Glastonbury Abbey Durable Blue Medieval Window Glass

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Analysis

Three fragments of blue medieval window glass and one of clear glass were selected by Dr Pam Graves and Dr Chris Caple for compositional analysis as part of the survey and report on the medieval window glass from Glastonbury Abbey. The samples selected for analysis were those with broken edges which had been created during the demolition or excavation processes. The broken edges could be cleaned to remove decayed surface glass, without any loss of archaeological evidence, such as grozing, and when analysed provide an analysis typical of the true composition of the glass fragment. The broken edges of the selected samples were lightly abraded with silicon carbide paper and then analysed using a Hitachi TM3000 Scanning Electron Microscope with an Oxford Instruments SWIFT ED microanalysis capability. Each sample was repeatedly lightly abraded and analysed so that a minimum of three analyses, in which the sodium and potassium levels had not been lowered by the decay process, were obtained. A mean value for the repeated analyses of undecayed glass was calculated and used as the composition of the glass fragment. This procedure is similar to the methods used by analysts such as Sanderson and Hunter who analysed glass using EDXRF at Bradford University during the 1980's and generated much of the data against which these analyses are compared. A glass standard CL70 was prepared and analysed in the same manner to provide a comparison and to establish the efficacy of the cleaning process and the accuracy of the analytical system.

Table 1 – Compositional analysis of the glass standard CL70

Element (atomic %)	Composition of the Glass Standard CL70	Standard CL70 analysed using the TM 3000 on an abraded surface
Silicon	72.1	69.3
Sodium	12.8	15.3
Calcium	7.9	8.3
Potassium	0.3	0.5
Aluminium	1.5	1.5
Chlorine	-	-
Copper	-	-
Iron	0.5	0.3
Magnesium	3.7	4.6
Sulphur	-	-
Phosphorous	0.4	0.07
Manganese	-	-
Cobalt	-	-
Titanium	-	-

Since the CL70 standard's composition was given in atomic % the initial analysis using the SEM was carried out using atomic %. However, the subsequent blue glass samples were analysed using oxide weight % to make them comparable with previously published work. From the above table it can be seen that whilst major element percentages are accurate to within 5% of the stated value, minor and trace elements have higher error margins. The absence of copper, chlorine and other elements in the standard means that their accuracy cannot be checked and although, if detected, the elements are present in the sample, their reported concentration levels should be treated with caution. Indeed, given these levels of accuracy and the limited number of samples, all percentage figures should be treated with caution during the subsequent discussion. It is interesting to note that in many of the discussions about blue window glass (Biddle and Hunter 1990; Biek 1990) there is no discussion of the accuracy of the analytical determinations. An awareness of the limitations to the interpretation of early medieval glass compositions caused by small sample numbers and samples from residual contexts is important.

Results

Table 2 – Compositional Analysis of Glastonbury Blue Glass Fragments

Element Oxide wt %	G14 Blue Glass	G24 - P Blue Glass	G24 - E Blue Glass	G25 Clear Glass
Silicon	65.48	58.90	55.08	61.25
Sodium	6.97	10.83	14.13	2.95
Calcium	6.92	9.03	11.20	15.03
Potassium	5.55	7.00	6.60	7.13
Aluminium	4.90	2.53	1.83	3.98
Chlorine	2.43	2.57	1.98	2.15
Copper	4.12	4.17	4.10	2.73
Iron	1.63	1.50	1.48	1.13
Magnesium	0.62	1.10	1.35	0.93
Sulphur	0.58	0.60	0.35	0.28
Phosphorous	0.32	1.03	1.08	1.60
Manganese	0.36	0.63	0.85	0.33
Cobalt	0.09	0.04	0.00	0.00
Titanium	0	0	0	0.40

These results show that the blue glass fragments (samples G14, G24P, G24E) are all durable soda lime glasses, of similar composition to that identified by Cox and Gillies (1986), Pollard (1990), Yates (1990), Heyworth and Warren (1990) as coming from 11th and 12th century contexts. The trace levels of cobalt and low concentration of copper was responsible for the blue colouration. The clear glass (sample G25) is similar in composition to other examples of the potash and lime rich 'forest glass' which is used for most medieval window glass during the 12th – 16th century.

Discussion

Previous work by Cox and Gillies (1986) had identified a blue glass which, unlike the potassium and calcium rich 'forest glass' of the 12th-16th century, was durable and weathered only very slowly. This was in marked contrast to the forest glass, which was often highly decayed, pitted, crusted and opaque (Newton and Davidson 1989). Following earlier work by Roy Newton (1976a, b), Cox and Gillies (1986) identified a large number of examples of the durable blue glass in the widows of York Minster and suggested they were primarily of 12th century date, though they were often re-used in later windows. Other authors also identified examples of durable blue window glass in other locations such as Chartres, Saint-Denis, Dover Castle and Old Sarum. Cox and Gillies identified that the glass was durable due to its composition; the presence of sodium rather than potassium, the high levels of silica in the glass and relatively low levels of calcium. They suggested that this composition arose from remelted Roman glass mosaic tesserae sometimes mixed with medieval forest glass – since this 'recipe' was one described as used by glass makers by the 12th century monk Theophilus. Based on their analyses, Cox and Gillies (1986) suggested three compositional groups of durable blue medieval window glass.

