*Staffordshire Hoard Research Report 18*

# Pilot XRF Study of the Silver Hilt-plates from the Staffordshire Hoard

E.S. Blakelock

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## Information about this report

This report was produced in 2015 during the first year of Stage 2 of the project, i.e. before the completion of the catalogue and the full joining of the fragments in this category of material. The concordance of the K numbers given in the report to the catalogue numbers as they appear in the final publication is as given below. The list also includes the names of the objects as used in the final publication.

When the work was carried out in early 2015 it was thought that K248/1823 were the same object. It was also thought that K1493/1534 were too. The work was carried out prior to the detailed study of the hilt-plates. This showed that K1823 and K1493 (renamed K2083) joined to form catalogue no. 381. Fragment K1534 (catalogue no. 382) is possibly part of the same plate as no. 381, or a pair to it.



The owners, Historic England and Barbican Research Associates are grateful to the Esmée Fairbairn Collections Fund for the resources which enabled the work to be carried out

| K number | Catalogue number | Name in publication |
|---|---|---|
| 13 | 379 | Hilt-plate cast in silver |
| 138 | 371 | Hilt-plate in cast silver of oval form with gilding |
| 179 | 375 | Hilt-plate cast in silver with line ornament |
| 239 | 372 | Hilt-plate cast in silver of oval form |
| 248 | 385 | Side of a hilt-plate in silver-gilt |
| 552 | 375 | Hilt-plate cast in silver with line ornament |
| 593 | 371 | Hilt-plate in cast silver of oval form with gilding |
| 995 | 379 | Hilt-plate cast in silver |
| 1029 | 372 | Hilt-plate cast in silver of oval form |
| 1493[1] | 381 | End of hilt-plate cast in silver |
| 1534 | 382 | End fragment of hilt-plate cast in silver |
| 1823 | 381 | End of hilt-plate cast in silver |

[1] This fragment now renumbered K2083.

Birmingham Museums

# Pilot XRF study of the silver hilt-plates from the Staffordshire Hoard

E. S. Blakelock

## Abstract:

At the British Museum a pilot study of foil fragments was carried out to determine whether surface X-ray fluorescence (XRF) analysis can be used to help identify groups of foil fragments from individual friezes, and therefore aid in the conservation work. This showed that surface analysis could not be reliably used to due to gilding, and corrosion products that had formed post-deposition.

In this study surface analysis was carried out on the fronts and backs of a selection of hilt-plate fragments, and compared with results from prepared sub-surface areas. This was to identify the differences between surface and subsurface analysis, and to determine whether fragments of hilt-plates, and potentially other objects, could be grouped based on sub-surface composition. Tests were carried out with the smaller 0.2 mm collimator to determine the effects of the count time on the results, and therefore establish a methodology for future work.

The composition of most of the hilt-plate fragments fell in the range of *c*.75-88 wt% silver, 5-12 wt% copper, 2-3% tin and 1-5 wt% gold. Lead and tin was present in all of the fragments. The XRF analysis of the fronts of hilt-plates revealed that half had been mercury gilded. The amount of gold and mercury varied across the front of a single fragment, confirming that surface XRF of the fronts cannot be used to group them. The surface analysis of the inside of the hilt-plate fragments showed a range of compositions due to surface depletion and presence of corrosion products, mostly silver chlorides. Subsurface analysis provided more consistent and reliable results of the bulk alloy.

When the sub-surface results for the different hilt-plate groups were compared to each other, it became clear that the majority overlapped. There were often differences in composition between fragments of the same hilt-plate, and in the case of K1823 there were observable differences between sub-surface areas on the same fragment, although this may be partially related to contamination from the surface. However it will mean that grouping by composition is likely to be problematic unless objects have a significantly different composition.

## Introduction

This pilot study forms part of a larger English Heritage-funded research project on the Staffordshire Hoard,[1] and was funded by a grant from the Esmée Fairbairn Collections Fund.

At the British Museum a pilot study of foil fragments was carried out to determine whether surface X-ray fluorescence (XRF) analysis can be used to help identify groups of foil fragments from individual friezes, and therefore aid in the conservation work.[2] With the exception of the interlace foils XRF analysis of the fronts of the foils revealed the presence of mercury gilding which prevents direct access to the silver alloy below. The analysis of the backs of the foils showed a range of compositions, which overlapped between friezes and therefore did not help in the identification of compositional groups linked to specific friezes. There was also evidence for contamination from the gilding process on the back of the foils although it was not always visibly present. The previous study demonstrated that a rapid surface XRF survey is not the appropriate technique to identify frieze groups.

In this study surface analysis was carried out on the fronts and backs of a selection of hilt-plate fragments, and compared with results from sub-surface areas on the same hilt-plates. This was to identify the differences between surface and subsurface analysis, and to determine whether fragments of hilt-plates, and potentially other objects, could be grouped based on sub-surface composition. Tests were carried out with the smaller 0.2 collimator to determine the effects of the count time on the results, and therefore establish a methodology for future work.

## Methodology

### *Instrument*

The XRF analysis was carried out using a Bruker Mistral M1 fitted with a tungsten X-ray tube with a silicon drift detector. The voltage used was 40 kV with a current of 800 µA. A variety of collimators and count times were investigated during this project, and these are discussed below.

### *Standards and quantification*

The XRF results were quantified using pure elements and fundamental parameters. The spectrum for each analysed area was examined to confirm the presence of elements being quantified especially where the peaks overlap, e.g. gold, zinc, mercury and bromine. Sulphur was not quantified but examination of the spectra revealed no traces.

Four standards were run during the course of this study (Table 1). The first is the MAC2 gold standard bought for the Staffordshire Hoard project. This standard was produced specifically for the gold study therefore it is not representative of the composition of the silver objects in the Hoard. The MAC2 standard was analysed each day the XRF was used. Analysis was carried out with both the 0.5 collimators (at 240 seconds) and 0.2 collimators (at 300 and 600 seconds), and compared to the previous analysis carried out with the 0.7 collimator at 30 seconds.[3]

Three silver standards were borrowed from the Institute of Archaeology, University College

[1] Cool 2015.
[2] Blakelock 2014a.
[3] Blakelock 2014b.

London, these standards also included some trace elements but these were below the detection limits of the instrument (Table 1). The three silver standards were analysed in five different areas under each of the following conditions;

- 0.7 collimator for 30 seconds,
- 0.5 collimator for 240 seconds,
- 0.2 collimators for 300 seconds,
- 0.2 collimators for 600 seconds.

| Standard | Ag (%) | Cu (%) | Sn (%) | Zn (%) | Pb (%) | Au (%) | Fe (%) | Bi (%) | Sb (%) |
|---|---|---|---|---|---|---|---|---|---|
| MAC2 | 19.2 | 5.1 | 1.03 | - | - | 74.7 | - | - | - |
| AGA1 | 77.37 | 19.95 | 0.29 | 0.21 | 0.21 | 1.48 | 0.04 | 0.19 | 0.05 |
| AGA2 | 86.97 | 10.00 | 0.52 | 0.50 | 1.02 | 0.51 | 0.03 | 0.11 | 0.19 |
| AGA3 | 90.53 | 4.91 | 0.92 | 0.82 | 1.89 | 0.26 | 0.02 | 0.05 | 0.46 |

**Table 1.** The compositions of the four standards analysed in this study.

### *Method and Samples*

Twelve silver hilt-plate fragments were chosen for the pilot study (Table 2). To determine the practicality of using composition to group the pieces the fragments were chosen from six different hilt-plate sets: so that the differences between fragments of the same plate could be investigated. The possible compositional variability of a single fragment was checked by carrying out multiple analyses on both parts of the same hilt-plate fragment K1823.

| Group | Object | |
|---|---|---|
| A | K179 | K552 |
| B | K13 | K995 |
| C | K1029 | K239 |
| D | K138 | K593 |
| E | K1493 | K1534 |
| F | K248 | K1823 |

**Table 2.** List of hilt-plate fragments analysed.

For each fragment five areas inside were analysed. Where obvious gilding was identified usually three areas of gilding and three areas with no apparent gilding were analysed. If no gilding was observed five areas on the front of the hilt-plate were examined.

The sub-surface areas were prepared by either scraping the surface in a similar manner to the gold analysis project[4] or by spot grinding with an 800 grit sand paper. In the majority of cases the sub-surface area was prepared on the inside of the piece but some areas were also prepared on the edge. In total five analyses were carried out using the 0.5 collimator with a 240 second count time. The same sub-surface areas were also analysed using the 0.2 collimator. To investigate the possible errors introduced two different count times, 300 and 600 seconds were carried out.

