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# Examination and Analysis of the Glass Beads from Alton, Hampshire

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## Introduction

The glass beads (AM852749) from the Pagan Saxon cemetery site at Alton were examined and a representative selection was analysed elementally using energy dispersive X-ray fluorescence (X.R.F.). The colour, opacity and porosity of the beads were considered as well as their chemical composition, and the probable colourants, decolourants and opacifiers present were identified. The results are compared to those obtained previously for glass beads from other sites of similar date.

Many of the beads found were made from materials other than glass, particularly amber, but only the glass beads were examined in detail and the term "bead" below implies "glass bead".

Apart from those which showed signs of having been burnt, most of the beads were analysed although where a large number of similar beads came from a single grave a random selection was made.

## Method

### 1) Colour, opacity and porosity

Two methods of describing the colour of the analysed beads were used. Firstly, each monochrome bead and each field of the polychrome beads was assigned to a general colour category (brown, yellow, clear etc).

Secondly, the colour of most of the beads was described more objectively in terms of a Munsell Number. However, Munsell

Numbers could not be sensibly assigned to the clear, the black or, in some cases, the white beads. The Munsell Number has three components, the hue (H), the value (V) (the lightness or darkness - low values indicate dark) and the chroma (C) (the intensity of hue - high values indicate high intensity). Some of the beads were not uniform in colour and the apparent colour of the translucent beads was affected by the thickness of the glass, but the Munsell Number should give a reasonable indication of the colour. Where only a selection of beads from a large number of similar beads was analysed, the Munsell Numbers given were typical of the beads as a whole.
Both the general colour categories and the Munsell Numbers of the analysed beads are given in appendix 1, together with comments on the opacity of the beads. The latter were based on visual examination of the beads using low power optical microscopy (x15-x45).

## 2) Elemental Analysis

Elemental analysis was carried out using an energy dispersive X-ray fluorescence system with an evacuated chamber. The area analysed was quite large and it was not always possible to analyse individual fields of polychrome beads separately. No sample preparation was possible because the technique was required to be completely non-destructive. No attempt was made to analyse for low atomic number elements such as sodium, magnesium and aluminium as results for these elements would have been unreliable because of the lack of sample preparation. The bulk glass could not, therefore, be categorised.
The elements detected were silicon, titanium, manganese, iron, copper, zinc, lead, tin and antimony. Cobalt may have been present at levels below the detection limit of the method used in some of the beads (it would be expected in the blue beads) but it was not positively identified in the beads analysed. Nickel and arsenic, which have been found occassionally in beads from other

sites of this period, were not detected in any of the beads analysed.

The $K_\alpha$ peak heights were recorded for each element, except for lead when the $L_\alpha$ peak height was used. The results were only semi-quantitative, but to enable comparisons to be made the ratio of the peak height and the silicon $K_\alpha$ peak height was obtained, as silicon would be expected to be present at a relatively constant level in each bead. This assumption is not valid for high lead glasses, but in practice only the yellow beads contained particularly high levels of lead. The ratios are given in appendix 2.

## Results and Discussion

The colour of a glass bead is affected both by the presence of certain metal ions in solution and by opaque particles in the matrix glass. Among the elements which can act as colourants in the form of ions are manganese, iron, cobalt and copper (in the oxidised state as cupric ions). Manganese and antimony can also act as decolourisers. The opaque particles which can be found in beads from Anglo-Saxon sites include copper, cuprous oxide, lead-tin oxide, tin oxide and lead and calcium antimonates. A more detailed discussion of the colourants found in Anglo-Saxon beads is given in Bayley (in press).

The opacity of the beads is affected by several factors including the presence of opaque particles and bubbles, the thickness of the bead and the intensity of colour. All, or almost all, the beads examined did contain bubbles but not at a sufficient density to opacify the beads and therefore the presence of bubbles is not commented on below.

The colourants and opacifiers used are discussed for each colour category below.

