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EXAMINATION AND ANALYSIS OF GLASS BEADS FROM WAKERLEY.

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Summary

Beads from a number of female burials at the Pagan Saxon cemetery site at Wakerley were examined. The beads were a range of shapes and colours and varied from translucent to opaque. They were analysed qualitatively to determine the range of colourants and decolourants used in their production.

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EXAMINATION AND ANALYSIS OF GLASS BEADS FROM WAKERLEY, NORTHAMPTONSHIRE

Introduction

Beads from 35 female burials at the Pagan Saxon cemetery site at Wakerley were examined. They included amber, jet, rock crystal and magnesium carbonate beads, but only the glass beads were examined in detail and analysed. The number of beads found in each grave varied considerably and a representative selection was made of the beads, from a number of graves, of various colours and types.

The beads analysed were all monochrome (see Appendix one). Two of the beads were decorated, but the area analysed covered only the bulk of the bead and did not include any of the decoration so they can be considered as monochrome as far as the analysis is concerned. The colours of the beads were determined subjectively by eye but should provide a reasonable basis for comparison with each other and with the analytical results. The opacity of the beads varied from translucent to completely opaque and these have been divided into two groups based on visual comparison.

Analysis

The beads were analysed using energy dispersive X-ray fluorescence (EDXRF) with an evacuated sample chamber. The elements analysed for were silicon, phosphorus, potassium, calcium, titanium, manganese, iron, cobalt, copper, zinc, lead, strontium, tin and antimony. No attempt was made to analyse low atomic number elements such as sodium and therefore the bulk composition of the glass could not be determined. No sample preparation was possible on the surface of the beads due to the necessity for non-destructive analysis so any results from light elements would have been unreliable. The calcium results, which may have been affected by contamination, and the phosphorus, potassium and strontium results, which were at a low but fairly constant level, have also not been listed. Since silicon is expected to be present at a relatively constant level in the beads as it is the major constituent of ancient glass it was used as an internal standard. The results were normalised by taking the ratio of the K-alpha peak height of each element (except for lead, when the L-alpha peak height was used) to that of the corresponding silicon K-alpha peak. The normalised results are listed in Appendix two. Only cobalt was not treated in this way as it was present in very low concentrations and the peak for cobalt overlaps with the iron K-beta peak. The cobalt content was therefore recorded as detected/not detected.

The ratio figures for each element quoted in Appendix two cannot be compared between elements (ie across the table) as the ratio bears little relation to the proportion of that element present. Different elements are excited with varying efficiencies by the primary X-rays, eg tin is excited far less than copper so the ratio will be a lot lower even when the amounts involved are similar. However, comparisons between analyses for a particular element (ie down the table) are valid.

Most of the elements recorded have an effect on the colour or opacity of the glass, the exceptions being titanium and zinc. Titanium is found at low levels in most glass and enters the glass melt as an impurity in the sand (silica) component. Zinc often enters the glass melt as an impurity or deliberate addition in the copper.

Results

Forty beads from Wakerley were analysed by EDXRF and they were of varying colours and types (for full descriptions of the beads see Appendix one). These can be divided into seven colours, some of which are found as both translucent and opaque glass:

Colour	Opaque	Translucent	Total
Blue (B)	11	6	17
Green (G)	4	1	5
Blue/Green (BG)	1	1	2
Yellow/Brown (Y)	-	5	5
Red (R)	4	-	4
Black (Bk)	1	-	1
'Colourless' (O)	-	6	6

The beads could be divided into six typological groups:

Type	Total
Cylinder	13
Annular	10
Globular	8
Barrel	4
Disc	4
Melon	1

The range of colours and bead types is similar to a number of other 6th and 7th century cemetery sites in Britain such as Sewerby (Hirst 1985: 62-85) and Buckland, Dover (Evison 1987: 61-82).

Discussion

The bulk composition of the glass beads cannot be determined from the elements recorded, however the titanium content may be a reflection of the silica source used, as it usually comes into the glass as an impurity in the sand, and variations in the titanium content may equate with variations in raw materials sources. The titanium levels in the Wakerley beads are mostly very low, with only one bead having a titanium ratio figure over 0.1. This means that there is no evidence for varying silica sources, though it does not necessarily follow that there was a constant source of silica for the manufacture of all the beads. The use of a single silica source could reflect a short period of production in which all the beads were made. This would tie in well with the archaeological evidence for the dating of the site which suggests that the cemetery was laid out within a fairly short space of time in the late 6th to early 7th century.

The beads are likely to be made of soda-lime-silica glass, and some will have had lead added at levels up to some 20-30%. This major element composition is a standard glass composition in the first millennium AD for all types of glass, vessels and windows as well as beads. The main components in the glass melt were sand, which provides the silica and possible the calcium in the form of shell, and an alkali, either natron or a marine plant ash, which provides the soda.

The other elements recorded were in the glass melt as either impurities in the main components or as deliberately added elements to achieve colouring or decolouring. Manganese, iron, cobalt, copper, tin, lead and antimony can all have a colouring effect, even when present in only very small quantities. Manganese and antimony can also act as decolourisers.