## Results and discussion

### *Standards and Quantification*

The results from the analysis of the MAC2 standards are shown in Table 3. The results given by the BMT XRF were similar to those obtained using the British Museum XRF. The largest difference in composition is between the SEM-EDX and both XRF systems. This is probably related to the method used to calibrate the SEM-EDX system which uses only one standard for calibration. The SEM-EDX system at the British Museum used a MAC2

[4] Blakelock 2013.

standard for calibration therefore the results appear much more accurate. Even so the results are within expectable margins for semi-quantitative analysis.

| | | Colimator (mm) | Count time (seconds) | Au (%) | Ag (%) | Cu (%) | Sn (%) |
|---|---|---|---|---|---|---|---|
| | | | | **74.7** | **19.2** | **5.1** | **1.03** |
| BMT | XRF | 0.7 | 30 | 75.3 | 18.7 | 4.7 | 1.3 |
| | | | | *0.12* | *0.18* | *0.10* | *0.11* |
| | | 0.5 | 240 | 75.5 | 18.7 | 4.5 | 1.3 |
| | | | | *0.1* | *0.08* | *0.06* | *0.06* |
| | | 0.2 | 300 | 76.3 | 18.6 | 4.5 | 0.6 |
| | | | | *0.4* | *0.2* | *0.1* | *0.4* |
| | | 0.2 | 600 | 75.9 | 18.6 | 4.5 | 0.9 |
| | | | | *0.2* | *0.2* | *0.1* | *0.4* |
| BM | XRF | 0.65 | 200 | 75.1 | 18.9 | 5.0 | 1.1 |
| | | | | *0.00* | *0.09* | *0.08* | *0.05* |
| BM | SEM-EDX | | 150 | 74.3 | 19.6 | 5.1 | 1.0 |
| | | | | *0.14* | *0.14* | *0.06* | *0.08* |

**Table 3.** Shows the results from the analysis of the MAC2 standard

| Object | Colimator (mm) | Count time (seconds) | | Ag (%) | Cu (%) | Sn (%) | Zn (%) | Pb (%) | Au (%) | Fe (%) | Bi (%) | Sb (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AGA1 | | | | **77.37** | **19.95** | **0.29** | **0.21** | **0.21** | **1.48** | **0.04** | **0.19** | **0.05** |
| | 0.7 | 30 | Avg | 77.0 | 20.8 | 0.2 | 0.1 | 0.2 | 1.5 | n.d. | 0.2 | n.d. |
| | | | *StDev* | *1.40* | *1.39* | *0.18* | *0.11* | *0.03* | *0.07* | | *0.05* | |
| | 0.5 | 240 | Avg | 76.6 | 21.1 | 0.3 | n.d. | 0.2 | 1.5 | n.d. | 0.2 | n.d. |
| | | | *StDev* | *0.74* | *0.65* | *0.07* | | *0.03* | *0.04* | | *0.04* | |
| | 0.2 | 300 | Avg | 76.2 | 21.7 | 0.1 | n.d. | 0.2 | 1.6 | n.d. | 0.2 | n.d. |
| | | | *StDev* | *0.33* | *0.43* | *0.13* | | *0.03* | *0.05* | | *0.03* | |
| | 0.2 | 600 | Avg | 76.2 | 21.6 | 0.2 | 0.1 | 0.2 | 1.5 | n.d. | 0.2 | n.d. |
| | | | *StDev* | *0.17* | *0.13* | *0.07* | *0.11* | *0.03* | *0.04* | | *0.03* | |
| AGA2 | | | | **86.97** | **10.00** | **0.52** | **0.50** | **1.02** | **0.51** | **0.03** | **0.11** | **0.19** |
| | 0.7 | 30 | Avg | 85.9 | 11.3 | 0.6 | 0.5 | 1.1 | 0.5 | n.d. | 0.2 | n.d. |
| | | | *StDev* | *0.63* | *0.42* | *0.31* | *0.02* | *0.08* | *0.02* | | *0.01* | |
| | 0.5 | 240 | Avg | 85.9 | 11.2 | 0.4 | 0.5 | 1.2 | 0.5 | n.d. | 0.2 | n.d. |
| | | | *StDev* | *0.28* | *0.18* | *0.05* | *0.02* | *0.08* | *0.01* | | *0.02* | |
| | 0.2 | 300 | Avg | 86.2 | 11.4 | 0.1 | 0.5 | 1.2 | 0.5 | n.d. | 0.2 | n.d. |
| | | | StDev | *0.52* | *0.40* | *0.13* | *0.05* | *0.09* | *0.11* | | *0.02* | |
| | 0.2 | 600 | Avg | 85.7 | 11.5 | 0.4 | 0.5 | 1.2 | 0.6 | n.d. | 0.2 | n.d. |
| | | | *StDev* | *0.44* | *0.37* | *0.05* | *0.02* | *0.03* | *0.01* | | *0.02* | |
| AGA3 | | | | **90.53** | **4.91** | **0.92** | **0.82** | **1.89** | **0.26** | **0.02** | **0.05** | **0.46** |
| | 0.7 | 30 | Avg | 85.6 | 7.1 | 1.1 | 1.0 | 4.3 | 0.2 | n.d. | 0.2 | 0.5 |
| | | | *StDev* | *0.74* | *0.39* | *0.60* | *0.17* | *0.44* | *0.05* | | *0.03* | *0.12* |
| | 0.5 | 240 | Avg | 84.8 | 7.1 | 2.0 | 1.0 | 4.6 | 0.3 | n.d. | 0.0 | 0.2 |
| | | | *StDev* | *0.80* | *0.51* | *0.46* | *0.29* | *0.65* | *0.01* | | *0.08* | *0.38* |
| | 0.2 | 300 | Avg | 85.3 | 7.0 | 1.0 | 1.0 | 4.7 | 0.3 | n.d. | 0.2 | 0.5 |
| | | | *StDev* | *1.25* | *0.67* | *0.48* | *0.24* | *0.64* | *0.02* | | *0.05* | *0.31* |
| | 0.2 | 600 | Avg | 85.1 | 7.2 | 1.0 | 1.0 | 4.6 | 0.3 | n.d. | 0.2 | 0.7 |
| | | | *StDev* | *1.14* | *0.53* | *0.34* | *0.23* | *0.71* | *0.01* | | *0.05* | *0.13* |

**Table 4.** Shows the results from the analysis of the three silver standards. n.d. indicates not detected and no observable peak.

Generally the Bruker XRF was overestimating the copper and lead contents when calculating the totals for the AGA standards. The largest discrepancy was the lead total given for standard AGA3, which was double that of the reference amount. There was variability in the results across each standard reflected in the relatively high standard deviations which may explain the discrepancy (Table 4). This is probably partially due to the dendritic coring of the silver alloy and segregation across the sample, which was particularly apparent on AGA3. XRF analysis carried out by Birch (pers comm.) of silver standards from the same batch revealed similar elevated copper and lead concentrations when using XRF, again suggesting that the standards themselves may not be homogenous.

There are known spectrum conflict issues with the tin K-alpha and silver K-beta peaks which may explain the lower detection and poorer quantification results given for tin.[5] The Bruker XRF allows the user to define the tin peak used when quantifying the results so to mitigate this conflict the Kβ peak was used, but this is a smaller peak and therefore more difficult for the system to quantify. This was particularly evident when analysing AGA2 with the smallest collimator and 300 seconds count time.

All XRF methods struggled to accurately quantify elements such as zinc, antimony, bismuth and iron when they were below 0.5%. The Bruker XRF could only quantify antimony when analysing AGA3 where the peak was clearly visible.

However the results seen in Table 4 again show that there is generally good agreement between the results for all collimators and count times.

### *Methodology development*

There was little difference noted in the compositions given when comparing the methods used to prepare the sub-surface (Table 5). However by using the scraping tool smaller areas could be prepared. For future work the scraping tool will be used to reduce the damage to the objects.

| Object | Method used | Ag (%) | Cu (%) | Sn (%) | Zn (%) | Pb (%) | Au (%) | Fe (%) |
|---|---|---|---|---|---|---|---|---|
| K1029 | Grind | 75.6 | 8.0 | 3.5 | 0.7 | 1.6 | 5.3 | 5.1 |
| K1029 | Grind | 75.2 | 7.9 | 3.5 | 0.7 | 1.6 | 5.4 | 5.6 |
| K1029 | Grind | 76.5 | 7.7 | 3.5 | 0.7 | 1.6 | 5.2 | 4.7 |
| K1029 | Scrape | 75.5 | 8.7 | 3.7 | 0.7 | 1.6 | 5.2 | 4.5 |
| K1029 | Scrape | 74.8 | 8.3 | 3.7 | 0.7 | 1.6 | 5.4 | 5.4 |

**Table 5.** Shows the similarity between the data for both methods used to reveal the sub-surface. n.d. indicates not detected and no observable peak.

| Object | Area | Areas analysed | | Ag (%) | Cu (%) | Sn (%) | Zn (%) | Pb (%) | Au (%) | Hg (%) | Fe (%) | Cl (%) | Br (%) | Bi (%) | Sb (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| K13 | Subsurface edge | 6 | Avg | 78.9 | 5.8 | 1.6 | 0.4 | 0.9 | 4.0 | 8.3 | n.d. | n.d. | n.d. | n.d. | n.d. |
| | | | StDev | *4.1* | *0.7* | *0.3* | *0.0* | *0.1* | *1.8* | *2.0* | | | | | |
| | Subsurface flat | 5 | Avg | 88.9 | 5.4 | 1.6 | 0.3 | 1.3 | 2.0 | 0.2 | 0.2 | 0.1 | n.d. | 0.1 | n.d. |
| | | | StDev | *0.3* | *0.3* | *0.1* | *0.0* | *0.0* | *0.1* | *0.0* | *0.2* | *0.2* | | *0.0* | |
| K1029 | Subsurface edge | 5 | Avg | 72.5 | 7.8 | 2.4 | 0.7 | 1.6 | 5.1 | n.d. | 4.7 | 5.0 | 0.3 | n.d. | n.d. |
| | | | StDev | *1.4* | *0.3* | *0.1* | *0.0* | *0.0* | *0.1* | | *0.3* | *1.1* | *0.0* | | |
| | Subsurface flat | 5 | Avg | 71.2 | 16.9 | 2.1 | 1.0 | 1.6 | 4.0 | n.d. | 3.2 | n.d. | n.d. | n.d. | n.d. |
| | | | StDev | *1.3* | *0.6* | *0.4* | *0.1* | *0.1* | *0.2* | | *0.4* | | | | |
| K593 | Subsurface edge | 7 | Avg | 64.2 | 10.1 | 1.7 | 0.9 | 0.9 | 10.0 | 8.1 | 1.0 | 3.0 | n.d. | n.d. | n.d. |
| | | | StDev | *5.0* | *1.1* | *0.5* | *0.1* | *0.1* | *1.7* | *0.5* | *0.6* | *6.7* | | | |
| | Subsurface flat | 5 | Avg | 83.9 | 7.4 | 1.5 | 0.7 | 1.4 | 2.4 | 0.1 | 0.7 | 1.9 | n.d. | n.d. | n.d. |
| | | | StDev | *0.6* | *0.4* | *0.1* | *0.0* | *0.0* | *0.1* | *0.1* | *0.2* | *0.7* | | | |

**Table 6.** Shows the difference between the edge and flat sub-surface areas. n.d. indicates not

[5] Kruse and Tate 1992, Blakelock 2013.

detected and no observable peak.

