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# COMPOSITIONAL ANALYSIS OF ROMAN GLASS FROM COLCHESTER, ESSEX.

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Summary

The composition of a group of colourless glasses from Colchester was analysed by inductively coupled plasma spectrometry. The analysed glasses represented several typological groups of tableware which can be dated from the mid 1st to the late 2nd century AD. The samples were chosen to investigate any compositional differences between the groups. The compositional data was examined using a variety of statistical methods which were known from previous studies to be appropriate for application to glass compostional data.

The statistical analysis showed that whilst all the glass was of the same basic soda-lime-silica compostion, suggesting that it came from the same production tradition, there was a lot of compositional variation within the typological groups. Despite this variation there were some differences between the typological groups, though they were not compositionally distinct and it is therefore difficult to suggest any substantive interpretation based on the analytical data. It is suggested that the variation may be explained by either a variation in the use of raw materials through time, or that it may reflect the output of different glasshouses. Further work will be needed to elucidate any potential relationship between composition and typology.

An extension of the project is suggested to include similar vessels from other sites in England.

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## COMPOSITIONAL ANALYSIS OF ROMAN GLASS FROM COLCHESTER, ESSEX

### Introduction

The manufacture of colourless glass requires a high degree of quality control if the end product is to be of good quality and, in the recent past, great care has been taken with the selection of raw materials. It seems reasonable to assume that similar care would have been exercised in the Roman period. This report covers the compositional analysis of samples of colourless glass from tableware. The samples were selected from typological groups which span the period from the first appearance of good quality colourless glass as a regular item of luxury tableware in c. A.D. 60-70 to the point in the late second century when colourless glass was in common use. The majority of the vessel types analysed are common forms found throughout Roman Britain. The aims of the analysis were (i) to examine the composition of colourless Roman glass which has been little studied previously; (ii) to investigate the compositional similarity within and between the typologically established groups; and (iii) to see whether the change in the status of colourless glass from a prestige material to a more commonplace one is reflected compositionally.

### The Glass

The glass analysed was all found at Colchester during excavations conducted by the Colchester Archaeological Trust between 1971 and 1985. The four different groups of glass included in the analytical programme are as follows:

| Vessel Type | Number Analysed |
|---|---|
| Cast vessels | 21 |
| Facet-cut beakers and other ground vessels | 15 |
| Wheel-cut beakers | 29 |
| Cylindrical cups | 53 |
| TOTAL | 118 |

The earliest vessels represented belong to the first two groups. Cast colourless glass was in production from c. A.D. 60-70 and continued in use into the early second century. Most of the twenty-one fragments analysed were colourless, though two had a greenish tinge. Most of the fragments came from the common variety of bowl with a wide rim and foot ring. The majority of these were plain but there were also two fragments of the much rarer facet-cut variety (nos. 209 & 211). The sample also includes some cast colourless fragments which were probably not from wide rimmed bowls, such as the handle fragment no. 210 which might have come from a cast saucepan.

The second group consists of vessels formed by grinding the exterior of a blown blank to shape. Ten of the samples came from facet-cut beakers, one came from a relief-cut beaker and four from vessels with linear ground-out decoration. This material was also in use from c. A.D. 60-70. The production of facet-cut beakers and relief-cut beakers had probably ceased by the end of the first century, but that of the linear ground vessels may have continued into the second century.

Wheel-cut beakers form the third group. At least one variant of these had come into use by the end of the first century, but the majority belong to the first two-thirds of the second century and are most numerous during the middle third of the century. The beakers were made in a variety of shapes and the sample included 19 fragments from ones with cylindrical, ovoid and carinated bodies, and with both tubular pushed-in base rings and separately blown feet. Ten other body fragments with wheel-cut lines were also analysed although their identification as wheel-cut beakers is not secure.

The fourth group are cylindrical cups. These were in use during the final third of the second century and the first half of the third. This was the largest group of fragments analysed reflecting the very large number of these cups found at Colchester and elsewhere. These cups appear to represent the first widespread use of colourless glass as a common item of tableware.

In addition to this material two fragments of facet-cut glass which were not externally ground were initially analysed as part of the second group (nos. 414 & 417). As these fragments do not belong typologically or chronologically to this group, they have been excluded from all subsequent statistical analyses though the details of their composition are given in Table 1.

## Analytical Method

The analyses were undertaken using inductively coupled plasma atomic emission spectrometry (ICPS). The ICPS technique is becoming increasingly widely used in the analysis of archaeological materials (see Heyworth et al 1988). It gives compositional data for a wide range of elements at the major, minor and trace levels (Thompson and Walsh 1986). This is especially important for the analysis of glass where major and some minor elements determine the general type of glass and other minor and trace elements have an important influence on its colour. In the present programme data was obtained for 32 oxides and elements: $Al_2O_3$, $Fe_2O_3$, MgO, CaO, $Na_2O$, $K_2O$, $TiO_2$, $P_2O_5$, MnO, Pb, Sb, Ba, Co, Cr, Cu, Li, Nb, Ni, Sc, Sr, V, Y, Zn, Zr, La, Ce, Nd, Sm, Eu, Dy, Yb and $SiO_2$. The figure for silica was obtained by difference as the silica is removed in the sample preparation procedure.

Samples for analysis were cut from the glass fragments, using a low speed diamond blade saw, and milled to a fine powder. A powdered sample of 100 mg was then evaporated to dryness with perchloric and hydrofluoric acid, and the residue dissolved in hydrochloric acid and distilled water before diluting to a standard solution strength. The sample preparation and ICPS analysis was undertaken in the Department of Geology at Royal Holloway and Bedford New College, University of London, under the supervision of Dr J.N.Walsh.

The ICPS analysis was carried out using a Philips polychromator

ICPS system calibrated for quantitative analysis with multi-element rock standards. The glass solutions were run through the system twice, the first time the majority of major, minor and trace elements were measured, and the second time the solution was diluted to 10% of its original strength to obtain the soda figures. The soda level in the glass is outside the calibration range of the instrument at the original solution strength and the dilution was necessary to maintain a linear calibration for the soda signal. Multi-element rock standards were analysed at regular intervals during the analytical run to allow for correction of any short-term fluctuations in the system. Three glass substandards were also analysed to check the ICPS calibration.

## Analytical Results

One hundred and twenty fragments of glass from Colchester were analysed. The full compositional data is listed in Table 1, together with a description of the glass colour and the vessel type to which the fragment belongs.

The order in which the analyses are listed is the same order as that in which they were analysed. A batch of samples analysed by ICPS are run one after the other with a short gap between each analysis. Analytical conditions should therefore be identical for each analysis undertaken during a batch run. Any short term drift in machine conditions should be corrected by repeatedly analysing a multi-element standard during the run and correcting the other samples according to this standard. However the standard used does not include data for the rare earth elements which are present at very low levels in the solution. These elements are therefore not corrected for short-term machine drift. An analysis of the data obtained from the Colchester glass showed that some of the rare earth elements had a significant correlation with the sequence in which they were analysed (see Table 2). This effect was particularly noticeable for samarium (see Figure 1), though this element is present at levels close to the minimum detection limits for the analytical method.

It was therefore decided that any elements which correlated with the run number at a coefficient of higher than +0.4 would be ignored in any analysis of the data. This affected the elements Li, Nb, Ni, Ce, Nd, Sm, Eu, Dy, and the other rare earth elements, La and Yb, were also excluded from the data analysis as all the rare earth elements are highly correlated. Other trace elements (Co, Ni, Sc, V, Zn) that were present in the glass at very low levels and which did not vary significantly between samples were also excluded. None of these elements would have had a significant effect on the colour or working properties of the colourless glasses and it was felt that this would simplify the data analysis without any loss of information on potentially significant compositional variability.

## Data Analysis

The data analysis was undertaken using the MINITAB statistical computer package. The data for all the oxides/elements was converted to parts per million format so that all the numbers were directly comparable. The first stage of the data analysis was to simply investigate the structure of the data using single element dot plots to look for groups in the data and to identify any outliers in the data population. Eleven 'odd' analyses were identified which had unusual readings for one or more oxides/elements and these were excluded from any further data analysis (nos 209, 210, 211, 414, 417, 427, 435, 436, 463, 530, 534). Some of these specimens, such as nos 209-211, were highly distinctive and are discussed below. Others may have been contaminated at some stage of the analytical process. In all cases specimens were omitted from the statistical analysis because they would, predictably, have been identified as unusual and might have prevented the perception of structure in the bulk of the data. The single element dot plots were then repeated for the reduced data set (see Figure 2). The mean, standard deviation, maximum and minimum values were calculated for all the vessel glass and for each of the vessel glass groups individually (see Table 3). The dot plots identified two oxide/elements, manganese oxide and lead, which had particularly skewed distributions, and the mean values for each typological group suggested that these oxides/elements may be significant in discriminating between the groups. Further, more sophisticated, statistical analysis was then required to attempt to relate the levels of manganese oxide and lead to other oxides/elements within each typological group.

Multivariate statistical methods, such as cluster analysis and principal components analysis, are commonly used for compositional data and have been applied to glass analyses. These methods are usually applied to the raw, standardised or log transformed data. Recent studies have suggested that such methods may be inappropriate for compositional data of the kind used here (Aitchison 1986). The problems described by Aitchison are largely due to the fact that the total composition is constrained to sum to 100%. This invalidates some of the underlying assumptions of the methods often used, though it is not clear how far these criticisms apply to typical glass compositions given the relatively low levels of most constituents. These criticisms were taken into account when undertaking the statistical analysis of the Colchester glass data and several approaches to the data analysis were tried. Principal components analysis was carried out using both the correlation matrix of the raw data and data that had been transformed using Aitchison's approach. Correspondence analysis was also undertaken on the raw data and on the data after it had been divided through by the mean value for each oxide/element. It was then possible to compare the results of the different approaches to see if they led to any substantive differences in the interpretation of the glass data.

Exploration of the various statistical methods, including correspondence analysis (Baxter 1989; Baxter & Heyworth forthcoming), with particular reference to glass compositional data, has shown the potential of the various approaches for revealing different, though complementary, aspects of the data structure. It is therefore important to compare the results of the various analyses before a full interpretation of the data can be achieved. It is now possible to do this interactively using modern computer based statistical packages such as MINITAB.

Figures 3 to 6 show the results of the different statistical analyses. Initially a principal components analysis was undertaken using the correlation matrix of the raw data (Figure 3). This is a standard approach to the statistical analysis of compositional data, though it is subject to the Aitchison's criticism (if this is applicable to glass compositions). The data was then transformed following Aitchison's approach and a second principal components analysis carried out (Figure 4). Correspondence analysis was then undertaken firstly on the raw data (Figure 5), and secondly on data modified by dividing by the column means (Figure 6). Correspondence analysis can be viewed as a form of principal component analysis after suitable data transformation (Baxter and Heyworth forthcoming) and has been treated as such here.

Previous studies by Baxter and Heyworth (forthcoming) have shown that the methods used to produce Figures 3 and 5 could produce a similar pattern, however only twelve oxides were used in their analyses and the similarity between the methods was largely empirical. In this case, with the inclusion of the trace elements in the analysis, the methods do not produce particularly similar results. Figures 4 and 6 should show a similar pattern, for mathematical reasons, and there is some suggestion of this in the plots, particularly if Figure 6(b) is reflected about the horizontal axis.

Figures 4(a) - 6(a) suggest that Figures 4(b) - 6(b) are largely determined by values of lead and manganese oxide, both of which have skewed distributions with long tails and several extreme values relative to the main body of the data (see above). Silica and lead oxide, but not manganese oxide, influence Figure 3(b). In this last plot the effect of silica chiefly arises as a consequence of the methodological difficulties identified by Aitchison (1986). In general there are no signs that the variations shown in the Figures are significant in discriminating between the groups of glass that had been identified typologically. It would seem from these analyses that the typological groups do not form distinct compositional groups, though some distinct sub-groups within the data can be recognised which will be discussed in detail below.

## Discussion

It is usually hoped that compositional analysis of ancient glasses will reveal distinct groups that may relate to date or area of origin. However analyses of glass produced within the Roman Empire has shown that these glasses were usually of a similar broad compositional type (eg Sanderson et al 1983). The main components of the glass were silica, soda and lime with the majority of the other oxides and elements being added to the glass batch as accidental impurities in these main ingredients. The silica, which probably entered the glass in the form of sand, was the main glass former and the soda provided the alkali flux which enabled the materials to fuse together into a glass. It is usually assumed that the source of the soda used in early glass production was either the mineral evaporite natron or plants of the genus *Salicornia*. In Roman glass low levels of potassium, phosphorus and manganese may indicate that natron was used, though it has been suggested that plant sources may have been used which could produce similar compositional ratios in the final glass (Brill 1970). The lime (calcium oxide) content acted as a stabiliser in the glass network and reduced weathering, but it may not have been recognised as a necessary separate ingredient in ancient glass. The most likely source of lime in ancient glasses is from shell, though where high magnesia levels are present it may suggest the use of carbonate rock. In the Colchester glass it is likely that shell was the source of the lime which may have been contained in the sand.

The minor components of the glass are mostly at low levels and are likely to have entered the glass as impurities in the main ingredients. The exception to this is antimony which is significantly higher than would be expected as an impurity and is therefore likely to have been added deliberately to the glass to remove the colouration due to iron. The use of antimony as a decolouriser was widespread in Roman glasses in Europe (Sayre 1963). The addition of antimony would also have had the effect of making the glass flow more readily and reducing the number of air bubbles trapped in the matrix producing a higher quality finished product. In some samples the manganese level was significantly higher than the average level, particularly no. 456, but this supported rather than replaced the antimony as a decolouriser and may not have been deliberately added for this purpose. The manganese-containing glasses may indicate the use of cullet in the production of the vessels, ie the remelting of scraps of glass that already contained manganese.

As the glasses analysed were all of the same general composition they are likely to have originated within the same glass production tradition. However despite the lack of clear groups in the multivariate statistical analyses there were some trends in the data related to compositional differences between the typological groups which could be identified. The trends noted are largely related to the variation in levels of lead and manganese which were noted earlier. In particular all the analyses with a lead content of greater than 0.03% were in the three typologically earlier groups (cast, facet-cut or wheel- cut vessels) and most analyses with manganese oxide contents greater than 0.03% were in the wheel-cut vessel group. This leaves the later typological group, the cylindrical cups, with the most uniform composition. This trend is reflected in Figures 3(b) - 6(b) where the cylindrical cups tend to cluster together in the main group of points (unfortunately due to the scale of the figures the individual points are often overlapping and impossible to identify), though they are not entirely separated from the other groups. There is much more variation within the compositions of the three earlier typological groups and this explains the greater spread of samples from these groups in Figures 3(b) - 6(b).

The cast vessels in Group 1 are not particularly distinctive compositionally from the other groups. There were some fragments within the cast vessel group which had unusually high levels of single oxides/elements in relation to the rest of the group, particularly no. 225 with a high lead content and no. 222 with a high manganese content. These may be a result of the use of different raw materials, possibly accidentally introduced into the glass batch. The fragments which were included in the cast vessel group but which were unlikely to come from wide rimmed bowls were also compositionally distinct. The two fragments of the rare facet-cut variety, nos. 209 & 211, were very similar in composition and had particularly high lead and antimony contents in comparison to the other cast vessels. The fragment of a possible saucepan, no. 210, could be distinguished from the other cast vessels on the basis of higher magnesium, iron, titanium and manganese oxide levels which suggests either the use of cullet or, more likely, a difference in the raw materials used in its production.

