

SHINRONE GLASSHOUSE, CO OFFALY, IRELAND ANALYSIS OF 17TH-CENTURY GLASS VESSEL FRAGMENTS

TECHNOLOGY REPORT

Matt Phelps



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Shinrone Glasshouse, Co. Offaly, Ireland

Analysis of 17th-century glass vessel fragments

Matt Phelps

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SUMMARY

Eleven glass vessel fragments were excavated from Shinrone glasshouse in Co. Offaly, Ireland, dating to the early 17th century. Three of the glass fragments were identified as English 'shaft and globe' bottle, an early wine bottle type commonly thought to have been put into production c1650. All the fragments were analysed using SEM-EDS and compositions compared to production debris analysed by Sarah Paynter (Paynter *et al*/ 2005). Results show that the 11 glass fragments, including the early wine bottle fragments, were produced at Shinrone glasshouse. This indicates that Shinrone, and the family running the glasshouse, possibly the Bigo family, were producing new and innovative 'shaft and globe' wine bottles approximately between 1620 and 1641. This date is earlier than 1650, the date commonly thought of as the start date for production of the bottles.

ACKNOWLEDGEMENTS

I would like to thank Jean Farrelly for the glass samples, Hugh Willmott for providing descriptions of the glass and Sarah Paynter for access to previous analytical data for comparison. I would also like to thank Clare Elsey for allowing me access to 17th-century patent documents held at the House of Lords archives in the Palace of Westminster.

ARCHIVE LOCATION

The samples taken for scientific analysis are held by English Heritage, Fort Cumberland, Portsmouth, PO4 9LD.

DATE OF RESEARCH

2010

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INTRODUCTION

Shinrone, Co. Offaly, Ireland, was a glassmaking site operated during the early 17th century. The site contains the only known example of a standing glass furnace and finds included associated production debris and finished glass fragments. Excavations were carried out by Farelly and O'Brien in 1999/2001 (Farelly and O'Brien 2000; 2003). Archaeomagnetic dating gives a date of last firing between 1620 and 1650 (McCann and Gould 1999). Legislation banning wood fuel use in glass production in Ireland in 1641 gives an earlier possible end date for this furnace (Westropp 1920, 36). There is no clear history on who owned and operated this site but two prominent glass making families were in the area at this time. Abraham Bigo was known to be leasing land in Castle town and Clonoghill near Shinrone for a glass works between 1623 and 1627 (Westropp 1920, 31). Abraham Bigo had previously owned a glassworks at Kimmeridge, Dorset, before its demolition in 1623. In 1627 the leases owned at Castle town and Clonoghill were passed on to his son, Philip Bigo. Years later in the 40s and 50s it is recorded that Philip Bigo was 'master and owner' of a glasshouse in nearby Glaster (Pender 1939, 443). The second glassmaking family is the Henzey family and were listed as owning land at Banagher, Lusmagh and Shinrone, all in Co. Offaly, in the 17th century (Lee 1936, 411, 443). The Henzey family had previously owned glasshouses in Staffordshire. For a summary of the site see Farrelly and O'Brien (2000 and 2003) and analysis of Shinrone glass debris and some glass products is provided by Paynter *et al* (2005).

This report deals with 11 of the 15 catalogued glass vessel fragments (GL1-15) that were recovered during the excavations at this site. The fragments have been described and identified by Willmott (pers. comms.) and were chosen for analysis due to their diagnostic features, which have been matched to known styles of the period. The most notable fragments are 3 pieces of an early English 'shaft and globe' wine bottle.

BACKGROUND TO 17TH CENTURY BOTTLES

During the early 17th century there was a progression towards more durable and fully sealable glass vessels. Earlier flasks had thinner glass and a wider and more open neck. These were fragile and had no easy sealing mechanisms and so were unsuitable for transport or long period storage of liquids. A number of innovations in bottle design allowed, and led to, increased bottle use and the development of two main bottle designs. Firstly, case bottles, which were square-sectioned bottles for packing in crates for ease and protection during transportation. The English-made versions of this bottle type were stopped using wooden bungs as opposed to the pewter threads used on continental bottles (Willmott 2002, 86-88). Secondly, innovations in bottle design led to the first wine bottles, termed 'English Bottles'. While these bottles were of a similar shape



Figure 1. Belgian shaft and globe bottles produced between c. 1630- c.1680 and attributed by Bossche to the Colinet glassmaking dynasty (from Bossche 2001, 44). Glass thickness 2mm.

to continental versions, they differed in significant ways that lead to their market dominance. The term 'English bottle' covers a progression of different forms, such as 'shaft and globe', onion, and mallet. It is the first of these studied in this report. 'Shaft and globe' bottles are globular in shape with a high kick and a long tapering neck with a collar for tying down the cork (Willmott 2002, 98; Figures 2 and 3). Early examples of the 'shaft and globe' form are shown in Figure 1. These are from Belgium and produced from c1630 to c1680 by the 'Colinet glassmaking dynasty' (Bossche 2005, 44). Figures 2 and 3 give examples of English made 'shaft and globe' bottles from c1650 and possibly earlier. The form is similar to the Belgian examples but the 'English bottles' were heavier, stronger and made of thicker glass; 5-9mm thick as opposed to a maximum of 2mm thickness in the Belgian examples. The increased thickness of the glass allowed the bottle to be more durable for transport and storage and the collar allowed the bottles to be corked with the corks tied down via the collar. The English bottles also tended to be made of a much darker glass (Godfrey 1975, 229).

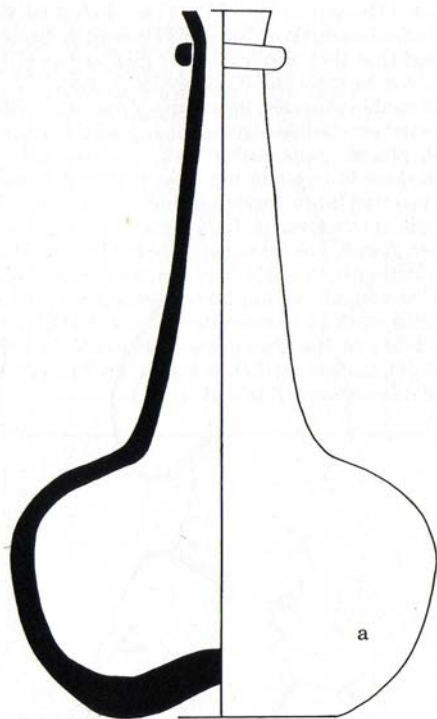


Figure 2. Schematic view of English made shaft and globe bottle dated by Willmott to 1650 onwards, note the thicker glass, 5-9mm. Example excavated in Nottingham (from Willmott 2002, 89).

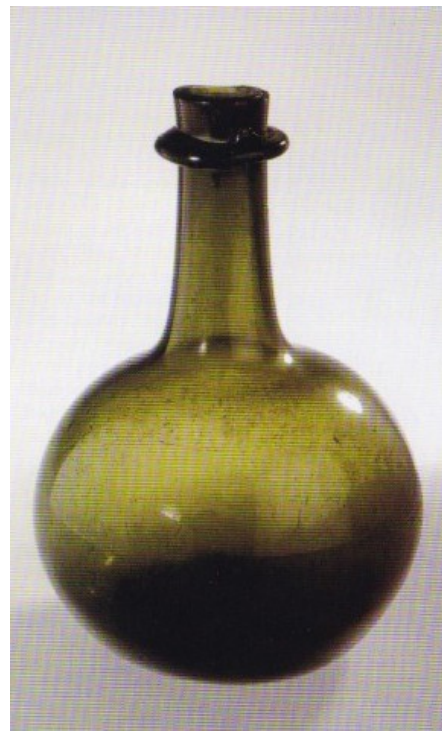


Figure 3. The 'earliest known example' of an English bottle, also called a shaft and globe bottle. Bossche dates the style of this bottle from c.1632 until 1640/60. Later bottles have a longer tapered neck (Bossche 2001, 66, see also p30)