### Green

Both iron and copper, under appropriate conditions, can colour glass green and two examples of the use of each were found. The iron coloured beads were translucent and contained no opaque particles and, at most, only traces of lead. They were clearly distinguishable, both analytically and visually, from the green beads containing copper. The latter contained relatively high lead levels and, although they were just translucent, occasional white (almost certainly tin oxide) particles.

Red - All the red beads were coloured by the presence of opaque copper or cuprous oxide particles. The density of the particles was sufficient to make the beads completely opaque.

Yellow - All the yellow beads contained high levels of lead and tin and their opacity and colour was due to the presence of opaque lead-tin oxide particles.

White - The colourant in the white beads was tin oxide. Although lead-tin oxide is unstable at high temperatures and forms tin oxide, the white and yellow were compositionally distinct. As has been found elsewhere (Bayley and Wilthew, 1985) the white beads generally contained higher levels of tin and lower levels of lead than the yellow beads (see figure 1).

Blue - Glass can be coloured blue by either cobalt which produces an intense colour even when present at very low concentrations, or by copper in the oxidised state which has to be present at a relatively high concentration and gives a more tuquoise hue. As none of the blue beads analysed in the present work contained significant levels of copper, they were almost certainly all cobalt coloured. There was no indication that any of the blue beads had been deliberately opacified.

Black - The colour of the black beads was due to the effect of high concentrations of iron (see figure 2). The beads' opaque appearance was not due to opaque particles but simply to the intensity of colour.

Brown - The colour of these beads was due to the combined effects of manganese and iron, with manganese the dominant element. They had not been opacified.

Clear - The clear beads contained higher levels of manganese relative to iron than the other types of bead apart from the iron/manganese coloured brown beads (see figure 2). None of those analysed contained significant levels of antimony so manganese would appear to be the decolourant used, which is to be expected in glass produced in the post-Roman period, at least in Northern Europe. The absence of antimony indicates that Roman glass, which would have been antimony decolourised, has not been reused.

The colourants and opacifiers present were the same as those found in beads from other sites of similar date (Bayley and Wilthew, 1985). Antimony was present at low levels in a few beads but in no case did it have a significant decolourising or opacifying effect. The most probable explanation for its presence would seem to be that the cullet used in producing the glass contained a small proportion of Roman glass.

Of the elements detected, zinc and titanium would not be expected to have a significant effect on the appearance of the beads. Zinc was only present in a few beads, all of which contained significant levels of copper and it was almost certainly introduced with the copper.

Titanium is an impurity introduced with the sand used in the production of the glass. It has been suggested that variations in titanium content between glass beads may indicate that different sources of sand were used in making them. However all the beads analysed in the present work contained either very low or not detectable amounts of titanium so there was no evidence that the beads came from more than one source.

The compositions of the polychrome beads were similar to those of monochrome beads of the same colour. Where more than one colour was included in the area analysed, the results could be explained in terms of the combined contributions of several glasses each of which had a similar composition to the monochrome beads of the same colour.

## References

Bayley, J. "Notes on the Composition of Coloured Glass", in Campbell, S., Bennett, P., et al, The Archaeology of Canturbury, Vol 3 : Excavations in the Cathedral Precincts, 1, in press

Bayley, J. and Wilthew, P., "Quantitative and Semi-Quantitative Analyses of Glass Beads", Proceedings of the 1984 Archaeometry Symposium, Washington, 1985