The vessels from Group 2 were a mixture of those which had been facet-cut (nos. 395-406), relief-cut (no. 411) or had linear ground-out decoration (nos. 407-410). Although there was some variation with the group overall there does not seem to be any clear compositional difference between the different types of beaker. Two samples of facet-cut beaker (nos. 404 & 405) have a very similar composition, including high lead levels, yet are unlikely to come from the same vessel due to the difference in thickness between the two fragments. The two fragments have an identical style of decoration and are likely to have been produced at the same time from the same glass batch. The two fragments of facet-cut glass which were not externally ground (nos. 414 & 417) were reasonably similar to the vessels in this group, however overall the vessels within Group 2 seem to be the most variable compositionally.

The wheel-cut beakers contain several fragments which have unusually high levels of phosphorus and manganese oxide and it appears from their correlation that these may be entering the glass together which suggests the use of a plant alkali source. The fragments with wheel-cut lines that were included as part of this group cannot be distinguished from the other samples compositionally.

The cylindrical cups seem to contain two compositional groups with one group of 13 fragments having higher levels of minor elements. Overall the cylindrical cups are more consistent compositionally with no high lead levels and very few glasses containing significant levels of manganese.

## Conclusion

The analysis of the data from Colchester suggests that while the glass comes from the same production tradition, there were variations in the materials being used. No clear-cut distinctions exist between the typological groups but certain interesting trends do emerge. The first three groups which correspond to the early luxury glass (Groups 1 and 2) and the early blown drinking vessels (Group 3) show the widest variation in composition, and contain the highest levels of Pb and MnO. By contrast the cylindrical cups (Group 4), which are later, tend to have a more uniform composition with no example having high levels of Pb and very few having significant levels of MnO. Two working hypotheses can be suggested as provisional explanations for this.

The first hypothesis is that the variation reflects changes in working practices over time. The first 100 years of colourless glass production could be seen as a period of experiment when different recipes were in use, whereas by the later period the recipes had become more uniform. Alternatively the variations may reflect the different materials used by glasshouses in different parts of the Empire. It should be stressed that the precise locations of the glasshouses producing this material are not known. From the distributions of the vessel types, however, there does appear to be a major difference between Groups 1 and 2 and Group 4. The former are found throughout the Roman Empire, whereas the latter are only found in the north-west provinces. The greater variability seen in Groups 1 and 2 might therefore reflect production at glasshouses scattered over a wide geographical area probably centred on the Mediterranean. The more consistent composition of Group 4 would reflect production in the restricted geographical area of the north-west provinces. There is, of course, no reason why these two hypotheses need be mutually exclusive and elements of both might have contributed to the observed variability.

It is obvious that the chemical composition of this colourless glass is complex and that it is not easy to explain the variation archaeologically. It may be, for example, that some of the variation is due to inevitable, and uncontrollable, variation in the raw material used. On the other hand, there are some indications that such variation may be deliberately related to typology. In the cast vessels, for example, the fragments from the vessels that are most distinct typologically (nos. 209-211) are also the most distinct compositionally, and were excluded from the detailed statistical analysis because preliminary examination of the data showed them to be outliers. It should also be noted that Group 2, which is the most variable compositionally, contains a greater amount of internal typological variation than, for example, Groups 1 or 4. No clear compositional differences could be detected between the typological variants in this analysis, but it should be noted that it was often not possible to identify the precise variant a fragment came from.

These analyses have shown that there is a large amount of variability in the composition of first and second century colourless glass, but it seems that further work on such material would be valuable. Whilst it has not been possible from these analyses to establish a clear-cut link between composition and typology, there are grounds for thinking that this relationship might be elucidated by further work on carefully selected fragments. This will be particularly helpful in increasing our understanding of colourless glass production in the Roman period.

## Suggestions for further work

To assist in the interpretation of the compositional trends noted in this study, it would be beneficial to investigate similar colourless glasses from other sites in Roman Britain. In a sample drawn from a larger number of sites it would be possible to select fragments of particular typological variants in a manner that is not possible in an analysis where all the material comes from one town, as here. In such an analysis it should be easier to establish if there is any relationship between typology and composition, and it might also reveal if there is any compositional variation between fragments from the same typological variant found in different parts of the country.

We suggest that, in future, samples should be derived as follows:

Group 1 - plain and facet-cut rim fragments from cast, wide-rimmed bowls, both with and without an overhang at the edge of the rim (see for example Charlesworth 1975; Charlesworth 1974: Fig.29.1; Bushe-Fox 1914: 21, Fig. 12);

Group 2 - fragments from externally ground facet-cut beakers which can be assigned to one of the well-defined typological variants, for example those established by Oliver 1984;

Group 3 - fragments from cylindrical thin-walled beakers with pushed-in base rings (like that from Wroxeter: Bushe-Fox 1916: Pl.XXIII Fig.1), and fragments from carinated beakers with separately blown feet (like those from Harlow: Price 1987: Fig.2 nos. 8-10);

Group 4 - rim fragments from undecorated cylindrical cups from the classic Airlie type (Charlesworth 1959: Pl.I.4) and the variant with out-turned rim and trail on the upper body (Charlesworth 1959: Pl.II.1).

All of these types, with the exception of the facet-cut cast bowls, are widespread and relatively common on Romano-British sites and it should not be difficult to gather an adequate sample of each.

## Acknowledgements

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**Table 1**

**ICPS data**

The glass samples were analysed using inductively coupled plasma atomic emission spectrometry (ICPS) and data was obtained for 31 oxides/elements. The data from each analysis is divided into the major and minor oxides (listed as oxide weight percentages), minor elements (listed as weight percentages) and trace elements (listed as parts per million). The figure for silica is obtained by subtracting the total figure of the measured oxides/elements from 100%. Consequently the sum of the concentrations, including silica, is always exactly 100%.

The data is listed together with the fragment catalogue number (taken from Cool & Price, forthcoming), fragment colour and the type of vessel to which the fragment belongs. The glass colours and vessel types are coded as follows:

Colour code

C - Colourless
G/C - Green Tinged Colourless

Vessel type

C - Cast bowl
CY - Cylindrical cup
F - Facet-cut beaker
R - Relief-cut beaker
W - Wheel-cut beaker
W? - probable wheel-cut beaker

| | | 209 | 210 | 211 | 212 | 213 | 214 |
|---|---|---|---|---|---|---|---|
| Number | | 209 | 210 | 211 | 212 | 213 | 214 |
| Colour | | C | G/C | C | C | C | C |
| Vessel type | | C | C | C | C | C | C |
| $Al_2O_3$ | (%) | 1.29 | 2.09 | 1.32 | 1.87 | 1.80 | 2.02 |
| $Fe_2O_3$ | (%) | .32 | .56 | .37 | .27 | .25 | .28 |
| MgO | (%) | .40 | .80 | .40 | .44 | .42 | .44 |
| CaO | (%) | 3.85 | 6.51 | 3.83 | 5.87 | 5.28 | 4.60 |
| $Na_2O$ | (%) | 18.6 | 20.8 | 17.4 | 19.0 | 18.6 | 17.9 |
| $K_2O$ | (%) | .68 | .52 | .66 | .45 | .43 | .50 |
| $TiO_2$ | (%) | .04 | .13 | .06 | .07 | .05 | .06 |
| $P_2O_5$ | (%) | .04 | .06 | .05 | .04 | .04 | .04 |
| MnO | (%) | .03 | .21 | .03 | .01 | .01 | .01 |
| Pb | (%) | .54 | .01 | .56 | .01 | .01 | .01 |
| Sb | (%) | .93 | .68 | 1.76 | .53 | .34 | .22 |
| Ba | (ppm) | 74 | 149 | 81 | 145 | 134 | 146 |
| Co | (ppm) | 6 | 8 | 5 | 7 | 7 | 6 |
| Cr | (ppm) | 10 | 20 | 11 | 13 | 11 | 10 |
| Cu | (ppm) | 22 | 21 | 26 | 8 | 8 | 6 |
| Li | (ppm) | 0 | 5 | 3 | 1 | 2 | 2 |
| Nb | (ppm) | 1 | 1 | 2 | 1 | 0 | 0 |
| Ni | (ppm) | 10 | 15 | 13 | 10 | 10 | 8 |
| Sc | (ppm) | 1 | 2 | 1 | 1 | 1 | 1 |
| Sr | (ppm) | 294 | 309 | 295 | 425 | 393 | 294 |
| V | (ppm) | 4 | 15 | 7 | 8 | 5 | 6 |
| Y | (ppm) | 5 | 8 | 5 | 7 | 6 | 6 |
| Zn | (ppm) | 15 | 17 | 20 | 15 | 12 | 11 |
| Zr | (ppm) | 18 | 77 | 36 | 38 | 29 | 39 |
| La | (ppm) | 11 | 13 | 11 | 12 | 12 | 12 |
| Ce | (ppm) | 14 | 16 | 14 | 12 | 11 | 11 |
| Nd | (ppm) | 20 | 21 | 21 | 19 | 19 | 19 |
| Sm | (ppm) | 2.3 | 3.0 | 2.1 | 1.9 | 1.4 | 1.1 |
| Eu | (ppm) | .3 | .4 | .3 | .3 | .3 | .3 |
| Dy | (ppm) | 1.1 | 1.6 | 1.1 | 1.1 | .9 | .8 |
| Yb | (ppm) | .6 | .9 | .6 | .6 | .5 | .5 |
| $SiO_2$ | (%) | 73.2 | 67.6 | 73.5 | 71.4 | 72.7 | 73.9 |

| Number | | 215 | 216 | 217 | 218 | 219 | 220 |
|---|---|---|---|---|---|---|---|
| Colour | | C | C | C | C | C | C |
| Vessel type | | C | C | C | C | C | C |
| $Al_2O_3$ | (%) | 2.08 | 2.01 | 1.92 | 1.96 | 1.97 | 1.86 |
| $Fe_2O_3$ | (%) | .43 | .35 | .38 | .32 | .27 | .32 |
| MgO | (%) | .51 | .49 | .52 | .49 | .40 | .48 |
| CaO | (%) | 4.34 | 5.76 | 6.00 | 7.14 | 5.04 | 7.67 |
| $Na_2O$ | (%) | 18.7 | 20.5 | 20.0 | 19.8 | 18.6 | 18.6 |
| $K_2O$ | (%) | .52 | .61 | .50 | .44 | .52 | .42 |
| $TiO_2$ | (%) | .12 | .07 | .09 | .05 | .05 | .06 |
| $P_2O_5$ | (%) | .05 | .05 | .05 | .05 | .04 | .05 |
| MnO | (%) | .01 | .01 | .02 | .01 | .01 | .01 |
| Pb | (%) | .01 | .07 | .12 | .02 | .11 | .01 |
| Sb | (%) | .39 | .34 | .41 | .46 | .29 | .40 |
| Ba | (ppm) | 140 | 144 | 136 | 128 | 141 | 126 |
| Co | (ppm) | 7 | 7 | 7 | 7 | 6 | 7 |
| Cr | (ppm) | 14 | 11 | 14 | 12 | 14 | 12 |
| Cu | (ppm) | 10 | 12 | 12 | 13 | 9 | 4 |
| Li | (ppm) | 1 | 4 | 1 | 0 | 1 | 1 |
| Nb | (ppm) | 0 | 0 | 0 | 0 | 0 | 0 |
| Ni | (ppm) | 10 | 11 | 11 | 10 | 7 | 10 |
| Sc | (ppm) | 1 | 1 | 1 | 1 | 1 | 1 |
| Sr | (ppm) | 357 | 433 | 529 | 698 | 366 | 715 |
| V | (ppm) | 9 | 6 | 8 | 5 | 5 | 6 |
| Y | (ppm) | 7 | 7 | 7 | 7 | 6 | 7 |
| Zn | (ppm) | 19 | 18 | 16 | 16 | 12 | 12 |
| Zr | (ppm) | 62 | 36 | 52 | 35 | 32 | 28 |
| La | (ppm) | 13 | 13 | 12 | 13 | 12 | 12 |
| Ce | (ppm) | 12 | 12 | 12 | 12 | 10 | 12 |
| Nd | (ppm) | 20 | 18 | 19 | 18 | 19 | 16 |
| Sm | (ppm) | 1.2 | 1.4 | 1.4 | 1.4 | 1.0 | 1.4 |
| Eu | (ppm) | .3 | .3 | .3 | .3 | .3 | .3 |
| Dy | (ppm) | .9 | .9 | 1.0 | 1.0 | .7 | 1.0 |
| Yb | (ppm) | .6 | .6 | .6 | .6 | .7 | .7 |
| $SiO_2$ | (%) | 72.8 | 69.7 | 69.9 | 69.2 | 72.6 | 70.0 |

| Number | | 221 | 222 | 223 | 224 | 225 | 226 |
|---|---|---|---|---|---|---|---|
| Colour | | G/C | C | C | C | C | C |
| Vessel type | | C | C | C | C | C | C |
| $Al_2O_3$ | (%) | 2.05 | 1.54 | 1.93 | 1.74 | 1.74 | 1.83 |
| $Fe_2O_3$ | (%) | .32 | .40 | .33 | .38 | .51 | .26 |
| MgO | (%) | .46 | .45 | .44 | .53 | .57 | .41 |
| CaO | (%) | 5.45 | 3.85 | 6.19 | 5.24 | 6.10 | 4.97 |
| $Na_2O$ | (%) | 17.6 | 17.8 | 19.8 | 17.6 | 19.7 | 18.2 |
| $K_2O$ | (%) | .50 | .84 | .45 | .91 | .52 | .48 |
| $TiO_2$ | (%) | .07 | .06 | .05 | .05 | .09 | .06 |
| $P_2O_5$ | (%) | .05 | .06 | .04 | .06 | .05 | .05 |
| MnO | (%) | .01 | .11 | .01 | .02 | .02 | .01 |
| Pb | (%) | .00 | .02 | .01 | .01 | .34 | .01 |
| Sb | (%) | .26 | .86 | .37 | .42 | .31 | .29 |
| Ba | (ppm) | 146 | 95 | 140 | 106 | 98 | 143 |
| Co | (ppm) | 6 | 6 | 7 | 6 | 7 | 6 |
| Cr | (ppm) | 11 | 14 | 11 | 11 | 17 | 9 |
| Cu | (ppm) | 7 | 25 | 7 | 10 | 13 | 6 |
| Li | (ppm) | 3 | 0 | 0 | 2 | 2 | 1 |
| Nb | (ppm) | 0 | 0 | 0 | 0 | 0 | 0 |
| Ni | (ppm) | 10 | 10 | 10 | 11 | 12 | 10 |
| Sc | (ppm) | 1 | 1 | 1 | 1 | 2 | 1 |
| Sr | (ppm) | 328 | 223 | 422 | 273 | 442 | 312 |
| V | (ppm) | 6 | 6 | 5 | 5 | 7 | 6 |
| Y | (ppm) | 8 | 6 | 7 | 7 | 7 | 6 |
| Zn | (ppm) | 14 | 14 | 14 | 14 | 16 | 12 |
| Zr | (ppm) | 40 | 18 | 37 | 21 | 33 | 33 |
| La | (ppm) | 18 | 11 | 12 | 13 | 13 | 12 |
| Ce | (ppm) | 21 | 10 | 12 | 13 | 13 | 10 |
| Nd | (ppm) | 21 | 20 | 18 | 19 | 19 | 18 |
| Sm | (ppm) | 1.9 | 1.1 | 1.4 | 1.3 | 1.5 | 1.0 |
| Eu | (ppm) | .3 | .3 | .3 | .3 | .3 | .3 |
| Dy | (ppm) | 1.1 | .8 | .9 | 1.0 | 1.1 | .8 |
| Yb | (ppm) | .6 | .6 | .6 | .7 | .7 | .5 |
| $SiO_2$ | (%) | 73.2 | 74.0 | 70.3 | 73.0 | 70.0 | 73.4 |