The results from the analysis clearly showed that there were differences in the totals for areas prepared on the inside of the fragment compared to an edge (Table 6). The sub-surface areas prepared on the edge of the hilt-plates appeared to have a higher mercury and gold content. It is possible this is residual traces from the gilding on the front of the object. It could also relate to the size and shape of the area being analysed under the surface, which may have included some of the gilded surface from the front of the object. Any future work should therefore avoid edges of pieces where possible and focus on preparing areas on flat interior surfaces.

Ideally future work should be carried out using the smallest collimator on the Bruker instrument, to limit the amount of damage to the object. However using the smaller collimator reduces the area of the incident x-ray beam, and hence the total number of x-ray photons emitted by the sample and reaching the detector. For example when using the 0.2 mm instead of the 0.7 mm collimator the number of counts per second shown by the instrument decreases from c.3000 to c.300 when analysing pure silver. To compensate longer count times are required to give more accurate and precise data. An experiment was carried out using the standards to determine the effect of using different collimator sizes and acquisition times. The results suggested that the error produced by using a 0.2 collimator with different acquisition times does not appear to be significant for major elements (Table 3 and 4, and Table 9 in the appendix). The differences between the compositions given using the 0.2 collimator at 300 seconds and 600 seconds was minimal, and generally the agreement with the 0.5 collimator counting for 240 seconds and the 0.7 collimator for 30 seconds was good. For future studies it is therefore recommended that the 0.2 collimator is used, for a count of 300 seconds, so that multiple measurements of the same sub-surface area can be taken. However, longer count times should be carried out when visible peaks are identified, to allow for better background resolution, lower detection limits and therefore quantification to take place.

### *Fronts of hilt-plates and gilding*

Half of the hilt-plate fragments (groups B, D and F) analysed demonstrated evidence that they had been gilded (Figure 1 and Table 8). Of the gilded fragments, all revealed traces of mercury indicating that the mercury amalgam method of gilding had been used. Even where no gilding was visible on the surface of these gilded objects there was often an increased gold and mercury content. Therefore surface analysis of the fronts of silver pieces should be carried out to determine or confirm whether gilding was present.


**Fig. 1.** Hilt-plates left) K593 and right) K239 showing the gilded surface and amounts of tarnish visible.

The compositional differences seen between gilded fragments are likely to be related to the thickness of the gilding layer, with part or most of the silver detected being located in the silver underneath the gilding layer. The variable thickness of the gilded layer may be affected by different manufacturing processes, but is equally likely to relate to wear during use or in the post-depositional environment.

**Pilot XRF study silver hilt plates from the Staffordshire Hoard**

| | | | | Visible gilding | | | | | | | | | | | | | No visible gilding | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Object | Group | | Number of analyses | Ag (%) | Cu (%) | Sn (%) | Zn (%) | Pb (%) | Au (%) | Hg (%) | Fe (%) | Cl (%) | Br (%) | Bi (%) | Sb (%) | Number of analyses | Ag (%) | Cu (%) | Sn (%) | Zn (%) | Pb (%) | Au (%) | Hg (%) | Fe (%) | Cl (%) | Br (%) | Bi (%) | Sb (%) |
| K552 | A | Avg | | | | | | | | | | | | | | 5 | 83.2 | 5.2 | 1.1 | 0.8 | 1.2 | 1.9 | n.d. | 0.5 | 6.1 | n.d. | n.d. | n.d. |
| | | *StDev* | | | | | | | | | | | | | | | *3.70* | *1.24* | *0.06* | *0.14* | *0.08* | *0.14* | | *0.29* | *3.97* | | | |
| K179 | A | Avg | | | | | | | | | | | | | | 5 | 86.9 | 6.3 | 1.4 | 0.9 | 1.4 | 2.1 | n.d. | 0.7 | 0.2 | n.d. | n.d. | n.d. |
| | | *StDev* | | | | | | | | | | | | | | | *1.58* | *2.06* | *0.55* | *0.12* | *0.09* | *0.29* | | *0.37* | *0.34* | | | |
| K13 | B | Avg | 2 | 33.6 | 1.6 | 0.9 | n.d. | 0.2 | 50.9 | 12.6 | 0.3 | n.d. | n.d. | n.d. | n.d. | 3 | 34.1 | 2.4 | 0.8 | 0.1 | 0.2 | 48.6 | 13.4 | 0.3 | n.d. | n.d. | n.d. | n.d. |
| | | *StDev* | | | | | | | | | | | | | | | *17.81* | *2.08* | *0.32* | *0.13* | *0.18* | *20.45* | *0.95* | *0.26* | | | | |
| K995 | B | Avg | 3 | 55.9 | 2.7 | 1.0 | n.d. | 0.3 | 21.2 | 17.2 | 1.3 | n.d. | 0.2 | 0.1 | n.d. | 2 | 82.1 | 3.7 | 1.4 | 0.3 | 0.9 | 3.0 | 7.8 | 0.5 | n.d. | n.d. | 0.1 | n.d. |
| | | *StDev* | | *7.11* | *0.70* | *0.02* | | *0.13* | *13.20* | *7.96* | *0.86* | | *0.18* | *0.01* | | | | | | | | | | | | | | |
| K1029 | C | Avg | | | | | | | | | | | | | | 5 | 68.6 | 10.2 | 2.1 | 0.6 | 1.5 | 4.8 | n.d. | 7.5 | 4.6 | 0.2 | n.d. | n.d. |
| | | *StDev* | | | | | | | | | | | | | | | *3.14* | *3.15* | *0.20* | *0.24* | *0.27* | *1.21* | | *0.54* | *6.52* | *0.07* | | |
| K239 | C | Avg | | | | | | | | | | | | | | 5 | 72.1 | 13.0 | 2.1 | 0.8 | 1.8 | 4.0 | n.d. | 3.9 | 2.1 | 0.1 | n.d. | n.d. |
| | | *StDev* | | | | | | | | | | | | | | | *5.00* | *8.30* | *0.26* | *0.14* | *0.13* | *1.07* | | *1.95* | *2.67* | *0.12* | | |
| K138 | D | Avg | 3 | 26.4 | 1.1 | 0.9 | n.d. | 0.2 | 58.0 | 12.9 | 0.4 | n.d. | n.d. | n.d. | n.d. | 3 | 66.2 | 9.6 | 1.6 | 0.8 | 1.5 | 13.9 | 3.5 | 3.0 | n.d. | n.d. | n.d. | n.d. |
| | | *StDev* | | *3.41* | *0.29* | *0.08* | | *0.05* | *3.75* | *0.36* | *0.47* | | | | | | *12.82* | *4.22* | *0.27* | *0.40* | *0.39* | *13.96* | *3.92* | *0.82* | | | | |
| K593 | D | Avg | 3 | 27.1 | 0.7 | 0.9 | n.d. | 0.1 | 58.7 | 12.6 | n.d. | n.d. | n.d. | n.d. | n.d. | 3 | 76.7 | 13.5 | 1.6 | 0.8 | 1.7 | 2.3 | 0.2 | 0.9 | 2.2 | n.d. | n.d. | n.d. |
| | | *StDev* | | *6.26* | *0.23* | *0.10* | | *0.08* | *6.05* | *0.64* | | | | | | | *3.54* | *4.78* | *0.15* | *0.09* | *0.24* | *0.24* | *0.10* | *0.37* | *3.74* | | | |
| K1534 | E | Avg | | | | | | | | | | | | | | 6 | 77.2 | 7.1 | 1.9 | 0.5 | 1.3 | 1.7 | n.d. | 0.4 | 9.8 | n.d. | 0.1 | n.d. |
| | | *StDev* | | | | | | | | | | | | | | | *3.56* | *1.78* | *0.29* | *0.11* | *0.16* | *0.22* | | *0.22* | *3.29* | | *0.02* | |
| K1493 | E | Avg | | | | | | | | | | | | | | 5 | 77.1 | 6.6 | 2.0 | 0.5 | 1.4 | 1.8 | n.d. | 0.2 | 10.3 | n.d. | 0.1 | n.d. |
| | | *StDev* | | | | | | | | | | | | | | | *2.02* | *3.30* | *0.08* | *0.06* | *0.05* | *0.06* | | *0.35* | *3.99* | | *0.01* | |
| K248 | F | Avg | 3 | 27.5 | 1.0 | 0.8 | n.d. | 0.2 | 57.4 | 11.3 | n.d. | 1.9 | n.d. | n.d. | n.d. | 3 | 19.0 | 3.5 | 0.6 | 0.1 | 0.3 | 30.9 | 3.3 | 0.4 | 41.8 | n.d. | n.d. | n.d. |
| | | *StDev* | | *36.38* | *1.50* | *0.79* | | *0.35* | *43.57* | *6.01* | | *3.23* | | | | | *16.62* | *4.56* | *0.65* | *0.09* | *0.51* | *31.05* | *2.43* | *0.35* | *18.38* | | | |
| K1823a | F | Avg | 5 | 4.0 | 0.0 | 0.2 | n.d. | n.d. | 87.7 | 7.9 | 0.2 | n.d. | n.d. | n.d. | n.d. | | | | | | | | | | | | | |
| | | *StDev* | | *1.93* | *0.11* | *0.11* | | | *2.93* | *1.41* | *0.22* | | | | | | | | | | | | | | | | | |
| K1823b | F | Avg | 3 | 9.2 | 0.2 | 0.3 | n.d. | n.d. | 79.8 | 10.5 | n.d. | n.d. | n.d. | n.d. | n.d. | 3 | 9.1 | 0.2 | 0.5 | n.d. | n.d. | 81.4 | 8.7 | 0.1 | n.d. | n.d. | n.d. | n.d. |
| | | *StDev* | | *8.77* | *0.32* | *0.26* | | | *12.54* | *3.33* | | | | | | | *5.80* | *0.15* | *0.17* | | | *7.31* | *1.43* | *0.23* | | | | |

**Table 8.** Showing the results from the surface analysis of the front of the hilt-plates. n.d. indicates not detected and no observable peak.

