Identifying Group and Meaning : An Investigation of Roman Colourless Glass

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The aim of this research project, sponsored by the British Academy, is to build upon results that had been derived from an analysis of colourless Roman vessel glass from Colchester (Heyworth *et al*. 1990; Baxter *et al*. 1995). Although the products of the Roman glass industry are commonly found throughout the Roman world, the organisation of the industry, location of glasshouses and place of origin of particular types of glass vessels are in most cases not fully known. This is in part due to the paucity of evidence for glass manufacture (for example, Price, Cool 1991; Foy 1991 and Follmann-Schulz 1991) and the difficulty in recognising glassmaking from the raw materials at such sites or glass production purely from the remelting of cullet (or in fact a mixture of the two). Most models in the literature tend to rely, therefore, on the study of the distribution patterns of regional types of glass as an indicator of general location of production, or at least of trade, and this has proved fruitful in the past. However, there is also one other way we can hope to make these assumptions more concrete, this is through the chemical analysis of glasses. The premise here, as in many other fields of analysis within archaeology, is that glass produced from the primary raw materials, at discrete centres, will have a chemical 'fingerprint' that will differentiate it from glasses produced at other locations (assuming it has been produced using standardised raw materials and manufacturing techniques and that these are different from other glassmaking centres).

However, Roman glasses are well known for their compositional homogeneity. Analysis of consumption assemblages, exhibiting glasses of apparently different types, thought to be produced at different centres, are generally indistinguishable chemically. In most cases the only differentiation is by colour (Jackson 1992) or broad chronology (Mirti *et al*. 1993). There are one or two exceptions in the case of early Roman glass (eg. Henderson 1996) but this is the general pattern for glasses dating from the second to fourth century AD. A number of reasons for this consistency have been proposed. The first is that the compositional homogeneity of Roman glass is due to the use of specific and generally homogeneous raw materials (Sanderson *et al*. 1984). Pliny (*Natural History* 36.194) writes that Roman glass was produced from sand and the mineral 'natron'. He suggests a number of different sources for sand - for example the rivers Volturnus and Belus - based upon their ability for glass forming and more importantly, for colourless glasses, based upon their purity. The most famous quote by Pliny ascribes the source of natron to the Wadi Natrun in Egypt. Lime is not mentioned as a component of the glass recipe. Both sand and natron are relatively 'simple' raw materials for glass formation. If as Pliny suggests, sand was chosen for its purity, the silica sand used for glassmaking would be predominantly composed of silica, with minor or trace levels of other compounds which would not significantly affect either the glass forming ability nor the broad compositional traits. Likewise natron is mainly composed of sodium compounds (carbonates, bicarbonates, etc) (Turner 1956) and if uncontaminated should contain few minor or trace components. Therefore, glasses produced from these two components should have a greater likelihood of showing a homogeneous composition than glasses produced from plant ash and sand combinations. (Sanderson, Hunter 1981).

Other theories put forward to explain the tight compositional grouping of Roman glasses relate to glass production processes rather than raw material homogeneity. A number of authors suggest that a strict formula or recipe was adhered to (eg. Lemke 1998). By following a strict routine or ritual, the glass would be produced in the same

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way each time, using the same raw materials, preparation processes, recipes and production technology, resulting in a glass of consistent composition. With more homogeneous raw materials the use of a strictly controlled recipe would aid in the production of a more homogeneous glass. Related to the theme of a ritual or formula employed in glass production, Rehren has put forward a model for partial melting, initially for Egyptian glasses, but also with a view to Roman glasses. This is where the glass composition is related to the cotectic trough leading from the eutectic region in an equilibrium phase diagram, for glass compositions based upon a three component system (Rehren 2000). In this way the raw materials are melted until this 'equilibrium composition' is achieved and any undissolved raw materials are 'removed' from the glass and discarded (Rehren *et al.* 1998, Rehren 2000, 2001). This equilibrium composition would necessarily be similar in glasses produced from similar raw materials for the three component system, such as natron, sand and lime. It is unclear how other minor components present in the raw materials in different forms would affect this equilibrium composition, or would be taken up by the resulting glass formation. He suggests this mechanism would account for the consistent composition seen in Roman glasses, with only small deviations between different groups of glasses.