| Number | | 227 | 228 | 230 | 395 | 396 | 397 |
|---|---|---|---|---|---|---|---|
| Colour | | C | C | C | C | C | C |
| Vessel type | | C | C | C | F | F | F |
| $Al_2O_3$ | (%) | 1.84 | 1.97 | 1.81 | 1.91 | 2.34 | 1.78 |
| $Fe_2O_3$ | (%) | .26 | .26 | .26 | .26 | .24 | .18 |
| MgO | (%) | .43 | .37 | .41 | .34 | .44 | .28 |
| CaO | (%) | 5.76 | 5.01 | 4.81 | 4.99 | 7.13 | 4.39 |
| $Na_2O$ | (%) | 18.7 | 17.1 | 16.9 | 17.9 | 14.9 | 16.5 |
| $K_2O$ | (%) | .45 | .49 | .50 | .49 | .62 | .40 |
| $TiO_2$ | (%) | .05 | .06 | .06 | .06 | .04 | .03 |
| $P_2O_5$ | (%) | .04 | .04 | .05 | .04 | .05 | .03 |
| MnO | (%) | .01 | .01 | .01 | .01 | .01 | .00 |
| Pb | (%) | .01 | .02 | .00 | .11 | .01 | .06 |
| Sb | (%) | .24 | .27 | .41 | .43 | .37 | .37 |
| Ba | (ppm) | 138 | 144 | 143 | 144 | 163 | 123 |
| Co | (ppm) | 7 | 6 | 6 | 4 | 6 | 6 |
| Cr | (ppm) | 11 | 10 | 10 | 11 | 13 | 10 |
| Cu | (ppm) | 8 | 7 | 11 | 10 | 6 | 5 |
| Li | (ppm) | 1 | 1 | 1 | 1 | 1 | 0 |
| Nb | (ppm) | 0 | 0 | 0 | 0 | 0 | 0 |
| Ni | (ppm) | 8 | 8 | 11 | 10 | 10 | 9 |
| Sc | (ppm) | 1 | 1 | 1 | 1 | 1 | 1 |
| Sr | (ppm) | 417 | 347 | 306 | 322 | 386 | 280 |
| V | (ppm) | 5 | 5 | 7 | 5 | 4 | 3 |
| Y | (ppm) | 7 | 6 | 6 | 7 | 9 | 6 |
| Zn | (ppm) | 11 | 11 | 15 | 12 | 11 | 8 |
| Zr | (ppm) | 25 | 32 | 35 | 30 | 24 | 17 |
| La | (ppm) | 13 | 11 | 11 | 12 | 14 | 12 |
| Ce | (ppm) | 13 | 11 | 11 | 11 | 15 | 11 |
| Nd | (ppm) | 19 | 18 | 19 | 19 | 19 | 20 |
| Sm | (ppm) | 1.5 | 1.1 | 1.1 | 1.2 | 2.0 | 1.2 |
| Eu | (ppm) | .3 | .3 | .3 | .3 | .4 | .3 |
| Dy | (ppm) | .9 | .7 | .8 | .9 | 1.2 | .9 |
| Yb | (ppm) | .6 | .5 | .5 | .6 | .7 | .6 |
| $SiO_2$ | (%) | 72.1 | 74.3 | 74.7 | 73.4 | 73.8 | 75.9 |

| Number | | 400 | 401 | 402 | 403 | 404 | 405 |
|---|---|---|---|---|---|---|---|
| Colour | | C | C | C | C | C | C |
| Vessel type | | F | F | F | F | F | F |
| $Al_2O_3$ | (%) | 2.00 | 1.93 | 2.36 | 1.88 | 1.89 | 2.04 |
| $Fe_2O_3$ | (%) | .37 | .24 | .22 | .25 | .20 | .22 |
| MgO | (%) | .54 | .34 | .46 | .34 | .28 | .30 |
| CaO | (%) | 6.74 | 5.12 | 7.19 | 4.83 | 4.96 | 5.01 |
| $Na_2O$ | (%) | 19.8 | 18.7 | 16.5 | 17.6 | 16.8 | 16.6 |
| $K_2O$ | (%) | .51 | .41 | .63 | .41 | .41 | .43 |
| $TiO_2$ | (%) | .07 | .04 | .04 | .06 | .03 | .04 |
| $P_2O_5$ | (%) | .06 | .04 | .05 | .04 | .04 | .04 |
| MnO | (%) | .02 | .01 | .01 | .01 | .01 | .01 |
| Pb | (%) | .01 | .00 | .01 | .07 | .43 | .44 |
| Sb | (%) | .43 | .33 | .37 | .25 | .37 | .44 |
| Ba | (ppm) | 140 | 137 | 162 | 138 | 141 | 152 |
| Co | (ppm) | 8 | 6 | 8 | 6 | 7 | 5 |
| Cr | (ppm) | 13 | 9 | 13 | 11 | 10 | 9 |
| Cu | (ppm) | 9 | 4 | 5 | 8 | 6 | 7 |
| Li | (ppm) | 2 | 1 | 1 | 1 | 0 | 0 |
| Nb | (ppm) | 1 | 0 | 1 | 0 | 0 | 0 |
| Ni | (ppm) | 11 | 12 | 11 | 8 | 11 | 9 |
| Sc | (ppm) | 1 | 1 | 1 | 1 | 1 | 1 |
| Sr | (ppm) | 516 | 345 | 478 | 293 | 344 | 366 |
| V | (ppm) | 7 | 4 | 5 | 5 | 4 | 4 |
| Y | (ppm) | 7 | 7 | 8 | 6 | 6 | 6 |
| Zn | (ppm) | 17 | 9 | 9 | 15 | 12 | 13 |
| Zr | (ppm) | 39 | 20 | 17 | 29 | 22 | 20 |
| La | (ppm) | 13 | 12 | 13 | 12 | 12 | 12 |
| Ce | (ppm) | 12 | 12 | 14 | 13 | 14 | 11 |
| Nd | (ppm) | 18 | 19 | 19 | 21 | 20 | 19 |
| Sm | (ppm) | 1.6 | 1.4 | 2.3 | 2.1 | 2.1 | 1.4 |
| Eu | (ppm) | .4 | .4 | .4 | .4 | .4 | .4 |
| Dy | (ppm) | 1.0 | .9 | 1.3 | 1.1 | 1.1 | .9 |
| Yb | (ppm) | .7 | .6 | .7 | .6 | .6 | .5 |
| $SiO_2$ | (%) | 69.4 | 72.8 | 72.1 | 74.2 | 74.5 | 74.4 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Number | | 406 | 407 | 408 | 409 | 410 | 411 |
| Colour | | C | C | C | C | C | C |
| Vessel type | | F | F | F | F | F | R |
| $Al_2O_3$ | (%) | 2.07 | 1.89 | 2.15 | 2.02 | 1.90 | 2.38 |
| $Fe_2O_3$ | (%) | .22 | .29 | .37 | .24 | .31 | .37 |
| MgO | (%) | .33 | .51 | .44 | .30 | .48 | .42 |
| CaO | (%) | 4.97 | 6.55 | 5.14 | 5.16 | 6.38 | 5.26 |
| $Na_2O$ | (%) | 18.7 | 19.0 | 17.6 | 17.9 | 18.7 | 18.2 |
| $K_2O$ | (%) | .55 | .49 | .58 | .46 | .56 | .51 |
| $TiO_2$ | (%) | .03 | .06 | .06 | .03 | .07 | .07 |
| $P_2O_5$ | (%) | .04 | .04 | .05 | .04 | .05 | .04 |
| MnO | (%) | .01 | .01 | .03 | .01 | .01 | .02 |
| Pb | (%) | .12 | .02 | .01 | .51 | .01 | .01 |
| Sb | (%) | .55 | .32 | .52 | .21 | .33 | .45 |
| Ba | (ppm) | 145 | 142 | 133 | 142 | 140 | 156 |
| Co | (ppm) | 5 | 8 | 6 | 6 | 8 | 5 |
| Cr | (ppm) | 9 | 13 | 16 | 13 | 13 | 17 |
| Cu | (ppm) | 6 | 10 | 6 | 6 | 9 | 6 |
| Li | (ppm) | 1 | 2 | 1 | 1 | 2 | 1 |
| Nb | (ppm) | 0 | 0 | 0 | 0 | 0 | 0 |
| Ni | (ppm) | 9 | 10 | 11 | 8 | 11 | 12 |
| Sc | (ppm) | 1 | 1 | 1 | 1 | 1 | 1 |
| Sr | (ppm) | 351 | 464 | 248 | 360 | 430 | 254 |
| V | (ppm) | 3 | 6 | 6 | 4 | 7 | 6 |
| Y | (ppm) | 6 | 7 | 7 | 7 | 7 | 7 |
| Zn | (ppm) | 10 | 16 | 13 | 8 | 18 | 29 |
| Zr | (ppm) | 24 | 28 | 47 | 21 | 33 | 43 |
| La | (ppm) | 12 | 12 | 12 | 12 | 12 | 12 |
| Ce | (ppm) | 11 | 12 | 12 | 14 | 12 | 14 |
| Nd | (ppm) | 20 | 18 | 19 | 20 | 18 | 19 |
| Sm | (ppm) | 1.4 | 1.7 | 1.8 | 2.0 | 1.7 | 2.1 |
| Eu | (ppm) | .4 | .3 | .3 | .3 | .3 | .3 |
| Dy | (ppm) | .9 | 1.0 | 1.0 | 1.0 | 1.1 | 1.1 |
| Yb | (ppm) | .6 | .6 | .7 | .6 | .7 | .7 |
| $SiO_2$ | (%) | 72.3 | 70.7 | 73.0 | 73.1 | 71.1 | 72.2 |

| | | 414 | 417 | 426 | 427 | 428 | 429 |
|---|---|---|---|---|---|---|---|
| Number | | 414 | 417 | 426 | 427 | 428 | 429 |
| Colour | | G/C | C | C | C | C | C |
| Vessel type | | F | F | W | W | W | W |
| $Al_2O_3$ | (%) | 1.94 | 1.27 | 1.85 | 2.28 | 2.24 | 1.80 |
| $Fe_2O_3$ | (%) | .36 | .36 | .29 | .50 | .46 | .28 |
| MgO | (%) | .46 | .43 | .46 | .57 | .64 | .47 |
| CaO | (%) | 6.08 | 4.90 | 6.88 | 5.84 | 8.35 | 6.36 |
| $Na_2O$ | (%) | 18.6 | 16.8 | 18.6 | 20.3 | 18.7 | 18.1 |
| $K_2O$ | (%) | .44 | .60 | .47 | .69 | .55 | .46 |
| $TiO_2$ | (%) | .08 | .07 | .07 | .12 | .09 | .06 |
| $P_2O_5$ | (%) | .05 | .07 | .05 | .11 | .07 | .05 |
| MnO | (%) | .01 | .02 | .01 | .40 | .01 | .01 |
| Pb | (%) | .01 | .00 | .22 | .05 | .01 | .01 |
| Sb | (%) | .41 | .77 | .26 | .43 | .50 | .33 |
| Ba | (ppm) | 127 | 74 | 140 | 199 | 148 | 135 |
| Co | (ppm) | 6 | 5 | 7 | 9 | 9 | 7 |
| Cr | (ppm) | 13 | 13 | 13 | 18 | 17 | 12 |
| Cu | (ppm) | 13 | 10 | 24 | 69 | 8 | 10 |
| Li | (ppm) | 3 | 1 | 4 | 5 | 3 | 3 |
| Nb | (ppm) | 1 | 0 | 1 | 1 | 0 | 1 |
| Ni | (ppm) | 13 | 8 | 12 | 19 | 16 | 10 |
| Sc | (ppm) | 1 | 1 | 1 | 1 | 2 | 1 |
| Sr | (ppm) | 475 | 289 | 487 | 401 | 606 | 441 |
| V | (ppm) | 7 | 7 | 7 | 18 | 10 | 7 |
| Y | (ppm) | 8 | 6 | 7 | 8 | 10 | 7 |
| Zn | (ppm) | 24 | 13 | 13 | 27 | 33 | 15 |
| Zr | (ppm) | 36 | 22 | 31 | 61 | 41 | 26 |
| La | (ppm) | 16 | 12 | 12 | 14 | 18 | 12 |
| Ce | (ppm) | 19 | 12 | 13 | 17 | 26 | 13 |
| Nd | (ppm) | 21 | 19 | 18 | 20 | 20 | 18 |
| Sm | (ppm) | 2.3 | 1.4 | 2.0 | 2.4 | 3.7 | 2.1 |
| Eu | (ppm) | .4 | .3 | .4 | .4 | .5 | .3 |
| Dy | (ppm) | 1.3 | .9 | 1.2 | 1.6 | 1.7 | 1.1 |
| Yb | (ppm) | .7 | .6 | .7 | .8 | .8 | .6 |
| $SiO_2$ | (%) | 71.5 | 74.7 | 70.8 | 68.6 | 68.3 | 72.0 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Number | | 430 | 431 | 432 | 433 | 435 | 436 |
| Colour | | C | C | C | C | C | C |
| Vessel type | | W | W | W | W | W | W |
| $Al_2O_3$ | (%) | 1.75 | 1.87 | 1.89 | 1.87 | 2.21 | 1.98 |
| $Fe_2O_3$ | (%) | .26 | .30 | .30 | .25 | .38 | .31 |
| MgO | (%) | .39 | .49 | .49 | .42 | .51 | .43 |
| CaO | (%) | 5.15 | 6.53 | 6.32 | 5.29 | 5.75 | 5.54 |
| $Na_2O$ | (%) | 17.3 | 19.4 | 19.0 | 17.8 | 18.9 | 17.1 |
| $K_2O$ | (%) | .39 | .52 | .52 | .47 | .64 | .75 |
| $TiO_2$ | (%) | .07 | .06 | .06 | .05 | .10 | .07 |
| $P_2O_5$ | (%) | .06 | .05 | .05 | .05 | .10 | .04 |
| MnO | (%) | .01 | .01 | .01 | .01 | .42 | .01 |
| Pb | (%) | .01 | .02 | .02 | .01 | .02 | .01 |
| Sb | (%) | .31 | .35 | .30 | .31 | .38 | .30 |
| Ba | (ppm) | 137 | 142 | 142 | 151 | 201 | 1259 |
| Co | (ppm) | 7 | 8 | 7 | 7 | 9 | 7 |
| Cr | (ppm) | 12 | 14 | 12 | 11 | 15 | 12 |
| Cu | (ppm) | 6 | 9 | 9 | 11 | 20 | 9 |
| Li | (ppm) | 3 | 2 | 1 | 2 | 4 | 2 |
| Nb | (ppm) | 0 | 1 | 0 | 0 | 2 | 0 |
| Ni | (ppm) | 11 | 14 | 11 | 11 | 17 | 12 |
| Sc | (ppm) | 1 | 1 | 1 | 1 | 1 | 1 |
| Sr | (ppm) | 319 | 435 | 436 | 363 | 391 | 350 |
| V | (ppm) | 7 | 7 | 7 | 5 | 16 | 7 |
| Y | (ppm) | 7 | 7 | 7 | 7 | 18 | 7 |
| Zn | (ppm) | 14 | 15 | 14 | 15 | 20 | 12 |
| Zr | (ppm) | 31 | 29 | 25 | 23 | 51 | 31 |
| La | (ppm) | 12 | 12 | 12 | 12 | 13 | 12 |
| Ce | (ppm) | 13 | 13 | 12 | 11 | 13 | 12 |
| Nd | (ppm) | 20 | 18 | 18 | 19 | 19 | 20 |
| Sm | (ppm) | 1.8 | 2.1 | 1.5 | 1.0 | 1.8 | 1.8 |
| Eu | (ppm) | .3 | .4 | .3 | .3 | .3 | .3 |
| Dy | (ppm) | 1.1 | 1.2 | 1.0 | .8 | 2.4 | 1.1 |
| Yb | (ppm) | .6 | .7 | .6 | .5 | 2.9 | .6 |
| $SiO_2$ | (%) | 74.2 | 70.3 | 71.0 | 73.4 | 70.5 | 73.3 |