### *Surface vs sub-surface*

The results from the inside surface and sub-surface analysis are shown in Table 10 in the appendix. Figures 2 and 3 clearly show the increased gold detected by surface analysis of the gilding layers on the front of some of the hilt-plates. Surface analysis of the inside of the object avoided the majority of the gilding, although in a few cases raised gold and mercury levels may indicate splashes of gold, not visible on the surface, from the gilding process. Generally the gold content was higher at the surface of the object when compared to the sub-surface, this is mostly due to gilding, or splashes of gilding inside the hilt-plate. The amount of gold seen also varied across hilt-plate fragments, most likely due to the irregular thickness of remaining silver and copper corrosion product. Corrosion and depletion of silver and copper from the surface may also have slightly enriched the surface (Figure 2 and 3).

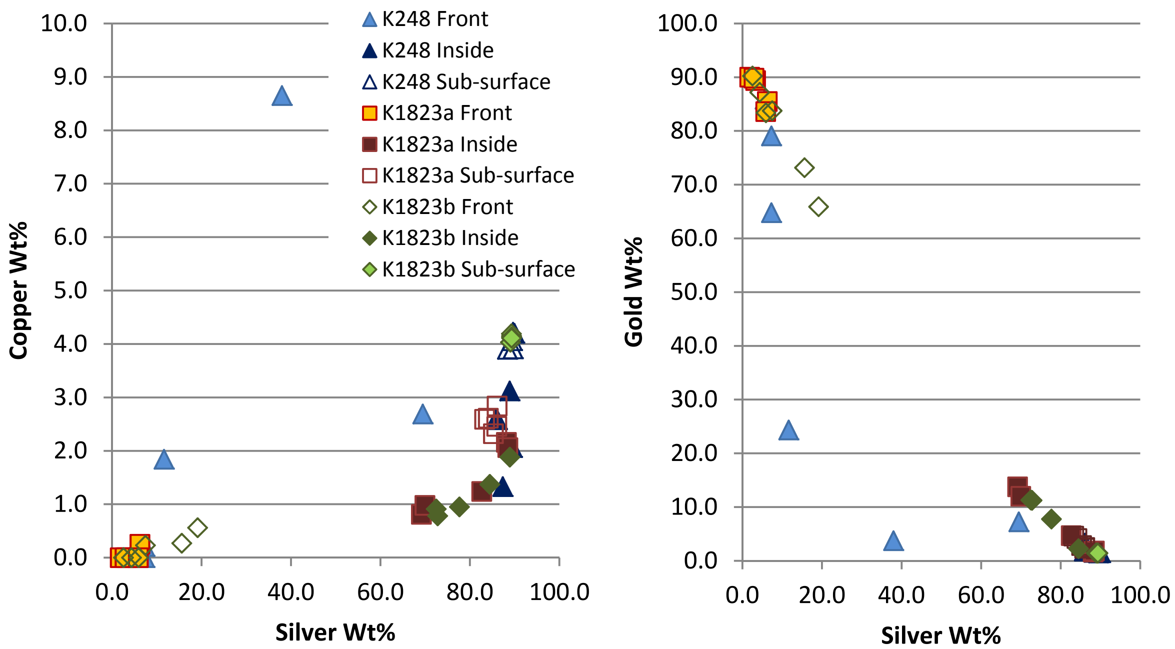


**Fig. 2.** Graphs showing the effects of corrosion and gilding on the surface measurements compared to the sub-surface areas on three fragments analysed from group F.

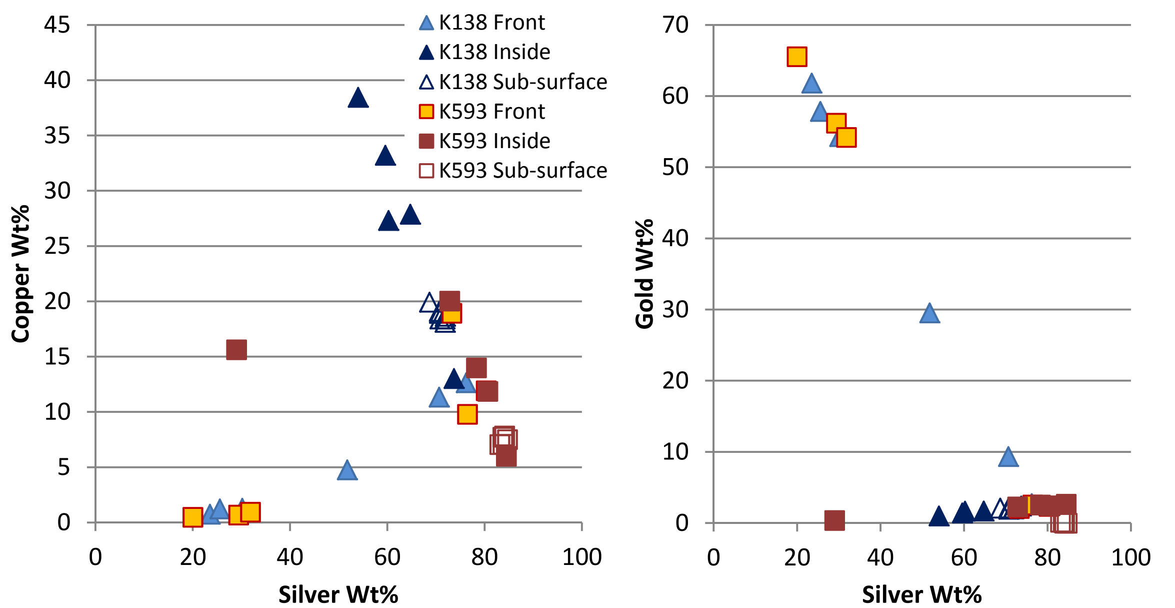


**Fig. 3.** Graphs showing the effects of corrosion and gilding on the surface measurements compared to the sub-surface areas on three fragments analysed from group D.

The composition of the majority of the hilt-plate fragments fell in the range of *c*.75-88 wt% silver, 5-12 wt% copper, 2-3% tin and 1-5 wt% gold. This composition range was significantly different to that detected when analysing the silver foils (Figure 4) which had a higher silver content.[6]

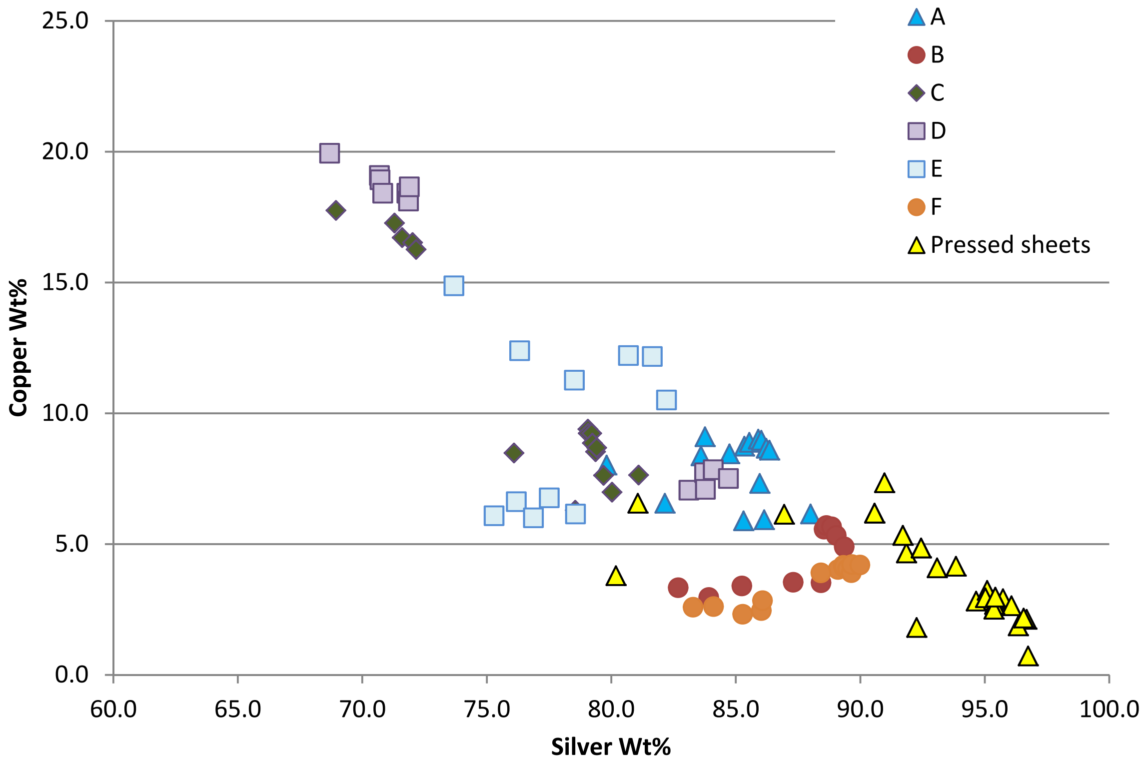


**Fig. 4.** Bi-variate graphs showing the results from the surface analysis of the inside of the hilt-plates compared to the backs of the pressed-sheets.