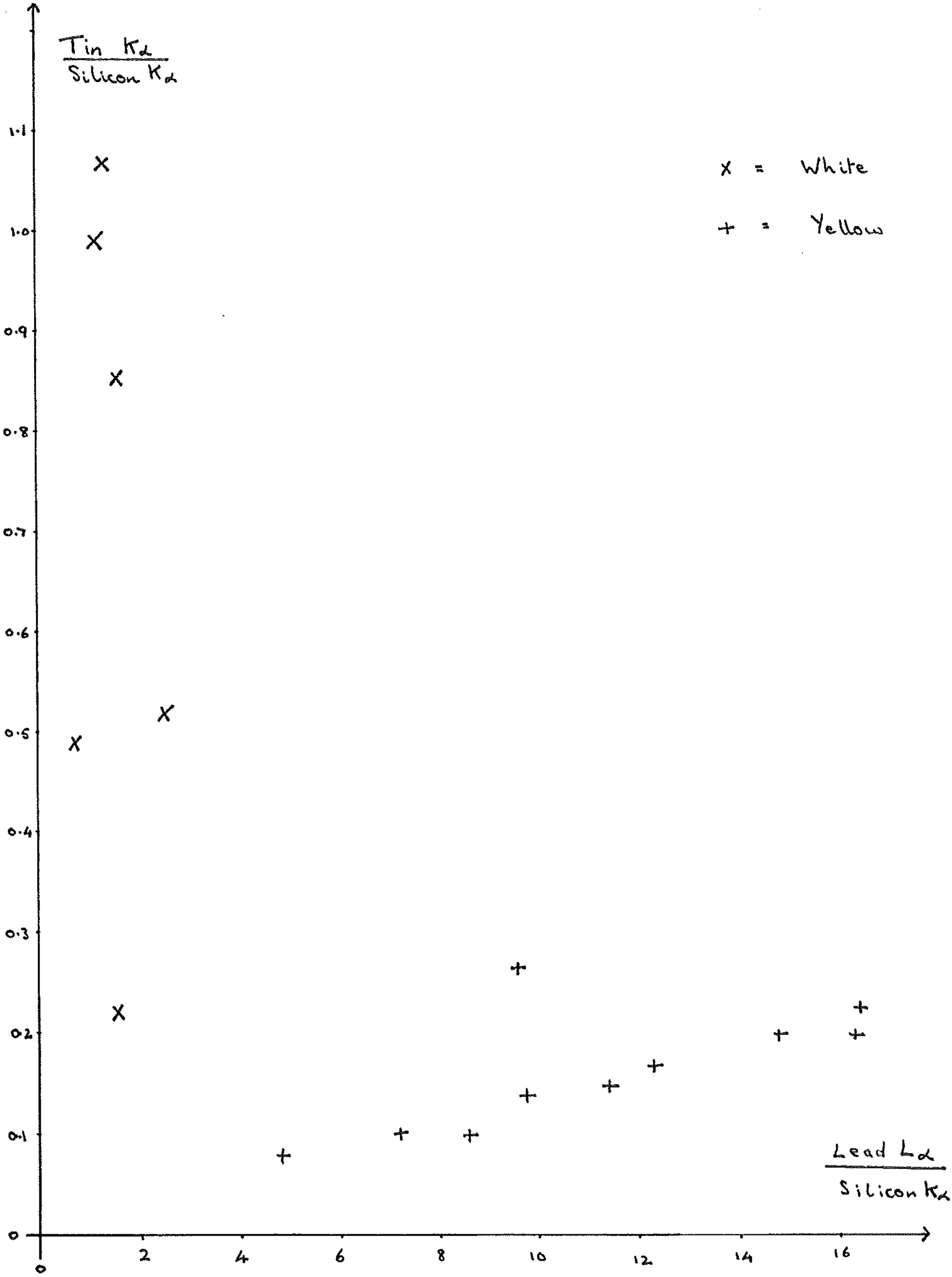


Figure 1 : The relationship between tin and lead levels in the white and the yellow beads