| Number | | 437 | 438 | 439 | 442 | 446 | 447 |
|---|---|---|---|---|---|---|---|
| Colour | | C | C | C | C | C | C |
| Vessel type | | W | W | W | W | W | W |
| $Al_2O_3$ | (%) | 1.99 | 1.94 | 1.66 | 2.01 | 2.46 | 2.10 |
| $Fe_2O_3$ | (%) | .39 | .32 | .24 | .37 | .30 | .47 |
| MgO | (%) | .49 | .46 | .36 | .48 | .45 | .60 |
| CaO | (%) | 5.94 | 5.97 | 5.99 | 6.04 | 7.91 | 7.13 |
| $Na_2O$ | (%) | 18.4 | 20.2 | 17.9 | 19.2 | 15.4 | 19.8 |
| $K_2O$ | (%) | .61 | .52 | .41 | .63 | .77 | .54 |
| $TiO_2$ | (%) | .09 | .07 | .05 | .08 | .07 | .12 |
| $P_2O_5$ | (%) | .06 | .07 | .04 | .06 | .17 | .07 |
| MnO | (%) | .08 | .27 | .01 | .08 | .07 | .10 |
| Pb | (%) | .05 | .01 | .29 | .05 | .01 | .06 |
| Sb | (%) | .67 | .24 | .26 | .49 | .57 | .77 |
| Ba | (ppm) | 146 | 187 | 128 | 145 | 182 | 150 |
| Co | (ppm) | 7 | 8 | 6 | 8 | 9 | 9 |
| Cr | (ppm) | 15 | 13 | 11 | 14 | 18 | 18 |
| Cu | (ppm) | 15 | 15 | 8 | 14 | 6 | 15 |
| Li | (ppm) | 3 | 4 | 1 | 1 | 2 | 5 |
| Nb | (ppm) | 0 | 0 | 0 | 1 | 0 | 2 |
| Ni | (ppm) | 14 | 13 | 11 | 11 | 14 | 15 |
| Sc | (ppm) | 1 | 1 | 1 | 1 | 1 | 1 |
| Sr | (ppm) | 523 | 389 | 378 | 529 | 386 | 556 |
| V | (ppm) | 10 | 11 | 5 | 9 | 9 | 13 |
| Y | (ppm) | 8 | 7 | 7 | 8 | 9 | 8 |
| Zn | (ppm) | 22 | 21 | 13 | 18 | 15 | 24 |
| Zr | (ppm) | 54 | 30 | 18 | 48 | 29 | 68 |
| La | (ppm) | 13 | 13 | 13 | 12 | 12 | 13 |
| Ce | (ppm) | 13 | 12 | 13 | 14 | 14 | 14 |
| Nd | (ppm) | 20 | 19 | 19 | 20 | 17 | 19 |
| Sm | (ppm) | 1.8 | 1.8 | 1.9 | 2.1 | 2.3 | 2.1 |
| Eu | (ppm) | .3 | .3 | .3 | .4 | .4 | .4 |
| Dy | (ppm) | 1.2 | 1.2 | 1.1 | 1.2 | 1.4 | 1.3 |
| Yb | (ppm) | 1.0 | .7 | .6 | .7 | .8 | .7 |
| $SiO_2$ | (%) | 71.1 | 69.9 | 72.7 | 70.4 | 71.7 | 68.1 |

| Number | | 448 | 449 | 450 | 451 | 452 | 453 |
|---|---|---|---|---|---|---|---|
| Colour | | C | C | C | C | C | C |
| Vessel type | | W | W | W | W? | W? | W? |
| $Al_2O_3$ | (%) | 1.74 | 2.09 | 1.98 | 1.80 | 2.18 | 1.89 |
| $Fe_2O_3$ | (%) | .20 | .42 | .37 | .29 | .48 | .37 |
| MgO | (%) | .27 | .51 | .49 | .47 | .51 | .46 |
| CaO | (%) | 4.16 | 5.94 | 5.99 | 7.20 | 5.42 | 5.17 |
| $Na_2O$ | (%) | 17.3 | 17.6 | 19.0 | 18.0 | 18.2 | 17.1 |
| $K_2O$ | (%) | .45 | .63 | .61 | .50 | .74 | .49 |
| $TiO_2$ | (%) | .03 | .11 | .08 | .07 | .12 | .10 |
| $P_2O_5$ | (%) | .03 | .13 | .06 | .05 | .13 | .05 |
| MnO | (%) | .01 | .27 | .08 | .01 | .29 | .01 |
| Pb | (%) | .27 | .06 | .05 | .23 | .11 | .13 |
| Sb | (%) | .40 | .56 | .45 | .22 | .56 | .33 |
| Ba | (ppm) | 129 | 180 | 143 | 139 | 182 | 137 |
| Co | (ppm) | 6 | 8 | 7 | 8 | 8 | 6 |
| Cr | (ppm) | 9 | 16 | 14 | 12 | 16 | 14 |
| Cu | (ppm) | 6 | 19 | 13 | 24 | 23 | 9 |
| Li | (ppm) | 0 | 4 | 3 | 2 | 6 | 3 |
| Nb | (ppm) | 0 | 1 | 0 | 1 | 0 | 0 |
| Ni | (ppm) | 10 | 15 | 13 | 13 | 16 | 12 |
| Sc | (ppm) | 1 | 1 | 1 | 1 | 1 | 1 |
| Sr | (ppm) | 288 | 407 | 524 | 521 | 402 | 368 |
| V | (ppm) | 3 | 16 | 8 | 8 | 16 | 8 |
| Y | (ppm) | 6 | 8 | 7 | 7 | 8 | 7 |
| Zn | (ppm) | 9 | 28 | 18 | 15 | 26 | 16 |
| Zr | (ppm) | 11 | 54 | 33 | 31 | 64 | 49 |
| La | (ppm) | 12 | 14 | 12 | 12 | 14 | 12 |
| Ce | (ppm) | 11 | 15 | 13 | 13 | 15 | 14 |
| Nd | (ppm) | 20 | 19 | 20 | 19 | 20 | 20 |
| Sm | (ppm) | 1.5 | 2.3 | 2.0 | 2.3 | 1.7 | 1.9 |
| Eu | (ppm) | .3 | .4 | .3 | .4 | .4 | .3 |
| Dy | (ppm) | 1.0 | 1.4 | 1.2 | 1.3 | 1.2 | 1.1 |
| Yb | (ppm) | .6 | .8 | .7 | .8 | .8 | .7 |
| $SiO_2$ | (%) | 75.1 | 71.6 | 70.8 | 71.1 | 71.2 | 73.8 |

| Number | | 454 | 455 | 456 | 460 | 462 | 463 |
|---|---|---|---|---|---|---|---|
| Colour | | C | C | C | C | C | C |
| Vessel type | | W? | W? | W? | W? | W? | W? |
| $Al_2O_3$ | (%) | 2.01 | 2.14 | 2.28 | 1.98 | 1.96 | 2.43 |
| $Fe_2O_3$ | (%) | .37 | .39 | .52 | .43 | .28 | .29 |
| MgO | (%) | .52 | .49 | .59 | .61 | .46 | .53 |
| CaO | (%) | 6.08 | 5.57 | 5.09 | 6.96 | 5.39 | 7.56 |
| $Na_2O$ | (%) | 18.9 | 18.2 | 18.1 | 18.4 | 18.1 | 14.2 |
| $K_2O$ | (%) | .59 | .56 | .78 | .65 | .57 | .56 |
| $TiO_2$ | (%) | .08 | .08 | .14 | .09 | .07 | .07 |
| $P_2O_5$ | (%) | .05 | .06 | .13 | .06 | .05 | .15 |
| MnO | (%) | .03 | .20 | .61 | .02 | .02 | 1.24 |
| Pb | (%) | .04 | .04 | .16 | .02 | .01 | .01 |
| Sb | (%) | .49 | .38 | .62 | .40 | .38 | .01 |
| Ba | (ppm) | 142 | 176 | 239 | 135 | 150 | 287 |
| Co | (ppm) | 7 | 8 | 10 | 8 | 7 | 12 |
| Cr | (ppm) | 14 | 14 | 20 | 15 | 13 | 18 |
| Cu | (ppm) | 14 | 16 | 21 | 13 | 10 | 13 |
| Li | (ppm) | 2 | 5 | 5 | 4 | 5 | 3 |
| Nb | (ppm) | 1 | 0 | 1 | 1 | 0 | 1 |
| Ni | (ppm) | 14 | 16 | 24 | 15 | 14 | 26 |
| Sc | (ppm) | 1 | 1 | 2 | 1 | 1 | 1 |
| Sr | (ppm) | 460 | 374 | 364 | 539 | 325 | 513 |
| V | (ppm) | 9 | 11 | 20 | 10 | 8 | 22 |
| Y | (ppm) | 7 | 8 | 8 | 8 | 7 | 9 |
| Zn | (ppm) | 21 | 20 | 29 | 25 | 23 | 25 |
| Zr | (ppm) | 47 | 48 | 71 | 52 | 41 | 32 |
| La | (ppm) | 12 | 13 | 14 | 13 | 12 | 12 |
| Ce | (ppm) | 14 | 15 | 18 | 15 | 14 | 15 |
| Nd | (ppm) | 19 | 20 | 22 | 19 | 20 | 19 |
| Sm | (ppm) | 2.3 | 2.4 | 2.7 | 2.5 | 2.2 | 2.7 |
| Eu | (ppm) | .4 | .4 | .4 | .4 | .3 | .5 |
| Dy | (ppm) | 1.2 | 1.4 | 1.8 | 1.4 | 1.2 | 2.6 |
| Yb | (ppm) | .7 | .8 | .9 | .8 | .7 | 1.0 |
| $SiO_2$ | (%) | 70.8 | 71.8 | 70.9 | 70.3 | 72.6 | 72.9 |

| | | 464 | 466 | 467 | 469 | 470 | 471 |
|---|---|---|---|---|---|---|---|
| Number | | 464 | 466 | 467 | 469 | 470 | 471 |
| Colour | | C | C | C | C | C | C |
| Vessel type | | W? | CY | CY | CY | CY | CY |
| $Al_2O_3$ | (%) | 1.91 | 1.84 | 1.80 | 2.08 | 2.23 | 2.16 |
| $Fe_2O_3$ | (%) | .31 | .26 | .28 | .40 | .41 | .35 |
| MgO | (%) | .48 | .47 | .46 | .57 | .60 | .51 |
| CaO | (%) | 5.09 | 5.00 | 5.89 | 6.33 | 6.10 | 5.66 |
| $Na_2O$ | (%) | 17.1 | 16.3 | 18.2 | 19.5 | 19.5 | 17.3 |
| $K_2O$ | (%) | .47 | .44 | .44 | .54 | .42 | .44 |
| $TiO_2$ | (%) | .07 | .06 | .06 | .09 | .08 | .07 |
| $P_2O_5$ | (%) | .05 | .04 | .04 | .06 | .05 | .05 |
| MnO | (%) | .01 | .01 | .01 | .03 | .01 | .01 |
| Pb | (%) | .01 | .01 | .01 | .01 | .01 | .01 |
| Sb | (%) | .33 | .36 | .33 | .44 | .34 | .37 |
| Ba | (ppm) | 146 | 138 | 134 | 138 | 141 | 146 |
| Co | (ppm) | 7 | 6 | 7 | 8 | 8 | 7 |
| Cr | (ppm) | 12 | 12 | 13 | 14 | 14 | 14 |
| Cu | (ppm) | 5 | 7 | 8 | 9 | 8 | 7 |
| Li | (ppm) | 3 | 3 | 3 | 4 | 3 | 3 |
| Nb | (ppm) | 0 | 1 | 1 | 1 | 1 | 1 |
| Ni | (ppm) | 11 | 10 | 15 | 16 | 12 | 15 |
| Sc | (ppm) | 1 | 1 | 1 | 1 | 1 | 1 |
| Sr | (ppm) | 304 | 303 | 386 | 374 | 358 | 353 |
| V | (ppm) | 8 | 6 | 7 | 8 | 8 | 7 |
| Y | (ppm) | 7 | 7 | 7 | 8 | 8 | 7 |
| Zn | (ppm) | 18 | 15 | 15 | 21 | 25 | 20 |
| Zr | (ppm) | 37 | 27 | 32 | 51 | 38 | 36 |
| La | (ppm) | 12 | 12 | 13 | 13 | 14 | 13 |
| Ce | (ppm) | 14 | 15 | 14 | 16 | 16 | 16 |
| Nd | (ppm) | 21 | 20 | 20 | 21 | 20 | 20 |
| Sm | (ppm) | 2.5 | 2.4 | 2.4 | 2.7 | 2.6 | 2.5 |
| Eu | (ppm) | .4 | .4 | .4 | .4 | .4 | .4 |
| Dy | (ppm) | 1.2 | 1.2 | 1.2 | 1.4 | 1.4 | 1.3 |
| Yb | (ppm) | .7 | .7 | .7 | .8 | .8 | .8 |
| $SiO_2$ | (%) | 74.1 | 75.2 | 72.4 | 69.9 | 70.2 | 73.0 |

