Staffordshire Hoard Research Report 21

The Analysis and Documentation of Niello Objects in the Staffordshire Hoard

E.S. Blakelock

2016

This report forms part of
The Staffordshire Hoard: an Anglo-Saxon Treasure
edited by C. Fern, T. Dickinson and L. Webster
and published by the Society of Antiquaries of London

Information about this report

This report was produced in 2015 as part of Stage 2 of the project. At that time the catalogue had not been finalised and the specimens in the tables of data are identified by their K numbers. 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.

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
101	-	Not part of the hoard
107	574	Pyramid-fitting in gold with filigree and garnet cloisonné. [Cast copper alloy core].
133	335	Hilt-plate in gold. [Cast copper-alloy liner].
189	77	Pommel in cast silver, of cocked-hat form with double sword-rings, gilded low relief decoration, and mounts with filigree and a gem-setting. [Pewter core in sword-ring].
204	691	Small fragments of copper alloy.
211	691	Small fragments of copper alloy.
214	691	Small fragments of copper alloy.
259	691	Small fragments of copper alloy.
280	1	Pommel in gold, of cocked-hat form with filigree decoration . [Cast copper-alloy core].
283	243	Pair of hilt-plates in gold of oval form with garnet bosses. [Cast copper alloy liner].
299	27	Pommel in gold, of cocked-hat form, with filigree decoration. [Cast coper-alloy core].
306	63	Pommel in silver, of cocked-hat form, with filigree decoration. [Cast silver core].
353	14	Pommel in gold, of cocked-hat form, with filigree decoration. [Cast copper-alloy core].
369	184	Hilt-collar in cast silver, of high form, with line and puch decoration, gilding and black niello inlay. [Copper alloy liner].
457	2	Pommel in gold, of cocked-hat form with filigree decoration . [Cast copper-alloy core].
479/3	336	Hilt-plate in gold. [Copper alloy liner].
497	691	Small fragments of copper alloy.
563	244	Pair of hilt-plates in gold of oval form with gemmed bosses. [Cast liner of copper alloy].
680	40	Pommel in gold, of cocked-hat form, with filigree and one side cloisonné decoration. [Cast copper alloy core].

Continued

K number	Catalogue number	Name in publication
709	283	Hilt-plate in gold of oval form [copper corrosion liner fragments]
761	371	Hilt-plate in cast silver of oval form with gilding. [Silver rivet]
763	600	Fragments of a large sheet covering in silver with multiple panels of animal art and gilded borders.
781	-	Fragment considered to be modern.
900	691	Small fragments of copper alloy.
949	663	Silver cast boss. [Corroded shank].
1042	458	Mount in gold of rectangular form with filigree decoration. [gripping remains of plate of copper alloy].
1079	413	Mount in gold from a tip of a hilt-guard. [Copper-alloy core-liner]
1104	-	Fragment considered to be modern.
1135	691	Small fragments of copper alloy.
1184	494	Mount in gold of rectangular form with garnet and glass cloisonné decoration. [Copper alloy staining, possibly small remains of backplate].
1201	575	Pyramid-fitting in gold with filigree and garnet cloisonné. [Cast copper alloy core].
1230	273	Hilt-plate in gold with a boss. [Copper-alloy liner]
1279	691	Small fragments of copper alloy.
1284	691	Small fragments of copper alloy.
1315	[131]	Small piece of copper alloy found during cleaning of catalogue no. 131 [Hilt-collar of gold, of narrow form, with filigree decoration]. Left *in situ* renamed K1965.
1438	691	Small fragments of copper alloy.
1454	190	Remains from one or possibly a pair of hilt-collars cast in copper alloy with gilding, imitating filigree wire.
1455	691	Small fragments of copper alloy.
1472	671	Silver-gilt boss. [Copper alloy core].
1511	691	Small fragments of copper alloy.
1526	691	Small fragments of copper alloy.
1543	669	Silver boss. [Pewter core].
1581	691	Small fragments of copper alloy.
1688	641	Gold boss with filigree collar.
1695	242	Four fragments of cast copper alloy, with gilding, imitating thick beaded wire, possibly from one hilt-ring or a pair.
1702	669	Silver boss. [Pewter core]
1704	669	Silver boss. [Pewter core]
1754	645	Gold boss with filigree collar. [Silver core]
1753	[619]	Copper alloy fragment inside boss 619 – probably intrusive.
1873	190	Remains from one or possibly a pair of hilt-collars cast in copper alloy with gilding, imitating filigree wire.

The analysis and documentation of niello objects in the Staffordshire Hoard

Eleanor Blakelock

Abstract

Within the Staffordshire Hoard there are some gold and silver objects that were decorated with a black inlay thought to be niello, a material comprised of one or more metal sulphides.[1] Some samples of niello in the Staffordshire Hoard have been analysed at the British Museum.[2] In addition during the conservation programme in stage 1, of the English Heritage-funded research project, the niello objects in the hoard were recorded by Cymbeline Storey. The aim of this study is to review and summarise the previous analysis and conservation work carried out on the Staffordshire Hoard niello and to incorporate these, and new data gathered, into a single report.

XRD analysis carried out at the British Museum suggested that all the samples taken were silver sulphides, rather than silver-copper sulphides.[3] The survey of the remaining objects by XRF suggested that many were silver sulphide niello with the exception of hilt-collars K369, K19 *et al.*, K34 *et al.* and pommel K711 which may be silver-copper sulphide.

Examination of the objects showed that the niello was inlaid into sharp, curved or flat based channels, or into stamped impressions, often triangular in shape. There seemed to be no consistent finish to the niello, with eight raised from the surface while twelve had been polished smooth.

[1] La Niece 1983.
[2] La Niece 2013.
[3] La Niece 2013.

Introduction

Within the Staffordshire Hoard there are some gold and silver objects that have been decorated with a black inlay thought to be niello, a material comprised of one or more metal sulphides.[4] It was popular in the first century AD in the Roman Empire but was continuously used throughout the Anglo-Saxon period and beyond.[5]

Some samples of niello in the Staffordshire Hoard have been analysed at the British Museum.[6] In addition during the conservation programme in stage 1 of the English Heritage-funded research project, the niello objects in the hoard were recorded by Cymbeline Storey. The aim of this study is to review and summarise the previous analysis and conservation work carried out on the Staffordshire Hoard niello and to incorporate this, and new data gathered, into a single report. This report forms part of a larger English Heritage-funded research project on the Staffordshire Hoard,[7], and was funded by a grant from the Esmée Fairbairn Collections Fund.