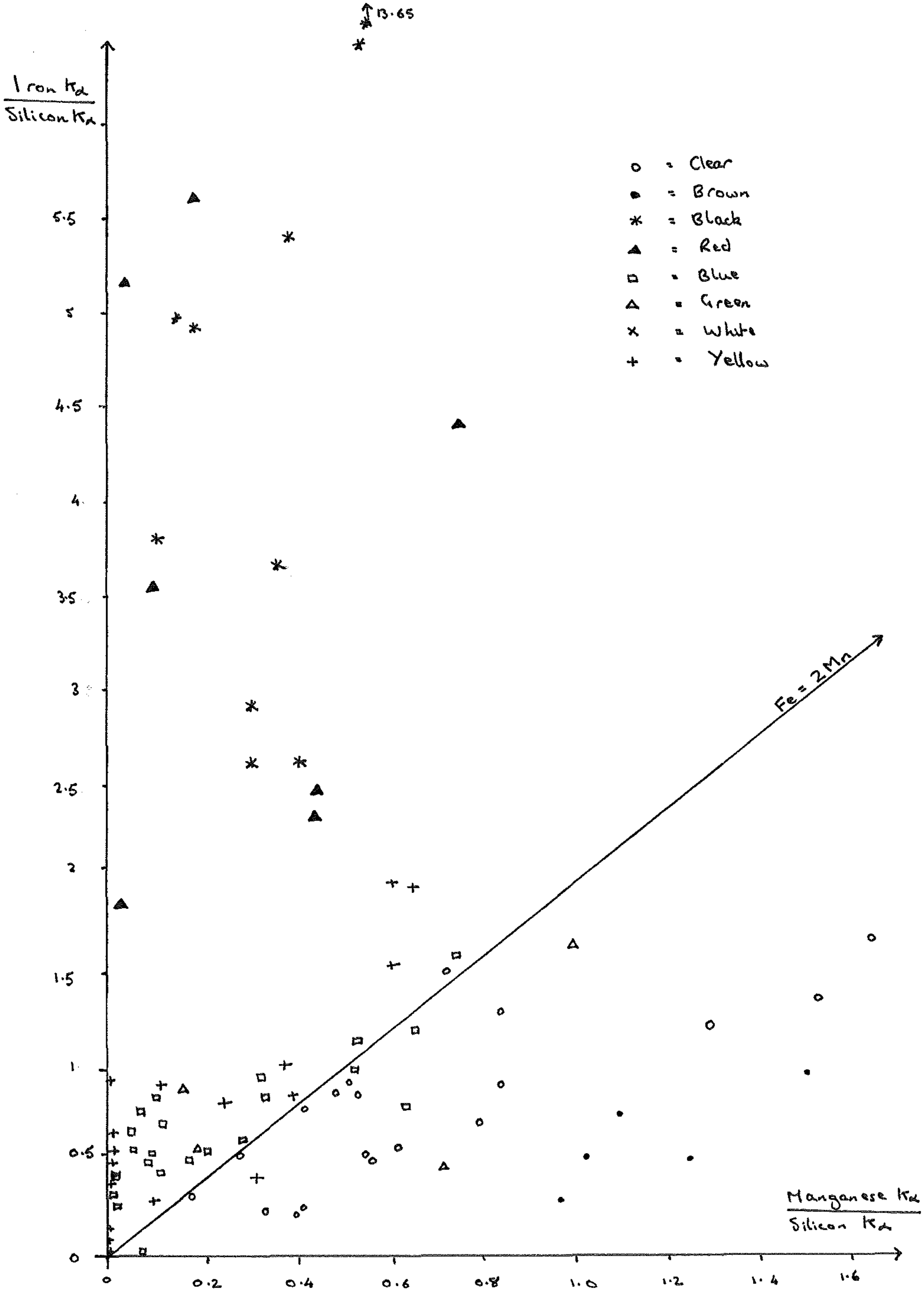


Figure 2: Relationship between Iron and Manganese levels in the beads

| Analysis No. | Gr. | F.N. | Colour | Munsell Number H | V | C | Opacity |
|---|---|---|---|---|---|---|---|
| 40 | 37 | 150 | brown | 5RP | 2.5 | 2 | Translucent |
| 41 | 37 | 150 | brown | 5RP | 2.5 | 2 | Translucent |
| 42 | 37 | 150 | brown | 5RP | 2.5 | 2 | Translucent |
| 43 | 37 | 150 | blue | 7.5PB | 3 | 10 | Translucent |
| 44 | 37 | 150 | blue | 7.5PB | 3 | 10 | Translucent |
| 45 | 37 | 150 | blue | 7.5PB | 3 | 10 | Translucent |
| 46 | 37 | 150 | brown | 5RP | 2.5 | 2 | Translucent |
| 47* | 37 | 150 | white | 2.5B | 9 | 2 | Opaque |
| | 37 | 150 | blue | 7.5PB | 3 | 10 | Translucent |
| 48 | 37 | 150 | blue | 5PB | 4 | 10 | Translucent |
| 49 | 37 | 150 | blue | 7.5PB | 3 | 8 | Translucent |
| 50 | 37 | 150 | clear | - | - | - | Transparent |
| 51 | 37 | 150 | brown | 10P | 2.5 | 1 | Translucent |
| 52* | 39 | 154 | blue | 10B | 5 | 4 | Translucent |
| | 39 | 154 | red | 5R | 4 | 10 | Opaque |
| | 39 | 154 | white | - | - | - | Opaque |
| 53* | 39 | 154 | blue | 10B | 5 | 6 | Translucent |
| | 39 | 154 | white | - | - | - | Opaque |
| 54* | 39 | 154 | white | 5G | 9 | 1 | Opaque |
| | 39 | 154 | blue | 5B | 7 | 4 | Translucent |
| 55* | 39 | 154 | blue | 2.5B | 6 | 2 | Translucent |
| | 39 | 154 | white | 5G | 9 | 1 | Opaque |
| 56 | 39 | 154 | red | 7.5R | 5 | 6 | Opaque |
| 57 | 39 | 154 | yellow | 7.5Y | 7 | 8 | Opaque |
| 58 | 39 | 154 | green | 2.5GY | 8 | 2 | Translucent |
| 59 | 39 | 154 | red | 7.5R | 5 | 6 | Opaque |
| 60 | 39 | 154 | red | 5R | 4 | 4 | Opaque |
| 61 | 39 | 154 | red | 7.5R | 5 | 8 | Opaque |