| | | 472 | 473 | 474 | 475 | 476 | 478 |
|---|---|---|---|---|---|---|---|
| Number | | 472 | 473 | 474 | 475 | 476 | 478 |
| Colour | | C | C | C | C | C | C |
| Vessel type | | CY | CY | CY | CY | CY | CY |
| $Al_2O_3$ | (%) | 2.02 | 1.80 | 1.74 | 1.81 | 1.71 | 1.74 |
| $Fe_2O_3$ | (%) | .33 | .25 | .27 | .30 | .22 | .22 |
| MgO | (%) | .51 | .39 | .42 | .66 | .35 | .32 |
| CaO | (%) | 5.34 | 5.35 | 5.41 | 5.86 | 5.48 | 5.03 |
| $Na_2O$ | (%) | 16.5 | 17.1 | 16.8 | 17.6 | 16.3 | 16.8 |
| $K_2O$ | (%) | .52 | .44 | .49 | .40 | .42 | .43 |
| $TiO_2$ | (%) | .07 | .06 | .06 | .07 | .06 | .05 |
| $P_2O_5$ | (%) | .05 | .04 | .05 | .04 | .05 | .05 |
| MnO | (%) | .01 | .01 | .01 | .01 | .01 | .01 |
| Pb | (%) | .01 | .01 | .01 | .01 | .01 | .01 |
| Sb | (%) | .35 | .31 | .31 | .33 | .51 | .30 |
| Ba | (ppm) | 153 | 142 | 136 | 139 | 132 | 132 |
| Co | (ppm) | 8 | 6 | 6 | 7 | 7 | 6 |
| Cr | (ppm) | 12 | 12 | 11 | 12 | 10 | 10 |
| Cu | (ppm) | 6 | 6 | 9 | 9 | 11 | 5 |
| Li | (ppm) | 4 | 4 | 5 | 4 | 1 | 3 |
| Nb | (ppm) | 0 | 1 | 1 | 1 | 1 | 0 |
| Ni | (ppm) | 13 | 11 | 12 | 12 | 13 | 12 |
| Sc | (ppm) | 1 | 1 | 1 | 1 | 1 | 1 |
| Sr | (ppm) | 336 | 344 | 350 | 397 | 368 | 334 |
| V | (ppm) | 8 | 7 | 7 | 9 | 7 | 6 |
| Y | (ppm) | 7 | 7 | 7 | 7 | 7 | 7 |
| Zn | (ppm) | 19 | 20 | 18 | 19 | 15 | 12 |
| Zr | (ppm) | 35 | 34 | 32 | 36 | 31 | 22 |
| La | (ppm) | 12 | 12 | 12 | 13 | 12 | 12 |
| Ce | (ppm) | 14 | 16 | 15 | 14 | 15 | 15 |
| Nd | (ppm) | 20 | 22 | 21 | 20 | 20 | 21 |
| Sm | (ppm) | 2.3 | 2.8 | 2.6 | 2.8 | 2.5 | 2.8 |
| Eu | (ppm) | .4 | .4 | .4 | .4 | .4 | .5 |
| Dy | (ppm) | 1.2 | 1.3 | 1.4 | 1.3 | 1.3 | 1.3 |
| Yb | (ppm) | .7 | .7 | .7 | .7 | .7 | .7 |
| $SiO_2$ | (%) | 74.2 | 74.2 | 74.4 | 72.8 | 74.8 | 75.0 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Number | | 479 | 480 | 481 | 483 | 484 | 485 |
| Colour | | C | C | C | C | C | C |
| Vessel type | | CY | CY | CY | CY | CY | CY |
| $Al_2O_3$ | (%) | 1.93 | 1.94 | 1.74 | 1.88 | 2.23 | 1.90 |
| $Fe_2O_3$ | (%) | .31 | .30 | .25 | .30 | .42 | .29 |
| MgO | (%) | .42 | .44 | .37 | .40 | .56 | .41 |
| CaO | (%) | 4.94 | 6.31 | 5.90 | 4.76 | 6.65 | 5.13 |
| $Na_2O$ | (%) | 17.6 | 19.5 | 17.8 | 17.3 | 18.7 | 18.2 |
| $K_2O$ | (%) | .43 | .57 | .50 | .41 | .61 | .45 |
| $TiO_2$ | (%) | .05 | .07 | .06 | .05 | .09 | .05 |
| $P_2O_5$ | (%) | .04 | .05 | .05 | .04 | .06 | .04 |
| MnO | (%) | .01 | .01 | .01 | .01 | .02 | .01 |
| Pb | (%) | .01 | .01 | .01 | .01 | .01 | .01 |
| Sb | (%) | .38 | .39 | .53 | .48 | .35 | .31 |
| Ba | (ppm) | 141 | 139 | 135 | 140 | 152 | 144 |
| Co | (ppm) | 8 | 9 | 7 | 9 | 9 | 8 |
| Cr | (ppm) | 11 | 13 | 12 | 11 | 14 | 11 |
| Cu | (ppm) | 15 | 11 | 11 | 13 | 13 | 10 |
| Li | (ppm) | 2 | 4 | 4 | 1 | 4 | 4 |
| Nb | (ppm) | 1 | 1 | 1 | 1 | 1 | 1 |
| Ni | (ppm) | 17 | 12 | 15 | 11 | 13 | 11 |
| Sc | (ppm) | 1 | 1 | 1 | 1 | 1 | 1 |
| Sr | (ppm) | 307 | 542 | 479 | 289 | 482 | 312 |
| V | (ppm) | 6 | 7 | 7 | 6 | 10 | 7 |
| Y | (ppm) | 6 | 7 | 7 | 6 | 8 | 7 |
| Zn | (ppm) | 22 | 22 | 19 | 20 | 23 | 20 |
| Zr | (ppm) | 25 | 32 | 34 | 22 | 36 | 20 |
| La | (ppm) | 12 | 12 | 13 | 12 | 13 | 12 |
| Ce | (ppm) | 15 | 15 | 15 | 14 | 17 | 15 |
| Nd | (ppm) | 21 | 21 | 20 | 22 | 20 | 22 |
| Sm | (ppm) | 2.8 | 2.7 | 2.7 | 2.9 | 3.0 | 2.9 |
| Eu | (ppm) | .5 | .4 | .4 | .5 | .4 | .4 |
| Dy | (ppm) | 1.2 | 1.4 | 1.4 | 1.3 | 1.5 | 1.3 |
| Yb | (ppm) | .7 | .7 | .7 | .7 | .8 | .7 |
| $SiO_2$ | (%) | 73.8 | 70.3 | 72.7 | 74.3 | 70.2 | 73.1 |

| Number | | 486 | 487 | 488 | 489 | 490 | 492 |
|---|---|---|---|---|---|---|---|
| Colour | | C | C | C | C | C | C |
| Vessel type | | CY | CY | CY | CY | CY | CY |
| $Al_2O_3$ | (%) | 1.78 | 1.89 | 1.75 | 1.80 | 1.91 | 1.82 |
| $Fe_2O_3$ | (%) | .23 | .30 | .27 | .25 | .29 | .23 |
| MgO | (%) | .32 | .41 | .42 | .36 | .43 | .32 |
| CaO | (%) | 4.98 | 5.37 | 6.04 | 5.15 | 5.49 | 5.13 |
| $Na_2O$ | (%) | 18.1 | 17.8 | 19.0 | 17.9 | 19.2 | 18.4 |
| $K_2O$ | (%) | .45 | .42 | .41 | .45 | .48 | .46 |
| $TiO_2$ | (%) | .06 | .07 | .06 | .06 | .06 | .06 |
| $P_2O_5$ | (%) | .04 | .04 | .05 | .04 | .06 | .04 |
| MnO | (%) | .01 | .01 | .01 | .01 | .11 | .01 |
| Pb | (%) | .01 | .01 | .01 | .01 | .01 | .01 |
| Sb | (%) | .27 | .30 | .24 | .18 | .32 | .38 |
| Ba | (ppm) | 134 | 144 | 137 | 142 | 157 | 137 |
| Co | (ppm) | 7 | 7 | 7 | 7 | 6 | 6 |
| Cr | (ppm) | 11 | 12 | 11 | 11 | 13 | 11 |
| Cu | (ppm) | 5 | 10 | 9 | 9 | 14 | 6 |
| Li | (ppm) | 4 | 5 | 3 | 5 | 5 | 4 |
| Nb | (ppm) | 1 | 1 | 1 | 1 | 1 | 1 |
| Ni | (ppm) | 11 | 12 | 15 | 13 | 12 | 12 |
| Sc | (ppm) | 1 | 1 | 1 | 1 | 1 | 1 |
| Sr | (ppm) | 318 | 342 | 373 | 312 | 349 | 346 |
| V | (ppm) | 7 | 8 | 7 | 7 | 9 | 7 |
| Y | (ppm) | 7 | 7 | 7 | 7 | 7 | 7 |
| Zn | (ppm) | 13 | 15 | 15 | 16 | 21 | 13 |
| Zr | (ppm) | 28 | 35 | 35 | 31 | 29 | 29 |
| La | (ppm) | 12 | 12 | 12 | 12 | 12 | 12 |
| Ce | (ppm) | 16 | 16 | 14 | 15 | 15 | 15 |
| Nd | (ppm) | 21 | 21 | 20 | 21 | 21 | 21 |
| Sm | (ppm) | 3.1 | 3.0 | 2.7 | 2.7 | 3.0 | 2.9 |
| Eu | (ppm) | .5 | .4 | .4 | .4 | .4 | .5 |
| Dy | (ppm) | 1.4 | 1.4 | 1.4 | 1.3 | 1.5 | 1.4 |
| Yb | (ppm) | .7 | .7 | .7 | .7 | .7 | .7 |
| $SiO_2$ | (%) | 73.7 | 73.3 | 71.7 | 73.7 | 71.6 | 73.1 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Number | | 493 | 494 | 495 | 496 | 497 | 498 |
| Colour | | C | C | C | C | C | C |
| Vessel type | | CY | CY | CY | CY | CY | CY |
| $Al_2O_3$ | (%) | 1.90 | 2.03 | 2.11 | 2.11 | 1.96 | 1.78 |
| $Fe_2O_3$ | (%) | .27 | .38 | .42 | .39 | .30 | .26 |
| MgO | (%) | .44 | .51 | .59 | .56 | .50 | .42 |
| CaO | (%) | 5.48 | 7.02 | 6.53 | 6.18 | 5.58 | 5.48 |
| $Na_2O$ | (%) | 17.9 | 20.0 | 19.0 | 19.1 | 17.9 | 17.9 |
| $K_2O$ | (%) | .52 | .59 | .53 | .57 | .52 | .46 |
| $TiO_2$ | (%) | .07 | .07 | .08 | .07 | .07 | .06 |
| $P_2O_5$ | (%) | .05 | .06 | .06 | .05 | .05 | .05 |
| MnO | (%) | .01 | .02 | .03 | .02 | .02 | .01 |
| Pb | (%) | .01 | .01 | .01 | .01 | .01 | .01 |
| Sb | (%) | .28 | .40 | .33 | .37 | .28 | .36 |
| Ba | (ppm) | 154 | 135 | 138 | 144 | 152 | 142 |
| Co | (ppm) | 7 | 8 | 8 | 8 | 7 | 7 |
| Cr | (ppm) | 12 | 14 | 14 | 14 | 13 | 11 |
| Cu | (ppm) | 8 | 15 | 10 | 10 | 11 | 10 |
| Li | (ppm) | 3 | 4 | 3 | 3 | 3 | 3 |
| Nb | (ppm) | 1 | 2 | 2 | 1 | 1 | 1 |
| Ni | (ppm) | 11 | 16 | 14 | 16 | 16 | 12 |
| Sc | (ppm) | 1 | 1 | 1 | 1 | 1 | 1 |
| Sr | (ppm) | 341 | 553 | 379 | 425 | 375 | 353 |
| V | (ppm) | 8 | 8 | 9 | 8 | 8 | 8 |
| Y | (ppm) | 7 | 8 | 8 | 8 | 7 | 7 |
| Zn | (ppm) | 18 | 30 | 22 | 23 | 21 | 17 |
| Zr | (ppm) | 35 | 32 | 31 | 43 | 36 | 36 |
| La | (ppm) | 12 | 13 | 13 | 12 | 13 | 12 |
| Ce | (ppm) | 16 | 18 | 17 | 17 | 17 | 16 |
| Nd | (ppm) | 21 | 20 | 20 | 21 | 22 | 21 |
| Sm | (ppm) | 3.1 | 3.3 | 3.4 | 3.4 | 3.1 | 3.2 |
| Eu | (ppm) | .4 | .5 | .5 | .5 | .4 | .4 |
| Dy | (ppm) | 1.4 | 1.6 | 1.6 | 1.5 | 1.5 | 1.5 |
| Yb | (ppm) | .7 | .9 | .9 | .9 | .7 | .7 |
| $SiO_2$ | (%) | 73.0 | 68.8 | 70.2 | 70.5 | 72.7 | 73.1 |

| Number | | 499 | 500 | 501 | 503 | 504 | 507 |
|---|---|---|---|---|---|---|---|
| Colour | | C | C | C | C | C | C |
| Vessel type | | CY | CY | CY | CY | CY | CY |
| $Al_2O_3$ | (%) | 2.21 | 2.25 | 1.94 | 1.94 | 2.02 | 1.90 |
| $Fe_2O_3$ | (%) | .45 | .43 | .31 | .26 | .31 | .26 |
| MgO | (%) | .54 | .54 | .44 | .46 | .45 | .46 |
| CaO | (%) | 6.87 | 6.77 | 5.35 | 5.07 | 5.98 | 5.04 |
| $Na_2O$ | (%) | 19.4 | 18.7 | 18.8 | 17.0 | 19.8 | 17.6 |
| $K_2O$ | (%) | .57 | .54 | .55 | .47 | .58 | .45 |
| $TiO_2$ | (%) | .10 | .09 | .07 | .07 | .07 | .07 |
| $P_2O_5$ | (%) | .06 | .06 | .06 | .05 | .07 | .04 |
| MnO | (%) | .02 | .02 | .14 | .01 | .21 | .01 |
| Pb | (%) | .01 | .01 | .02 | .01 | .03 | .01 |
| Sb | (%) | .41 | .31 | .30 | .18 | .40 | .20 |
| Ba | (ppm) | 153 | 150 | 162 | 150 | 187 | 149 |
| Co | (ppm) | 8 | 8 | 7 | 7 | 9 | 6 |
| Cr | (ppm) | 14 | 14 | 13 | 13 | 13 | 13 |
| Cu | (ppm) | 15 | 15 | 24 | 6 | 18 | 6 |
| Li | (ppm) | 4 | 4 | 7 | 4 | 8 | 5 |
| Nb | (ppm) | 3 | 2 | 1 | 1 | 1 | 2 |
| Ni | (ppm) | 16 | 15 | 16 | 17 | 16 | 14 |
| Sc | (ppm) | 1 | 1 | 1 | 1 | 1 | 1 |
| Sr | (ppm) | 479 | 474 | 347 | 334 | 382 | 326 |
| V | (ppm) | 11 | 10 | 10 | 8 | 13 | 8 |
| Y | (ppm) | 8 | 8 | 7 | 7 | 8 | 7 |
| Zn | (ppm) | 26 | 22 | 28 | 16 | 30 | 15 |
| Zr | (ppm) | 46 | 40 | 35 | 35 | 38 | 36 |
| La | (ppm) | 13 | 13 | 13 | 12 | 13 | 12 |
| Ce | (ppm) | 18 | 17 | 16 | 17 | 17 | 17 |
| Nd | (ppm) | 20 | 21 | 22 | 22 | 21 | 22 |
| Sm | (ppm) | 3.5 | 3.4 | 3.3 | 3.1 | 3.2 | 3.2 |
| Eu | (ppm) | .5 | .5 | .4 | .4 | .4 | .5 |
| Dy | (ppm) | 1.7 | 1.6 | 1.6 | 1.5 | 1.6 | 1.5 |
| Yb | (ppm) | .9 | .9 | .8 | .7 | .8 | .7 |
| $SiO_2$ | (%) | 69.3 | 70.2 | 71.9 | 74.4 | 70.0 | 73.9 |