Niello in the Roman period was usually either copper-sulphide or silver-sulphide.[8] Neither of these forms of niello could be melted into place but at temperatures around 600°C it would be soft enough to compact into the channel.[9] In the Roman period there is a noticeable preference to create and apply niello of the same metal as the object to be decorated.[10] The type of niello applied on Anglo-Saxon gold tended to be a purer silver-sulphide type. However during the sixth and seventh centuries the goldsmiths began to use a mixture of copper and silver sulphides to decorate silver, silver gilt, copper-gilt or copper objects.[11] This niello would have had a lower melting temperature of *c.* 680°C which would have made it easier to apply,[12] although there appears to be some continuity in the Roman method of applying the niello.[13]

Documentary sources

A table summarising the documentary evidence for niello is included in the Appendix. The earliest recipe for niello is in Pliny's *Natural History* written in c. 77-79 AD where he describes the method used in Egypt and Roman triumphal statues to stain or paint silver. The recipe given is follows '*the silver is mixed one third its amount of the very fine Cyprus copper called chaplet-copper and the same amount of live sulphur as of silver, and then they are melted in an earthenware vessel having its lid stopped with potters clay; the heating goes on till the lids of the vessels open of their own accord.*'.[14]. The sealed container would have stopped the copper and silver oxidising. This recipe would have produced a niello

[4] La Niece 1983.
[5] Northover and La Niece 2009.
[6] La Niece 2013.
[7] Cool 2015.
[8] La Niece 1983.
[9] La Niece 1983.
[10] La Niece 1983, 19.
[11] La Niece 1983; 1988.
[12] La Niece 1988.
[13] La Niece 1983.
[14] Rackham 1952, 99. *Natural history* XXXIII.46

similar to what is found archaeologically in the Anglo-Saxon period, however since silver-copper sulphide niello is rare in the Roman period when this recipe was recorded it is possible that it refers a surface treatment to blacken the silver rather than an inlay.[15] The *Leyden Papyrus X*, is a metallurgical text written in the third-fourth century AD has two recipes that could have been used to make niello. The first recipe (36) uses a combination of silver and lead with sulphur,[16] while the second (62) combines copper with sulphur[17] which are not seen archaeologically in this period.

More contemporary to the Staffordshire Hoard a sixth to eighth century Latin document known as the *Compositiones Variae* provides a detailed description of metalworking processes, but there are no recipes for niello like substances.[18] There are a number of Arabic treatises that have niello recipes, the most contemporary example is the Al-Hamdānī written in *c.* 942 AD which describes the manufacture of a silver sulphide niello for applying on to silver.[19]

The *Mappae Clavicula* a compilation of recipes for craftsmen surviving from the ninth century which has the most comparable recipes for niello, to those surviving in the Anglo-Saxon period. Two methods (56 and 206) are described that produce a niello which can be applied to the surface of the object, rather than inlaid into channels, these involve melting silver, copper and lead combined with sulphur,[20] although the second recipe (206) includes instructions for a niello with no copper.[21] Recipe 58 describes the manufacture of silver sulphide niello by adding sulphur to hot silver.[22] The final recipes produce a silver-copper niello which is suitable to apply on to gold and silver, the ratios depend on the alloy of the object to be decorated .[23] The *Mappae Clavicula* also includes a description on how silver-copper niello was applied.

> '*temper some atincar [i.e. borax] with water, and with this temper the niello, and place it where you wish. Sprinkle soda [natronum] powder on top, and put it on coals until the niello runs well. In those places where you do not want it to run, put some very fine chalk tempered. When this is done, take it out of the furnace to cool, and rub it with a maple polishing stick. Heat it slightly but often on the fire, continuing until it is in good shape. Afterwards scrape the niello right down to the [level of the surface of the] almenbus and polish it again as you know full well, and leave it*'.[24]

The *Parisinus graecus 2327* is a collective manuscript dated to the eleventh century containing 69 recipes, including another detailed reference to the manufacture of a silver sulphide niello, and the procedures for applying it to objects.[25]

---

[15] La Niece 1983.
[16] Caley and Jensen 2008, 27.
[17] Caley and Jensen 2008, 32.
[18] Oddy *et al.* 1983.
[19] Oddy *et al.* 1983.
[20] Smith and Hawthorne 1974, 36, 58.
[21] Smith and Hawthorne 1974, 58.
[22] Smith and Hawthorne 1974, 36.
[23] Smith and Hawthorne 1974, 57-8.
[24] Smith and Hawthorne 1974, 57.
[25] Wolters 2006.

'Take 2 parts refined silver and place them in a crucible into the middle of the fire. Cover the crucible with [bone ash from] mutton legs and add sulphur in small amounts so that the vapours can escape. In this manner, put [it into] the crucible. Crush another portion [of silver with] sulphur, pour it into a crucible until this is half full and cover it well. Let this half melt and crush it on the anvil. Pour it into a water vessel and wash it well. Then add a little flux into a lead vessel [filled with water] and let it boil. Next pour it into another vessel and sprinkle the work of silver or chased gold with soda or borax. Place the work into the fire. After you have taken it out of the fire, polish with pumice stone, rub it off with a feather, and warm again with [char]coal in a clay vessel' (Wolters 2006, 72). The author suggests that this type of niello could be applied to both gold and silver objects, but there is no description to suggest that the niello was molten, or that the niello was pushed into channels, instead it is applied as a powder and then heated.

Niello continued in use in the medieval period up to the sixteenth century.[26] The recipes for manufacturing niello and application methods are described by many of the medieval goldsmith texts, such as Theophilus Presbyter '*On Divers Arts',*[27] Vannoccio Biringuccio's *'The Pirotechnia'*.[28] and Benvenuto Cellini's text on '*Goldsmithing and Sculpture*'.[29] All the niello recipes are a mixture of silver, copper and lead with sulphur. Theophilus describes two methods for applying this niello. The first involves turning the niello to powder and filling a quill with it, this powder is then tapped on to the surface which has been covered in watered down borax before being heated.[30] The niello when heated becomes a liquid, most likely due to the lead sulphide present, and can be moved into the channels.[31] The second method is make the niello into a thin rod, this rod is then heated and rubbed over the channels to fill them.[32]

Methodology

During this study twenty-six silver and six gold objects with niello have been identified in the Staffordshire Hoard, these are listed in Tables 1 and 2. Some of these objects no longer have any niello remaining. Optical microscopy using the Keyence VHX-S50F with a Z-axis auto stage and a VHX-1000 digital microscope was used to identify and classify the shape of the channels used to inlay the niello and to determine whether the niello was proud of the surface or flush. This microscope is able to take multiple photos on the vertical axis and combine them providing a photograph with a greater depth of field. The software can also produce 3D models from these photos and these were also used during the documentation phase, and are included in the discussion section of this report.

[26] Oddy *et al.* 1983.
[27] Hawthorne and Smith 1979, 104-105, 108, 115.,
[28] Smith and Gnudi 1990, 356-6.
[29] Ashbee 1967, 7-8.
[30] Hawthorne and Smith 1979, 104-105.
[31] Hawthorne and Smith 1979, 105.
[32] Hawthorne and Smith 1979, 108.

K310 and (K620, K638, K1021 *et al.*)	K82, K83, K168, K182, K251, K1700 *et al.*	K304, (K160, K595, K186 et al) and (K39 and K1007)	K711	K453 and (K97 and K5004)	K298 and (K181, K755, K1152 *et al*.)
K592, K641, 1235, K1168 *et al.*	K369 and (K19, K430, K537 *et al.*)	K242, K291, K301, K831 *et al.*	K825	K577	K1277
K161, K241, K639 *et al.*	K34, K53, K993, K1026 *et al.*	K20, K1112, K1185 *et al.*	(K63, K137, K529 *et al.)* and K1449	K1106	K596
K1449					

Table 1. Silver objects with suspected niello in the Staffordshire Hoard, the brackets and/or '*et al*.' indicates where multiple fragments make up a single object.

K347	(K358 and K27)	K550	K731 and K1365	K972

Table 2. Gold objects with niello in the Staffordshire Hoard.