| 62* | 39 | 154 | green | 5GY | 5 | 8 | Opaque |
| | 39 | 154 | yellow | 7.5Y | 9 | 10 | Opaque |
| 63* | 39 | 154 | red | 7.5R | 4 | 8 | Opaque |
| | 39 | 154 | yellow | 7.5Y | 8.5 | 12 | Opaque |
| 64* | 39 | 154 | red | 7.5R | 3 | 4 | Opaque |
| | 39 | 154 | yellow | 7.5Y | 8.5 | 10 | Opaque |
| 65* | 39 | 154 | blue | 7.5PB | 3 | 8 | Translucent |
| | 39 | 154 | white | 10GY | 9 | 1 | Opaque |
| 66 | 41 | 161 | clear | - | - | - | Transparent |
| 67 | 41 | 161 | blue | 2.5PB | 6 | 6 | Translucent |
| 68 | 41 | 161 | blue | 5PB | 3 | 6 | Translucent |
| 69 | 41 | 161 | clear | - | - | - | Transparent |
| 70 | 41 | 161 | clear | - | - | - | Transparent |
| 71 | 41 | 161 | blue | 5PB | 4 | 4 | Translucent |
| 72 | 41 | 161 | blue | 10B | 5 | 6 | Translucent |

* = Polychrome

| Analysis No. | Gr. | F.N. | Colour | Munsell Number H | V | C | Opacity |
|---|---|---|---|---|---|---|---|
| 73 | 47 | 186a | clear | - | - | - | Transparent |
| 74 | 47 | 186a | clear | - | - | - | Transparent |
| 75 | 47 | 186a | clear | - | - | - | Transparent |
| 76 | 47 | 186a | clear | - | - | - | Transparent |
| 77 | 47 | 186a | clear | - | - | - | Transparent |
| 78 | 47 | 186a | clear | - | - | - | Transparent |
| 79 | 47 | 186a | clear | - | - | - | Transparent |
| 80 | 47 | 186a | clear | - | - | - | Transparent |
| 81 | 47 | 186a | clear | - | - | - | Transparent |
| 82 | 47 | 186a | clear | - | - | - | Transparent |
| 83 | 47 | 186a | clear | - | - | - | Transparent |
| 84 | 47 | 186b | clear | - | - | - | Transparent |
| 85 | 47 | 186b | clear | - | - | - | Transparent |
| 86 | 47 | 186b | clear | - | - | - | Transparent |