The start date generally reported for the production of these bottles in England is c1650 (Willmott 2002, 86; Hume 1961, 93). The earliest glass seals found on archaeological examples date from 1650 (Egan 1999). Although whether this is the date of bottle production or the wine vintage is uncertain. But there is some documentary evidence for an earlier date for production and information of who invented these bottles. On the 10th April, 1661 a draft of an act confirming John Colnett (Jean Colinet) as a patent holder for the invention and manufacture of glass bottles was produced. Colnett claimed to have 'first invented, made and attained to ye perfection of making glass bottles' (House of Lords Bill 1661) and that his bottles had been used by others during the 'rebellious times' (Civil War) and thus after the Restoration he sought to redress the issue. The patent was very quickly petitioned against firstly in a petition by John Vinion and Robert Ward, and a second petition included the names Edward Percival and William Sadler, all of them glass makers and who were writing 'in the name of all the trade'. They said that John Colnett was not the sole inventor and that the bottles 'had been of trade and public use for 30 years' (Petition 1662 A) and that glass makers had been 'making glass bottles for public

use at several glass houses in England near 30 years' (Petition 1662 B). Colnett had no evidence in defence and the Attorney General's report agreed with the glass makers, writing that 'Sir Kenelm Digby first invented the glass bottles nearly 30 years since, and employed Colnett and others to make them for him and they have since been frequently made by him and also by the petitioners' (Attorney Generals Report 1662). If the 30 years prior date is taken then the invention of the bottles would have occurred in 1631-2, the date given by Bossche (2001, 21). The documents make a compelling argument against Colnett, though neither side can be conclusively proven to have invented the glass bottles. But what is clear is that the documents point to the bottles being older than the 1650 date given by Hume (1961) and Willmott (2002). If Sir Digby had invented the bottles and had run a glass works that produced the glass bottles with John Colnett then it must have been before 1642, because that is the year Sir Digby was arrested and imprisoned (Godfrey 1975, 232). Or, if it was indeed Colnett who invented the bottles then it has to have been before the Civil War (1642) because during the war he says that his bottles were used and manufactured by others. Both sides agree that the bottles were produced at least before the Civil War, and the Attorney General's conclusion that the bottles had been in public use for 30 years prior gives an earliest date of 1631-2.

The first half the 17th century was particularly fraught for glass makers in England. In 1615 Sir Robert Mansell was awarded a monopoly on all types of glassmaking in England and the use of wood fuel was banned (Charleston 1984, 71). Furnaces had to be quickly redesigned for use with mineral fuel (eg coal). Charleston notes the 'continuing and intensified struggle to obtain from the crown patents' despite the 'stiffening resistance in parliament to the whole system of monopolies' (Charleston 1984, 71) In reviewing the documentary evidence from 1661 Hume notes that it is 'hard to believe' that Digby could have invented these bottles in the 1630s when 'numerous previous petitions and patents were in existence' (Hume 1961, 93) and while Mansell's monopoly could have stifled creativity in bottle design furnaces could still be operated under license. Bossche (2001, 21) and Godfrey (1975, 230) speculate that Sir Digby's furnace could have been at Newnham-on-Severn. Hart mentions that Sir Mansell erected a glassworks at Newnham in 1620 (Hart 1971, 398), which could have been later leased to Sir Digby; remains of a glass furnace and some black glass slag have been found there but there is no report of bottle finds.

While the documentary evidence argues for an earliest date of 1631-32, backed by Godfrey (1975) and Bossche (2001), Hume notes the simple lack of archaeological evidence to back up this date (1961, 93). Very few bottles from well dated pre-1650 sites have been found. For example, in Civil War contexts no 'shaft and globe' bottles have been found at Pontefract Castle (Roberts 2002) or in the large assemblage of glass found at Sandal Castle (Mayes and Butler 1983, 226-7), but this might not be the full picture. At Basing House, Hampshire, occupied until Oct 1645 when the house fell to a siege and caught fire (Moorhouse 1970, 41) wine bottles of both case and the English 'shaft and globe' sorts have been found (Moorhouse 1971, 68-9). The bottles were dated stylistically using Hume (1961). Some bottles are clearly late, dating to the late 17th to early 18th

century and explained as post occupation deposition by brick robbers (Moorhouse 1970, 41) but one example is a dull green early 'shaft and globe' form with thick walls. This bottle is dated stylistically using Hume (1961) to 1655-70, but as it is the dating of the bottle that is in dispute stylistic dating cannot be used, and as Moorhouse (1970, 40) admits that during the excavation 'little or no' attention was paid to stratification and no independent dating through context was possible. If stylistic dating is standard practise then a lack pre-1650 can be easily explained due to finds being stylistically dated to post that. Other examples of this practice, also using dates and styles from Hume (1961), are glass bottles finds at Portchester Castle (Cuncliffe and Garratt 1994, 84-7) and Richmond Palace (Dixon 1975, 110-1).

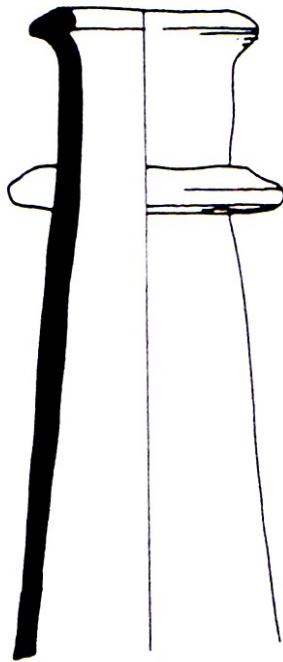


Figure 4. Thick walled (5mm) tapering necked bottle with collar for tying string from Kimmeridge, Dorset (Crossley 1987, 359). Neck diameter 3cm.



Figure 5. Upper portion of a bottle neck with collar for tying string from Shinrone, collar is higher up the neck than the Kimmeridge example. Wall thickness 3-5mm, neck diameter 3cm. Sample GL 15.

Some archaeological evidence for bottle production has been provided by excavations of glass houses. Excavations at a glass working site at Kimmeridge, Dorset, founded by Sir William Clevell and Abraham Bigo under license from Mansell in 1618 has produced fragments of thick glass (up to 9mm) with long necks plus a thick rim for tying down the cork (Crossley 1987, 357 and 360; Figure 4). This closely matches descriptions of 'shaft

and globe' bottles discussed above but is dated to a 1618-1623 context. The bottle fragments point to the existence of 'English bottles' before 1623 and are evidence of the Bigo families involvement in the production of early wine bottles at Kimmeridge. The furnace was demolished by Mansell in 1623 and the Bigo family subsequently moved to Ireland. The recovery of similar bottle fragments (Figure 5) at the Shinrone glassworks points to similar wine bottle production and possibly indicates a Bigo family connection. This report aims to confirm the possible link between the bottle fragments and the Shinrone glassworks thus verifying a manufacturing connection and a date for the bottles.

MATERIAL

The material analysed in this study consists of 11 glass vessel fragments excavated from the Shinrone glassworks by Farrelly and O'Brien, and selected for analysis by Willmott, who also provided the following descriptions of the glass fragments (pers. comms). Samples GL 1, 3 and 4 – 6 are fragments and wasters from a small spouted jug or cruet; this style is dated to the first half of the 17th century. GL 8 is a small bottle. GL 10 is a bottle with a squared cross-section like the case bottles mentioned above. GL 12 is a rim of a large thick glass jar. GL 13-15 are 3-12mm thick bottle fragments of two thick bases and a neck with a collar (Figure 5). These latter three fragments are from English 'shaft and globe' style wine bottles. All the glass fragments are of a similar light greenish colour. This colour differs from the much darker green and browns of English made glass from coal-fired furnaces. Sample numbers, descriptions and context numbers are provided in Table 5 of the appendix.

AIMS

The aim of this study is to categorise compositionally each of the glass fragments using a scanning electron microscope with energy dispersive x-ray spectrometer (SEM-EDS). The results will then be compared to the glass working debris, lumps and wasters made at Shinrone and analysed previously by Paynter *et al* (2005). A positive match between the glass fragments analysed here and the Shinrone production debris would indicate a common manufacture linking the glass fragments to the Shinrone glasshouse. It would also give the fragments a date range of manufacture. The manufacture of wine bottles at Shinrone would indicate an early date for 'English bottle' production and point to this glassworks being at the forefront of bottle innovation and design during this time. This would indicate the glassmaking family running the Shinrone glassworks, possibly the Bigo family, to have been important in the development of wine bottles during this period.

METHODS

Each fragment was photographed and a small (2-10mm) sample was removed from each fragment using a combination of a diamond edged circular saw and wire cutters. The samples were embedded in resin and polished down to 1 micron making a polished block section. Principle analysis was carried out using a scanning electron microscope (SEM) with an energy dispersive x-ray spectrometer (EDS). The SEM used was an FEI Inspect F with an Oxford Instruments X-act detector and INCA software for element quantification. The working parameters were set to an accelerating potential of 25kV, a current of 1.2nA, 100s counting time and 10mm working distance. Three representative areas of approximately 300 by 500 microns were analysed in each sample to determine the glass bulk composition. The results are presented as normalised compound weight % with oxygen calculated stoichiometrically for all elements except chlorine which is reported as element weight%.