The production of coloured glass is extremely complex with a number of factors to take into account, such as deliberately added colourants or decolourants, the furnace conditions in which it is produced and the bulk composition of the glass. The colouring effect of different elements can be summarised as follows (for more detailed consideration see Bayley in press; Biek and Bayley 1979). The colour of iron-containing glass is strongly influenced by the furnace conditions, it will appear blue in strongly reducing conditions, green in less strongly reducing conditions and yellow or brown in oxidising conditions. This can be complicated by the presence of manganese which can either produce a wider range of colours including purple, or can act as a decolouriser to produce 'colourless' glass. Cobalt produces an intense blue colour, whereas copper produces a more turquoise blue or green in oxidising conditions. In reducing conditions copper can produce an opaque red colour, though it may range through to a brown. Tin is usually associated with opaque glass as tin oxide gives an opaque white colour, though if the glass contains lead it will give an opaque yellow colour. Lead does not actually produce colour but has an effect on the hue produced by colourants, and it plays an important role in the production of opaque glass. Antimony is another decolouriser in its reduced state, though in its oxidised state it produces opacity. Calcium antimonates are white, whilst lead antimonates are yellow.

There seems to be a shift from the use of antimony to manganese as a decolourant around the first century BC and first century AD (Henderson & Warren 1983: 169) and it would therefore be expected that the Wakerley beads would be decolourised by manganese. Antimony was detected in a small number of beads at significant levels, and it does seem to have been used specifically as a decolourant in one Wakerley bead (see below). Its presence in some beads in small quantities may reflect the re-use of Roman glass in the manufacture of the beads, however exceptions are known where antimony was used as a decolourant in post-Roman beads (eg Henderson and Warren 1983: 169). The use of manganese as a decolourant in the Wakerley beads can be clearly seen from the iron:manganese (Fe:Mn) ratios. All the glass contains detectable amounts of iron which would have coloured the glass, unless masked by a stronger colouring agent, but its effect could be neutralised by the addition of manganese.

The beads which have Fe:Mn ratios of about one are all 'colourless' suggesting that the manganese was added deliberately in the correct proportion to decolourise the iron. The yellow and brown beads all have Fe:Mn ratios of less than one and the colour is due to the manganese, which has not only neutralised the iron colour but is present in sufficient quantity to colour the glass itself. However the green beads mostly have Fe:Mn ratios of over five and the iron colour is dominant. The one exception to this is a 'colourless' bead (690585a) which has a lower manganese content but a much higher antimony content and appears to have been decolourised by the addition of antimony. This is rather unusual for glass of this period, though post-Roman parallels are known, eg Ribe (Henderson and Warren 1983: 178). This bead may be a Roman survival, though it is identical in appearance and style to the manganese decolourised 'colourless' beads which would suggest they are all contemporary.

The blue beads are probably all coloured by cobalt which is detectable in most cases. Cobalt is capable of producing an intense colour even when present at very low concentrations (ppm level) and it was therefore difficult to confirm its presence in all cases. However the cobalt blue is a distinctive deep blue colour and all the translucent blue beads and most of the opaque blue beads were of this characteristic blue. Also copper, which can also produce a blue colour under the right conditions, was not present at significant levels in the blue beads. It therefore seems that the cobalt was added deliberately as a blue pcolourant.

The black glass bead has a high iron content which produces the colour, however the other elements are at varying levels, and unlike any other colour beads, which may indicate that the glass was made by mixing left-over glass scraps together.

The opaque beads all have higher lead contents and particularly the opaque green and opaque red beads, which also have higher copper contents. The zinc figures are highly correlated with the copper figures which confirms that the zinc came into the glass with the copper. The tin figures are also higher in the high copper glasses and may suggest that gunmetals (copper alloys containing both zinc and tin) were being added as the source of these elements.

There is little evidence for any correlation between shape and colour, other than the group of identical 'colourless' globular beads which are mentioned above. All the other bead shapes are found in a range of colours, though the cylinder beads are all blues and greens whereas the other shapes such as barrel and disc include other colours such as red and yellow.