The compositional variability of a fragment was measured by carrying out analysis on two pieces of the same hilt-plate (Figure 2). There were often differences in composition between fragments of the two pieces of the same hilt-plate, and in the case of K1823 there were differences between sub-surface areas on the same fragment. The high proportion of gold and mercury present in these fragments suggested that there was contamination from the surface, even though sound metal had been revealed. However the amount of gold, mercury, chlorine and iron detected, was reduced when the smaller collimator was used; the larger collimator was most likely analysing beyond the sub-surface area prepared.

When the different hilt-plate groups were compared to each other, it became clear that the majority overlapped (Figure 5). This therefore means that grouping by composition would only be possible if the object to be grouped has a significantly different composition from other silver objects in the hoard.

[6] Blakelock 2014a.

Pilot XRF study silver hilt plates from the Staffordshire Hoard

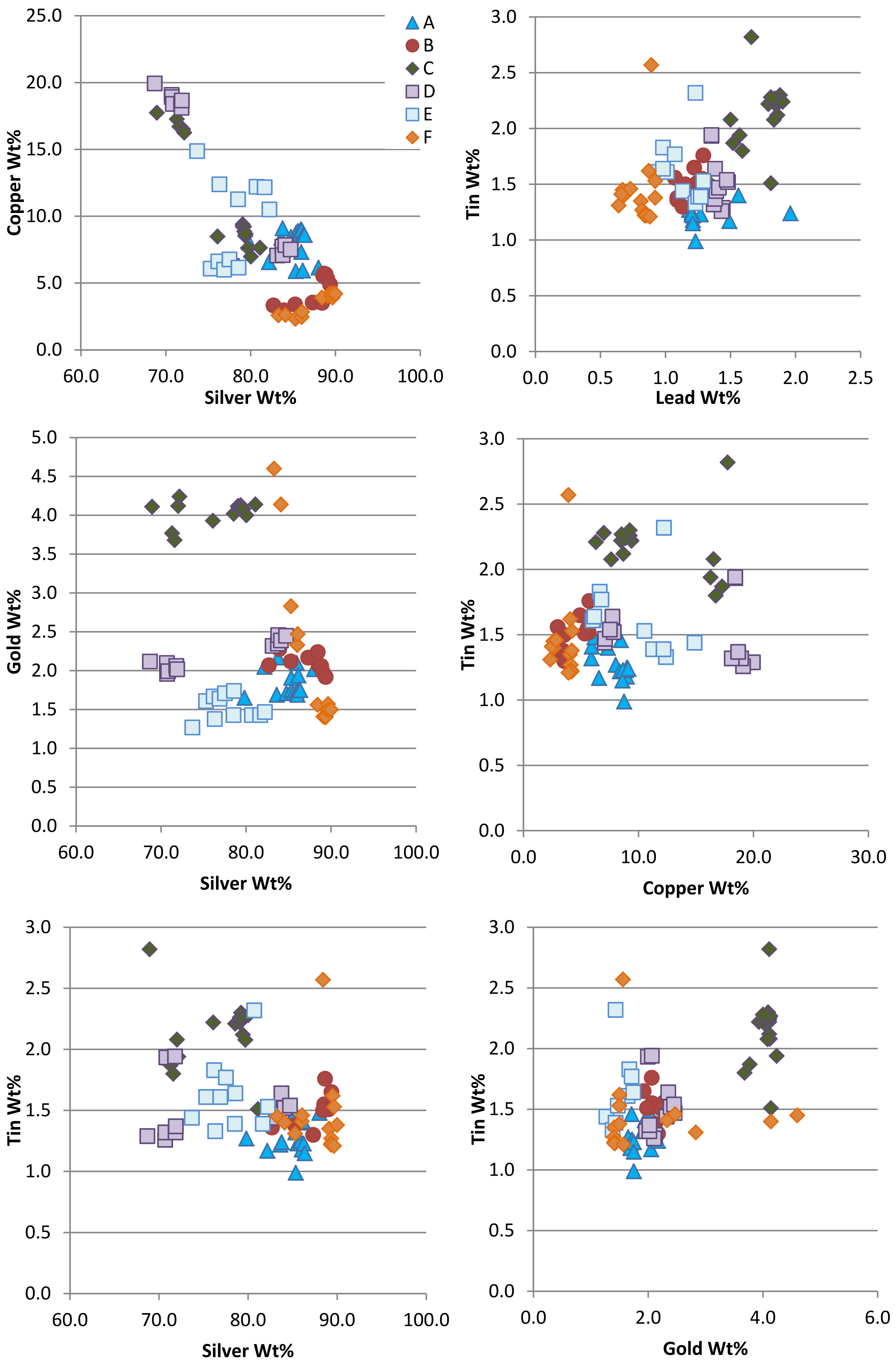


**Fig 5.** Bi-variate graphs showing the subsurface results from each of the hilt-plate groups, there is considerable overlap between some hilt-plates.

## Conclusion

The composition of most of the hilt-plate fragments fell in the range of *c.*75-88 wt% silver, 5-12 wt% copper, 2-3% tin and 1-5 wt% gold. Copper, lead, gold and tin were present in all of the fragments. The XRF analysis of the fronts of hilt-plates revealed that half had been mercury gilded. The amount of gold and mercury varied across the front of a single fragment, confirming that surface XRF of the fronts cannot be used to group them. The surface analysis of the inside of the hilt-plate fragments showed a range of compositions due to surface depletion and presence of corrosion products. Sub-surface analysis provided more consistent and reliable results.

When the sub-surface results for the different hilt-plate groups were compared to each other, it became clear that the majority overlapped. There were often differences in composition between fragments of the same hilt-plate, and in the case of K1823 there were observable differences between sub-surface areas on the same fragment. This will therefore mean that grouping by composition is likely to be problematic unless objects have a significantly different composition.

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Eleanor Blakelock
March 2015

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## Appendix

| Object | Group | | Collimator | Count time | | Ag (%) | Cu (%) | Sn (%) | Zn (%) | Pb (%) | Au (%) | Hg (%) | Fe (%) | Cl (%) | Br (%) | Bi (%) | Sb (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **K552** | A | Sub-surface | 0.5 | 240 | Avg | 85.5 | 6.4 | 1.4 | 1.0 | 1.4 | 2.0 | n.d. | 0.1 | 2.1 | n.d. | n.d. | n.d. |
| | | | 0.2 | 300 | | 86.6 | 6.8 | 1.2 | 1.0 | 1.5 | 2.2 | n.d. | 0.7 | n.d. | n.d. | 0.1 | n.d. |
| | | | 0.2 | 600 | | 85.5 | 6.8 | 2.3 | 1.0 | 1.6 | 2.2 | n.d. | 0.7 | n.d. | n.d. | n.d. | n.d. |
| **K179** | A | Sub-surface | 0.5 | 240 | Avg | 81.5 | 8.4 | 1.2 | 0.9 | 1.2 | 1.7 | n.d. | 0.0 | 5.1 | n.d. | n.d. | n.d. |
| | | | 0.2 | 300 | | 87.4 | 8.2 | 0.5 | 1.0 | 1.3 | 1.7 | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. |
| | | | 0.2 | 600 | | 86.2 | 8.7 | 1.3 | 1.0 | 1.2 | 1.6 | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. |
| **K13** | B | Sub-surface edge | 0.5 | 240 | Avg | 78.9 | 5.8 | 1.6 | 0.4 | 0.9 | 4.0 | 8.3 | n.d. | n.d. | n.d. | n.d. | n.d. |
| | | | 0.2 | 300 | | 72.0 | 6.6 | 0.7 | 0.3 | 0.7 | 7.0 | 12.5 | n.d. | n.d. | n.d. | 0.1 | n.d. |
| | | | 0.2 | 600 | | 71.4 | 6.6 | 1.1 | 0.4 | 0.7 | 7.2 | 12.5 | n.d. | n.d. | n.d. | 0.1 | n.d. |
| **K13** | B | Sub-surface flat | 0.5 | 240 | Avg | 88.9 | 5.4 | 1.6 | 0.3 | 1.3 | 2.0 | 0.2 | 0.2 | 0.1 | n.d. | 0.1 | n.d. |
| | | | 0.2 | 300 | | 89.5 | 5.7 | 1.2 | 0.3 | 1.2 | 2.0 | n.d. | n.d. | n.d. | n.d. | 0.1 | n.d. |
| | | | 0.2 | 600 | | 89.2 | 5.8 | 1.3 | 0.3 | 1.2 | 2.0 | n.d. | n.d. | n.d. | n.d. | 0.1 | n.d. |
| **K995** | B | Sub-surface | 0.5 | 240 | Avg | 85.5 | 3.3 | 1.4 | 0.1 | 1.1 | 2.2 | 0.2 | 0.3 | 5.7 | n.d. | 0.1 | n.d. |
| | | | 0.2 | 300 | | 91.7 | 3.2 | 1.4 | n.d. | 1.1 | 2.3 | 0.2 | n.d. | n.d. | n.d. | 0.1 | n.d. |
| | | | 0.2 | 600 | | 91.7 | 3.1 | 1.4 | n.d. | 1.1 | 2.3 | 0.1 | n.d. | n.d. | 0.1 | 0.1 | n.d. |
| **K1029** | C | Sub-surface edge | 0.5 | 240 | Avg | 72.5 | 7.8 | 2.4 | 0.7 | 1.6 | 5.1 | n.d. | 4.7 | 5.0 | 0.3 | n.d. | n.d. |
| | | | 0.2 | 300 | | 78.3 | 9.1 | 2.1 | 0.6 | 1.5 | 4.8 | n.d. | 3.4 | n.d. | 0.2 | n.d. | n.d. |
| | | | 0.2 | 600 | | 72.8 | 8.7 | 0.4 | 0.8 | 1.6 | 4.9 | n.d. | 3.1 | 7.4 | 0.2 | 0.1 | n.d. |
| **K1029** | C | Sub-surface flat | 0.5 | 240 | Avg | 71.2 | 16.9 | 2.1 | 1.0 | 1.6 | 4.0 | n.d. | 3.2 | n.d. | n.d. | n.d. | n.d. |
| | | | 0.2 | 300 | | 75.8 | 14.6 | 1.5 | 0.6 | 1.3 | 4.2 | n.d. | 2.0 | n.d. | n.d. | n.d. | n.d. |
| | | | 0.2 | 600 | | 74.8 | 14.7 | 1.9 | 0.8 | 1.4 | 4.3 | n.d. | 2.2 | n.d. | n.d. | n.d. | n.d. |
| **K239** | C | Sub-surface | 0.5 | 240 | Avg | 78.5 | 9.0 | 2.2 | 0.8 | 1.9 | 4.1 | n.d. | 2.7 | 0.7 | n.d. | n.d. | n.d. |
| | | | 0.2 | 300 | | 78.3 | 10.7 | 3.4 | 0.7 | 1.7 | 4.0 | n.d. | 1.1 | n.d. | n.d. | n.d. | n.d. |
| | | | 0.2 | 600 | | 78.0 | 10.7 | 3.5 | 0.7 | 1.7 | 4.2 | n.d. | 1.2 | n.d. | n.d. | n.d. | n.d. |