Calibration of the spectra was performed using a cobalt standard. To ascertain the accuracy of the results, glass reference materials of a similar composition were also analysed. Analysis of Corning glass standard D (Appendix Table 6) indicated relative percentage variation of results from the known value of approximately 15% for Na_2O , Fe_2O_3 and SO_3 ; 2-3% for P_2O_5 , Al_2O_3 and K_2O ; and approximately 1% for MgO , CaO and SiO_2 . Minimum detection limits for most of the measured elements was 0.1wt% and 0.3wt% for P_2O_5 and SO_3 . Locations for analysis were chosen to avoid any glass corrosion.

Additional analysis was carried out for three selected elements (manganese, zinc and strontium) using X-ray fluorescence spectroscopy (XRF) due to its superior detection limits over the SEM. These elements had shown up as minor and trace amounts in the SEM analysis and strontium is particularly interesting as it can indicate the use of seaweed ash. The XRF was an Eagle II, set to 40kV accelerating potential and 1000 μA current. Calibration was carried out with a range of suitable standards and comparative material (Corning A, B and C; Nist 1834; Shaw House 100, 106 and 107; LOP 06 and 57). Calibration results for manganese, zinc and strontium are shown in Figures 9-11 in the Appendix. Detection limits indicated by the graphs were 0.02% for all three elements.

RESULTS

Averaged readings for the glass vessel fragments are shown in Table 1 and full results in Table 7 (Appendix). The combined soda and potash levels of 5.7-6.8wt% and 23.2-26.7wt% lime indicate the glass vessel fragments to be high-lime, low-alkali (HLLA) types as defined by Mortimer (1991). This type of glass was produced from the late 16th century in England. HLLA glass was produced using ashes from plants and varies from the potash glass produced in England in the first half the 16th century by having increased lime and reduced potash. The plant ash is combined with silica from sand or crushed quartz

pebbles to create the glass. Compositionally there was very little difference between the samples indicating they came from a common manufacturing origin with a high degree of consistency in manufacture. This indicates that the same raw materials from the same locations were used throughout the working period of the glassworks.

To ascertain their manufacturing origin the glass vessel fragments results were compared to glass production waste and products from Shinrone and also glass production waste from the nearby and broadly contemporary glasshouse at Glaster (Table 2). The Glaster results are used as a standard to indicate the range of variation that can be expected between two contemporary nearby glasshouses. Diagrams of the results are shown in Figures 6, 7 and 8. Figures 6 and 7 show a very good correspondence of the glass vessel fragments with the Shinrone production waste and product compositions. The Glaster material has a very similar composition to the Shinrone glass, and so overlaps partly with the Shinrone material in some bi-plots but tends to have slightly lower magnesia and soda and higher potash than the Shinrone material. Figure 8 brings out the differences between the Glaster material and Shinrone material more clearly as the levels of manganese and phosphorus in the glass from each site differ, probably due to compositional changes in the plant ash used, which is influenced by geology. The compositional differences between Shinrone and nearby Glaster are an indicator of just how similar the glass vessel fragments are to the Shinrone material from Paynter *et al*/ (2005). The glass vessel fragments excavated from Shinrone are shown to be indistinguishable from the Shinrone waste and glass products.

Table 1: Averaged results of SEM-EDS analysis as normalised compound wt% (apart from chlorine which is element wt% only)

Sample	Na ₂ O	MgO	Al ₂ O ₃	SiO ₂	P ₂ O ₅	SO ₃	Cl	K ₂ O	CaO	TiO ₂	MnO	Fe ₂ O ₃
GL 1	2.28	2.66	2.04	59.00	1.40	0.58	0.25	3.89	26.67	0.18	0.24	0.81
GL 3	1.98	2.57	2.33	62.16	1.29	0.62	0.30	3.74	23.64	0.23	0.27	0.85
GL 4	2.07	2.62	1.54	61.52	1.50	0.65	0.29	4.18	24.71	0.16	0.19	0.55
GL 5	2.02	2.74	2.25	59.63	1.58	0.76	0.27	4.42	25.05	0.18	0.25	0.86
GL 6	1.89	2.71	2.25	60.70	1.53	0.74	0.30	4.30	24.30	0.20	0.26	0.86
GL 8	1.70	2.54	1.97	60.55	1.50	0.59	0.18	4.45	25.26	0.18	0.31	0.76
GL 10	1.61	2.44	2.15	60.97	1.51	0.75	0.22	4.26	24.76	0.19	0.24	0.90
GL 12	1.28	2.48	2.24	60.60	1.65	0.50	0.18	4.76	25.13	0.19	0.24	0.75
GL 13	1.72	2.64	1.96	61.68	1.59	0.67	0.24	5.04	23.21	0.18	0.28	0.81
GL 14	1.82	2.98	2.11	58.99	1.47	0.77	0.27	3.98	26.30	0.21	0.30	0.81
GL 15	1.86	2.64	1.85	60.52	1.44	0.59	0.29	4.73	24.99	0.16	0.25	0.67

Table 2: Averaged results for the glass vessel fragments compared to averaged Shinrone production waste, glass products and Glaster production waste from Paynter et al 2005. All normalised compound wt% stoichiometric with oxygen.

Sample Group		Na ₂ O	MgO	Al ₂ O ₃	SiO ₂	P ₂ O ₅	SO ₃	K ₂ O	CaO	TiO ₂	MnO	Fe ₂ O ₃
Glass Vessel	Av	1.84	2.64	2.06	60.57	1.50	0.66	4.34	24.91	0.19	0.26	0.79
Fragments	Sd	0.27	0.14	0.23	1.03	0.10	0.09	0.40	1.01	0.02	0.03	0.10
Shinrone	Av	1.67	2.46	1.88	61.76	1.52	0.63	3.95	24.81	0.15	0.24	0.86
production waste	Sd	0.51	0.24	0.32	1.62	0.10	0.14	0.38	1.13	0.04	0.05	0.18
Shinrone glass	Av	1.72	2.62	2.09	62.01	1.63	0.65	3.86	24.06	0.15	0.26	0.87
products	Sd	0.58	0.29	0.43	1.46	0.33	0.17	0.27	0.45	0.06	0.11	0.18
Glaster	Av	1.25	2.05	1.35	63.31	1.05	0.55	4.56	25.11	0.13	0.10	0.50
production waste	Sd	0.16	0.15	0.23	1.00	0.07	0.07	0.28	0.79	0.03	0.04	0.11

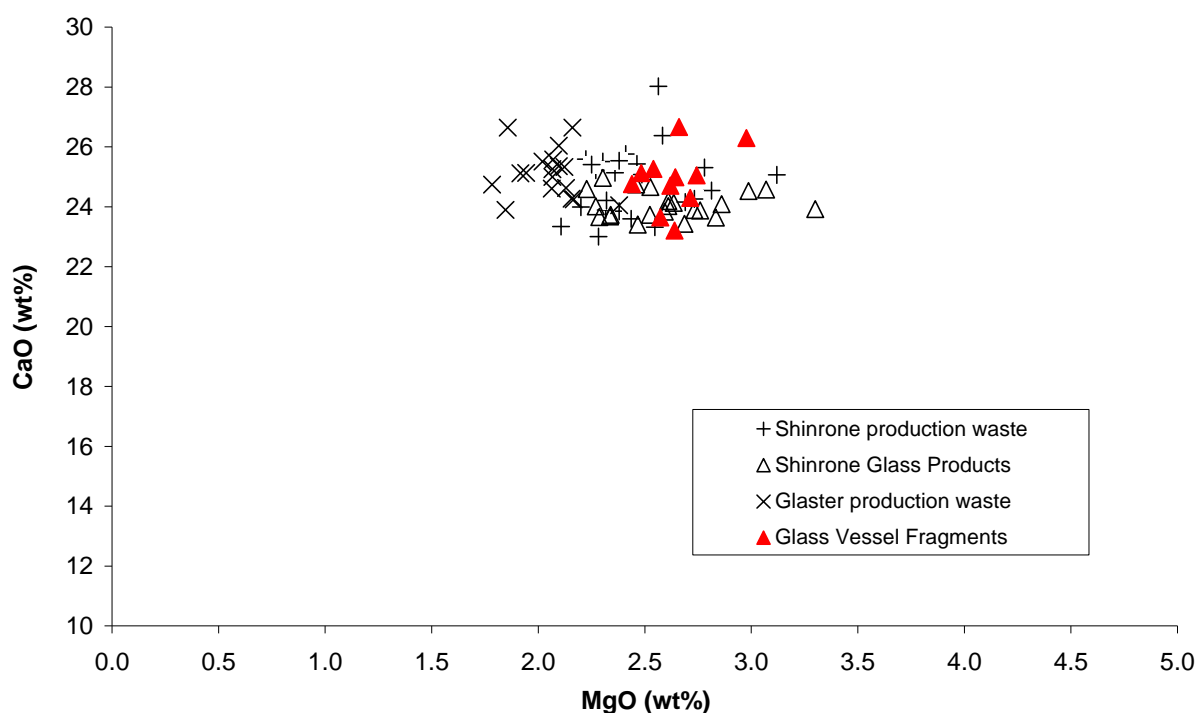


Figure 6: Lime versus magnesia for the glass vessel fragments against Shinrone production waste and products and Glaster production waste from Paynter et al (2005).