The preferred method for identifying the metal sulphides used in the niello is X-ray diffraction (XRD). This is because it isolates the compound present, rather than the individual elements. Surface X-ray fluorescence (XRF) or scanning electron microscope with energy dispersive X-ray analysis (SEM-EDX) analysis of an inlay in a corroded silver artefact will detect silver and copper together with chlorine, bromine etc. from any metal corrosion products present as well as the elements present in the inlay. It can therefore be difficult to be confident that any copper detected is an ingredient of the niello, or if it is simply a carbonate or chloride corrosion product on the metal.[33] In addition with XRF analysis any copper or silver present may represent the alloy composition of the object rather than the niello, this is particularly likely if the niello remaining on the artefact is small.[34]

A small number of samples were analysed by the British Museum using XRD, and in some cases SEM-EDX, some of these samples were however recovered during the cleaning process and may not be representative of the niello present on the object. Other objects were never analysed at the British Museum. This present study was being carried out alongside the English Heritage funded research but was not included in the project design, therefore no samples could be taken, so a survey using surface XRF was carried out on the majority of the niello pieces to classify the type of niello used.

The XRF analysis was carried out on the surface of the metal 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, the 0.5mm collimator was used with a count time of 150 seconds. Several areas of niello on each piece were analysed. The alloying elements that were quantified included; silver, copper, gold, tin, lead and zinc. Any areas where large quantities of iron or mercury due to corrosion products or gilding were excluded. The instrument is unable to accurately quantify sulphur as the air in the chamber will interfere with lighter energy x-ray fluorescence emitted. However the spectrum for each object was examined to identify the presence of a sulphur K alpha peak (Fig. 58 in appendix) and to check for other

[33] La Niece 2013.
[34] La Niece 2013.

elements not quantified. The analytical results of this survey are therefore not quantified for this report, and the data will be treated as qualitative with the amount of copper detected in the sulphide discussed for each object.

Results

A summary of the results below is provided in the Appendix, and each object or group of objects is briefly discussed below with the optical microscopy evidence to show how the niello was applied. The results from the XRD analysis carried out at the British Museum[35] are also discussed alongside the XRF analysis.

[35] La Niece 2013.

Silver niello mounts

K310[36] and (K620, K638, K1021 *et al.*)[37]

K310 represents a complete object. Fragments K620, K638 and K1021 are clearly fragments of what appears to be the pair of K310. XRD analysis of a sample from both K310 and K1021 was undertaken at the British Museum and this revealed a silver sulphide (La Niece 2013). SEM-EDX analysis of the niello at the British Museum revealed a niello with 85 wt% silver and 15 wt% sulphur (La Niece 2013). XRF analysis of the niello in situ also showed the absence of copper, confirming a silver sulphide. The niello in a zig-zag motif is inset into either a v shaped channel or flat based channel and is flush with the surface.

Fig. 1. Photograph of K310 and the fragments K620, K638, K1021 *et al.* that comprise its pair

Fig. 2. Photo-micrograph of the niello inset into channels (left) and the v shaped channels visible in cross section (right).

[36] Catalogue no. 567. Eye-shaped mount in silver with geometric inlay and filigree trim.
[37] Catalogue no. 568. Small fragments of a mount of eye-shaped form in silver with geometric niello inlay.

K592, K641, K1235, K1168 *et al*.[38]

K592 and other associated fragments form a niello strip mount with a zig-zag pattern, it is heavily fragmented due to silver enbrittlement. XRF analysis of the surface showed that the border is mercury gilded.[39] XRD analysis of a sample from K1235 was undertaken at the British Museum and this revealed a silver sulphide.[40] SEM-EDX analysis of the niello at the British Museum revealed a niello with 87 wt% silver, 1 wt% copper and 12 wt% sulphur.[41]. XRF analysis of the niello in situ also showed the absence of copper, confirming a silver sulphide. The niello is inset into a flat based channel and is flush with the surface.

Fig. 3. Photograph of mount K592, K641, 1235, K1168 *et al.*

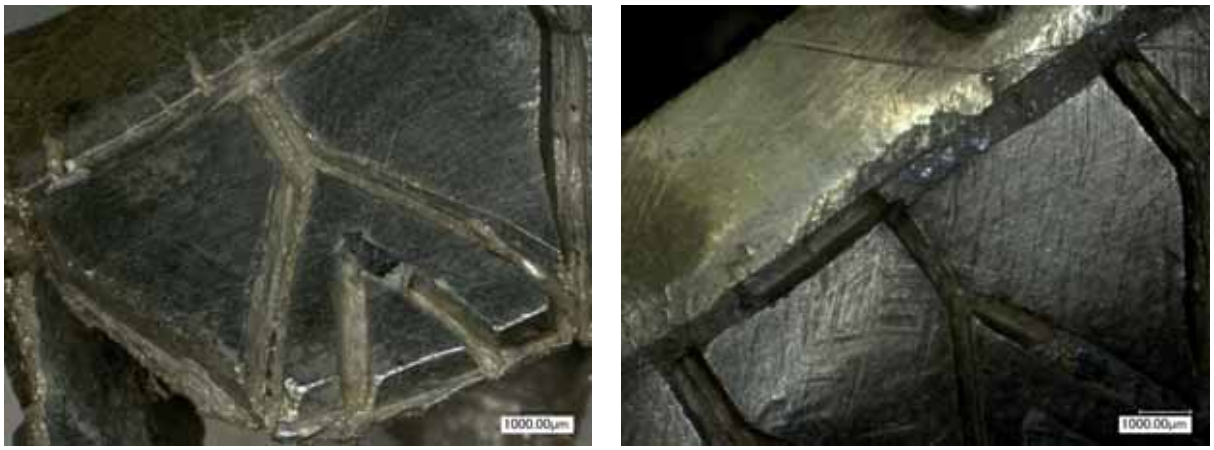

Fig. 4. Photo-micrographs of K592 showing the niello inlay and channels.

[38] Catalogue no. 571. Strip-mount in silver with pointed turned ends, geometric niello inlay and gilded border.
[39] Blakelock 2015.
[40] La Niece 2013.
[41] La Niece 2013.

Fig. 5. Photo-micrograph of the channels seen in section of K1192.

K161, K241, K639 *et al.*[42]

Like K64 *et al.*, K161 and other associated fragments form a niello strip mount with a zig-zag pattern, it is heavily fragmented due to silver enbrittlement. The main difference between this mount and the previous example above is that there is an extra zig-zag channel. XRF analysis of the surface showed that the border is mercury gilded.[43] XRD analysis of a sample from both K713 and K1069 was undertaken at the British Museum and this revealed a silver sulphide.[44] SEM-EDX analysis of the niello at the British Museum revealed a niello with 86 wt% silver and 4 wt% sulphur, with the remaining 9% contamination from gilding and iron (La Niece 2013). XRF analysis of the niello in situ also showed the absence of copper, confirming a silver sulphide. The niello is inset into a flat based channel and is flush with the surface.

Fig. 6. Photograph of mount K161, K241, K639 *et al.*

Fig. 7. Photo-micrograph of K1069 (left) and K161 (right)

[42] Catalogue no. 570. Fragments from possibly two strip-mounts in silver with geometric niello inlay and gilded borders.
[43] Blakelock 2015.
[44] Blakelock 2015.