Appendix 2 - Peak height ratios with $SiK_{\alpha}$

Key : nd = not detectable
? = Possibly present at trace levels

| Analysis No. | Gr. | F.N. | Colour | Ti | Mn | Fe | Cu | Zn | Pb | Sn | Sb |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 9 | 15 | blue | nd | .26 | .64 | .08 | nd | .04 | ? | nd |
| 2 | 9 | 15 | blue | nd | .08 | .55 | .05 | nd | ? | ? | nd |
| 3 | 9 | 15 | blue | ? | .73 | 1.58 | .21 | nd | .05 | ? | nd |
| 4 | 9 | 15 | black | nd | .54 | 6.55 | .01 | nd | .13 | ? | nd |
| 5 | 9 | 15 | black | nd | .10 | 3.86 | .01 | nd | .01 | ? | .02 |
| 6 | 9 | 15 | black | nd | .14 | 5.03 | nd | nd | .03 | ? | .02 |
| 7 | 9 | 15 | red | nd | .18 | 5.68 | 2.12 | .08 | 3.47 | .06 | ? |
| 8 | 9 | 15 | yellow | nd | nd | .93 | nd | nd | 9.76 | .27 | ? |
| 9 | 9 | 15 | yellow | nd | nd | .36 | nd | nd | 12.52 | .17 | ? |
| 10 | 9 | 15 | green | nd | .18 | .58 | 3.79 | .07 | 3.28 | .06 | ? |
| 11 | 9 | 15 | blue | .02 | .33 | .85 | .06 | nd | .02 | ? | nd |
| 12 | 9 | 15 | white | nd | .31 | .42 | nd | nd | 1.64 | .23 | ? |
| 13 | 9 | 15 | blue | nd | .32 | .96 | .15 | nd | .06 | ? | nd |
| 14 | 9 | 15 | black | .02 | .17 | 4.98 | .03 | nd | .02 | .01 | .02 |
| 15 | 9 | 15 | black | nd | .54 | 13.65 | .11 | nd | .26 | ? | nd |
| 16 | 9 | 15 | green | .07 | .99 | 1.67 | nd | nd | .02 | ? | nd |
| 17 | 9 | 15 | yellow | nd | .10 | .27 | nd | nd | 7.44 | .10 | ? |
| 18 | 9 | 15 | green | nd | .15 | .91 | 1.98 | .03 | 2.08 | .04 | ? |
| 19 | 9 | 15 | red | nd | .09 | 3.58 | 2.29 | .14 | 2.88 | .04 | ? |
| 20 | 9 | 15 | black | nd | .31 | 2.65 | nd | nd | .02 | ? | nd |
| 21 | 9 | 15 | blue | nd | .06 | .80 | .13 | nd | ? | ? | nd |
| 22 | 12 | 32a | black | nd | .36 | 3.70 | .03 | nd | ? | nd | nd |
| 23 | 12 | 32a | black | nd | .38 | 5.48 | .05 | nd | nd | .01 | ? |
| 24 | 12 | 32a | blue | nd | .65 | 1.21 | .10 | nd | .28 | ? | nd |
| 25 | 12 | 32 | clear | nd | .55 | .52 | nd | nd | ? | ? | nd |
| 26 | 19 | 89 | yellow | nd | nd | nd | nd | nd | 5.06 | .08 | nd |
| 27 | 19 | 89 | yellow | nd | nd | .67 | nd | nd | 16.63 | .20 | nd |
| 28 | 19 | 89 | yellow | nd | nd | .55 | nd | nd | 15.11 | .20 | nd |
| 29 | 19 | 89 | yellow | nd | nd | .08 | nd | nd | 8.72 | .10 | nd |
| 30 | 19 | 89 | yellow | nd | nd | .57 | nd | nd | 16.73 | .23 | nd |
| 31 | 19 | 89 | yellow | nd | nd | .09 | nd | nd | 9.95 | .14 | nd |
| 32 | 19 | 89 | white | .02 | .68 | 1.95 | ? | nd | 1.20 | 1.01 | nd |
| | 19 | 89 | blue | ? | .28 | 1.75 | .07 | ? | .56 | .66 | nd |
| 33 | 23 | 100 | red+black | nd | .29 | 1.71 | .62 | .22 | 1.49 | .07 | nd |
| | 23 | 100 | black | nd | .31 | 2.94 | .43 | .06 | .41 | .05 | nd |
| 34 | 23 | 100 | red+black | nd | .28 | 1.51 | .64 | .23 | 2.42 | .10 | nd |
| | 23 | 100 | black | nd | .41 | 2.66 | .25 | .04 | 2.89 | .11 | ? |
| 35 | 23 | 100 | blue+white | ? | .45 | 1.33 | .10 | nd | .91 | .94 | nd |
| 36 | 27 | 112 | blue | nd | .01 | .31 | .08 | nd | .21 | ? | ? |
| 37 | 33 | 135 | blue | nd | nd | .29 | .09 | nd | .21 | ? | nd |
| 38 | 35 | 141 | blue | nd | .52 | 1.17 | .13 | nd | .45 | ? | nd |
| 39 | 35 | 141 | blue | nd | .09 | .85 | .11 | ? | .09 | ? | nd |