| Number | | 508 | 512 | 513 | 514 | 515 | 518 |
|---|---|---|---|---|---|---|---|
| Colour | | C | C | C | C | C | C |
| Vessel type | | CY | CY | CY | CY | CY | CY |
| $Al_2O_3$ | (%) | 1.81 | 1.87 | 1.90 | 2.04 | 2.08 | 2.00 |
| $Fe_2O_3$ | (%) | .27 | .32 | .30 | .36 | .36 | .33 |
| MgO | (%) | .41 | .46 | .43 | .48 | .53 | .59 |
| CaO | (%) | 5.48 | 6.34 | 5.69 | 6.20 | 5.47 | 5.83 |
| $Na_2O$ | (%) | 18.5 | 19.8 | 18.8 | 19.8 | 18.0 | 19.8 |
| $K_2O$ | (%) | .37 | .58 | .52 | .56 | .58 | .42 |
| $TiO_2$ | (%) | .07 | .07 | .07 | .07 | .08 | .09 |
| $P_2O_5$ | (%) | .05 | .06 | .04 | .06 | .06 | .05 |
| MnO | (%) | .01 | .02 | .09 | .01 | .01 | .01 |
| Pb | (%) | .01 | .01 | .01 | .01 | .01 | .01 |
| Sb | (%) | .31 | .49 | .42 | .58 | .49 | .33 |
| Ba | (ppm) | 141 | 135 | 157 | 144 | 162 | 148 |
| Co | (ppm) | 7 | 8 | 7 | 8 | 7 | 8 |
| Cr | (ppm) | 12 | 13 | 13 | 13 | 13 | 14 |
| Cu | (ppm) | 11 | 19 | 15 | 15 | 6 | 10 |
| Li | (ppm) | 4 | 5 | 6 | 5 | 5 | 4 |
| Nb | (ppm) | 2 | 2 | 1 | 2 | 2 | 2 |
| Ni | (ppm) | 14 | 11 | 14 | 13 | 14 | 15 |
| Sc | (ppm) | 1 | 1 | 1 | 1 | 1 | 1 |
| Sr | (ppm) | 344 | 454 | 371 | 598 | 343 | 380 |
| V | (ppm) | 8 | 8 | 10 | 8 | 10 | 10 |
| Y | (ppm) | 7 | 8 | 7 | 7 | 7 | 8 |
| Zn | (ppm) | 16 | 27 | 25 | 25 | 21 | 18 |
| Zr | (ppm) | 34 | 25 | 36 | 33 | 46 | 41 |
| La | (ppm) | 12 | 13 | 13 | 12 | 13 | 13 |
| Ce | (ppm) | 16 | 16 | 15 | 17 | 16 | 16 |
| Nd | (ppm) | 21 | 21 | 22 | 21 | 22 | 21 |
| Sm | (ppm) | 3.2 | 3.1 | 2.9 | 3.5 | 3.1 | 3.2 |
| Eu | (ppm) | .4 | .5 | .4 | .5 | .4 | .4 |
| Dy | (ppm) | 1.5 | 1.6 | 1.4 | 1.5 | 1.5 | 1.5 |
| Yb | (ppm) | .7 | .8 | .8 | .8 | .8 | .8 |
| $SiO_2$ | (%) | 72.6 | 69.9 | 71.7 | 69.7 | 72.3 | 70.5 |

| Number | | 519 | 520 | 525 | 526 | 527 | 528 |
|---|---|---|---|---|---|---|---|
| Colour | | C | C | C | C | C | C |
| Vessel type | | CY | CY | CY | CY | CY | CY |
| $Al_2O_3$ | (%) | 1.71 | 2.02 | 1.88 | 1.92 | 2.00 | 1.90 |
| $Fe_2O_3$ | (%) | .21 | .34 | .26 | .29 | .33 | .27 |
| MgO | (%) | .36 | .51 | .45 | .48 | .46 | .48 |
| CaO | (%) | 5.27 | 5.36 | 5.12 | 5.45 | 5.41 | 5.32 |
| $Na_2O$ | (%) | 18.8 | 18.4 | 17.6 | 18.4 | 17.7 | 19.4 |
| $K_2O$ | (%) | .48 | .54 | .45 | .51 | .75 | .47 |
| $TiO_2$ | (%) | .06 | .08 | .07 | .07 | .08 | .06 |
| $P_2O_5$ | (%) | .07 | .05 | .05 | .05 | .08 | .05 |
| MnO | (%) | .01 | .01 | .01 | .02 | .01 | .01 |
| Pb | (%) | .01 | .01 | .01 | .01 | .01 | .01 |
| Sb | (%) | .63 | .46 | .21 | .38 | .54 | .35 |
| Ba | (ppm) | 142 | 156 | 147 | 148 | 145 | 146 |
| Co | (ppm) | 7 | 7 | 7 | 8 | 8 | 7 |
| Cr | (ppm) | 10 | 12 | 12 | 12 | 13 | 12 |
| Cu | (ppm) | 13 | 5 | 6 | 11 | 7 | 8 |
| Li | (ppm) | 4 | 5 | 5 | 5 | 3 | 2 |
| Nb | (ppm) | 1 | 2 | 2 | 1 | 2 | 1 |
| Ni | (ppm) | 14 | 13 | 11 | 10 | 14 | 11 |
| Sc | (ppm) | 1 | 1 | 1 | 1 | 1 | 1 |
| Sr | (ppm) | 358 | 321 | 326 | 368 | 350 | 358 |
| V | (ppm) | 7 | 10 | 9 | 9 | 8 | 7 |
| Y | (ppm) | 7 | 7 | 7 | 7 | 7 | 7 |
| Zn | (ppm) | 26 | 20 | 14 | 22 | 18 | 19 |
| Zr | (ppm) | 26 | 42 | 37 | 38 | 33 | 22 |
| La | (ppm) | 12 | 12 | 12 | 13 | 13 | 12 |
| Ce | (ppm) | 16 | 17 | 17 | 16 | 17 | 16 |
| Nd | (ppm) | 22 | 22 | 22 | 22 | 21 | 22 |
| Sm | (ppm) | 3.0 | 3.2 | 3.3 | 3.2 | 3.0 | 3.0 |
| Eu | (ppm) | .4 | .4 | .4 | .4 | .4 | .4 |
| Dy | (ppm) | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.4 |
| Yb | (ppm) | .7 | .8 | .7 | .7 | .8 | .7 |
| $SiO_2$ | (%) | 72.3 | 72.2 | 73.8 | 72.4 | 72.6 | 71.6 |

| | | 529 | 530 | 531 | 532 | 534 | 535 |
|---|---|---|---|---|---|---|---|
| Number | | 529 | 530 | 531 | 532 | 534 | 535 |
| Colour | | C | C | C | C | C | C |
| Vessel type | | CY | CY | CY | CY | CY | CY |
| $Al_2O_3$ | (%) | 2.03 | 1.74 | 1.93 | 2.02 | 2.02 | 2.04 |
| $Fe_2O_3$ | (%) | .30 | .27 | .24 | .42 | .38 | .40 |
| MgO | (%) | .48 | .36 | .37 | .53 | .47 | .50 |
| CaO | (%) | 5.41 | 4.71 | 5.18 | 5.73 | 6.15 | 6.85 |
| $Na_2O$ | (%) | 18.6 | 19.6 | 17.8 | 18.3 | 19.9 | 19.5 |
| $K_2O$ | (%) | .50 | .39 | .55 | .62 | .56 | .62 |
| $TiO_2$ | (%) | .07 | .11 | .06 | .10 | .09 | .08 |
| $P_2O_5$ | (%) | .05 | .05 | .04 | .06 | .08 | .06 |
| MnO | (%) | .01 | .01 | .01 | .02 | .01 | .02 |
| Pb | (%) | .01 | .01 | .01 | .02 | .01 | .01 |
| Sb | (%) | .21 | 1.46 | .30 | .39 | .85 | .57 |
| Ba | (ppm) | 160 | 154 | 156 | 141 | 256 | 140 |
| Co | (ppm) | 8 | 7 | 7 | 8 | 9 | 9 |
| Cr | (ppm) | 12 | 12 | 11 | 16 | 14 | 14 |
| Cu | (ppm) | 11 | 8 | 7 | 11 | 40 | 18 |
| Li | (ppm) | 3 | 7 | 5 | 4 | 5 | 7 |
| Nb | (ppm) | 1 | 5 | 1 | 1 | 3 | 3 |
| Ni | (ppm) | 13 | 11 | 14 | 16 | 17 | 14 |
| Sc | (ppm) | 1 | 1 | 1 | 1 | 1 | 1 |
| Sr | (ppm) | 327 | 300 | 341 | 406 | 596 | 557 |
| V | (ppm) | 8 | 10 | 8 | 11 | 10 | 9 |
| Y | (ppm) | 7 | 6 | 7 | 7 | 7 | 8 |
| Zn | (ppm) | 15 | 16 | 16 | 19 | 177 | 39 |
| Zr | (ppm) | 34 | 91 | 27 | 38 | 45 | 45 |
| La | (ppm) | 13 | 12 | 12 | 14 | 12 | 13 |
| Ce | (ppm) | 16 | 15 | 16 | 19 | 16 | 17 |
| Nd | (ppm) | 21 | 22 | 21 | 21 | 21 | 21 |
| Sm | (ppm) | 3.0 | 2.9 | 2.8 | 2.9 | 3.0 | 3.2 |
| Eu | (ppm) | .4 | .5 | .4 | .4 | .4 | .5 |
| Dy | (ppm) | 1.5 | 1.3 | 1.4 | 1.5 | 1.5 | 1.6 |
| Yb | (ppm) | .8 | .6 | .7 | .8 | .8 | .9 |
| $SiO_2$ | (%) | 72.3 | 71.2 | 73.4 | 71.7 | 69.4 | 69.3 |

**Table 2**

**Correlations of individual oxides/elements with sequential run number throughout the analytical batch**

| | | |
|---|---|---|
| $Al_2O_3$ | 0.0989 | |
| $Fe_2O_3$ | -0.0381 | |
| MgO | 0.0594 | |
| CaO | 0.0555 | |
| $Na_2O$ | 0.0611 | |
| $K_2O$ | -0.0778 | |
| $TiO_2$ | 0.1973 | |
| $P_2O_5$ | 0.0921 | |
| MnO | -0.0146 | |
| Pb | -0.3333 | |
| Sb | -0.0810 | |
| Ba | 0.0369 | |
| Co | 0.3492 | |
| Cr | 0.0452 | |
| Cu | 0.0224 | |
| Li | 0.6735 | * |
| Nb | 0.6477 | * |
| Ni | 0.4412 | * |
| Sc | -0.1595 | |
| Sr | -0.0030 | |
| V | 0.2995 | |
| Y | 0.1090 | |
| Zn | 0.3032 | |
| Zr | 0.0951 | |
| La | 0.0094 | |
| Ce | 0.5980 | * |
| Nd | 0.6925 | * |
| Sm | 0.8374 | * |
| Eu | 0.6699 | * |
| Dy | 0.6420 | * |
| Yb | 0.2181 | |
| $SiO_2$ | -0.0469 | |

(* = correlation over +0.4)

**Table 3**

**Simple statistics for glass vessel groups and for the combined groups (all numbers in ppm) (after removal of outliers)**

where Group 1 = Cast bowls
Group 2 = Facet-cut and relief-cut beakers
Group 3 = Wheel-cut beakers
Group 4 = Cylindrical cups
ALL = All 4 groups combined

| | Group | No | MEAN | STDEV | MIN | MAX |
|---|---|---|---|---|---|---|
| $Al_2O_3$ | 1 | 18 | 18856 | 1333 | 15400 | 20800 |
| | 2 | 15 | 20360 | 1908 | 17800 | 23800 |
| | 3 | 25 | 19756 | 1852 | 16600 | 24600 |
| | 4 | 51 | 19373 | 1418 | 17100 | 22500 |
| | ALL | 109 | 19511 | 1625 | 15400 | 24600 |
| $Fe_2O_3$ | 1 | 18 | 3250 | 720 | 2500 | 5100 |
| | 2 | 15 | 2653 | 629 | 1800 | 3700 |
| | 3 | 25 | 3464 | 836 | 2000 | 5200 |
| | 4 | 51 | 3092 | 624 | 2100 | 4500 |
| | ALL | 109 | 3143 | 727 | 1800 | 5200 |
| MgO | 1 | 18 | 4589 | 519 | 3700 | 5700 |
| | 2 | 15 | 3867 | 875 | 2800 | 5400 |
| | 3 | 25 | 4824 | 779 | 2700 | 6400 |
| | 4 | 51 | 4618 | 769 | 3200 | 6600 |
| | ALL | 109 | 4557 | 797 | 2700 | 6600 |
| CaO | 1 | 18 | 55044 | 9381 | 38500 | 76700 |
| | 2 | 15 | 55880 | 9263 | 43900 | 71900 |
| | 3 | 25 | 60768 | 9534 | 41600 | 83500 |
| | 4 | 51 | 56620 | 5673 | 47600 | 70200 |
| | ALL | 109 | 57209 | 8012 | 38500 | 83500 |
| $Na_2O$ | 1 | 18 | 186167 | 10365 | 169000 | 205000 |
| | 2 | 15 | 176933 | 12589 | 149000 | 198000 |
| | 3 | 25 | 182320 | 9957 | 154000 | 202000 |
| | 4 | 51 | 183078 | 9844 | 163000 | 200000 |
| | ALL | 109 | 182569 | 10539 | 149000 | 205000 |
| $K_2O$ | 1 | 18 | 5294 | 1338 | 4200 | 9100 |
| | 2 | 15 | 4973 | 779 | 4000 | 6300 |
| | 3 | 25 | 5560 | 1041 | 3900 | 7800 |
| | 4 | 51 | 4998 | 739 | 3700 | 7500 |
| | ALL | 109 | 5173 | 954 | 3700 | 9100 |
| $TiO_2$ | 1 | 18 | 650 | 186 | 500 | 1200 |
| | 2 | 15 | 487 | 160 | 300 | 700 |
| | 3 | 25 | 792 | 247 | 300 | 1400 |
| | 4 | 51 | 694 | 119 | 500 | 1000 |
| | ALL | 109 | 681 | 193 | 300 | 1400 |

| | Group | No | MEAN | STDEV | MIN | MAX |
|---|---|---|---|---|---|---|
| $P_2O_5$ | 1 | 18 | 472 | 67 | 400 | 600 |
| | 2 | 15 | 433 | 72 | 300 | 600 |
| | 3 | 25 | 680 | 340 | 300 | 1700 |
| | 4 | 51 | 512 | 93 | 400 | 800 |
| | ALL | 109 | 533 | 196 | 300 | 1700 |
| MnO | 1 | 18 | 172 | 235 | 100 | 1100 |
| | 2 | 15 | 120 | 68 | 0 | 300 |
| | 3 | 25 | 896 | 1412 | 100 | 6100 |
| | 4 | 51 | 228 | 366 | 100 | 2100 |
| | ALL | 109 | 357 | 776 | 0 | 6100 |
| Pb | 1 | 18 | 439 | 820 | 0 | 3400 |
| | 2 | 15 | 1213 | 1800 | 0 | 5100 |
| | 3 | 25 | 760 | 886 | 100 | 2900 |
| | 4 | 51 | 108 | 34 | 100 | 300 |
| | ALL | 109 | 464 | 927 | 0 | 5100 |
| Sb | 1 | 18 | 3783 | 1454 | 2200 | 8600 |
| | 2 | 15 | 3827 | 913 | 2100 | 5500 |
| | 3 | 25 | 4192 | 1442 | 2200 | 7700 |
| | 4 | 51 | 3639 | 1029 | 1800 | 6300 |
| | ALL | 109 | 3816 | 1200 | 1800 | 8600 |
| Ba | 1 | 18 | 133 | 16 | 95 | 146 |
| | 2 | 15 | 144 | 11 | 123 | 163 |
| | 3 | 25 | 153 | 25 | 128 | 239 |
| | 4 | 51 | 145 | 10 | 132 | 187 |
| | ALL | 109 | 145 | 17 | 95 | 239 |
| Cr | 1 | 18 | 12 | 2 | 9 | 17 |
| | 2 | 15 | 12 | 2 | 9 | 17 |
| | 3 | 25 | 14 | 3 | 9 | 20 |
| | 4 | 51 | 12 | 1 | 10 | 16 |
| | ALL | 109 | 13 | 2 | 9 | 20 |
| Cu | 1 | 18 | 10 | 5 | 4 | 25 |
| | 2 | 15 | 7 | 2 | 4 | 10 |
| | 3 | 25 | 13 | 6 | 5 | 24 |
| | 4 | 51 | 10 | 4 | 5 | 24 |
| | ALL | 109 | 10 | 5 | 4 | 25 |
| Sr | 1 | 18 | 404 | 132 | 223 | 715 |
| | 2 | 15 | 363 | 81 | 248 | 516 |
| | 3 | 25 | 429 | 87 | 288 | 606 |
| | 4 | 51 | 379 | 71 | 289 | 598 |
| | ALL | 109 | 392 | 90 | 223 | 715 |
| Y | 1 | 18 | 7 | 1 | 6 | 8 |
| | 2 | 15 | 7 | 1 | 6 | 9 |
| | 3 | 25 | 7 | 1 | 6 | 10 |
| | 4 | 51 | 7 | 0 | 6 | 8 |
| | ALL | 109 | 7 | 1 | 6 | 10 |

| | Group | No | MEAN | STDEV | MIN | MAX |
|---|---|---|---|---|---|---|
| Zr | 1 | 18 | 35 | 10 | 18 | 62 |
| | 2 | 15 | 28 | 9 | 17 | 47 |
| | 3 | 25 | 40 | 16 | 11 | 71 |
| | 4 | 51 | 34 | 7 | 20 | 51 |
| | ALL | 109 | 35 | 11 | 11 | 71 |
| $SiO_2$ | 1 | 18 | 720667 | 17954 | 692000 | 747000 |
| | 2 | 15 | 728600 | 16565 | 694000 | 759000 |
| | 3 | 25 | 715200 | 17064 | 681000 | 751000 |
| | 4 | 51 | 722333 | 16899 | 688000 | 752000 |
| | ALL | 109 | 721284 | 17315 | 681000 | 759000 |