**Tables 9.** Showing the similarity between results when using the 0.5 and 0.2 collimators at different count times. n.d. indicates not detected and no observable peak.

**Pilot XRF study silver hilt plates from the Staffordshire Hoard**

| Object | Group | | Collimator | Count time | | Ag (%) | Cu (%) | Sn (%) | Zn (%) | Pb (%) | Au (%) | Hg (%) | Fe (%) | Cl (%) | Br (%) | Bi (%) | Sb (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **K239** | C | Sub-surface | 0.5 | 240 | Avg | 78.5 | 9.0 | 2.2 | 0.8 | 1.9 | 4.1 | n.d. | 2.7 | 0.7 | n.d. | n.d. | n.d. |
| | | | 0.2 | 300 | | 78.3 | 10.7 | 3.4 | 0.7 | 1.7 | 4.0 | n.d. | 1.1 | n.d. | n.d. | n.d. | n.d. |
| | | | 0.2 | 600 | | 78.0 | 10.7 | 3.5 | 0.7 | 1.7 | 4.2 | n.d. | 1.2 | n.d. | n.d. | n.d. | n.d. |
| **K138** | D | Sub-surface | 0.5 | 240 | Avg | 70.9 | 18.8 | 1.5 | 1.0 | 1.4 | 2.0 | 0.1 | 4.3 | n.d. | n.d. | n.d. | n.d. |
| | | | 0.2 | 300 | | 77.9 | 14.6 | 1.4 | 1.0 | 1.3 | 2.2 | n.d. | 1.6 | n.d. | n.d. | n.d. | n.d. |
| | | | 0.2 | 600 | | 78.6 | 14.2 | 1.3 | 1.0 | 1.3 | 2.3 | n.d. | 1.3 | n.d. | n.d. | n.d. | n.d. |
| **K593** | D | Sub-surface edge | 0.5 | 240 | Avg | 64.2 | 10.1 | 1.7 | 0.9 | 0.9 | 10.0 | 8.1 | 1.0 | 3.0 | n.d. | n.d. | n.d. |
| | | | 0.2 | 300 | | 73.6 | 13.5 | 0.5 | 1.2 | 1.3 | 6.1 | 3.7 | n.d. | n.d. | n.d. | n.d. | n.d. |
| | | | 0.2 | 600 | | 70.9 | 13.4 | 1.6 | 1.1 | 1.3 | 6.6 | 5.1 | n.d. | n.d. | n.d. | n.d. | n.d. |
| **K593** | D | Sub-surface flat | 0.5 | 240 | Avg | 83.9 | 7.4 | 1.5 | 0.7 | 1.4 | 2.4 | 0.1 | 0.7 | 1.9 | n.d. | n.d. | n.d. |
| | | | 0.2 | 300 | | 86.7 | 7.1 | 1.4 | 0.8 | 1.6 | 2.4 | n.d. | n.d. | n.d. | n.d. | 0.1 | n.d. |
| | | | 0.2 | 600 | | 86.3 | 7.2 | 1.8 | 0.7 | 1.6 | 2.4 | n.d. | n.d. | n.d. | n.d. | 0.1 | n.d. |
| **K1534** | E | Sub-surface | 0.5 | 240 | Avg | 79.9 | 11.7 | 1.6 | 1.1 | 1.3 | 1.4 | n.d. | 0.9 | 2.1 | n.d. | n.d. | n.d. |
| | | | 0.2 | 300 | | 83.2 | 11.6 | 0.9 | 1.3 | 1.2 | 1.4 | n.d. | 0.4 | n.d. | n.d. | n.d. | n.d. |
| | | | 0.2 | 600 | | 83.3 | 10.8 | 1.7 | 1.0 | 1.2 | 1.5 | n.d. | 0.4 | n.d. | n.d. | 0.1 | n.d. |
| **K1493** | E | Sub-surface | 0.5 | 240 | Avg | 76.9 | 6.3 | 1.7 | 2.1 | 1.0 | 1.7 | n.d. | 1.1 | 9.2 | n.d. | n.d. | n.d. |
| | | | 0.2 | 300 | | 85.4 | 7.4 | 1.4 | 1.8 | 1.3 | 1.9 | n.d. | 0.8 | n.d. | n.d. | n.d. | n.d. |
| | | | 0.2 | 600 | | 84.5 | 7.5 | 2.0 | 1.8 | 1.2 | 1.8 | n.d. | 1.1 | n.d. | n.d. | n.d. | n.d. |
| **K248** | F | Sub-surface | 0.5 | 240 | Avg | 89.4 | 4.1 | 1.7 | n.d. | 0.9 | 1.5 | 2.4 | n.d. | n.d. | n.d. | n.d. | n.d. |
| | | | 0.2 | 300 | | 90.5 | 4.5 | 0.9 | n.d. | 1.0 | 1.4 | 1.6 | n.d. | n.d. | n.d. | n.d. | n.d. |
| | | | 0.2 | 600 | | 90.1 | 4.2 | 1.2 | n.d. | 0.9 | 1.5 | 2.1 | n.d. | n.d. | n.d. | 0.1 | n.d. |
| **K1823a** | F | Sub-surface | 0.5 | 240 | Avg | 84.9 | 2.6 | 1.4 | n.d. | 0.7 | 3.3 | 7.1 | n.d. | n.d. | n.d. | n.d. | n.d. |
| | | | 0.2 | 300 | | 89.3 | 4.5 | 1.3 | n.d. | 0.9 | 1.5 | 2.6 | n.d. | n.d. | n.d. | n.d. | n.d. |
| | | | 0.2 | 600 | | 89.2 | 4.2 | 1.2 | n.d. | 0.8 | 1.5 | 3.1 | n.d. | n.d. | n.d. | n.d. | n.d. |
| **K1823b** | F | Sub-surface | 0.5 | 240 | Avg | 89.3 | 4.1 | 1.3 | n.d. | 0.8 | 1.4 | 3.1 | n.d. | n.d. | n.d. | n.d. | n.d. |
| | | | 0.2 | 300 | | 88.1 | 4.1 | 0.4 | n.d. | 1.0 | 2.8 | 3.6 | n.d. | n.d. | n.d. | n.d. | n.d. |
| | | | 0.2 | 600 | | 86.4 | 4.1 | 1.3 | n.d. | 0.9 | 3.4 | 3.9 | n.d. | n.d. | n.d. | n.d. | n.d. |

**Tables 9 cont.** Showing the similarity between results when using the 0.5 and 0.2 collimators at different count times. n.d. indicates not detected and no observable peak.