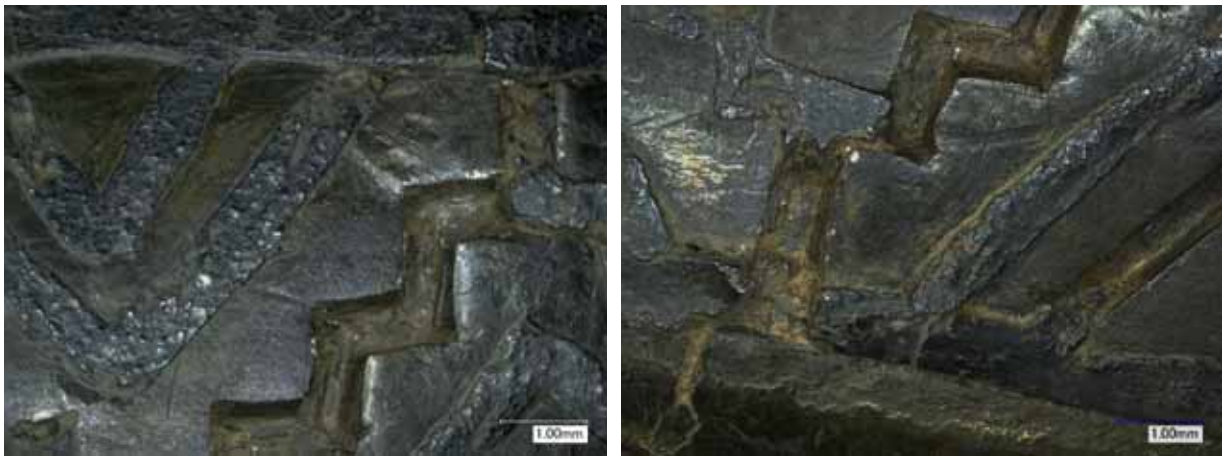

Fig. 8. Photo-micrograph of K713 showing the channels and the niello which appears to overlap.

K82, K83, K168, K182, K251, K1700 *et al*.[45]

K82 and related fragments together form a fish shaped mount with mushroom shaped cells. XRF analysis of the surface showed that the border is mercury gilded.[46] XRD analysis of samples from K82, K182, K1005 and K1630 was undertaken at the British Museum and this revealed a silver sulphide.[47] SEM-EDX analysis of the niello at the British Museum revealed a niello with 85-88 wt% silver, 0-1 wt% copper and 11-15 wt% sulphur.[48] XRF analysis of the niello in situ also showed the absence of copper, confirming a silver sulphide. The niello is inset into a flat based channel and is flush with the surface.

Fig. 9. Photograph of mount K82, K83, K168, K1700 *et al.*

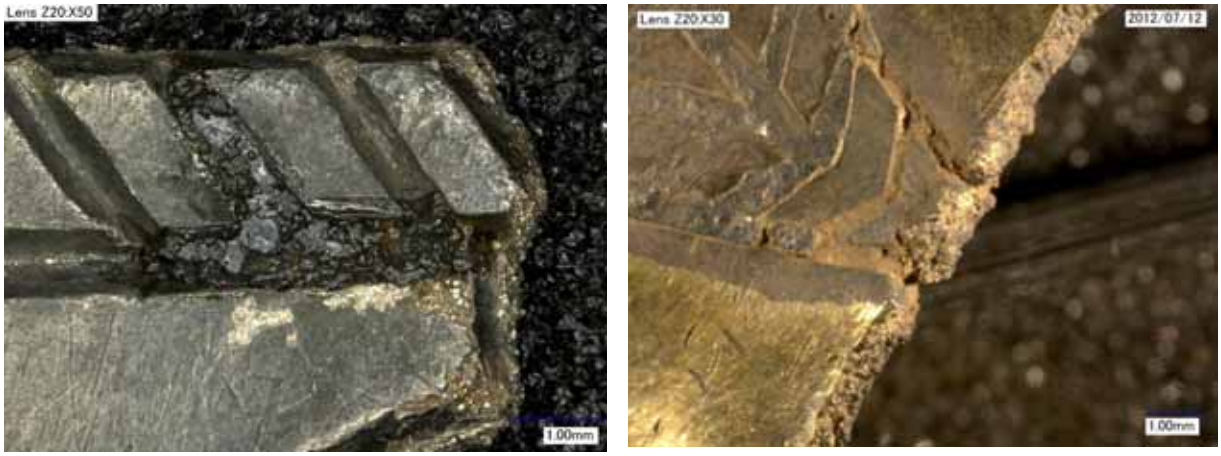

Fig. 10. Photo-micrograph of K1669 (left) and K82 (right)

[45] Catalogue no. 569. Mount with fantail in silver with geometric niello inlay and gilded borders.
[46] Blakelock 2015.
[47] La Niece 2013.
[48] La Niece 2013.

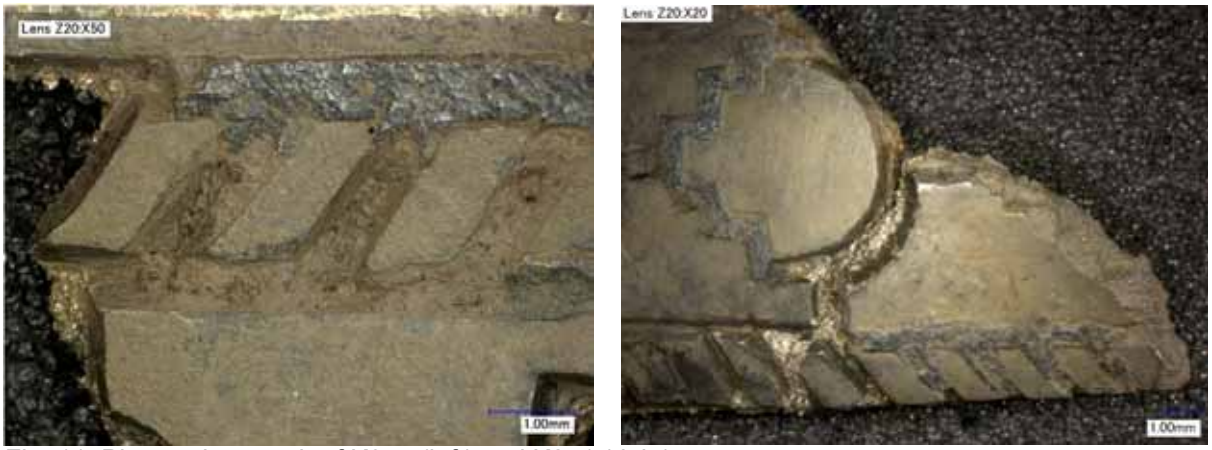

Fig. 11. Photo-micrograph of K975 (left) and K251 (right)

Silver hilt-collars and pommels

K369[49] and (K19, K430, K537 *et al.*)[50]

K369 represents a complete hilt-collar with a copper alloy core. Fragments K19, K430, K537 *et al.* are clearly fragments of what appears to be the pair of K369. The niello was applied into the triangular stamped decoration; the only remains of the inlay however are to be seen on the lowest bands of K369. These remains are raised from the surface which may explain why so much of the inlay had fallen out. No samples were taken for XRD analysis at the British Museum. XRF analysis was therefore carried out on the few niello inlays that remain. The analysis suggested a highly elevated copper content in the niello, over 10 wt% more copper was present than in the alloy (Fig. 59 in the appendix). This strongly suggests that the niello used was a silver-copper sulphide.