These theories all relate to the production of glass from the raw materials. One major factor which should not be overlooked in the Roman world is the re-use of glass in the form of cullet. It has been widely documented (e.g. Price 1978) that Roman glass was collected for remelting and traded some distances. This is also known to have continued into later periods (Hawthorne, Smith 1979; Freestone 1992). The continual remelting of glass is thought to have produced a stable and constant composition.

If we move away from raw materials and glass production processes and move towards the organisation of production as a means of explanation for compositional continuity or change, two models dominate the current literature. The first, and perhaps what may be considered the longest held view, assumes glass was made from the raw materials on a relatively 'small' scale at a large number of local or regional glasshouses. However, few glasshouses have been discovered where it can be suggested that glass was produced from the raw materials and that glass production was not a feature of the continual remelting of cullet (although this may be a feature of the complexity of identifying manufacturing locations). For example for sites identified in Britain, small scale remelting appears to have taken place at Mancetter, Leicester, Wilderspool and others (Price, Cool 1991). So far, only at one site in York is there tentative evidence that glass production may have taken place (Jackson *et al.* 1998). Even at more extensive glassmaking locations such at the fourth century site at Jalame the evidence suggests glass melting rather than production from the raw materials (Weinberg 1988). In contrast to this, however, recent material analysed by Wedepohl suggests that the large complex of fourth century glass furnaces found in the Hambach forest, Germany, may have been producing glass from the raw materials (Glaitzsch 1991; Wedepohl, Baumann 2000). This last site may be a first indication of the missing link in the archaeological record, others have yet to be identified. In each of these cases, whether the raw materials are local or imported, it could be assumed, that the composition of the glass *may* be similar within each glassmaking complex, but different from other glass production centres. In this model it should be possible to identify different groups which have regional identity if the glass producing locations are known.

An alternative model for glass production in the immediate post-Roman and Roman world has recently been put forward by Freestone *et al.* (2002). He argues that glass may not have been manufactured in a large number of small workshops located throughout the empire, but produced in a small number of very large primary glass making installations, such as those from the Graeco-Roman, Byzantine and early Islamic periods found in Egypt and Israel (Freestone *et al.* 2002, Nenna *et al.* 2000, Gorin-Rosen 2000). Glass chunks would then be moved to small 'forming' locations where final shaping and forming of glass would take place. Whilst providing a coherent explanation for glass production in these periods, similar installations have yet to be found in the Roman world. And for those small scale installations where it is evident glass blowing was taking place using preformed glass, the form of waste recovered is cullet only rather than the raw glass chunks or ingots which would support this model.

Therefore, in the absence of a definitive model for Roman glassmaking and the evidence for its production, chemical analysis must use the evidence available to understand either compositional groups formed by differences in chemistry, or chemically similar types of glass. And, if we are to understand glass manufacture in the Roman world, in the absence of suitable archaeological evidence in the form of identifiable primary glass production locations, a comprehensive and structured analysis of glass must be undertaken using the contextual, typological and technological evidence from consumption assemblages of glass.

The next step is therefore to look at specific typologically defined groups of glasses to ascertain if different compositional groups can be identified and what these compositional groups may mean. Colourless glass was chosen for the initial work at Colchester because it is relatively easy to trace changes in its use. It tends to be used for good quality tablewares and is subject to changing fashions meaning that particular forms can have quite short lifespans. Colourless glass, also, requires care in selection of raw materials and presumably selective recycling of cullet - so that the colour, clarity and quality of the glass can be maintained.

The initial project, published in 1995, on colourless glass from Colchester analysed fragments from four typologically distinct groups of vessels that spanned the mid 1st to mid 3rd century period by inductively coupled plasma spectrometry (ICPS) (Baxter *et al.* 1995). The initial results showed that although the groups did not separate easily, the compositional variation within the groups varied raising hopes that it would be possible to explore the development of the Roman colourless glass making and working industry. The principle aim of the current work was to gather a much larger number of colourless glass fragments from the same four typological groups from a range of sites in Britain to check whether the differences in compositional variation seen at one site, Colchester, were present throughout Roman Britain.

1. The glass

In total 243 vessels were chosen for analysis and subsequently sampled. All of the fragments were selected on the basis that they could be assigned with certainty to one of the four types.

Type 1 is the cast colourless bowl (Cool, Price 1995, 37).