| Analysis No. | Gr. | F.N. | Colour | Ti | Mn | Fe | Cu | Zn | Pb | Sn | Sb |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 40 | 37 | 150 | brown | nd | 1.50 | .95 | .10 | nd | nd | .01 | nd |
| 41 | 37 | 150 | brown | nd | .97 | .29 | nd | nd | nd | .01 | nd |
| 42 | 37 | 150 | brown | nd | 1.25 | .49 | nd | nd | nd | ? | nd |
| 43 | 37 | 150 | blue | nd | .11 | .72 | .01 | nd | nd | .01 | ? |
| 44 | 37 | 150 | blue | nd | .08 | .53 | .09 | nd | nd | ? | ? |
| 45 | 37 | 150 | blue | nd | .20 | .58 | .05 | nd | .04 | ? | nd |
| 46 | 37 | 150 | brown | nd | 1.03 | .52 | nd | nd | nd | ? | nd |
| 47 | 37 | 150 | white | nd | .40 | .84 | .03 | nd | .79 | .50 | .01 |
|  | 37 | 150 | white+blue | nd | .41 | .62 | .17 | nd | .27 | .39 | ? |
| 48 | 37 | 150 | blue | nd | .16 | .54 | .13 | nd | .03 | ? | nd |
| 49 | 37 | 150 | blue | nd | .10 | .44 | .06 | nd | nd | ? | ? |
| 50 | 37 | 150 | clear | nd | 1.29 | 1.23 | nd | nd | nd | ? | .02 |
| 51 | 37 | 150 | brown | nd | 1.10 | .74 | ? | nd | nd | .01 | nd |
| 52 | 39 | 154 | blue | nd | .01 | .52 | .04 | nd | .33 | .11 | ? |
|  | 39 | 154 | white+red | nd | .27 | 1.14 | .16 | .04 | 1.97 | .32 | nd |
| 53 | 39 | 154 | white+blue | nd | .26 | 1.12 | .04 | nd | .70 | .43 | nd |
|  | 39 | 154 | white | nd | .60 | 1.99 | .08 | nd | 1.35 | 1.09 | ? |
| 54 | 39 | 154 | white | nd | .60 | 1.56 | nd | nd | 1.65 | .87 | nd |
|  | 39 | 154 | white+blue | nd | .21 | .81 | nd | nd | .67 | .33 | nd |
| 55 | 39 | 154 | white+blue | nd | .20 | .59 | nd | nd | 2.11 | .42 | ? |
|  | 39 | 154 | white+blue | nd | .25 | .92 | nd | nd | 1.35 | .47 | nd |
|  | 39 | 154 | white | nd | .22 | .87 | nd | nd | 2.70 | .53 | nd |
| 56 | 39 | 154 | red | nd | .75 | 4.45 | 1.25 | .04 | .74 | .02 | nd |
| 57 | 39 | 154 | yellow | nd | .11 | .91 | nd | nd | 11.65 | .15 | nd |
| 58 | 39 | 154 | green | nd | .71 | .48 | nd | nd | nd | ? | nd |
| 59 | 39 | 154 | red | nd | .03 | 5.23 | 2.44 | ? | 4.75 | .01 | .03 |
| 60 | 39 | 154 | red | nd | .44 | 2.49 | .62 | nd | .96 | .06 | ? |
| 61 | 39 | 154 | red | nd | .44 | 2.35 | .54 | .02 | .73 | .03 | nd |
| 62 | 39 | 154 | green+yellow | nd | .53 | .83 | ? | nd | .32 | .03 | ? |
|  | 39 | 154 | yellow+green | nd | .44 | 1.45 | .02 | nd | 6.76 | .18 | nd |
| 63 | 39 | 154 | red | ? | .02 | 1.87 | 1.26 | .09 | 2.22 | .04 | nd |
|  | 39 | 154 | red+yellow | nd | .12 | 1.37 | .90 | .04 | 6.31 | .12 | ? |
| 64 | 39 | 154 | red | nd | .36 | 2.47 | .78 | .07 | 3.12 | .05 | nd |
|  | 39 | 154 | yellow | nd | .26 | 1.77 | .45 | ? | 6.27 | .12 | nd |
| 65 | 39 | 154 | blue | nd | .04 | .57 | .11 | ? | .30 | .04 | nd |
|  | 39 | 154 | blue+white | ? | .16 | 1.08 | .07 | ? | .48 | .12 | ? |
| 66 | 41 | 161 | clear | nd | .18 | .31 | nd | nd | nd | ? | nd |
| 67 | 41 | 161 | blue | nd | ? | .33 | .05 | nd | .30 | ? | ? |
| 68 | 41 | 161 | blue | nd | .07 | nd | nd | nd | .20 | .02 | ? |
| 69 | 41 | 161b | clear | nd | .62 | .58 | nd | nd | .04 | .01 | ? |
| 70 | 41 | 161b | clear | nd | .28 | .53 | nd | nd | nd | .01 | nd |
| 71 | 41 | 161 | blue | nd | .62 | .80 | .07 | nd | .50 | ? | nd |
| 72 | 41 | 161 | blue | nd | .52 | .99 | .22 | .05 | .39 | ? | ? |