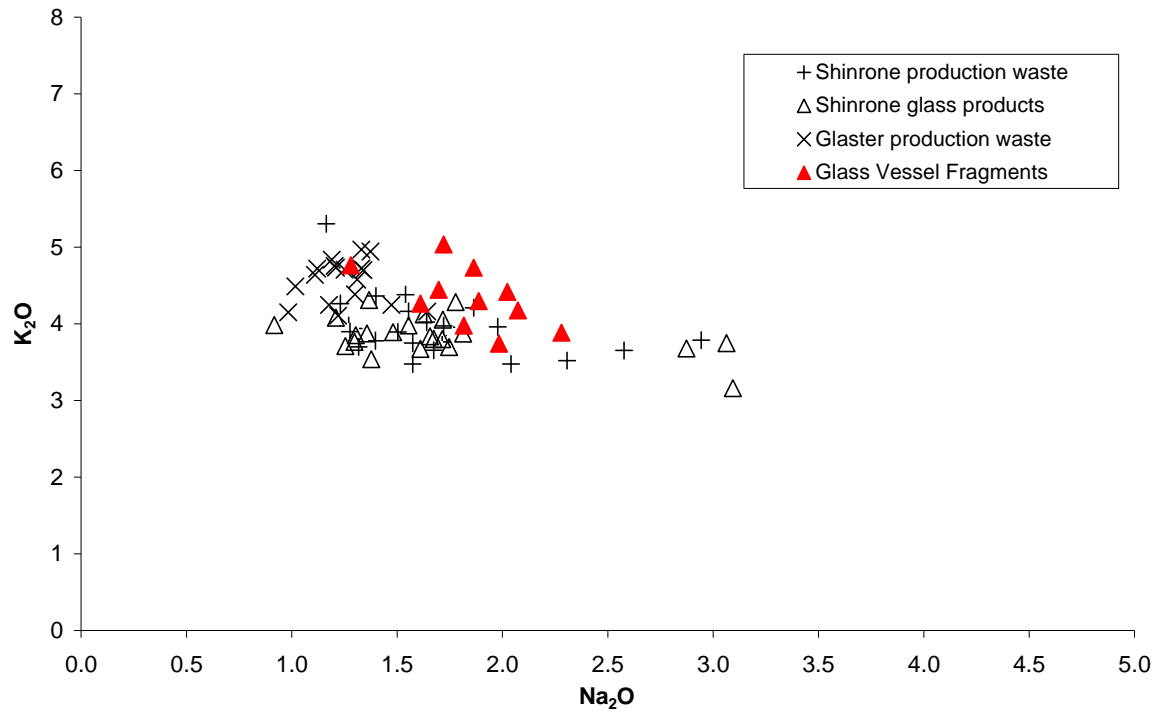


Figure 7: Potash versus soda for the glass vessel fragments against Shinrone production waste and products and Glaster production waste from Paynter et al (2005).

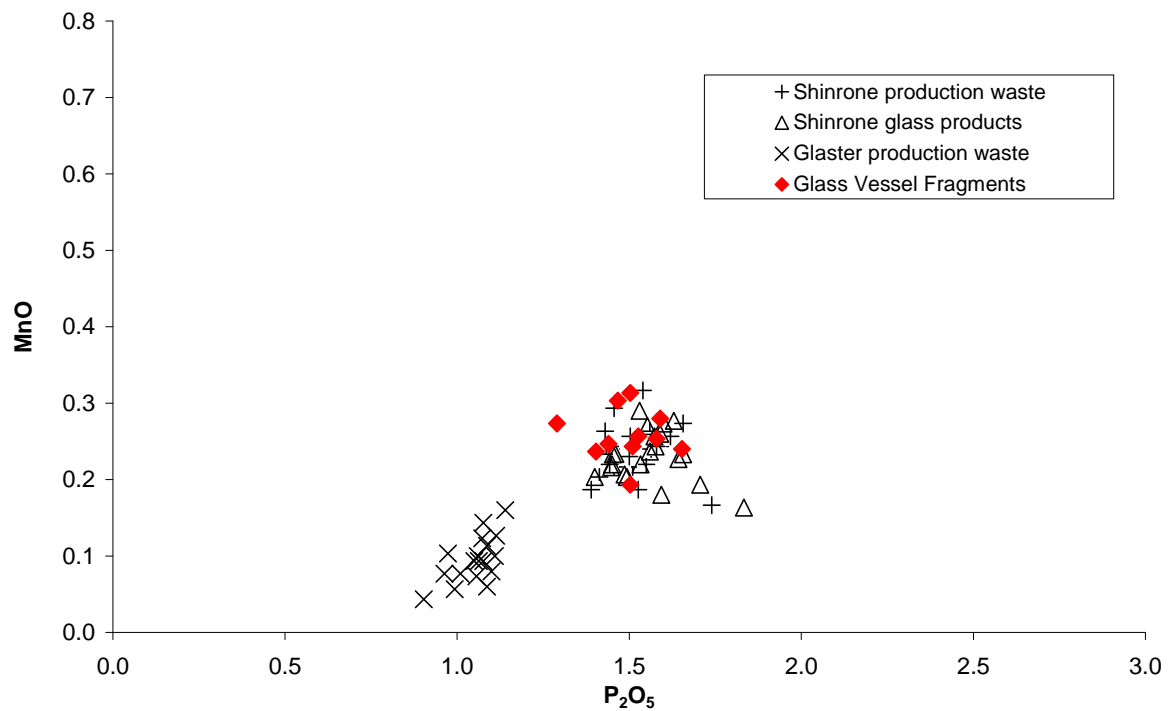


Figure 8: Manganese versus phosphorus oxides for the glass vessel fragments against Shinrone production waste and products and Glaster production waste from Paynter et al (2005).

Table 3: XRF analysis of glass vessel fragments. Results as oxide wt %.

Sample	MnO	ZnO	SrO
GL 1	0.19	0.09	0.06
GL 2	0.22	0.09	0.06
GL 4	0.16	0.10	0.06
GL 5	0.20	0.09	0.06
GL 6	0.19	0.09	0.06
GL 8	0.23	0.08	0.05
GL 10	0.20	0.09	0.05
GL 12	0.23	0.10	0.05
GL 13	0.22	0.09	0.06
GL 14	0.24	0.09	0.06
GL 15	0.19	0.10	0.06
Average	0.21	0.09	0.06
StDev	0.02	0.01	0.00

In addition to the SEM-EDS data acquired, X-ray fluorescence spectroscopy (XRF) was used to obtain more detailed data on a further three elements; manganese, zinc and strontium. The manganese data was collected to confirm the concentrations shown by the SEM, zinc as amounts were below the detection limit of the SEM, and the strontium so as to test for use of seaweed as a constituent of the glass. Results for the glass vessel fragments are shown in Table 3. A large proportion of the Shinrone material published in Paynter *et al* (2005) was also reanalysed, the full data is shown in Table 8, Appendix, and a summary of the averaged results is in Table 4 below.

Table 4: Averaged XRF results for the glass vessel fragments and glass material found at Shinrone as published in Paynter *et al* 2005. Results as oxide wt%.

Glass produced at Shinrone	MnO	ZnO	SrO
Glass vessel fragments	0.21	0.09	0.06
Shinrone waste glass	0.20	0.05	0.06
Shinrone glass products	0.20	0.04	0.06
Glass found at Shinrone but made elsewhere			
Bottle Glass	0.16	0.03	0.09
Pale olive vessel glass	0.11	0.08	0.13
Pale green window glass	0.06	0.02	0.32

The glass vessel fragment results are identical to the other Shinrone glasses in manganese and strontium, showing medium amounts of manganese and low strontium levels. The zinc levels are higher at 0.09% than the Shinrone averages but Shinrone waste glass samples I8F, I8G and I8H show similar high amounts (0.10, 0.11, 0.09). The slightly different zinc levels could equate to different glass batches or to slow variation in the zinc content over time. The results show the glass produced at Shinrone to be clearly dissimilar to the material classed as being made elsewhere. The bottle glass and pale olive

vessel glass were both HLLA types but contained less manganese and higher strontium showing them to differ from the Shinrone glass. The pale green window glass was a mixed alkali sort and contained much higher strontium levels. Similar high levels of strontium have been found in other 17th-century window glasses; 0.5% SrO in window glass from Shaw House (Dungworth and Loaring 2009) and 0.27% SrO at Silkstone (Dungworth and Cromwell 2006). The higher strontium levels have been shown to indicate use of seaweed ash in the glass production (Dungworth *et al* 2009).

