 40). With the introduction of the Leblanc process of converting common salt (NaCl) into sodium carbonate (Na_2CO_3), the chemical composition becomes quite different with little to no phosphorous being detected and the iron content low (Dungworth 2011, 40). In synthetic soda glass made until *c*1870 arsenic is generally detected, which was used as a glass refining agent (Douglas and Frank 1972, 25). After this date this composition disappears and potassium is detected instead; this is evidence of the use of probably saltpetre, another refining agent (Douglas and Frank 1972, 66).

Table 1. Average chemical composition of domestic window glass during the 19th century (Dungworth 2011)

	Kelp c1700–c1835	Synthetic 1 c1835–c1870	Synthetic 2 c1870–c1930	Mechanised 1 c1930–c1960
Na_2O	7.9 ± 0.7	12.7 ± 0.9	17.9 ± 7.1	13.9 ± 0.5
MgO	5.3 ± 0.3	0.2 ± 0.1	0.7 ± 0.7	2.8 ± 0.2
Al_2O_3	2.6 ± 0.6	0.5 ± 0.1	1.2 ± 0.3	0.9 ± 0.5
SiO_2	66.5 ± 0.4	70.8 ±.1.2	71.9 ± 0.4	77.7 ± 0.7
P_2O_5	1.1 ± 0.2	<0.2	<0.2	<0.2
SO_3	0.7 ± 0.1	0.4 ± 0.1	0.4 ± 0.2	0.4 ± 0.2
Cl	0.6 ± 0.1	0.1 ± 0.1	<0. 1	<0. 1
K_2O	4.2 ± 0.2	0.1 ± 0.1	0.5 ± 0.2	0.1 ± 0.1
CaO	10.4 ± 1.0	14.0 ± 0.8	12.9 ± 0.6	9.7 ± 0.8
Fe_2O_3	0.71 ± 0.14	0.22 ± 0.06	0.21 ± 0.06	0.13 ± 0.03
As_2O_3	< 0.2	0.22 ± 0.16	<0.2	<0.2
SrO	0.45 ± 0.1	0.03 ± 0.01	0.02 ± 0.01	0.01 ± 0.01

THE GLASS

Fragments from two panes of glass were submitted for chemical analysis to determine a date of possible manufacture. The window panes had been broken from the outside, and small pieces of the material were gathered from the ground below.

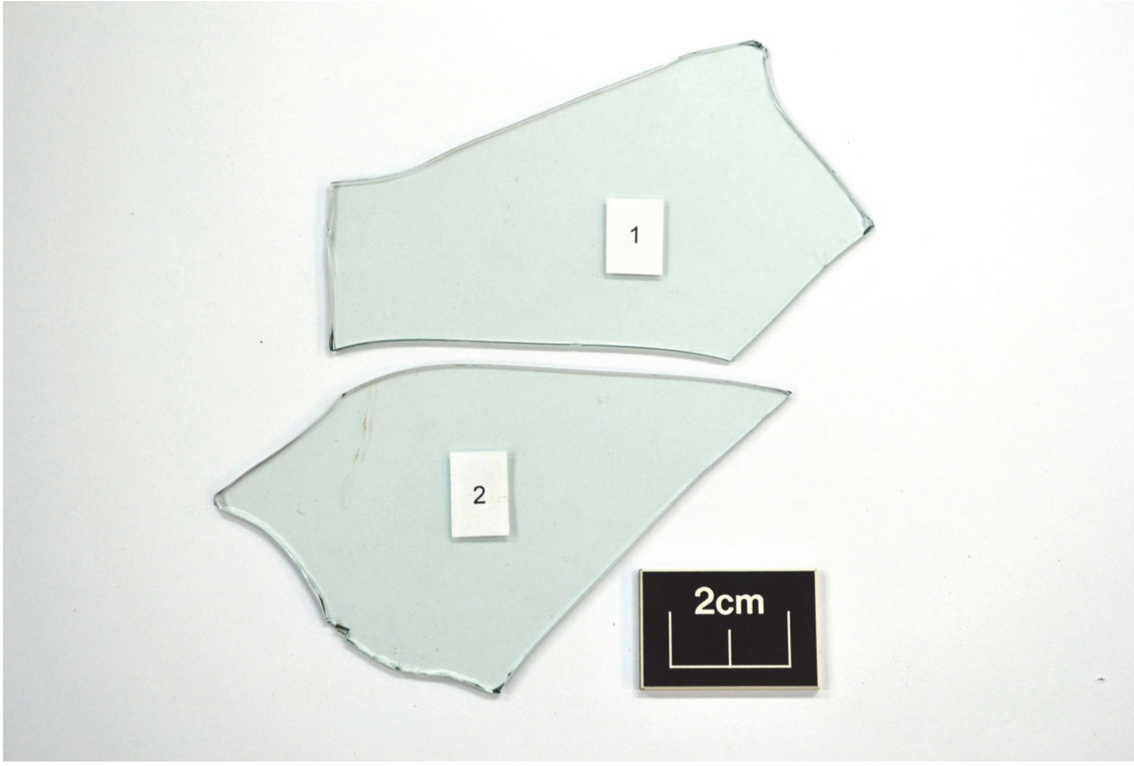

Figure 1: Sash window glass samples from Barmoor Castle.