Fig. 12. Photographs of K369 and fragments K19, K430, K537 *et al.* that consist of the other hilt-collar pair

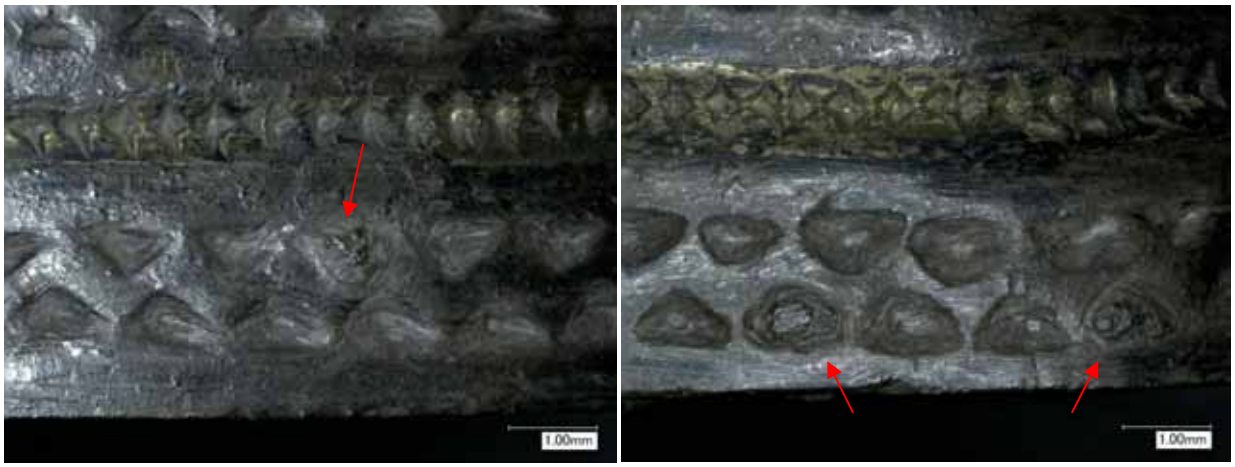

Fig. 13. The photomicrographs show the punched decoration on K369 which was originally filled with niello, the red arrows point to the remaining niello.

[49] Catalogue no. 184. Hilt-collar in cast silver, of high form, with line and punch decoration, gilding and black niello inlay.
[50] Catalogue no. 185. Hilt-collar in cast silver, of high form, with gilded line and punch decoration.

K34, K53, K993, K1026 *et al.*[51]

This fragment of a gilded hilt-collar has niello inlaid into the v-shaped channels on the side. Only a small amount of niello has survived in situ and this appeared flush to the surface. No samples were taken for analysis at the British Museum. The analysis suggested a highly elevated copper content in the niello, over 10 wt% more copper was present than in the alloy. This strongly suggests that the niello used was a silver-copper sulphide. Copper alloy corrosion products are clearly visible on the surface of other fragments of this now joined piece but the fragment with niello still in situ had no visible corrosion products, so confirmation using XRD is required to determine whether the copper is present in the niello (Fig. 14).

Fig. 14. Photograph of K53, K180, K1248 *et al.*

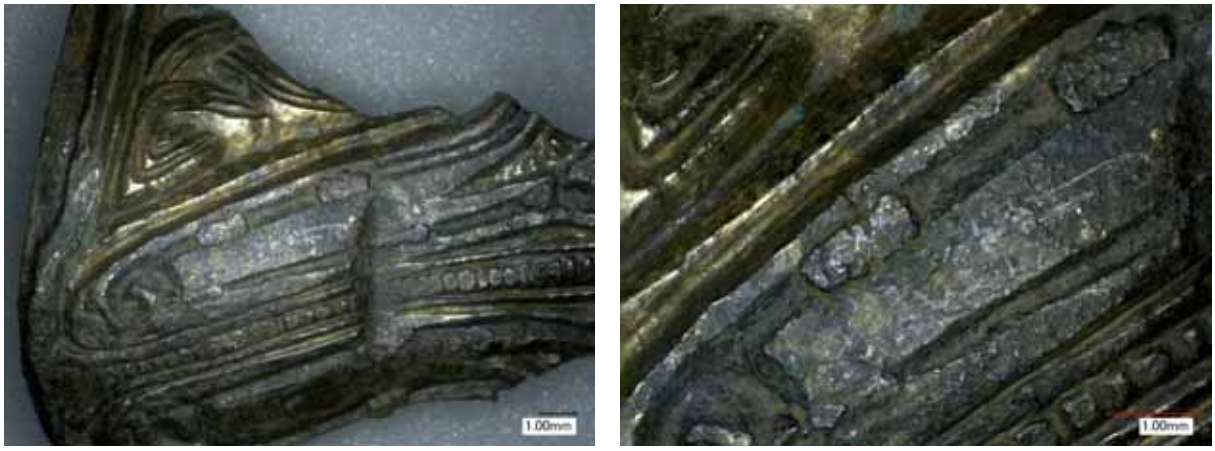
Fig. 15. Photo-micrographs showing the side of K53 with niello (left) and a detailed photograph of the v-shaped channels and niello in situ (right).

[51] Catalogue no. 188. Remains probably of a pair of hilt-collars in cast silver, of high form, with gold filigree mounts.

K304,[52] (K160, K595, K186 *et al*)[53] and (K39 and K1007)[54]

Two hilt-collars, K304 and K160 *et al.*, and pommel K39/K1007 appear to form a suite with similar forms of decoration and niello inlay. XRD analysis of a sample from K160 and K1364 from the same object was undertaken at the British Museum and this revealed a silver sulphide.[55] However the XRF analysis of the niello in situ revealed the presence of copper but this may have been contamination from the surrounding metal as the copper content in the niello is lower than the copper present in the silver. The XRF analysis of niello on K39/K1007 and K304 revealed a slightly elevated copper content; this again is most likely contamination from the metal itself or nearby corrosion products. The niello is inset into a v-shaped channel and is slightly raised from the surface.

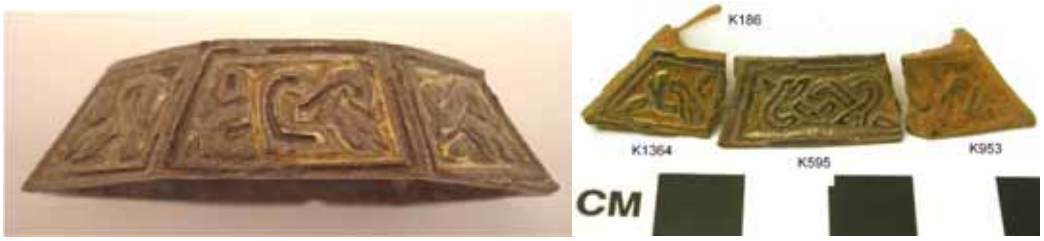

Fig. 16. Photo of K304 (left) and fragments of K160, K186 *et al.* that form a pair (right)

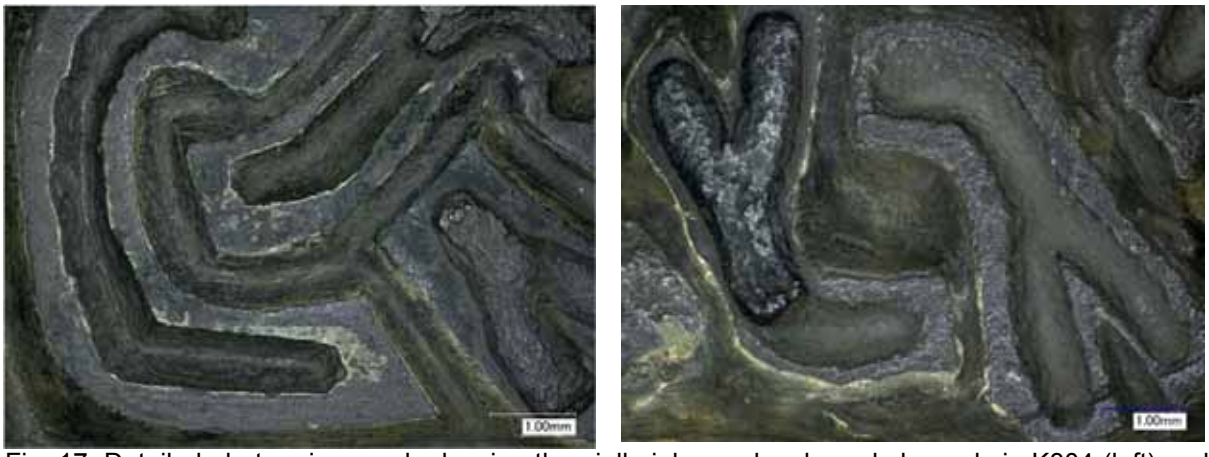

Fig. 17. Detailed photo-micrograph showing the niello inlay and v-shaped channels in K304 (left) and K1364 (right).