DISCUSSION

The 11 glass vessel and bottle fragments from Shinrone were found to be high-lime, low-alkali types, consistent with this time period. The fragments were compositionally very similar indicating a good degree of standardisation in the manufacturing process and access to the same raw materials over their period of manufacture. Comparisons with Shinrone production waste and glass products analysed previously (Paynter *et al* 2005) indicated a very good correlation and that the glass fragments were manufactured at Shinrone using the same techniques and raw materials. The results have wider implications for the history of early wine bottle making as this shows that glassmakers at Shinrone were experimenting in wine bottle production between 1620 and 1641 and were producing bottles of the English 'shaft and globe' sort at a very early date. This date is earlier than the normal given date of invention of 1650. This evidence is in addition to the wine bottle like fragments already found at Kimmeridge in Dorset (Crossley 1987, 359), which was run by Abraham Bigo and Sir William Clavell between 1618 and 1623 pointing at even earlier bottle innovation. The close geographical association between known Bigo glassworks at Glaster, the similarity in composition between the Glaster glass and the Shinrone glass indicating similar recipes, and the fact early wine bottles have been found at Kimmeridge and also at Shinrone, makes a strong case towards the Shinrone glassworks being controlled by the Bigo family. Therefore it is possible the Bigo family were experimenting and innovating with wine bottle production at two locations, Kimmeridge and Shinrone, over a 23-year period pre-dating the 1632-3 date given for the invention of the 'shaft and globe' bottle by Sir Digby (Bossche 2001, 21; Godfrey 1975, 229) and is further evidence for pre-1650 production of 'English' bottles.

CONCLUSIONS

The glass fragments from Shinrone analysed in this report have been shown to be manufactured at the Shinrone glass works. The fragments contained three early examples of 'shaft and globe' English bottles and their early date and location of production have repercussions for the current perceived history of wine bottle production during this period. The similarity with material from Kimmeridge strengthens this case and indicates

the Bigo family to have had a very early role in the development and production of early 'shaft and globe' wine bottles at two different locations over a possible 23-year period; 1618 to 1641. This is earlier than their supposed invention by Sir Digby in 1632-3, and up to 30 years before 1650 when dated examples appear and is generally thought to be the start date of wine bottle production. This casts doubt on the currently perceived history of these bottles. Further work would be to examine the wine bottle fragments at Kimmeridge in greater detail; to examine the glass fragments from Glaster for early 'shaft and globe' bottles fragments; and to locate and excavate an earlier glass works in Staffordshire known to be owned by the Bigo family in 1612/13 with the possibility of finding even earlier wine bottle fragments.

REFERENCES

Bossche, W V 2001 *Antique Glass Bottles: their history and evolution (1500-1850)*. Woodbridge, Suffolk: Antique Collectors' Club

Brill R H 1999 *Chemical Analyses of Early Glasses. Volume 1. The Catalogue and Volume 2, The Tables*. New York: Corning

Charleston, R L 1984 *English Glass and the Glass used in England c400-1940*. London: George Allen and Unwin

Crossley, D W 1987 'Sir William Clavell's glasshouse at Kimmeridge, Dorset: the excavations of 1980-1981'. *Archaeological Journal* 144, 340-382

Cunliffe, B and Garratt, B 1994 *Excavations at Portchester Castle Vol. 5: Post Medieval 1609-1819*. Oxford: The Society of Antiquaries London

Dixon, P 1975 'Excavations at Richmond Palace, Surrey.' *Post-Medieval Archaeology* 9, 103-116

Dungworth, D and Cromwell, T 2006. 'Glass and pottery manufacture at Silkstone, Yorkshire.' *Post-Medieval Archaeology* 40/1, 160-190

Dungworth, D, Degryse, P and Schneider, J 2009 'Kelp in historic glass: the application of strontium isotope analysis' in Degryse, P, Henderson, J and Hodgins, G (Eds.) *Studies in Archaeological Sciences: Isotopes in Vitreous Materials*. Belgium: Leuven University Press, 113-130

Dungworth, D and Loaring, A 2009 *Shaw House, Newbury, Berkshire: An investigation of the window glass*. Research Department Report Series 57/2009 Portsmouth: English Heritage

- Egan, G 1999 'London – axis of the Commonwealth?' in Egan, G and Michael, R L (eds.) *Old and New Worlds*. Oxford: Oxbow Books, 61-71
- Farrelly, J and O'Brien, C 2000 'Glasshouse, 17th-century glasshouse' in Bennett, I (ed.) *Excavations 1999; Summary accounts of archaeological excavations in Ireland*. Bray, Ireland: Wordwell, 260-261
- Farrelly, J and O'Brien, C 2003, 'Glasshouse, Shinrone, 17th-century glasshouse,' in Bennett, I, (ed.) *Excavations 2001; Summary accounts of archaeological excavations in Ireland*. Bray, Ireland: Wordwell, 250-1
- Godfrey, E S 1975 *The Development of English Glassmaking 1560-1640*. Chapel Hill: University of North Carolina Press
- Hart, C 1971 *The Industrial History of Dean*. Newton Abbott: David and Charles
- Hume, N 1961 'The glass wine bottle in colonial Virginia'. *Journal of Glass Studies* 3, 99-117
- Lee, G L 1936 *The Huguenot Settlements in Ireland*. London and New York: Green and Co
- Mayes, P and Butler L A S 1983 *Sandel Caste Excavations 1964 – 1973: a detailed archaeological report*. Wakefield: Wakefield Historical Publications
- McCann, W A and Gould, M 1999 *Archaeomagnetic dating at Glasshouse, Shinrone, County Offaly, Ireland. Final Report*. Museum of London Archaeology Service Report number 780699. London: The Clark laboratory
- Mortimer C 1991 *Analysis of Medieval and Post Medieval Glass from the City of London*. Ancient Monuments Laboratory Report 135/1991. London: English Heritage.
- Moorhouse, S 1970 'Finds from Basing House, Hampshire (c. 1540-1645): Part One.' *Post-Medieval Archaeology* 4, 31-91
- Moorhouse, S 1971 'Finds from Basing House, Hampshire (c. 1540-1645): Part Two.' *Post-Medieval Archaeology* 5, 35-76
- Paynter, S, O'Brien, C and Farrelly, J 2005 *The 17th-Century Glasshouse at Shinrone, Co. Offaly, Ireland*, Research Department Report Series 39/2005 Portsmouth: English Heritage
- Pender, S (ed.) 1939 *A Census of Ireland, circa 1659*. Irish Manuscripts Commission. Dublin: Stationery Office

Roberts, I 2002 *Pontefract Castle: Archaeological Excavations 1982-86*. Leeds: West Yorkshire Archaeological Services

Westropp, D 1920 *Irish Glass* (revised edition, ed. M. Boydell 1978). Dublin: Allen Figgis

Willmott, H 2002 *Early Post-Medieval Vessel Glass in England c. 1500-1670*. London: Council for British Archaeology

PRIMARY SOURCES

'Draft of an Act to confirm invention and manufacture of glass bottles...' London: House of Lords Record Office. 10th April 1662

'Petition of John Vinion and Robert Ward' London: House of Lords Record Office. 1662A

'Petition of John Vinion, Robert Ward, Edward Percival and William Sadler'. London: House of Lords Record Office. 1662B

'Report of the Attorney General' London: House of Lords Record Office. 2nd April 1662

APPENDIX

Table 5. Sample numbers, contexts and descriptions for the glass vessel fragments.

Sample	Find number	Context	Object	Glass thickness	Width
GL1	379	57 - 1	base of small spouted jug	2.5-3mm	base 5.2cm
GL3	894	27 - 289	jug spout	1-1.5mm	
GL4	1196	sod - 143	jug handle	1-2mm	
GL5	1570	27 - 6300	jug handle	7mm	
GL6	1166	27 - 2539	jug neck	2mm	
GL8	742	81 - 271	base from small spouted jug	2-3mm	base ~5cm
GL10	364	57 - 2	base of square cross-sectioned bottle	1-2.5mm	base ~5cm
GL12	922	68 - 11	rim of large thick jar	6-6.5mm	
GL13	376	57 - 3	thick base of 'shaft and globe' wine bottle	9-12mm	base ~7.5cm
GL14	1480	sod - 107	thick base of 'shaft and globe' wine bottle	5-7mm	base ~6cm
GL15	1160	sod - 111	neck with collar of 'shaft and globe' wine bottle	3-5mm	outside diameter 3cm, 6mm collar

Table 6. Known standard compositions compared to compositions measured by EDS for Corning glass standard D. Known compositions from Brill, 1999.