Type 2 is the externally ground facet-cut beaker (Isings Form 21; Cool, Price 1995, 71).

Type 3 is the wheel-cut beaker (Cool, Price 1995, 79).

Type 4 is the cylindrical cup with double base ring (Isings Form 85b; Cool, Price 1995, 82).

Types 1 and 2 were in use contemporaneously between *c.* AD 70 and AD 160 and have an empire-wide distribution. Type 3 appears in the late 1st century but is most popular in the middle third of the 2nd century. It would appear to have gone out of use by *c.* AD 175. Type 4 which comes into use *c.* AD 160/70, is the dominant drinking vessel form of the later 2nd to early 3rd century and probably goes out of use by the mid 3rd century. Both types 3 and 4 have a more restricted distribution than types 1 and 2 as they are characteristic of the north-western provinces of the Empire.

The samples came from 16 different sites whose location is indicated in Table 1. The aim was to select a core of sites which could both provide a number of samples from each type and which were geographically distributed throughout Roman Britain. The majority of glass came from the sites of Caerleon, Canterbury, Castleford, Chester, Colchester, Gloucester, Leicester, Lincoln, Verulamium and York. Smaller groups of material were also analysed from London, Sleaford, Stanwick, Wilcote, Winchester and Wroxeter. The number of samples analysed, belonging to each type, is shown in Table 1.

Site	*Type 1*	*Type 2*	*Type 3*	*Type 4*	**Total**
Caerleon	2	3	3	7	**15**
Canterbury	1	2	3	13	**19**
Castleford	2	9	10	6	**27**
Chester	-	6	1	5	**12**
Colchester	6	7	9	10	**32**
Gloucester	4	3	2	8	**17**
Leicester	2	1	1	5	**9**
Lincoln	1	4	3	12	**20**
London	-	14	-	-	**14**
Sleaford	-	-	-	1	**1**
Stanwick	-	-	-	1	**1**
Verulamium	11	3	10	19	**43**
Wilcote	1	2	-	1	**4**
Winchester	1	2	-	3	**6**
Wroxeter	-	-	4	1	**5**
York	2	6	5	5	**18**
Total	**33**	**62**	**51**	**97**	**243**

Table 1 — Number of samples analysed by type and find location.

2. Analysis

The analysis was carried out at the NERC Inductively Coupled Plasma Spectrometry (ICPS) facility within the Department of Geology, University of London, Royal Holloway, Egham, using a Philips PV8050 Spectrometer with PV8490 ICP source unit. In excess of 20 major, minor and trace elements were analysed for, of which 11 are pertinent to the following discussion, these are Al_2O_3, Fe_2O_3, MgO, CaO, Na_2O, K_2O, TiO_2, P_2O_5, MnO, Pb, Sb. The methodology applied is that given by Thompson and Walsh (1983) for silicate analysis, adapted for glass analysis (Heyworth *et al.* 1991, Jackson 1992). Dissolution of powdered samples of glass takes place in a mixture of hydrofluoric and perchloric acids, silica being removed in the process as silicon tetrafluoride.

The results of the analysis were calibrated for drift, checked against glass standards (Corning A and B, Society of Glass Technology Glass Standard no. 4, National Bureau of Standards SRM 621 and Pilkingtons Synthetic glass standard 76-C-150), and any further corrections applied. A more detailed account of the procedures involved will be documented in a future paper. A statistical analysis of this data was carried out and a selection of the provisional results are presented below.

3. Provisional results

Standard methods of multivariate analysis, applied to the data for each type separately, suggested distinct groupings *within* each type. These trends within the data were unexpected, as they were not apparent in the initial analysis of the glass from Colchester. However, the full results of this study will not be presented here; the following section gives an illustration of the preliminary findings using a sub-set of the data, that of cylindrical cups.

Colourless cylindrical cups presented the most surprising results. In the analysis of the Colchester data (Baxter *et al*. 1995) of the four typological groups analysed cylindrical cups were compositionally the most stable (53 specimens). However, with the larger data set presented here (97 specimens), distinct compositional groupings were detected *within* this type.