METHODS

Visual Analysis

Prior to sectioning, the window glass fragments were visually examined for colour, thickness, clarity, then measured and photographed. Both fragments were optically examined with the use of a Zeiss inverted microscope to detect manufacturing flaws and areas of corrosion. No areas of imperfection or corrosion were found on either sample.

Chemical Analysis

Small samples (<2mm) of the window glass were taken from the fragments provided, and mounted in epoxy resin before being ground and polished to a 1-micron finish. The samples were analysed using EDXRF to determine their chemical composition. EDXRF can detect elements such as calcium, lead, silica and zinc, but cannot detect light elements, such as fluorine or carbon. It does provide improved sensitivity and accuracy for some of the minor elements, in particular iron, arsenic, manganese and strontium. The EDXRF used is an EDAX Eagle II, which targets an area of approximately 0.5mm across, using a tube voltage of 40kV and 1mA. The data was gathered for a live time of 500 seconds to ensure a greater reduction of background noise. Three target areas were analysed and an overall compositional average taken for each sample. The data produced was compared to a range of certified standards of archaeological reference glass (Corning, NIST, DGG etc).

Additionally, the samples were analysed using a scanning electron microscope (SEM) with an energy-dispersive x-ray spectrometer (EDS) attachment. The SEM used was a FEI Inspect F which was operated at 25kV with a beam current of approximately 1nA. The x-ray spectra generated by the electron beam were detected using an Oxford Instruments X-act SDD detector. In advance of the analysis, the EDS spectra were calibrated using a cobalt standard. The data were quantified using the Oxford Instruments INCA software. SEM-EDS is often more sensitive in detecting light elements (Na, Mg, Al and Si), whereas it is easier to detect heavier elements with the EDXRF. Nevertheless quantification of heavy elements is often better with SEM-EDS, if the element is readily abundant (per comm D Dungworth). Three target areas were analysed and an overall compositional average taken for each sample.

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	0.01
K_2O	0.1	0.1	ZnO	0.02	0.01
CaO	0.1	0.1	As_2O_3	0.0`	0.01
TiO_2	0.1	0.1	SnO_2	0.1	0.05
BaO	0.2	0.1	Sb_2O_5	0.01	0.005
			Rb_2O	0.01	0.005
			SrO	0.01	0.005
			ZrO_2	0.01	0.002
			PbO	0.05	0.02

RESULTS

Both samples of window glass from Barmoor Castle are mixed alkali glasses (Table 3) Both contain phosphorous (P_2O_5 1.27 wt %) confirms the use of plant ash and a date of pre-1835 (Dungworth 2011, 40). The samples also contain relatively high levels of strontium. This signifies that both panes were made of a glass with a marine plant ash component (Dungworth 2011, 40), most probably kelp. The two samples have compositions which are effectively identical (once the precision of analysis is taken into account). It is likely that both of these panes were made at the same time and the same place and may even have both been cut from the same sheet of glass.

Table 3. Chemical composition of the Barmoor glass samples

	Barmoor 1	Barmoor 2
Na_2O	8.13	8.10
MgO	5.33	5.31
Al_2O_3	1.74	1.75
SiO_2	66.45	66.23
P_2O_5	1.34	1.36
SO_3	0.23	<0.2
Cl	0.74	0.77
K_2O	4.21	4.27
CaO	11.05	11.07
Fe_2O_3	0.54	0.55
As_2O_3	<0.01	<0.01
SrO	0.47	0.45

DISCUSSION

There are two main methods of window glass manufacture during this era, broad glass and crown glass (Douglas and Frank 1972, 137–9). Broad glass consisted of gathers of molten glass being blown into elongated cylinder. From there, both ends of the cylinder were snipped off; the body opened down the length and flattened whilst still malleable to form a sheet of glass. With the crown method instead of a cylinder being formed, a bubble of glass was pierced at one end and spun around on the pontil to form a disc. This process allowed for a thinner sheet of glass to be produced (Augus-Butterworth 1948, 153). Crown glass became the more popular method of manufacture, with its fire-polish finish, after the window tax of 1745 due to its lighter weight; however, it was impossible to produce larger sheets of glass necessary (Dungworth 2011, 28). The visual analysis of the window glass from Barmoor castle fragments shows it to be pale blue-green in colour, fine in thickness (average of 1.76mm thickness) and with a watery appearance when viewed through. The pane size of the window glass analysed was approximately 600x250mm (Chris Baglee pers comm) and fits neatly into the average size of a crown glass pane (600x500mm) and well within the maximum produced from a 70" (1750mm) disc of crown window glass (Louw 2007, 55).