| Object | Pair | Area | No of areas analysed | Visible gilding | Col | Time | | Ag (%) | Cu (%) | Sn (%) | Zn (%) | Pb (%) | Au (%) | Hg (%) | Fe (%) | Cl (%) | Br (%) | Bi (%) | Sb (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **K552** | A | Front | 5 | | 0.5 | 240 | Avg | 83.2 | 5.2 | 1.1 | 0.8 | 1.2 | 1.9 | n.d. | 0.5 | 6.1 | n.d. | n.d. | n.d. |
| | | | | | | | StDev | *3.70* | *1.24* | *0.06* | *0.14* | *0.08* | *0.14* | | *0.29* | *3.97* | | | |
| | | Inside | 5 | | 0.5 | 240 | Avg | 82.7 | 7.9 | 1.4 | 0.9 | 1.4 | 2.0 | n.d. | 0.7 | 2.9 | n.d. | n.d. | n.d. |
| | | | | | | | StDev | *2.18* | *1.59* | *0.08* | *0.06* | *0.07* | *0.12* | | *0.09* | *2.25* | | | |
| | | Sub-surface | 5 | | 0.5 | 240 | Avg | 85.5 | 6.4 | 1.4 | 1.0 | 1.4 | 2.0 | n.d. | 0.1 | 2.1 | n.d. | n.d. | n.d. |
| | | | | | | | StDev | *2.1* | *0.59* | *0.12* | *0.12* | *0.10* | *0.08* | | *0.20* | *2.18* | | | |
| **K179** | A | Front | 5 | | 0.5 | 240 | Avg | 86.9 | 6.3 | 1.4 | 0.9 | 1.4 | 2.1 | n.d. | 0.7 | 0.2 | n.d. | n.d. | n.d. |
| | | | | | | | StDev | *1.6* | *2.06* | *0.55* | *0.12* | *0.09* | *0.29* | | *0.37* | *0.34* | | | |
| | | Inside | 5 | | 0.5 | 240 | Avg | 84.0 | 8.1 | 1.0 | 0.9 | 1.2 | 1.8 | n.d. | 0.6 | 2.4 | n.d. | n.d. | n.d. |
| | | | | | | | StDev | *4.7* | *2.35* | *0.19* | *0.09* | *0.09* | *0.20* | | *0.35* | *3.37* | | | |
| | | Sub-surface | 11 | | 0.5 | 240 | Avg | 81.5 | 8.4 | 1.2 | 0.9 | 1.2 | 1.7 | n.d. | 0.0 | 5.1 | n.d. | n.d. | n.d. |
| | | | | | | | StDev | *10.7* | *0.92* | *0.15* | *0.07* | *0.11* | *0.16* | | *0.14* | *11.88* | | | |
| **K13** | B | Inside | 5 | | 0.5 | 240 | Avg | 88.5 | 5.1 | 1.5 | 0.1 | 1.3 | 2.2 | 0.4 | 0.6 | 0.3 | n.d. | n.d. | n.d. |
| | | | | | | | StDev | *0.3* | *0.60* | *0.09* | *0.13* | *0.04* | *0.17* | *0.18* | *0.43* | *0.59* | | | |
| | | Front | 2 | Y | 0.5 | 240 | Avg | 33.6 | 1.6 | 0.9 | n.d. | 0.2 | 50.9 | 12.6 | 0.3 | n.d. | n.d. | n.d. | n.d. |
| | | | | | | | StDev | *8.5* | *0.55* | *0.16* | | *0.07* | *8.43* | *0.86* | *0.05* | | | | |
| | | Front | 3 | | 0.5 | 240 | Avg | 34.1 | 2.4 | 0.8 | 0.1 | 0.2 | 48.6 | 13.4 | 0.3 | n.d. | n.d. | n.d. | n.d. |
| | | | | | | | StDev | *17.8* | *2.08* | *0.32* | *0.13* | *0.18* | *20.45* | *0.95* | *0.26* | | | | |
| | | Sub-surface edge | 6 | | 0.5 | 240 | Avg | 78.9 | 5.8 | 1.6 | 0.4 | 0.9 | 4.0 | 8.3 | n.d. | n.d. | n.d. | n.d. | n.d. |
| | | | | | | | StDev | *4.1* | *0.72* | *0.35* | *0.02* | *0.10* | *1.78* | *2.01* | | | | | |
| | | Sub-surface flat | 5 | | 0.5 | 240 | Avg | 88.9 | 5.4 | 1.6 | 0.3 | 1.3 | 2.0 | 0.2 | 0.2 | 0.1 | n.d. | 0.1 | n.d. |
| | | | | | | | StDev | *0.3* | *0.33* | *0.11* | *0.02* | *0.04* | *0.07* | *0.03* | *0.22* | *0.19* | | *0.01* | |
| **K995** | B | Inside | 5 | | 0.5 | 240 | Avg | 81.4 | 4.0 | 1.4 | 0.1 | 1.0 | 2.7 | 4.8 | 0.8 | 3.7 | n.d. | 0.1 | n.d. |
| | | | | | | | StDev | *8.8* | *0.70* | *0.22* | *0.12* | *0.31* | *0.86* | *9.92* | *0.29* | *3.55* | | *0.02* | |
| | | Front | 2 | | 0.5 | 240 | Avg | 82.1 | 3.7 | 1.4 | 0.3 | 0.9 | 3.0 | 7.8 | 0.5 | n.d. | n.d. | 0.1 | n.d. |
| | | | | | | | StDev | *1.4* | *1.78* | *0.18* | *0.06* | *0.10* | *0.52* | *2.54* | *0.50* | | | *0.01* | |
| | | Front | 3 | Y | 0.5 | 240 | Avg | 55.9 | 2.7 | 1.0 | n.d. | 0.3 | 21.2 | 17.2 | 1.3 | n.d. | 0.2 | 0.1 | n.d. |
| | | | | | | | StDev | *7.1* | *0.70* | *0.02* | | *0.13* | *13.20* | *7.96* | *0.86* | | *0.18* | *0.01* | |
| | | Subsurface (scrape) | 5 | | 0.5 | 240 | Avg | 85.5 | 3.3 | 1.4 | 0.1 | 1.1 | 2.2 | 0.2 | 0.3 | 5.7 | n.d. | 0.1 | n.d. |
| | | | | | | | StDev | *2.4* | *0.23* | *0.11* | *0.12* | *0.03* | *0.09* | *0.03* | *0.18* | *2.66* | | *0.01* | |

**Tables 10.** Table of results from the surface and sub-surface analysis of the silver hilt-plates. n.d. indicates not detected and no observable peak.

| Object | Pair | Area | No of areas analysed | Visible gilding | Col | Time | | Ag (%) | Cu (%) | Sn (%) | Zn (%) | Pb (%) | Au (%) | Hg (%) | Fe (%) | Cl (%) | Br (%) | Bi (%) | Sb (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **K1029** | C | Front | 5 | | 0.5 | 240 | Avg | 68.6 | 10.2 | 2.1 | 0.6 | 1.5 | 4.8 | n.d. | 7.5 | 4.6 | 0.2 | n.d. | n.d. |
| | | | | | | | StDev | *3.1* | *3.15* | *0.20* | *0.24* | *0.27* | *1.21* | | *0.54* | *6.52* | *0.07* | | |
| | | Inside | 5 | | 0.5 | 240 | Avg | 58.0 | 30.2 | 1.7 | 1.0 | 1.3 | 2.0 | n.d. | 3.6 | 2.1 | n.d. | n.d. | n.d. |
| | | | | | | | StDev | *3.8* | *3.06* | *0.31* | *0.28* | *0.07* | *0.95* | | *0.65* | *3.00* | | | |
| | | Sub-surface edge | 5 | | 0.5 | 240 | Avg | 72.5 | 7.8 | 2.4 | 0.7 | 1.6 | 5.1 | n.d. | 4.7 | 5.0 | 0.3 | n.d. | n.d. |
| | | | | | | | StDev | *1.4* | *0.34* | *0.10* | *0.02* | *0.01* | *0.08* | | *0.32* | *1.14* | *0.01* | | |
| | | Sub-surface flat | 5 | | 0.5 | 240 | Avg | 71.2 | 16.9 | 2.1 | 1.0 | 1.6 | 4.0 | n.d. | 3.2 | n.d. | n.d. | n.d. | n.d. |
| | | | | | | | StDev | *1.3* | *0.60* | *0.41* | *0.07* | *0.06* | *0.24* | | *0.37* | | | | |
| **K239** | C | Inside | 5 | | 0.5 | 240 | Avg | 72.1 | 13.0 | 2.1 | 0.8 | 1.8 | 4.0 | n.d. | 3.9 | 2.1 | 0.1 | n.d. | n.d. |
| | | | | | | | StDev | *5.0* | *8.30* | *0.26* | *0.14* | *0.13* | *1.07* | | *1.95* | *2.67* | *0.12* | | |
| | | Front | 5 | | 0.5 | 240 | Avg | 76.9 | 4.8 | 2.7 | 0.7 | 1.7 | 5.7 | n.d. | 7.3 | 0.0 | 0.2 | n.d. | n.d. |
| | | | | | | | StDev | *3.0* | *0.74* | *0.10* | *0.10* | *0.11* | *0.56* | | *2.73* | *0.00* | *0.06* | | |
| | | Sub-surface | 6 | | 0.5 | 240 | Avg | 78.5 | 9.0 | 2.2 | 0.8 | 1.9 | 4.1 | n.d. | 2.7 | 0.7 | n.d. | n.d. | n.d. |
| | | | | | | | StDev | *1.4* | *0.37* | *0.03* | *0.03* | *0.04* | *0.08* | | *0.21* | *1.61* | | | |
| **K138** | D | Front | 3 | Y | 0.5 | 240 | Avg | 26.4 | 1.1 | 0.9 | n.d. | 0.2 | 58.0 | 12.9 | 0.4 | n.d. | n.d. | n.d. | n.d. |
| | | | | | | | StDev | *3.4* | *0.29* | *0.08* | | *0.05* | *3.75* | *0.36* | *0.47* | | | | |
| | | Front | 3 | | 0.5 | 240 | Avg | 66.2 | 9.6 | 1.6 | 0.8 | 1.5 | 13.9 | 3.5 | 3.0 | n.d. | n.d. | n.d. | n.d. |
| | | | | | | | StDev | *12.8* | *4.22* | *0.27* | *0.40* | *0.39* | *13.96* | *3.92* | *0.82* | | | | |
| | | Inside | 5 | | 0.5 | 240 | Avg | 62.5 | 28.0 | 1.4 | 0.9 | 1.3 | 1.6 | 0.3 | 4.1 | n.d. | n.d. | n.d. | n.d. |
| | | | | | | | StDev | *7.3* | *9.50* | *0.33* | *0.29* | *0.15* | *0.51* | *0.09* | *2.26* | | | | |
| | | Sub-surface | 7 | | 0.5 | 240 | Avg | 70.9 | 18.8 | 1.5 | 1.0 | 1.4 | 2.0 | 0.1 | 4.3 | n.d. | n.d. | n.d. | n.d. |
| | | | | | | | StDev | *1.1* | *0.60* | *0.31* | *0.02* | *0.04* | *0.06* | *0.10* | *0.62* | | | | |
| **K593** | D | Front | 3 | Y | 0.5 | 240 | Avg | 27.1 | 0.7 | 0.9 | n.d. | 0.1 | 58.7 | 12.6 | n.d. | n.d. | n.d. | n.d. | n.d. |
| | | | | | | | StDev | *6.3* | *0.23* | *0.10* | | *0.08* | *6.05* | *0.64* | | | | | |
| | | Front | 3 | | 0.5 | 240 | Avg | 76.7 | 13.5 | 1.6 | 0.8 | 1.7 | 2.3 | 0.2 | 0.9 | 2.2 | n.d. | n.d. | n.d. |
| | | | | | | | StDev | *3.5* | *4.78* | *0.15* | *0.09* | *0.24* | *0.24* | *0.10* | *0.37* | *3.74* | | | |
| | | Inside | 5 | | 0.5 | 240 | Avg | 69.0 | 13.5 | 1.4 | 0.5 | 1.2 | 2.1 | 0.3 | 1.0 | 10.7 | n.d. | 0.1 | 0.3 |
| | | | | | | | StDev | *22.8* | *5.16* | *0.27* | *0.29* | *0.41* | *0.96* | *0.11* | *0.44* | *22.81* | | *0.12* | *0.59* |
| | | Sub-surface flat | 5 | | 0.5 | 240 | Avg | 83.9 | 7.4 | 1.5 | 0.7 | 1.4 | 2.4 | 0.1 | 0.7 | 1.9 | n.d. | n.d. | n.d. |
| | | | | | | | StDev | *0.6* | *0.36* | *0.08* | *0.03* | *0.05* | *0.06* | *0.07* | *0.22* | *0.75* | | | |
| | | Sub-surface edge | 7 | | 0.5 | 240 | Avg | 64.2 | 10.1 | 1.7 | 0.9 | 0.9 | 10.0 | 8.1 | 1.0 | 3.0 | n.d. | n.d. | n.d. |
| | | | | | | | StDev | *5.0* | *1.15* | *0.48* | *0.10* | *0.07* | *1.66* | *0.51* | *0.60* | *6.68* | | | |