The statistical analysis of the chemical data suggests there may be either two or three groups (Fig. 1). Group 1 differs most noticeably from the other two in having higher levels of Mn, K, Na, Ca and Fe. Groups 2 and 3 can be almost completely separated out from Group 1 by values of Mn. Groups 2 and 3 differ most obviously with respect to the levels of Mg and Sb (Table 2). The distribution of the different groups according to the sites they were found on is shown in Table 3. As can be seen though some sites tend to be dominated by examples in a single group (Colchester and Winchester - Group 1; Caerleon and York - Group 3), there is a tendency for the sites with 5 or more specimens to be more evenly split between the groups. There is the possibility that Groups 2 and 3 may not be distinct compositions but merely parts of a continuum, however, when these two groups are combined again no obvious geographical distribution is apparent.

The interpretation of these groups is still underway. If these compositions represent the products of different glass-houses as may be suggested if we assume glass was produced in a number of regional centres, then, on the whole, their products seem to be being traded throughout the province as there is no *simple* geographical explanation for the distribution. A similar hypothesis can be assumed for large-scale mass production (see discussion below).

If we are to assume that findspot is not a contributory factor in group, but trade may be, by analysing trade patterns of other materials, some correlation may be apparent. The most comprehensively studied material known to have been produced in Britain is pottery. However, initial enquiries into the link between the glass groupings illustrated above and specialist pottery trade distributions such as those of mortaria at the same sites (eg. Tyers 1996, Monaghan 1997, Bidwell 1999, Rush *et al*. 2000, Zienkiewicz 1992) have not shown any discernible pattern. Chronological analysis of the groups has shown some tentatively positive results, however this work is still underway and will be reported in a subsequent paper.

Site	Cluster 1	Cluster 2	Cluster 3	Total
Caerleon	1	0	6	7
Canterbury	6	4	3	13
Castleford	3	2	0	5
Chester	2	2	1	5
Colchester	7	1	2	10
Gloucester	4	0	2	6
Leicester	2	1	2	5
Lincoln	4	3	5	12
Sleaford	0	1	0	1
Stanwick	0	1	0	1
Verulamium	7	6	5	18
Wilcote	1	0	0	1
Winchester	3	0	0	3
York	1	1	3	5
Total	**41**	**22**	**29**	**92**

Table 3 — Distribution of cylindrical cups by site and chemical group.

Therefore with the cylindrical cups we have shown that there appear to be either two or three clear compositional groups formed by subtle differences in composition. Thus, we have a very well understood and studied group of glass, where we know their type, their geographical findspots, and in many cases they come from dated contexts, yet at this point in time these chemical groups cannot be explained in any simple manner.

4. Discussion and Conclusions

The aim of compositional analysis is to form groups of glasses based upon similarities or differences in their compositional patterns in order to make assessments concerning their mode of manufacture (most often related to technology or provenance of an artefact). Inextricably linked to this, is an assumption that a glass group is a unit which has meaning within a framework of known archaeological parameters such as chronology, finds location and type. It is only by the use of all these factors that we can hope to obtain a meaningful interpretation of glass in the Roman world.

The difficulties in the interpretation of compositional data were outlined in the introduction. This study alone cannot hope to fully resolve these difficulties. One such problem is the consistent and homogenous composition of Roman glasses through time and space. The analysis of cylindrical cups above shows that these glasses fit within the generally defined composition of Roman glasses and

Sample	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	MnO	Pb	Sb
Group 1	1.88	0.42	0.43	6.01	19.03	0.55	0.07	0.06	0.12	0.00	0.48
Group 2	1.88	0.38	0.48	5.28	18.17	0.49	0.07	0.06	0.02	0.00	0.35
Group 3	1.72	0.33	0.36	5.12	18.26	0.45	0.06	0.05	0.02	0.00	0.53

Table 2 — Mean Values of Oxides Within Each Group.