Figure 1

**Plot of Sumerium values during the course of the analytical batch showing an steady increase in Sumerium content**

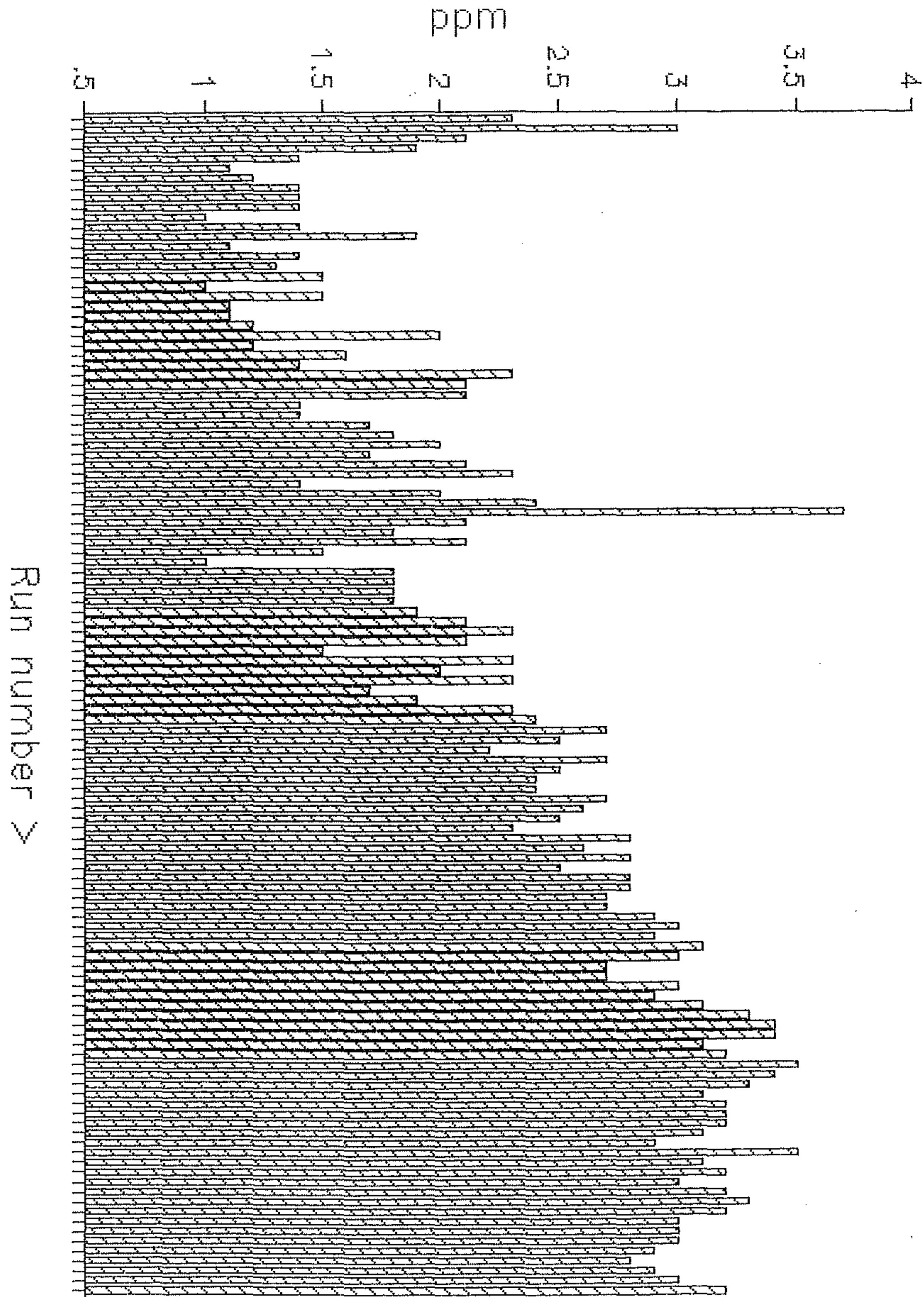
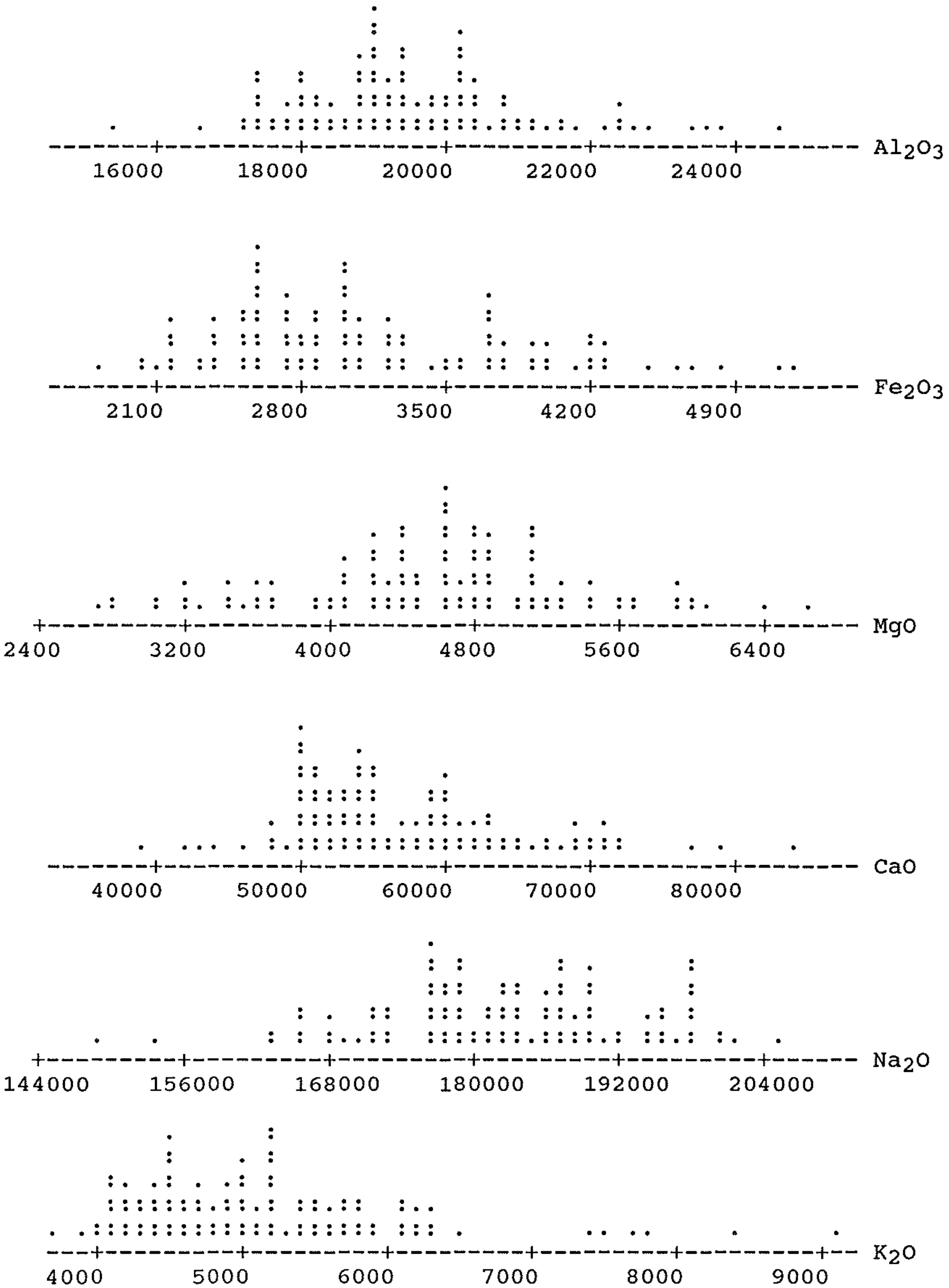
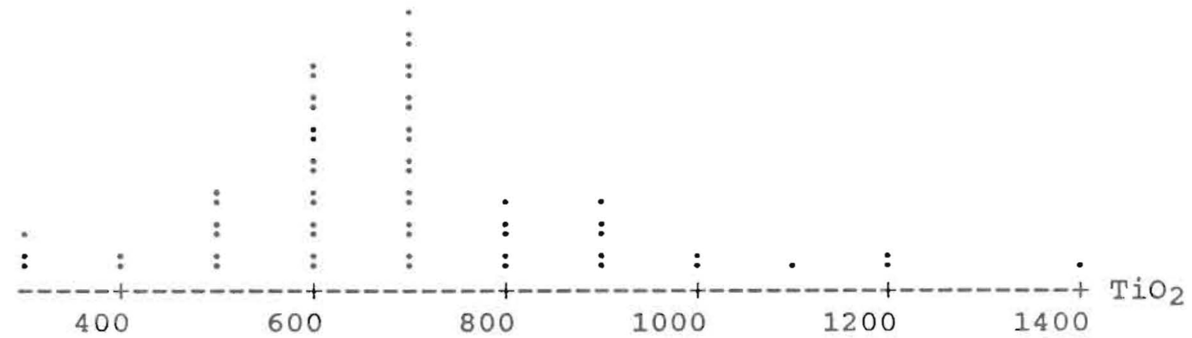


**Figure 2**

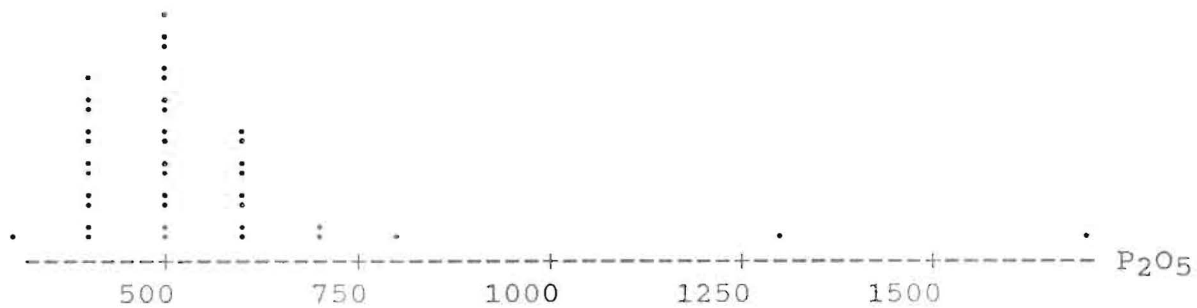
**Single element dot plots for all the Colchester vessel glass data (after removal of outliers) with data quoted as parts per million**