[52] Catalogue no. 186. Hilt-collar in cast silver, of narrow form, with gilded low relief decoration and black niello inlay.
[53] Catalogue no. 187. Hilt-collar in cast silver, of narrow form, with gilded low relief decoration and black niello inlay.
[54] Catalogue no. 69. Pommel in cast silver, of cocked-hat form, with gilded low relief decoration and niello inlay.
[55] La Niece 2013.

Fig. 18. Photo of K39/1007 (left) and detailed photo-micrograph showing the niello inlay and v-shaped channels (right).

K242, K291, K301, K831 *et al.*[56]

This complex form of pommel is comprised of several components. The niello was present on a central panel (K1384) but also on the side of the shoulders of the object (K242 and K1087) and parts of the sword rings (K831). XRD analysis of two samples from this object (K242 and K291) was undertaken at the British Museum and this revealed a silver sulphide.[57] However the XRF analysis of the niello in situ revealed the presence of copper but this was most likely contamination from the surrounding metal as there was also some tin and lead present. The niello is inset into a v-shaped channel and is flush with the surface. The central decoration has the design cast in relief with large fills of niello which is similar to British or Irish champlevé enamelling techniques (Fern *pers comm*.).

Fig. 19 Photograph of K242, K291, K301, K831 *et al.*

Fig. 20. Photo-micrograph of the decorated panel showing silver snake design (drawing by C Fern), outlined by the niello, the red arrows indicate the niello inlay.

[56] Catalogue no. 76. Pommel in cast silver, of cocked-hat form with double sword-rings with cast interlace and niello inlay, and mounts with cloisonné and filigree decoration.
[57] La Niece 2013.

Fig. 21. Photo-micrograph of K242 shoulder (left) and sword ring K831 (right), the red arrows indicate the niello inlay.

K20, K1112, K1185 *et al.*[58]

This complex form of pommel is comprised of several components. The niello was present on a central panel (K1112), the border surrounding in the niello decorated part (K20) and also on the shoulders of the object (K1185). XRD analysis of two samples from this object (K137 and K290) was undertaken at the British Museum and this revealed a silver sulphide.[59] However the XRF analysis of the niello in situ on K20, K290 and K1185 revealed the presence of copper but this may have been contamination from the surrounding metal. The niello is inset into a v-shaped channel and is raised from the surface. The triangle decoration is formed of cast leaf shapes with a large fill of raised niello surrounding them which, like K242, K291, *et al.* above, is similar to British or Irish enamelling techniques.

Fig. 22. Photograph of K20, K1112, K1185 *et al.*

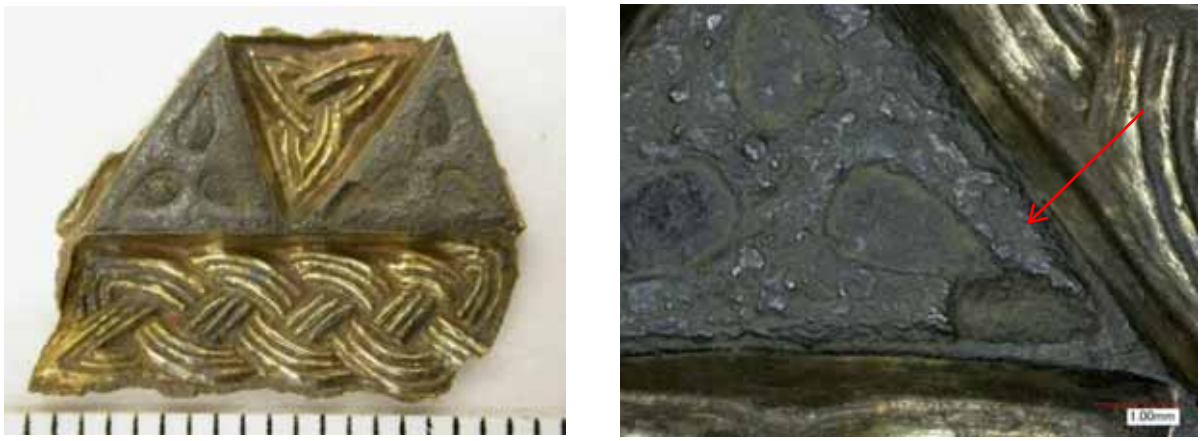

Fig. 23. Photograph of K1112 (left) and detailed shot of missing niello revealing the shape of the channel, the red arrow points to the niello inlay which would have surrounded three silver leaves.

[58] Catalogue no. 75. Pommel in cast silver, of cocked-hat form with double sword-rings, with cast interlace, niello and glass decoration.
[59] La Niece 2013.

Fig. 24. Photo-micrographs showing the niello used on the border of K20, and shoulder K1185, the red arrow points to the niello inlay.

K711[60]

The niello used in gilded pommel K711 forms the eyes of the human figure or the boars, or boar leg nodules. These small domes of niello often conceal the channel to which they were inlaid, but where the niello has fallen out there is a conical shaped void. It would also have filled some of the details on both sides of the pommel such as the teeth and features of the boars and potential ravens on either side of the head. The channels for the niello are free from traces of gilding and are v-shaped, however there are other wider and deeper channels which have gilding present; this appears to be part of the original design (Figure 26 left). All the channels in this piece are much neater than in many of the other objects analysed. The XRF analysis of the niello inlay suggested that it may be a silver-copper sulphide, as there was more copper present than in the core silver. No samples were sent to the British Museum for XRD analysis.

Fig. 25. Photograph of K711

Fig. 26.Photo-micrograph of the niello channels and humanoid eyes.

[60] Catalogue no. 68. Pommel in cast silver, of cocked-hat form, with gilded low relief decoration and niello inlay.


Fig. 27. Photo-micrograph of the niello in the leg nodules on the reverse, and some of the details of the boar.

K825[61]

This fragment of a pommel is similar to K39/K1007 in that it has wide silver bands with a central stripe of niello inlaid into the v-shaped channel. Only a small amount of niello has survived in situ and this appeared flush to the surface. The XRF analysis of the niello inlay suggested that it may be a silver sulphide, as there was only a small quantity of copper present and this most likely derived from the copper within the silver object (Fig. 60 in the appendix).