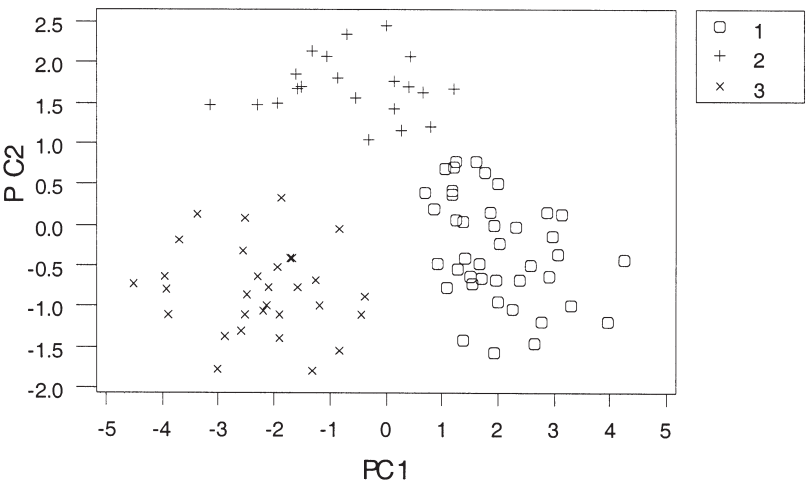

Fig. 1 — Principal components plot of cylindrical cups.

that as a group, on a broad level they are relatively compositionally consistent. However, on a more subtle level, there are compositional differences which suggest that within this overall composition there are three subgroups.

The sub-groups are formed by differences in suites of elements, often dominated by one or two. Some of these differences may be due to human factors such as intentional additives in the glassmaking process (for example difference in the levels of antimony which acts as a decolorizer in colourless glass) but others are probably due to natural variations within the raw materials used in each case (for example differences in magnesium). How can we interpret these differences with respect to the models of glass production presented earlier in this paper?

Small differences between groups of glass can be explained by subtle differences in raw materials and recipes, suggested by the work of Sanderson and Hunter 1981, Henderson 1996 and Lemke 1998 amongst others. There is an inherent difficulty at this level separating those differences due to raw materials and those due to recipe. These differences do not suggest that the glass industry was not a highly organised one within the Roman world, in fact they reinforce it. It is to be expected that small differences will occur within an overall tightly controlled manufacturing procedure, due to raw materials and manufacturing procedures. These differences can only be observed when statistically valid typological groups of glasses have been analysed, such as this study.

How these differences, if produced by natural variations within the raw materials, fit into the Rehren partial melting model remains to be seen with further experimentation, but they suggest there may be other factors which need to be taken account of in this model. For instance the consistent presence of manganese in many of the samples may indicate recycling, which is not taken into account within a partial melting regime based on raw materials. Therefore, it is an extremely difficult task to understand the procedures involved in the production of Roman glass throughout the empire unless we can fully understand the nature of the raw materials, their compositions and the procedures used in glass manufacture. This is ongoing work.

If we now move from raw materials to glass production, does this small case study help us to understand the organisation of production of the glass industry within the Roman world? Do these groups conform to a model of small-scale regional production or large-scale primary workshops? The model proposed by Freestone suggests large-scale glassmaking installations serving a number of secondary remelting centres. The data presented here would fit this model if we assume there are (at least) three large-scale primary workshops producing (but not necessarily specialising) in colourless glass. The primary glass (with its 'unique' composition) would then be sent to smaller scale secondary working centres where the finished vessels would be produced. The model does not assume that each secondary centre would obtain its glass from only one producer, and the continuum seen in Figure 1 between groups 2 and 3 may suggest some degree of mixing of glass from two centres. It is not apparent from the data how many secondary centres would be producing cylindrical cup as differences in base glass compositions would be defined at the original centre of manufacture. We have yet to find and identify large scale glass installations in the Roman world for the period under study.

However, the data presented above does not preclude small-scale regional centres of production. These could be equally as probable; as in the case of the cylindrical cups discussed above, the model would fit three (or more) small-scale production centres producing glass of a slightly different composition, but to a similar recipe. These have been identified in the archaeological record, although primary glass production at these manufactories cannot be proved.

The work by Freestone is based upon trace and rare earth element analysis and relates to a model based on the use of different sand sources. Therefore, trace element analysis on a subset of the data presented here may throw light upon the findings above. Further work is projected, but it should not be discounted that the presence of recycled material in the compositional analysis makes any interpretation complex.

These models are useful as they try and explain how and where glass was made in the Roman world. However, it is only through the use of a combined approach of analytical, typological and archaeological evidence that we will hope to understand the complex nature of the Roman glass industry. The data collected in this project is still in the preliminary stages of analysis; future results upon different colourless glass types may throw further light upon the development and organisation of the Roman colourless glass industry from the first to third centuries.

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