| Analysis No. | Gr. | F.N. | Colour | Ti | Mn | Fe | Cu | Zn | Pb | Sn | Sb |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 73 | 47 | 186a | clear | nd | .72 | 1.52 | nd | nd | nd | ? | nd |
| 74 | 47 | 186a | clear | nd | 1.53 | 1.38 | nd | nd | nd | ? | nd |
| 75 | 47 | 186a | clear | nd | .84 | .91 | nd | nd | nd | ? | nd |
| 76 | 47 | 186a | clear | .42 | .41 | .79 | nd | nd | nd | nd | nd |
| 77 | 47 | 186a | clear | .48 | .48 | .86 | nd | nd | nd | ? | nd |
| 78 | 47 | 186a | clear | .54 | .53 | .87 | nd | nd | nd | ? | ? |
| 79 | 47 | 186a | clear | .84 | .84 | 1.30 | nd | nd | .01 | ? | nd |
| 80 | 47 | 186a | clear | .80 | .80 | .71 | nd | nd | nd | ? | ? |
| 81 | 47 | 186a | clear | nd | .56 | .49 | nd | nd | nd | ? | nd |
| 82 | 47 | 186a | clear | nd | .34 | .23 | nd | nd | nd | ? | nd |
| 83 | 47 | 186a | clear | nd | 1.64 | 1.68 | nd | nd | nd | ? | nd |
| 84 | 47 | 186b | clear | nd | .40 | .21 | nd | nd | nd | ? | nd |
| 85 | 47 | 186b | clear | nd | .41 | .23 | nd | nd | nd | ? | ? |
| 86 | 47 | 186b | clear | nd | .51 | .93 | nd | nd | nd | ? | nd |