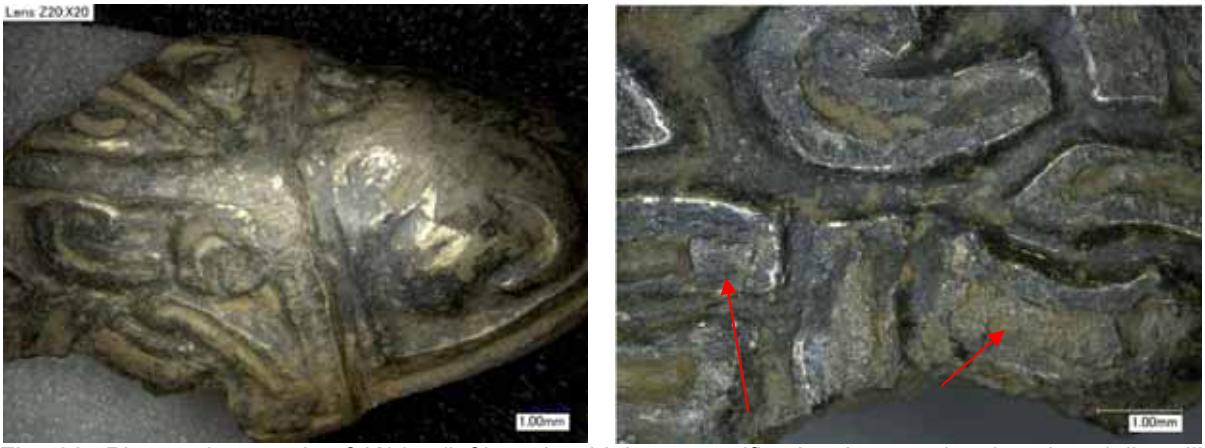
Fig. 28. Photo-micrograph of K825 (left) and a higher magnification image showing the niello still present in the channels (red arrows).

[61] Catalogue no. 78. End fragment from a pommel in cast silver with gilded low relief decoration.

Other silver objects

K577[62]

This mount has wide silver bands with a central stripe of niello inlaid into the v-shaped channel. Only a small amount of niello has survived in situ and this appeared flush to the surface. The XRF analysis of the niello inlay suggested that it may be a silver sulphide, as there was only a small quantity of copper present and this most likely derived from the copper within the silver object.

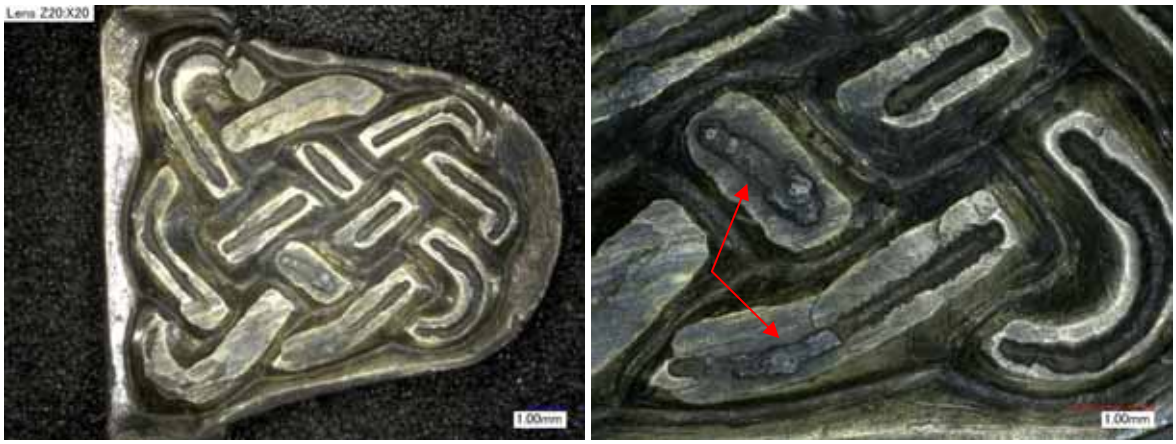

Fig 29. Photo of K577 (left) and photo-micrograph showing the niello inlay and v-shaped channels (right), the red arrows point to niello in situ.

[62] Catalogue no. 533. Mount in cast silver, of tongue-shaped form, with gilded low relief interlace ornament and niello inlay.

K1106[63]

This mount is similar to K577 and has wide silver bands with a central stripe of niello inlaid into the v-shaped channel. Only a small amount of niello has survived in situ and this appeared flush to the surface. The XRF analysis of the niello inlay suggested that it may be a silver sulphide, as there was only a small quantity of copper present and this most likely derived from the copper within the silver object.

Fig. 30. Photo of K1106 (left) and photo-micrograph showing the niello inlay and v-shaped channels (right), the red arrow point to niello in situ.

[63] Catalogue no. 534. Mount in cast silver, of tongue-shaped form, with gilded low relief interlace ornament and niello inlay.

K453[64] and K97/K5004[65]

The two cheek pieces K453 and K5004 both have inlays of niello separating four different bands of zoomorphic art. The niello is inlaid in a line of triangular punch shapes to form a zig-zag pattern; the remaining niello appears raised from the surface. No samples of niello from the cheek pieces were analysed by the British Museum. The results from the XRF analysis of both cheek pieces contradict each other. The four analyses of niello from K453 has more copper present in the inlay than in metal suggesting a possible silver-copper sulphide; however K5004 has no copper, only silver.

Fig. 31. Photo of K453 (left) and photo-micrograph showing the niello inlay within the triangle shaped punch marks (right).

K97 is a fragment of helmet cheek piece K5004. The niello seems to have been applied into triangular shaped channels, similar to those on the cheek piece. XRF analysis of the niello in situ also showed the absence of copper suggesting a silver sulphide. It is therefore likely that the copper seen in the niello on K453 is simply contamination, and that all the inlays on these related objects are silver sulphides.

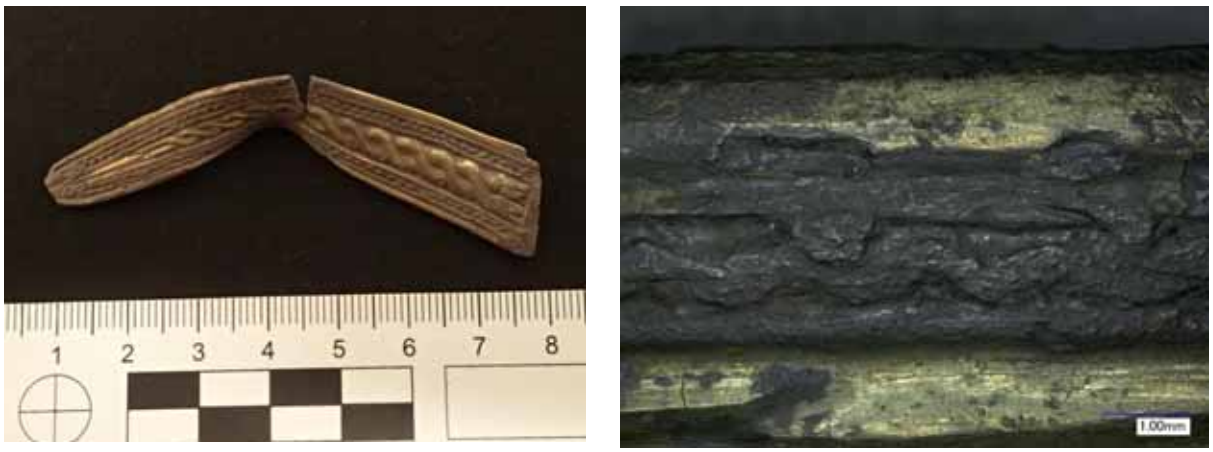

Fig. 32. Photo of K97 (left) and photo-micrograph showing the niello inlay within the triangle shaped channels (right).