<i>Sample</i>	<i>Na₂O</i>	<i>MgO</i>	<i>Al₂O₃</i>	<i>SiO₂</i>	<i>P₂O₅</i>	<i>SO₃</i>	<i>K₂O</i>	<i>CaO</i>	<i>TiO₂</i>	<i>MnO</i>	<i>Fe₂O₃</i>	<i>CoO</i>	<i>CuO</i>	<i>ZnO</i>	<i>SnO₂</i>	<i>Sb₂O₅</i>	<i>BaO</i>	<i>PbO</i>
	1.46	4.01	5.30	54.87	3.85	0.25	11.75	15.00	0.38	0.56	0.45	0.00	0.32	0.05	0.26	0.83	0.32	0.38
<i>Corning D</i>	1.40	4.00	5.14	54.48	4.05	0.27	11.61	15.01	0.39	0.53	0.46	0.00	0.38	0.06	0.38	1.20	0.35	0.31
	1.29	3.97	5.08	54.49	4.06	0.25	11.57	14.99	0.39	0.48	0.46	0.00	0.33	0.08	0.44	1.48	0.36	0.31
	1.46	3.90	5.18	54.52	4.05	0.25	11.71	14.79	0.42	0.52	0.44	0.01	0.29	0.15	0.46	1.19	0.29	0.36
<i>Mean</i>	1.40	3.97	5.18	54.59	4.00	0.26	11.66	14.95	0.40	0.52	0.45	0.00	0.33	0.09	0.39	1.18	0.33	0.34
<i>Std. deviation</i>	0.08	0.05	0.09	0.19	0.10	0.01	0.08	0.11	0.02	0.03	0.01	0.01	0.04	0.05	0.09	0.27	0.03	0.04
<i>Known</i>	1.20	3.94	5.30	54.82	3.93	0.30	11.30	14.80	0.38	0.55	0.52	0.02	0.38	0.10	0.10	0.97	0.51	0.48

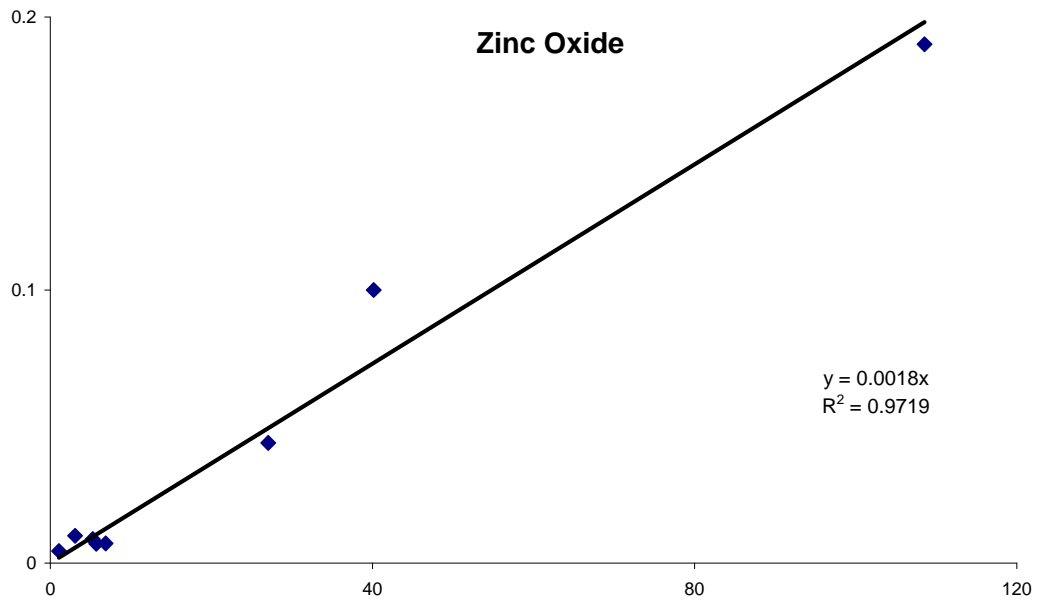


Figure 9. Calibration graph for zinc oxide using XRF.

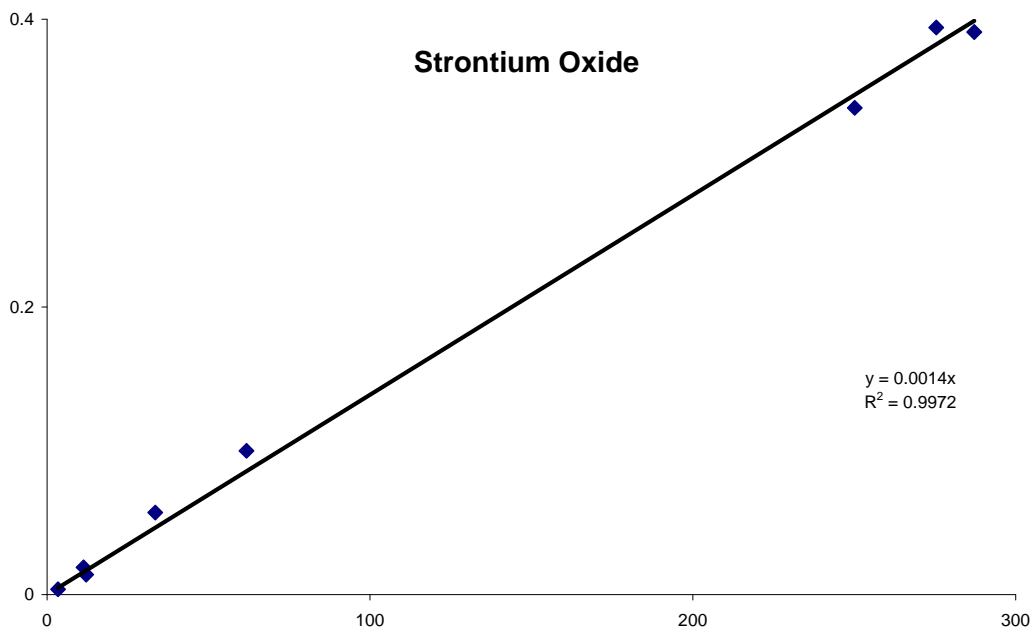


Figure 10. Calibration graph for strontium oxide using XRF.

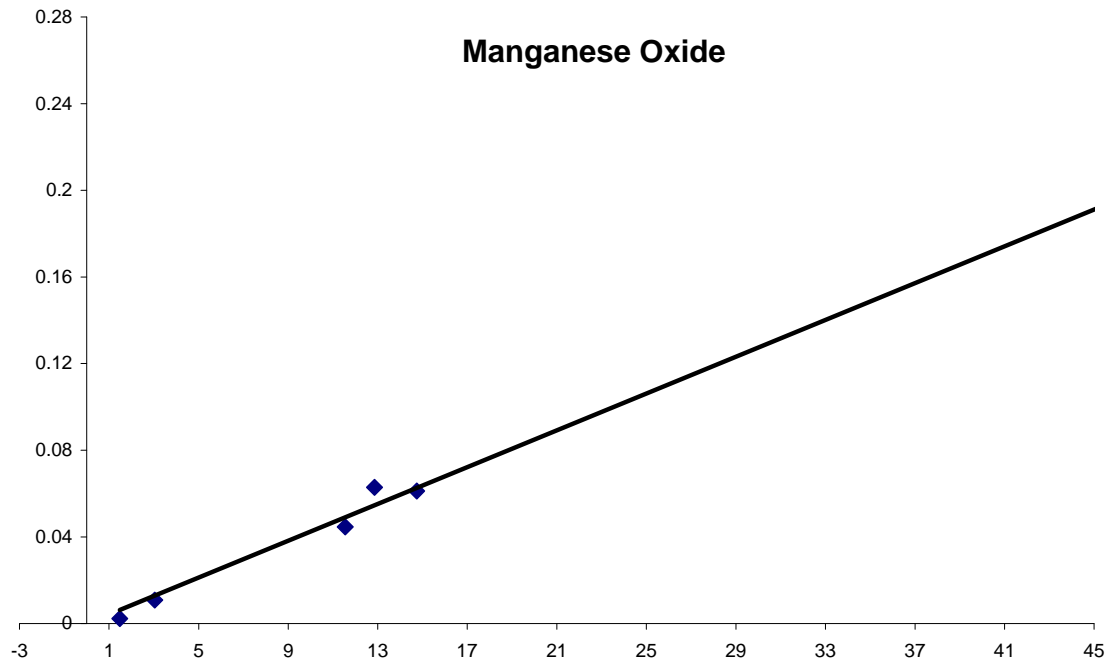


Figure 11. Calibration data for manganese oxide using XRF.