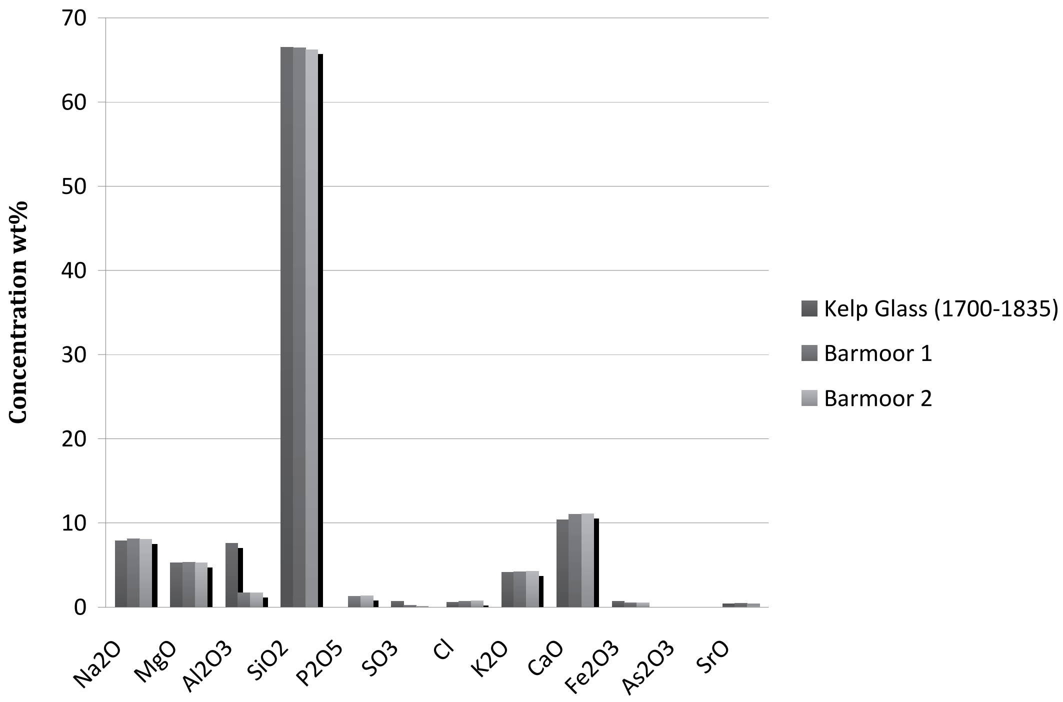

Figure 1: The chemical composition of the window glass from Barmoor castle is compared to the average for kelp glass from the period 1700–1835

For all of the elements that were detected (Table 3; Fig 1) the two Barmoor samples share the same composition and this is well within the range of kelp glass. Alumina and iron are both present, although at slightly low values compared to most kelp glass. These results would suggest possibly higher quality sand was used in the production of this glass (Douglas and Frank 1972, 66). The use of high quality sand, with a low level of iron would have resulted in greater clarity and visibility through the glass (Angus-Butterworth 1948, 65). It is possible that high quality sand was a purposeful acquisition for such windows.

CONCLUSION

In summary, the chemical analysis of the glass from the sash window at Barmoor Castle displays a chemical composition consistent with the glass technology of the period when the castle was constructed thus indicating it is the original glass. The chemical composition shows that their construction was before the introduction of synthetic soda glass *c*1835. The analysis confirms that the glass has the chemical composition of kelp glass and optical analysis shows it to be of thin crown glass manufacture type.

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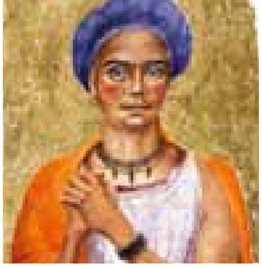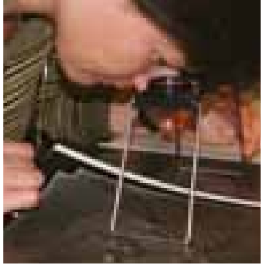

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ISSN 2046-9799 (Print)
ISSN 2046-9802 (Online)