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APPENDIX ONE

Catalogue of beads analysed by EDXRF

Number	Grave	Colour	Opacity	Description
681762a	4	Red	Opaque	Annular
681762b	4	Green	Opaque	Cylinder, four-sided
681762c	4	Blue	Opaque	Annular
681763a	5	Colourless	Translucent	Globular, double
681763b	5	Blue	Opaque	Cylinder
681763c	5	Light blue	Opaque	Short cylinder
681763d	5	Blue	Translucent	Annular
682009	10	Yellow/Brown	Translucent	Annular
681998a	18	Yellow	Translucent	Short barrel
681998b	18	Colourless	Translucent	Globular, triple
681998c	18	Blue	Opaque	Cylinder, twisted
	19	Red	Opaque	Disc
682002a	30	Blue/Green	Opaque	Annular
682002b	30	Blue	Translucent	Annular
690583	42	Yellow/Brown	Tranclucent	Annular
690585a	44	Colourless	Translucent	Globular
690585b	44	Colourless	Translucent	Globular (gold skin)
690585c	44	Blue	Opaque	Cylinder
690587a	47	Colourless	Translucent	Globular
690587b	47	Blue	Opaque	Cylinder, twisted
690589a	49	Black	Opaque	Disc
690589b	49	Yellow	Translucent	Melon, seven lobes
690589c	49	Yellow	Translucent	Disc
690590a	50	Blue	Opaque	Cylinder
690590b	50	Blue	Translucent	Annular
706125a	58	Blue/Green	Translucent	Disc
706125b	58	Red	Opaque	Barrel (decorated)
706129	71	Blue	Opaque	Globular
706095	73	Red	Opaque	Barrel (decorated)
706130a	73	Green	Opaque	Fluted barrel
706130b	73	Green	Opaque	Cylinder, squared
706130c	73	Blue	Opaque	Cylinder
706132a	74	Blue	Opaque	Cylinder
706132b	74	Blue	Translucent	Annular
706135a	80	Blue	Translucent	Cylinder
706135b	80	Green	Translucent	Cylinder
706136a	82	Blue	Opaque	Cylinder
706136b	82	Colourless	Translucent	Globular, triple
681999	?	Blue	Translucent	Annular
	?	Green	Opaque	Globular

APPENDIX TWO

Results of EDXRF analysis, all figures normalised to silicon, except cobalt, which is either detected (+), not detected (-) or uncertain (?).

Number	Colour	Ti	Mn	Fe	Co	Cu	Zn	Pb	Sn	Sb
681999	B	0.03	0.31	0.79	+	0.11	0.04	0.08		
681763d	B	0.04	0.20	0.85	+	0.13	0.03	0.09		
682002b	B	0.07	0.18	0.90	?	0.15	0.20	0.10		
706135a	B	0.02	0.21	0.45	+	0.13	0.02	0.13	0.02	0.13
690590b	B	0.10	0.17	1.64	+	0.23	0.06	0.14	0.05	
706132b	B	0.03	0.31	0.73	+	0.12	0.03	0.05		
681763b	B	0.02	0.13	0.67	+	0.15		0.29	0.02	
690587b	B	0.03	0.41	0.99	+	0.30	0.04	0.58	0.02	
681998c	B	0.04	0.31	0.89	?	0.25	0.26	0.36	0.02	
706129	B	0.03	0.53	0.96	+	0.22	0.03	0.59		
690585c	B	0.03	0.37	0.75	+	0.19	0.03	0.27	0.02	
706130c	B	0.03	0.42	0.87	+	0.18		0.41	0.02	
706136a	B	0.03	0.49	0.99	+	0.27	0.04	0.52		
681762c	B	0.05	0.30	1.10	+	0.16	0.05	0.12		
690590a	B	0.04	0.56	0.99	?	0.10		0.55	0.03	
706132a	B	0.04	0.50	0.86	+	0.24	0.03	0.56		
681763c	B	0.10	0.54	2.37	-	0.18	0.04	0.16	0.05	0.04
706125a	BG	0.03	0.19	0.68	-	0.03	0.03	0.07	0.04	
682002a	BG	0.07	0.21	1.46	-	5.48	0.09	1.62	0.05	0.04
706135b	G	0.02	0.13	0.32	-	1.28	0.05	0.67	0.03	0.05
?	G	0.07	0.35	1.10	-	2.77	0.06	4.43	0.09	
706130a	G	0.06	0.11	0.66	-	2.01	0.14	8.02	0.04	0.02
706130b	G	0.06	0.23	1.19	-	1.81	0.14	11.96	0.04	
681762b	G	0.14	0.30	1.74	-	4.39	0.23	18.69	0.58	
681998a	Y	0.06	0.64	0.59	-	0.04	0.03		0.04	
690589b	Y	0.03	0.76	0.56	-	0.03	0.02	0.03		
690589c	Y	0.03	0.73	0.51	-	0.04	0.03	0.03		
682009	Y	0.01	0.07	0.14	-	0.02			0.02	
690583	Y	0.07	0.09	1.07	-	0.06		0.05		
Burial 19	R	0.09	0.39	5.57	-	1.65	0.27	7.61	0.06	
706095	R	0.06	0.17	3.87	-	2.05	0.14	4.10	0.05	0.03
706125b	R	0.06	0.31	3.95	-	1.31	0.17	4.43	0.11	
681762a	R	0.05	0.14	2.27	-	0.82	0.11	6.27	0.02	
690589a	Bk	0.04	0.56	2.49	-	0.05		0.07	0.06	
681763a	O	0.06	0.53	0.86	-	0.03				
690587a	O	0.03	0.48	0.50	-	0.06		0.03	0.03	
681998b	O	0.03	0.51	0.55	-	0.03		0.03	0.03	
690585a	O	0.02	0.08	0.24	-	0.02		0.03	0.03	0.08
690585b	O	0.04	0.44	0.51	-	0.05	0.02	0.03	0.03	
690585b	O	0.02	0.12	0.41	-	0.08		0.02	0.02	
706136b	O	0.05	0.57	0.79	-	0.14	0.03		0.02	

The symbols representing the bead colours are as follows:
B - blue, G - green, BG - blue/green, Y - yellow/brown,
R - red, Bk - black, O - 'colourless'.