Table 7. SEM-EDS analyses (normalised) for the glass vessel fragments

Sample	Na ₂ O	MgO	Al ₂ O ₃	SiO ₂	P ₂ O ₅	SO ₃	Cl	K ₂ O	CaO	TiO ₂	MnO	Fe ₂ O ₃
GL 1	2.29	2.66	2.04	59.04	1.45	0.59	0.25	3.91	26.58	0.17	0.21	0.79
	2.28	2.66	2.01	58.86	1.44	0.59	0.26	3.83	26.78	0.22	0.28	0.79
	2.27	2.66	2.06	59.09	1.32	0.55	0.24	3.92	26.64	0.16	0.22	0.86
GL 3	2.04	2.54	2.33	62.13	1.35	0.61	0.36	3.77	23.58	0.23	0.25	0.81
	1.96	2.62	2.36	62.12	1.29	0.65	0.26	3.74	23.65	0.19	0.27	0.88
	1.95	2.56	2.31	62.23	1.23	0.61	0.28	3.71	23.70	0.28	0.30	0.85
GL 4	1.95	2.55	1.51	61.80	1.52	0.69	0.31	4.23	24.54	0.17	0.18	0.54
	2.17	2.65	1.60	61.53	1.40	0.57	0.26	4.15	24.72	0.17	0.19	0.59
	2.10	2.66	1.52	61.24	1.59	0.68	0.30	4.15	24.86	0.15	0.21	0.53
GL 5	2.11	2.80	2.19	59.76	1.50	0.77	0.29	4.36	24.91	0.21	0.28	0.84
	2.00	2.73	2.29	59.38	1.63	0.79	0.27	4.46	25.19	0.13	0.22	0.92
	1.96	2.70	2.28	59.74	1.61	0.71	0.26	4.43	25.05	0.19	0.26	0.81
GL 6	1.87	2.60	2.29	60.66	1.48	0.79	0.30	4.27	24.40	0.19	0.30	0.86
	1.93	2.74	2.25	60.94	1.57	0.67	0.30	4.25	24.10	0.17	0.25	0.85
	1.86	2.80	2.20	60.49	1.53	0.77	0.30	4.37	24.39	0.23	0.22	0.86
GL 8	1.70	2.53	1.98	60.25	1.48	0.63	0.20	4.45	25.49	0.19	0.32	0.78
	1.74	2.61	2.00	60.46	1.54	0.58	0.19	4.42	25.23	0.16	0.35	0.73
	1.65	2.48	1.94	60.94	1.49	0.57	0.14	4.47	25.07	0.20	0.27	0.77
GL 10	1.58	2.50	2.13	60.94	1.46	0.73	0.21	4.28	24.85	0.17	0.26	0.91
	1.60	2.40	2.21	61.03	1.52	0.76	0.23	4.26	24.70	0.21	0.21	0.87
	1.65	2.42	2.11	60.93	1.55	0.76	0.23	4.25	24.73	0.18	0.26	0.93
GL 12	1.28	2.49	2.20	60.67	1.63	0.54	0.16	4.78	25.05	0.17	0.25	0.79
	1.23	2.41	2.24	60.67	1.59	0.50	0.19	4.72	25.22	0.21	0.26	0.75
	1.33	2.55	2.28	60.46	1.74	0.45	0.18	4.79	25.11	0.19	0.21	0.72
GL 13	1.69	2.62	1.93	61.84	1.59	0.67	0.23	5.00	23.12	0.16	0.32	0.83
	1.72	2.65	1.99	61.56	1.61	0.65	0.23	5.07	23.24	0.21	0.28	0.80
	1.75	2.65	1.96	61.64	1.57	0.69	0.25	5.04	23.27	0.16	0.24	0.79
GL 14	1.83	3.01	2.17	58.88	1.59	0.78	0.26	3.93	26.25	0.21	0.31	0.78
	1.84	2.98	2.08	58.92	1.40	0.76	0.29	4.04	26.35	0.21	0.32	0.82
	1.78	2.94	2.08	59.18	1.41	0.76	0.26	3.96	26.29	0.21	0.28	0.84
GL 15	1.89	2.63	1.87	60.60	1.41	0.59	0.29	4.73	24.92	0.20	0.22	0.64
	1.85	2.61	1.85	60.42	1.45	0.63	0.30	4.76	25.06	0.12	0.26	0.69
	1.85	2.69	1.82	60.55	1.46	0.55	0.29	4.71	24.98	0.16	0.26	0.69

Table 8: Complete Shinrone glass SEM-EDS data from Paynter et al 2005 with attached XRF data for manganese oxide, zinc oxide and strontium oxide. All values are normalised wt% of the oxides.

	Na ₂ O	MgO	Al ₂ O ₃	SiO ₂	P ₂ O ₅	SO ₃	K ₂ O	CaO	TiO ₂	MnO	Fe ₂ O ₃	MnO	ZnO	SrO
Shinrone waste glass														
6E	2.94	3.12	2.00	59.79	1.51	0.53	3.79	25.07	0.15	0.22	0.83			
6J	1.61	2.38	1.51	63.76	1.49	0.81	3.48	23.85	0.12	0.24	0.68			
6C	1.45	2.41	2.06	59.89	1.66	0.79	4.38	25.76	0.17	0.27	1.06			
6F	1.69	2.56	2.29	57.54	1.54	0.71	3.76	28.02	0.17	0.32	1.32	0.21	0.04	0.03
6I	1.70	2.30	1.50	61.82	1.43	0.58	4.02	25.51	0.13	0.23	0.75	0.16	0.04	0.06
6A	1.37	2.36	2.05	61.16	1.59	0.72	4.16	25.14	0.19	0.24	0.97	0.20	0.03	0.05
6B	2.01	2.78	2.02	60.34	1.50	0.62	3.96	25.31	0.16	0.24	1.01	0.18	0.03	0.06
6H	1.90	2.38	1.48	61.95	1.41	0.33	3.96	25.54	0.12	0.20	0.68			
6G	1.48	2.22	1.50	61.57	1.55	0.64	4.36	25.59	0.12	0.22	0.72	0.16	0.04	0.05
6D	1.30	2.27	2.07	61.39	1.50	0.76	3.97	25.23	0.16	0.26	0.98	0.20	0.03	0.05
18F	2.57	2.81	1.77	61.49	1.43	0.52	3.65	24.44	0.15	0.26	0.80	0.17	0.10	0.07
18G	2.41	2.69	1.90	61.75	1.48	0.78	3.48	24.15	0.16	0.23	0.97	0.18	0.11	0.06
18E	1.38	2.20	1.94	63.08	1.39	0.68	4.21	23.99	0.18	0.19	0.73	0.17	0.06	0.06
18H	2.64	2.73	2.01	61.11	1.46	0.89	3.49	24.26	0.15	0.22	0.97	0.18	0.09	0.07
96I	1.80	2.46	1.61	61.91	1.44	0.60	3.66	25.43	0.11	0.22	0.71	0.18	0.04	0.05
96A	1.55	2.28	1.45	64.82	1.53	0.62	3.75	23.00	0.12	0.19	0.60	0.16	0.04	0.06
96G	1.47	2.58	1.96	60.36	1.50	0.62	3.78	26.38	0.15	0.23	0.88	0.33	0.08	0.11
96E	1.30	2.32	2.51	62.36	1.62	0.59	3.94	23.89	0.16	0.26	1.02	0.21	0.04	0.05
96F	1.17	2.25	1.64	61.83	1.74	0.66	4.26	25.41	0.12	0.17	0.71			
96J	1.33	2.49	2.17	61.17	1.56	0.65	3.98	25.08	0.20	0.26	1.03	0.21	0.04	0.05
96H	1.17	2.44	2.34	61.81	1.46	0.38	5.31	23.60	0.20	0.29	0.81	0.23	0.03	0.06
96B	1.36	2.55	2.26	62.92	1.58	0.69	3.89	23.32	0.18	0.25	1.02	0.19	0.04	0.05
96C	1.50	2.32	1.46	63.36	1.56	0.60	3.90	24.21	0.10	0.24	0.66	0.21	0.05	0.06
96D	1.01	2.11	1.63	65.17	1.58	0.42	3.70	23.34	0.16	0.24	0.62	0.18	0.04	0.04
Average	1.67	2.46	1.88	61.76	1.52	0.63	3.95	24.81	0.15	0.24	0.86	0.20	0.05	0.06
StDev	0.51	0.24	0.32	1.64	0.08	0.13	0.39	1.13	0.03	0.03	0.18	0.04	0.02	0.02