**Tables 10 cont.** Table of results from the surface and sub-surface analysis of the silver hilt-plates. n.d. indicates not detected and no observable peak, tr indicates not quantified but a peak is present.

| Object | Pair | Area | No of areas analysed | Visible gilding | Col | Time | | Ag (%) | Cu (%) | Sn (%) | Zn (%) | Pb (%) | Au (%) | Hg (%) | Fe (%) | Cl (%) | Br (%) | Bi (%) | Sb (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **K1534** | E | Front | 6 | | 0.5 | 240 | Avg | 77.2 | 7.1 | 1.9 | 0.5 | 1.3 | 1.7 | n.d. | 0.4 | 9.8 | n.d. | 0.1 | n.d. |
| | | | | | | | StDev | *3.6* | *1.78* | *0.29* | *0.11* | *0.16* | *0.22* | | *0.22* | *3.29* | | *0.02* | |
| | | Inside | 5 | | 0.5 | 240 | Avg | 76.3 | 16.6 | 1.4 | 1.4 | 0.9 | 1.2 | n.d. | 1.3 | 0.8 | n.d. | n.d. | n.d. |
| | | | | | | | StDev | *11.6* | *11.31* | *0.19* | *0.67* | *0.20* | *0.27* | | *0.86* | *0.87* | | | |
| | | Sub-surface | 5 | | 0.5 | 240 | Avg | 79.9 | 11.7 | 1.6 | 1.1 | 1.3 | 1.4 | n.d. | 0.9 | 2.1 | n.d. | n.d. | n.d. |
| | | | | | | | StDev | *2.4* | *0.80* | *0.41* | *0.06* | *0.03* | *0.03* | | *0.09* | *2.46* | | | |
| **K1493** | E | Front | 5 | | 0.5 | 240 | Avg | 77.1 | 6.6 | 2.0 | 0.5 | 1.4 | 1.8 | n.d. | 0.2 | 10.3 | n.d. | 0.1 | n.d. |
| | | | | | | | StDev | *2.0* | *3.30* | *0.08* | *0.06* | *0.05* | *0.06* | | *0.35* | *3.99* | | *0.01* | |
| | | Inside | 5 | | 0.5 | 240 | Avg | 75.4 | 7.3 | 1.6 | 1.9 | 1.1 | 1.7 | n.d. | 1.2 | 9.7 | n.d. | n.d. | n.d. |
| | | | | | | | StDev | *2.6* | *1.57* | *0.19* | *1.19* | *0.22* | *0.09* | | *0.69* | *2.76* | | | |
| | | Sub-surface | 5 | | 0.5 | 240 | Avg | 76.9 | 6.3 | 1.7 | 2.1 | 1.0 | 1.7 | n.d. | 1.1 | 9.2 | n.d. | n.d. | n.d. |
| | | | | | | | StDev | *1.2* | *0.35* | *0.10* | *0.24* | *0.05* | *0.05* | | *0.03* | *1.47* | | | |
| **K248** | F | Front | 3 | Y | 0.5 | 240 | Avg | 27.5 | 1.0 | 0.8 | n.d. | 0.2 | 57.4 | 11.3 | n.d. | 1.9 | n.d. | n.d. | n.d. |
| | | | | | | | StDev | *36.4* | *1.50* | *0.79* | | *0.35* | *43.57* | *6.01* | | *3.23* | | | |
| | | Front | 3 | | 0.5 | 240 | Avg | 19.0 | 3.5 | 0.6 | 0.1 | 0.3 | 30.9 | 3.3 | 0.4 | 41.8 | n.d. | n.d. | n.d. |
| | | | | | | | StDev | *16.6* | *4.56* | *0.65* | *0.09* | *0.51* | *31.05* | *2.43* | *0.35* | *18.38* | | | |
| | | Inside | 5 | | 0.5 | 240 | Avg | 87.6 | 2.3 | 1.4 | n.d. | 0.5 | 2.0 | 5.3 | 0.9 | 0.1 | n.d. | n.d. | n.d. |
| | | | | | | | StDev | *1.6* | *0.68* | *0.11* | | *0.09* | *0.74* | *1.26* | *0.37* | *0.19* | | | |
| | | Sub-surface | 5 | | 0.5 | 240 | Avg | 89.4 | 4.1 | 1.7 | n.d. | 0.9 | 1.5 | 2.4 | n.d. | n.d. | n.d. | n.d. | n.d. |
| | | | | | | | StDev | *0.6* | *0.15* | *0.53* | | *0.02* | *0.04* | *0.32* | | | | | |
| **K1823a** | F | Front | 5 | Y | 0.5 | 240 | Avg | 4.0 | 0.0 | 0.2 | n.d. | n.d. | 87.7 | 7.9 | 0.2 | n.d. | n.d. | n.d. | n.d. |
| | | | | | | | StDev | *1.9* | *0.11* | *0.11* | | | *2.93* | *1.41* | *0.22* | | | | |
| | | Inside | 5 | | 0.5 | 240 | Avg | 79.7 | 1.5 | 1.2 | n.d. | 0.4 | 6.8 | 10.2 | 0.3 | n.d. | n.d. | n.d. | n.d. |
| | | | | | | | StDev | *9.5* | *0.62* | *0.15* | | *0.15* | *5.74* | *4.45* | *0.27* | | | | |
| | | Sub-surface | 5 | | 0.5 | 240 | Avg | 84.9 | 2.6 | 1.4 | n.d. | 0.7 | 3.3 | 7.1 | n.d. | n.d. | n.d. | n.d. | n.d. |
| | | | | | | | StDev | *1.2* | *0.19* | *0.06* | | *0.03* | *1.03* | *0.44* | | | | | |
| **K1823b** | F | Front | 3 | Y | 0.5 | 240 | Avg | 9.2 | 0.2 | 0.3 | n.d. | n.d. | 79.8 | 10.5 | n.d. | n.d. | n.d. | n.d. | n.d. |
| | | | | | | | StDev | *8.8* | *0.32* | *0.26* | | | *12.54* | *3.33* | | | | | |
| | | Front | 3 | | 0.5 | 240 | Avg | 9.1 | 0.2 | 0.5 | n.d. | n.d. | 81.4 | 8.7 | 0.1 | n.d. | n.d. | n.d. | n.d. |
| | | | | | | | StDev | *5.8* | *0.15* | *0.17* | | | *7.31* | *1.43* | *0.23* | | | | |
| | | Inside | 5 | | 0.5 | 240 | Avg | 79.3 | 1.2 | 1.3 | n.d. | 0.4 | 6.8 | 11.1 | n.d. | n.d. | n.d. | n.d. | n.d. |
| | | | | | | | StDev | *7.3* | *0.45* | *0.18* | | *0.13* | *4.75* | *3.40* | | | | | |
| | | Sub-surface | 5 | | 0.5 | 240 | Avg | 89.3 | 4.1 | 1.3 | n.d. | 0.8 | 1.4 | 3.1 | n.d. | n.d. | n.d. | n.d. | n.d. |
| | | | | | | | StDev | *0.1* | *0.06* | *0.06* | | *0.02* | *0.01* | *0.12* | | | | | |

**Tables 10 cont.** Table of results from the surface and sub-surface analysis of the silver hilt-plates. n.d. indicates not detected and no observable peak, tr indicates not quantified but a peak is present.

# *Staffordshire Hoard Research Reports*

Staffordshire Hoard Research Reports were produced by the project

## *Contextualising Metal-Detected Discoveries: Staffordshire Anglo-Saxon Hoard*

Historic England Project 5892

The Staffordshire Hoard is owned by the Birmingham City Council and the Stoke-on-Trent City Council and cared for on their behalf by Birmingham Museums Trust and The Potteries Museum & Art Gallery.

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