- Group 2 – typical Roman and Saxon soda lime glass composition, low in potash (K), medium lime (Ca), high silica composition.

- Group 1 – mixture of Group 2 glass and forest glass – thus it has both soda (Na) and potash (K), lower silica than Group 2 though still higher than the forest glass, higher magnesium (Mg) and phosphorous (P) levels.

- Group 3 – as Group 2, but with higher alumina (Al) and potash (K) levels.

The Glastonbury blue glass samples appear to be three further examples of the Cox and Gillies Group 1.

Cox and Gillies suggest an impure cobalt oxide 'zaffre' – also known as 'Damascus pigment' as the colouring agent. Henderson (1990,30), however, suggests the cobalt copper mineral 'trianite' ($2Co_2O.CuO.6H_20$) as one of a number of possible colouring minerals for cobalt blue coloured glasses which were produced in Ancient Egyptian and other ancient civilisations. The use of such a mineral would explain the presence of both copper and cobalt in the samples. The characteristic blue colour is primarily produced by low concentrations of cobalt, circa 100 – 500 ppm (Biek 1990, 446). Cox and Gillies did not detect cobalt due to spectral interference, but did detect copper at levels around 0.1-0.2%. Cobalt was detected in two of the blue durable glass fragments from Glastonbury; it is almost certainly present in the third but at levels below the (0.04%) detection limit. The copper concentration in the Glastonbury fragments is higher than in comparable analyses and thus the accuracy of these percentage figures should be treated with caution, though the generally higher levels of copper in the blue glass does correspond with the findings of other analysts.

Subsequent work on the medieval window glass from Winchester by a variety of analysts, Heyworth, Hunter, Newton Pollard, Sanderson, Warren and Yates generated a larger number of analyses which Biddle and Hunter (1990) suggested showed a complex picture of four major and a number of sub groups of widow glass composition during the 6th to 16th century.

- Group 1 – durable 'early' Saxon soda lime glass, a continuation of the Roman glass making tradition of 6th to 10th century date, though Henderson (2000, 68) suggests that impurity levels suggest it is not a simple continuation of the same industries with the same raw material supplies. In this period, window glass is primarily seen in 7th and 8th century monasteries such as Jarrow and Wearmouth (Cramp 2006). The Winchester evidence suggests non-ecclesiastical buildings throughout the city had access to glass for windows, and its presence at Whithorn and Flixborough (Cramp 2009) indicates that there was glazing in wooden as well as stone buildings.

- Group 2 – durable glass of 'late' Saxon date – of 9th to late 11th / early 12th century. This is largely a clear or pale blue coloured soda lime glass, with occasional mixed soda potash glasses. Distributed throughout Winchester, Biddle and Hunter (1990, 357) suggest this glass may have been used for domestic as well as ecclesiastic glazing.

- Group 3 - durable blue glass 10th to 12th century, either a potash or a soda lime glass or a mixed soda and potash glass probably emerging from and part of the Group 2 glass making tradition. Its highly durable nature and appreciated intense colour meant that it was frequently reused. The blue glass, coloured with 0.1% cobalt (Yates 1990) appears to have been popular and made in much larger quantities than other colours / colourless Group 2 material. This may be illusory since its distinctive colour has led to its ready recognition by archaeologists and it has now been identified and analysed on a number of occasions.

- Group 4 – high potash and lime 'forest glass' which starts around the 10th century and later dominates the glass production, in the 12th to 16th century due to the ready availability of the raw materials.

Though very little ecclesiastical or domestic medieval window glass from before the 13th century survives in well dated contexts, on the basis of their analyses, the analysts of the Winchester glass agree on the four major glass groups, though the three (a-c) subgroups of Groups 1 and 2 are more conjectural and it is uncertain how far these groups are viable beyond Winchester. The discovery of durable clear or pale coloured glass in 9th -12th century contexts at Winchester Biddle and Hunter's Group 2, led them to suggest that Winchester Group 2 and Group 3 glass were produced in a 'primary glass making process without cullet' (Biddle and Hunter 1990, 360), though no clear mechanism for a soda rich or mixed soda and potash glass production at this date in England or specified trade route for such glass was identified. The occurrence of blue glass tesserae found at Winchester (Biddle & Hunter 1990, 354) and Flixborough (Evison 2009, 103,113) though without evidence on these sites of Roman mosaics with blue glass tesserae, does raise the possibility of a traded blue glass in tesserae form in the Post-Roman period. The importation or creation of blue soda lime glass (tesserae) which may be remelted and used raw or extended by melting with potash 'forest' (Biddle and Hunter's Group 4) glass would explain the soda rich and mixed soda and potash compositions of blue glass found by Cox and Gillies (1996) and the Winchester analysts.

These fragments from Glastonbury extend the range of the durable blue glass into the West Country. Extensive reuse of glass in stained glass windows prevents specific dating of the creation of this type of glass being confidently ascribed, save that from York and Winchester it dates from at least 12th century contexts. The increasing number of pieces of this glass which have now been identified suggests that although still useful and valued, it is not as conspicuous a sign of wealth as once imagined. The question of the origin of durable blue soda (or mixed soda potash) glass; France, Eastern Mediterranean or even England remains open.

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