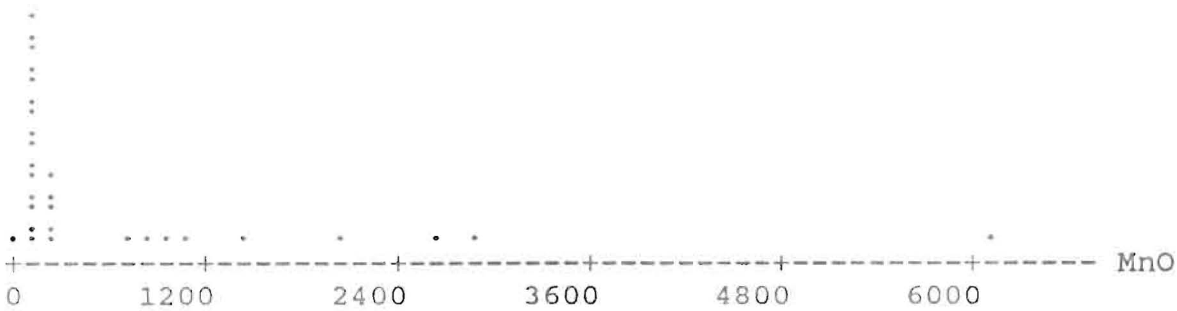
Each dot represents 2 points



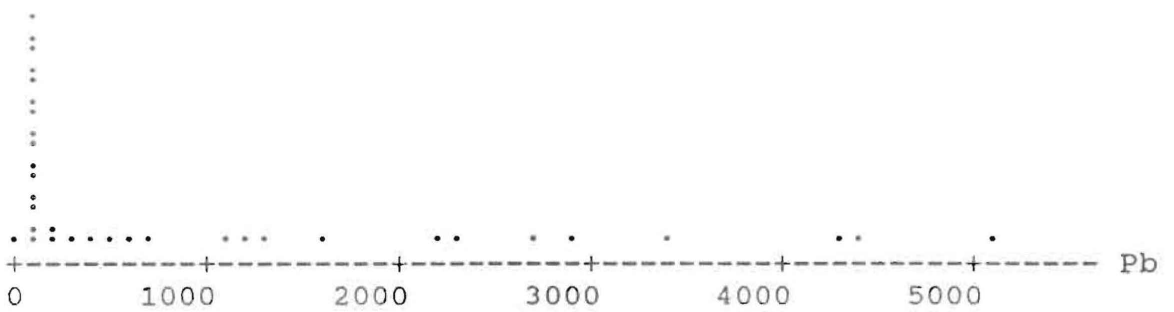

Each dot represents 3 points

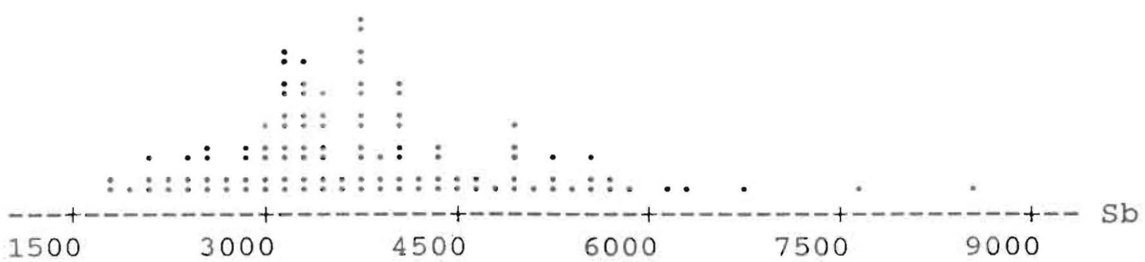


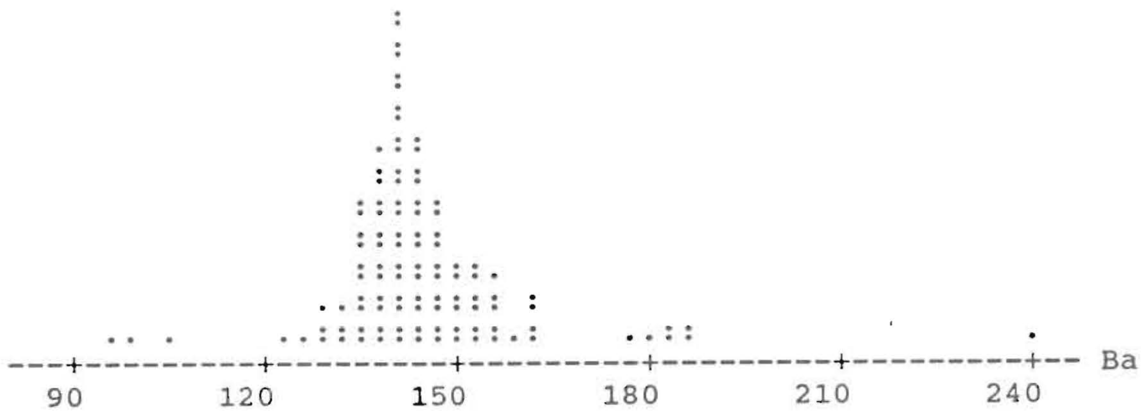

Each dot represents 5 points

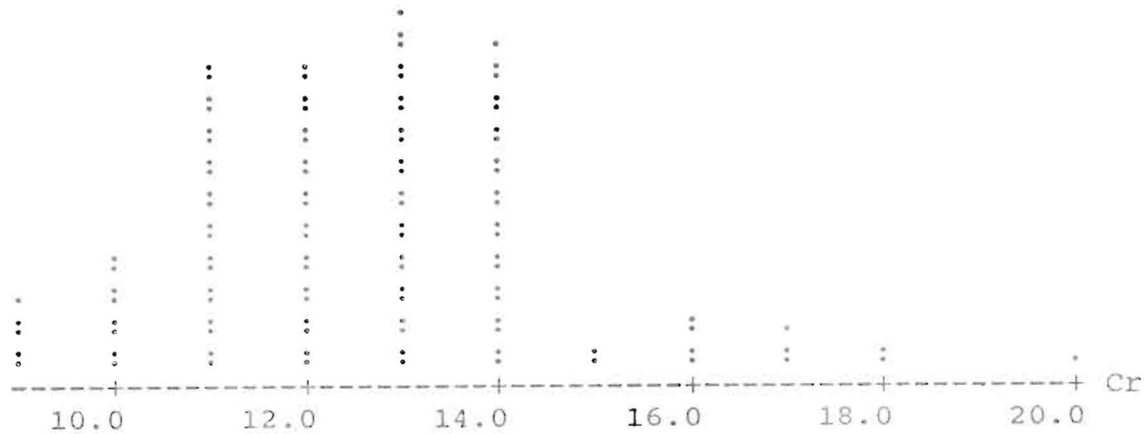


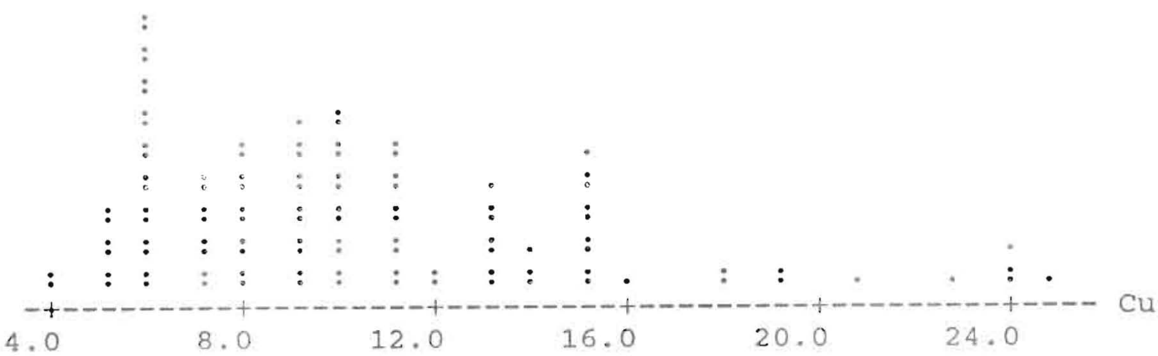

Each dot represents 5 points

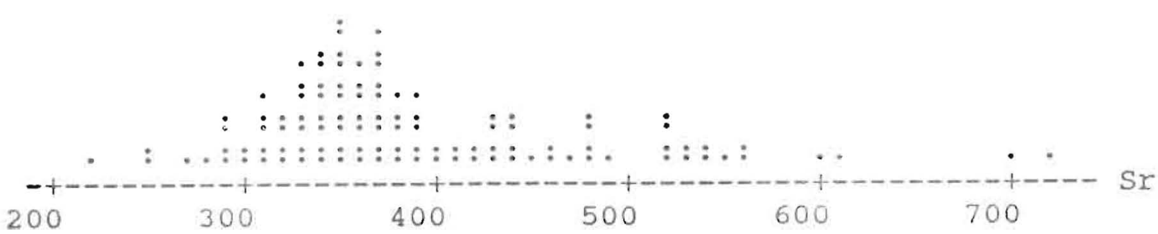



Ba
90
120
150
180
210
240


Cr
10.0
12.0
14.0
16.0
18.0
20.0


Cu
4.0
8.0
12.0
16.0
20.0
24.0


Sr
200
300
400
500
600
700

Each dot represents 4 points

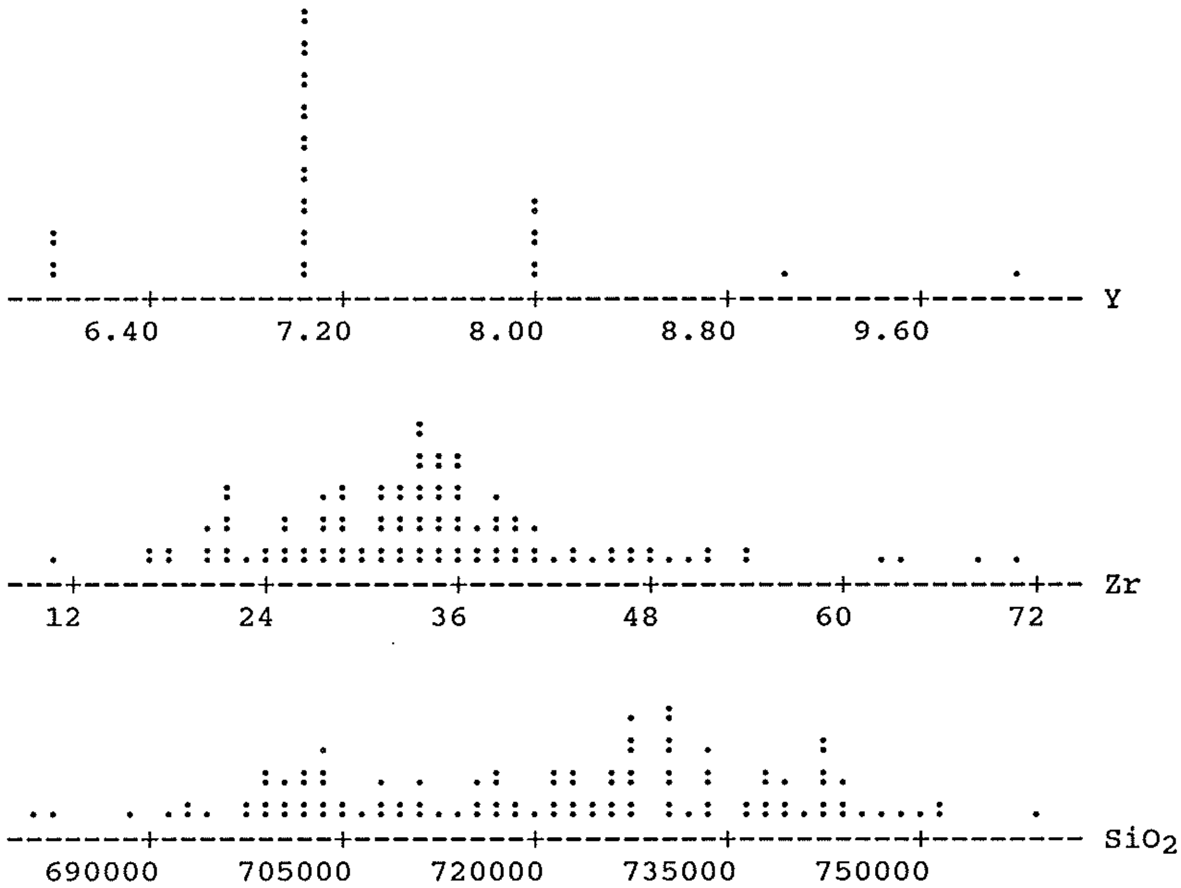


**Figure 3**

**Coefficient and Component plots with results of Principal Components Analysis of data correlation matrix (overlapping points are shown as numbers reflecting the number of points in that area)**

(a) Showing oxides/elements
(A = $SiO_2$, B = $Al_2O_3$, C = $Fe_2O_3$, D = MgO, E = CaO, F = $Na_2O$, G = $K_2O$, H = $TiO_2$, I = $P_2O_5$, J = MnO, K = Pb, L = Sb, M = Ba N = Cr, O = Cu, P = Sr, Q = Y, R = Zr)

```
s      -
e      -
c      -              J  M                                    A
o  0.30+          I
n      -
d      -             G
       -      H  R  B    L
c      -     N         O                    K
o  0.00+     C
e      -         Q
f      -
f      -       D
i      -
c -0.30+
i      -             E    F
e      -               P
n      -
t       +---------+---------+---------+---------+---------+------
    -0.36     -0.24     -0.12      0.00      0.12       0.2

                          first coefficient
```

(b) Showing individual analyses
(A = Cast bowls, B = Facet-cut and Relief-cut beakers, C = Wheel-cut beakers, D = Cylindrical cups)

```
s   8.0+   C
e      -
c      -
o      -
n      -
d   4.0+              C   C
       -                     C
c      -                                      A
o      -                           C      3 B   D     A    B
m      -                            D  2 D  D4C2D C32523 BD  B
p   0.0+                         C   D      D22   4ACD2B2        2
o      -              C           22 D2     B 2 D2    A 2
n      -                       D2    D3DD 2C2B2 C DA
e      -                           D  BA
n      -                 C
t  -4.0+                                 A  A
       -
         ------+---------+---------+---------+---------+---------+
            -9.0      -6.0      -3.0       0.0       3.0       6.0

                         first component
```

**Figure 4**

**Coefficient and Component plots with results of Principal Components Analysis of data transformed by Aitchison's method (overlapping points are shown as numbers reflecting the number of points in that area)**

(a) Showing oxides/elements
(A = $SiO_2$, B = $Al_2O_3$, C = $Fe_2O_3$, D = MgO, E = CaO, F = $Na_2O$, G = $K_2O$, H = $TiO_2$, I = $P_2O_5$, J = MnO, K = Pb, L = Sb, M = Ba N = Cr, O = Cu, P = Sr, Q = Y, R = Zr)

```
s      -                                                        K
e      -     E4
c      -   D Q2
o  0.00+   HRCGL
n      -      I
d      -          O
       -
c      -
o -0.35+
e      -
f      -
f      -
i      -
c -0.70+
i      -
e      -
n      -                J
t        --------+---------+---------+---------+---------+-------
              0.00      0.20      0.40      0.60      0.80

                     first coefficient
```

(b) Showing individual analyses
(A = Cast bowls, B = Facet-cut and Relief-cut beakers, C = Wheel-cut beakers, D = Cylindrical cups)

```
s      -
e      -                                                C C   2 B
c   4.5+                            A  BB  C2 B    2
o      -  C D6++5B    3CA                                A
n      -    A D85                          A
d      -     33B     CD
       -     D 4A           C
c   3.0+      D2
o      -
m      -       C                  C3
p      -          D
o      -           D       DA
n   1.5+                       D  C
e      -                             C      C
n      -           C                             C
t      -
       -
         --+---------+---------+---------+---------+---------+---
       -3.20     -2.40     -1.60     -0.80      0.00      0.80

                     first component
```

**Figure 5**

**Coefficient and Component plots with results of Correspondence Analysis of the raw data (overlapping points are shown as numbers reflecting the number of points in that area)**

(a) Showing oxides/elements
(A = $SiO_2$, B = $Al_2O_3$, C = $Fe_2O_3$, D = MgO, E = CaO, F = $Na_2O$, G = $K_2O$, H = $TiO_2$, I = $P_2O_5$, J = MnO, K = Pb, L = Sb, M = Ba N = Cr, O = Cu, P = Sr, Q = Y, R = Zr)

```
s      -         E
e      -
c  0.00+                 F    D     P  32               A
o      -                     C  G2H
n      -                      L
d      -
       -
c -0.30+
o      -
e      -
f      -
f      -
i -0.60+
c      -      J
i      -                                                     K
e      -
n      -
t        +---------+---------+---------+---------+---------+------
     -0.60     -0.40     -0.20      0.00      0.20      0.40

                          first coefficient
```

(b) Showing individual analyses
(A = Cast bowls, B = Facet-cut and Relief-cut beakers, C = Wheel-cut beakers, D = Cylindrical cups)

```
s      -                       A
e      -                 C   2D44D4332289356772D
c     0+                     C     2A   B       B   B
o      -                C        C2DD A       2 2
n      -                               A  2
d      -                C D    C                   C
       -                                                  C
c   -100+                 C                 A
o      -                  C                                  2
m      -                                                     B
p      -
o      -
n   -200+
e      -
n      -
t      -      C
       -
         +---------+---------+---------+---------+---------+------
      -180      -120       -60         0        60       120

                          first component
```

**Figure 6**

**Coefficient and Component plots with results of Correspondence Analysis of data transformed by dividing by column means (overlapping points are shown as numbers reflecting the number of points in that area)**

(a) Showing oxides/elements
(A = $SiO_2$, B = $Al_2O_3$, C = $Fe_2O_3$, D = MgO, E = CaO, F = $Na_2O$, G = $K_2O$, H = $TiO_2$, I = $P_2O_5$, J = MnO, K = Pb, L = Sb, M = Ba N = Cr, O = Cu, P = Sr, Q = Y, R = Zr)

```
s      -  J
e      -
c      -
o      -
n  0.70+
d      -
       -
c      -
o      -
e  0.35+
f      -
f      -
i      -
c      -     O                                                 K
i  0.00+   I
e      -   347
n      -
t        ------+---------+---------+---------+---------+---------+
            0.00      0.20      0.40      0.60      0.80      1.00

                          first coefficient
```

(b) Showing individual analyses
(A = Cast bowls, B = Facet-cut and Relief-cut beakers, C = Wheel-cut beakers, D = Cylindrical cups)

```
s      -            C
e      -
c      -
o      -
n   7.0+
d      -
       -     C
c      -        C   C
o      -       D
m   3.5+        C
p      -       D
o      -      DA
n      -       D  C
e      -      C   3
n   0.0+       3  C                         2A          2     B
t      -      2++4    A2  A3B       2
       -
         +---------+---------+---------+---------+---------+------
      -2.0       0.0       2.0       4.0       6.0       8.0

                         first component
```