	Na ₂ O	MgO	Al ₂ O ₃	SiO ₂	P ₂ O ₅	SO ₃	K ₂ O	CaO	TiO ₂	MnO	Fe ₂ O ₃	MnO	ZnO	SrO
Shinrone glass products														
18D	1.79	2.71	1.84	62.32	1.46	0.60	4.29	23.83	0.16	0.20	0.70			
18I	1.81	2.61	2.01	62.05	1.53	0.82	3.87	24.02	0.13	0.22	0.84			
47D	1.36	2.53	2.19	61.63	1.57	0.76	3.88	24.66	0.18	0.26	0.98	0.22	0.04	0.05
47H	1.63	2.73	2.28	61.40	1.66	0.80	4.12	23.89	0.15	0.23	1.04	0.20	0.04	0.06
47I	1.67	2.64	2.13	61.83	1.60	0.85	3.80	24.13	0.12	0.27	0.90	0.22	0.04	0.06
47B	1.66	2.61	2.15	61.81	1.59	0.79	3.84	24.19	0.15	0.26	0.93	0.22	0.04	0.06
47F	1.61	2.27	1.97	62.96	1.45	0.74	3.67	24.01	0.18	0.23	0.84	0.18	0.04	0.06
47C	1.30	2.46	2.20	61.73	1.55	0.71	3.85	24.74	0.12	0.27	0.96	0.22	0.04	0.05
47G	1.25	2.52	2.16	62.87	1.53	0.72	3.71	23.73	0.18	0.29	0.96	0.22	0.04	0.05
47E	1.48	2.47	2.06	62.94	1.56	0.77	3.89	23.40	0.14	0.24	0.93	0.20	0.04	0.05
47J	1.72	2.59	2.19	61.70	1.64	0.81	4.05	23.84	0.13	0.23	0.95	0.20	0.03	0.06
47A	1.37	2.29	1.75	63.62	1.40	0.53	4.31	23.66	0.13	0.20	0.66	0.18	0.03	0.06
39C	1.21	2.34	1.92	63.35	1.59	0.55	4.08	23.73	0.18	0.18	0.81	0.17	0.04	0.05
39B	3.06	2.99	1.83	60.42	1.49	0.64	3.75	24.53	0.13	0.21	0.84	0.18	0.04	0.08
39J	1.38	2.30	1.67	63.07	1.45	0.56	3.54	24.97	0.13	0.22	0.63			
39A	2.87	3.07	2.04	60.32	1.49	0.59	3.68	24.57	0.18	0.20	0.95	0.18	0.04	0.06
39D	1.55	2.69	2.11	62.60	1.58	0.70	3.98	23.43	0.18	0.24	0.90	0.21	0.04	0.06
39H	0.92	2.23	1.58	63.39	1.71	0.55	3.98	24.59	0.04	0.19	0.67	0.17	0.01	0.05
39G	1.71	2.83	2.31	62.08	1.46	0.70	3.80	23.64	0.17	0.23	0.87	0.20	0.03	0.05
39F	1.75	2.86	2.18	61.63	1.63	0.71	3.70	24.09	0.14	0.28	1.04	0.20	0.03	0.06
39E	1.30	2.34	1.45	64.26	1.83	0.55	3.76	23.68	0.08	0.16	0.47	0.16	0.04	0.05
Average	1.64	2.57	2.00	62.28	1.56	0.69	3.88	24.06	0.14	0.23	0.85	0.20	0.04	0.06
StDev	0.50	0.24	0.24	1.00	0.10	0.10	0.20	0.45	0.04	0.03	0.15	0.02	0.01	0.01

	Na ₂ O	MgO	Al ₂ O ₃	SiO ₂	P ₂ O ₅	SO ₃	K ₂ O	CaO	TiO ₂	MnO	Fe ₂ O ₃	MnO	ZnO	SrO
Glass products recovered from Shinrone but made elsewhere														
Bottle Glass														
313J	1.32	3.78	4.77	57.10	1.35	0.44	2.22	26.16	0.26	0.19	2.27	0.19	0.04	0.11
313H	1.36	3.77	4.78	57.05	1.28	0.48	2.19	26.05	0.28	0.26	2.23	0.19	0.04	0.11
313B	1.98	1.95	7.47	58.61	0.16	0.52	1.13	24.13	0.51	0.16	3.35	0.13	0.07	0.04
313I	1.23	4.43	5.01	60.60	0.26	0.42	2.11	22.88	0.27	0.26	1.86	0.20	0.01	0.13
313C	2.45	3.24	5.41	58.77	0.62	0.60	1.02	25.14	0.28	0.09	2.29	0.09	0.05	0.14
313E	1.76	3.82	4.17	60.05	0.76	0.52	2.47	23.55	0.23	0.19	1.79	0.15	0.02	0.19
313F	1.20	4.36	5.04	60.75	0.16	0.37	2.09	22.94	0.29	0.23	1.84	0.19	0.01	0.13
313A	2.03	1.92	7.35	58.79	0.17	0.48	1.13	24.06	0.42	0.14	3.38	0.13	0.04	0.04
313E	1.24	3.49	4.59	59.85	0.46	0.43	2.24	24.94	0.26	0.20	1.99	0.15	0.02	0.19
313D	1.21	3.30	4.77	59.81	0.30	0.40	2.12	25.38	0.30	0.19	2.11			
Average	1.58	3.41	5.34	59.14	0.55	0.47	1.87	24.52	0.31	0.19	2.31	0.16	0.03	0.09
StDev	0.45	0.87	1.14	1.32	0.45	0.07	0.55	1.19	0.09	0.05	0.58	0.04	0.02	0.05
Weathered window glass (HLLA but not Shinrone)														
39I	3.09	3.30	3.52	57.62	2.83	0.15	3.16	23.92	0.19	0.70	1.25	0.60	0.02	0.05
Pale green window glass (mixed-alkali)														
43G	7.76	4.93	3.07	67.17	1.10	0.13	4.59	10.34	0.08	0.03	0.66	0.07	0.01	0.39
43F	8.01	4.56	2.56	69.92	1.06	0.13	4.51	7.88	0.15	0.03	1.10	0.06	0.03	0.30
43J	8.04	4.59	2.52	69.90	1.15	0.09	4.72	7.71	0.13	0.04	1.06	0.06	0.03	0.31
43I	7.27	7.03	2.09	67.43	1.37	0.40	3.47	10.15	0.14	0.08	0.56	0.07	0.02	0.38
43B	7.72	4.89	3.03	67.29	0.98	0.22	4.66	10.28	0.14	0.03	0.69	0.06	0.01	0.23
43A	6.96	4.66	2.96	67.91	1.14	0.05	4.56	10.47	0.05	0.06	1.08	0.05	0.01	0.35
43E	7.05	5.28	2.52	68.38	1.03	0.32	4.14	10.40	0.07	0.04	0.74	0.06	0.01	0.34
43D	8.10	4.58	2.54	69.91	1.24	0.15	4.59	7.64	0.15	0.06	1.03	0.07	0.02	0.31
43C	8.09	4.48	2.55	69.84	1.24	0.20	4.60	7.76	0.13	0.05	1.05	0.06	0.03	0.30
Average	7.67	5.00	2.65	68.64	1.14	0.19	4.43	9.18	0.11	0.05	0.88	0.06	0.02	0.32
StDev	0.46	0.80	0.31	1.24	0.12	0.11	0.40	1.36	0.04	0.02	0.22	0.01	0.01	0.05

	N ₂ O	MO	Al ₂ O ₃	SiO ₂	P ₂ O ₅	SO ₃	K ₂ O	CaO	TiO ₂	MnO	Fe ₂ O ₃	MnO	ZnO	SrO
Pale green window glass (synthetic soda)														
43H	10.07	0.27	0.90	71.94	0.10	0.56	0.15	15.69	0.09	0.00	0.21	0.02	0.01	0.02
Pale olive vessel glass														
18C	1.88	3.63	4.20	59.59	0.87	0.69	2.20	24.91	0.25	0.08	1.69			
18A	2.08	3.74	4.15	58.68	0.90	0.27	1.46	26.67	0.25	0.08	1.66	0.18	0.11	0.06
18B	3.00	4.01	3.60	61.25	0.77	0.60	0.72	24.31	0.26	0.07	1.37	0.07	0.07	0.18
18J	3.24	4.13	4.47	60.72	0.94	0.34	0.80	23.41	0.18	0.07	1.64	0.09	0.05	0.16
Average	2.55	3.88	4.10	60.06	0.87	0.47	1.30	24.83	0.23	0.08	1.59	0.11	0.08	0.13
StDev	0.67	0.23	0.36	1.15	0.07	0.20	0.69	1.38	0.04	0.00	0.15	0.06	0.03	0.06



ENGLISH HERITAGE RESEARCH DEPARTMENT

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- * Aerial Survey and Investigation*
- * Archaeological Projects (excavation)*
- * Archaeological Science*
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- * Architectural Investigation*
- * Imaging, Graphics and Survey (including measured and metric survey, and photography)*
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