[64] Catalogue no. 591. Helmet cheek piece, cast in silver and gilded, with animal ornament and a gold collar.
[65] Catalogue no. 592. Helmet cheek piece, cast in silver and gilded, with animal ornament and a gold collar.

Hilt-guards K63, K137, K529 *et al.* and K1449[66]

Several fragments have been joined to form a hilt-guard, this includes K63, K137 and K151 *et al.* which form a niello zig-zag border along the top of the hilt-guard, with a leaf shaped design along the bottom. The niello has been inserted into v-shaped channels and is flush with the surface of the metal. XRD analysis of a sample from K137 was undertaken at the British Museum and this revealed a silver sulphide.[67] (La Niece 2013). However the XRF analysis of the niello in situ on K63, K137 and K151 revealed the presence of copper but this may have been contamination from the surrounding metal as the copper content is lower than the copper present in the silver.

Fig. 33. Hilt-guard K63 *et al.* and the niello border decoration.

Fig. 34. Photo-micrographs showing the different designs used on the border of K151 and K137 (left) and a photograph of the v-shaped channels and niello in K151 (right).

[66] Catalogue no. 409. Pair of hilt-guards in cast silver, with panels of gilded interlace, and gold mounts with filigree decoration and a gem-setting.
[67] La Niece 2013.

K1449 is a fragment from the second hilt-guard from the same suite. Examination revealed a zig-zag of silver, with possible indentations for niello, it is therefore likely that niello decoration was present on the upper hilt-guard.

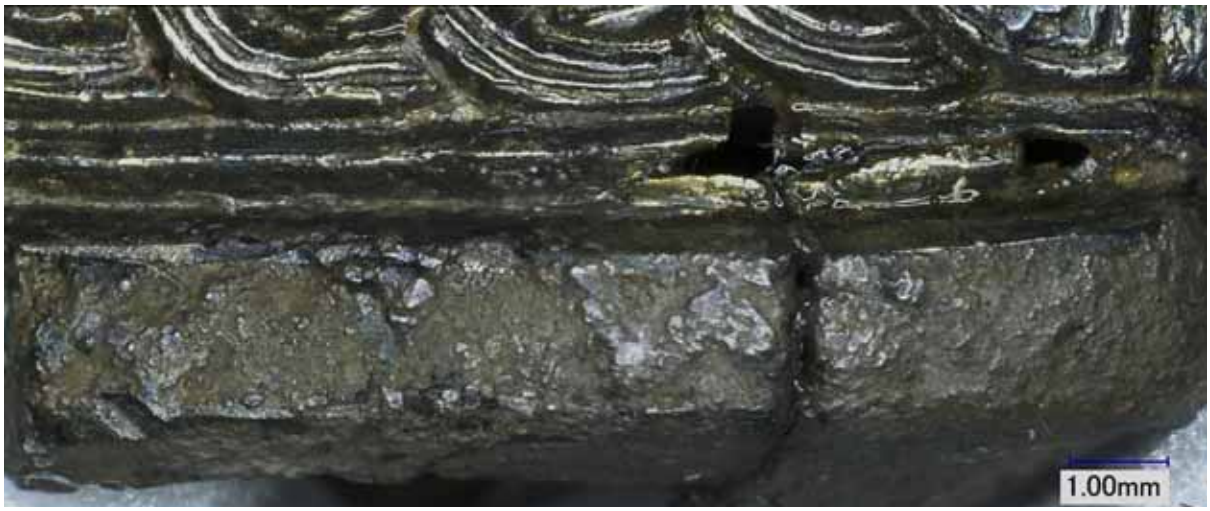

Fig. 35. Photo of the corroded border of K1449, showing a zig-zag of silver, the indentations present probably once held niello.

Gold objects

K347[68]

The niello is slightly proud of the surface and has been applied into v-shaped channels engraved into pommel K347. XRD analysis of a sample of the niello was undertaken at the British Museum and this revealed a silver sulphide.[69] However the XRF analysis of the niello in situ revealed large quantities of copper but this may have been contamination from the surrounding metal. More XRD analysis should be carried out to determine whether the niello is silver or silver copper sulphide.

Fig. 36. Photo of K347 (left) and photo-micrograph showing the niello inlay and v-shaped channels (right).

[68] Catalogue no. 56. Pommel in gold, of round-back form, with incised decoration inlaid with niello and filigree ornament.
[69] La Niece 2013.

K358 and K27[70]

The niello on pommel K358 was inset into v shaped channels that run the entire length of the gold panel inserted into the cast pommel. No samples were taken for XRD analysis at the British Museum. The XRF analysis of the niello inlay suggested that it is a silver sulphide, as there were only traces of copper detected.

Fig. 37. Photograph of K358 and inserted panel K27

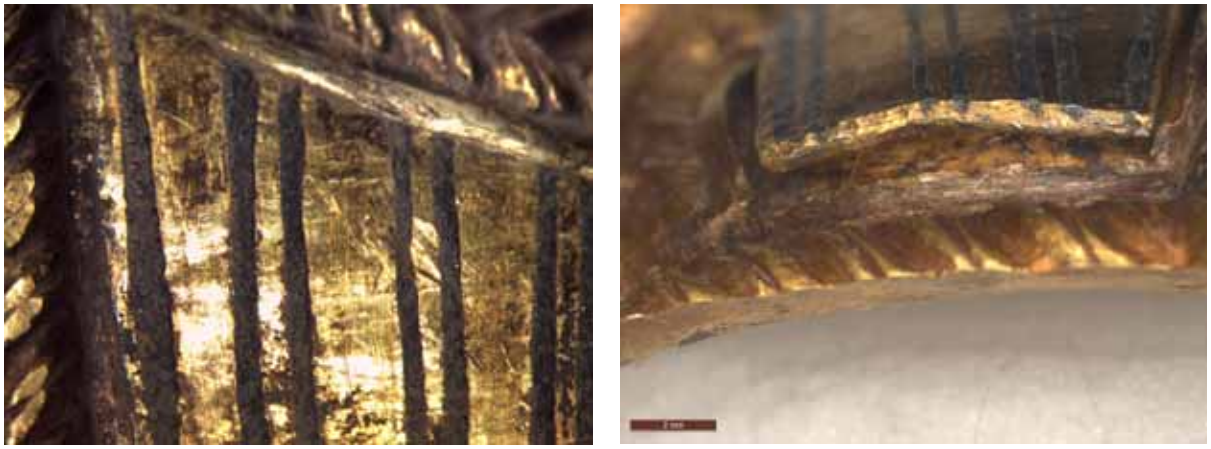
Fig. 38. Photo-micrograph showing the niello inlay (left) and v-shaped channels (right).

[70] Catalogue no. 57. Pommel in gold, of cocked-hat form, cast with animal-heads, with incised Style II decoration, and panels with niello lines, all framed by imitation wire.

K550[71]

The raised niello has been applied into flat based channels cut into the sheet that is wrapped around a core. No samples were taken for XRD analysis at the British Museum. The XRF analysis of the niello inlay suggested that it is a silver sulphide, as no copper was detected.

Fig. 39. Photo of K550 (top) and photo-micrographs showing the niello inlay (left) and flat based channels cut into the gold sheet (right).

[71] Catalogue no. 540. Strip-mount in gold with Latin inscriptions and gem-setting.

K972[72]

Sword guard K972 has an interlace serpent design, decorated with dots. The niello is flush to the surface and still firmly applied so it was therefore not possible to determine the shape of the channel. No samples were sent to the British Museum for XRD analysis. The XRF analysis confirmed the absence of copper suggesting the niello applied was a silver sulphide.

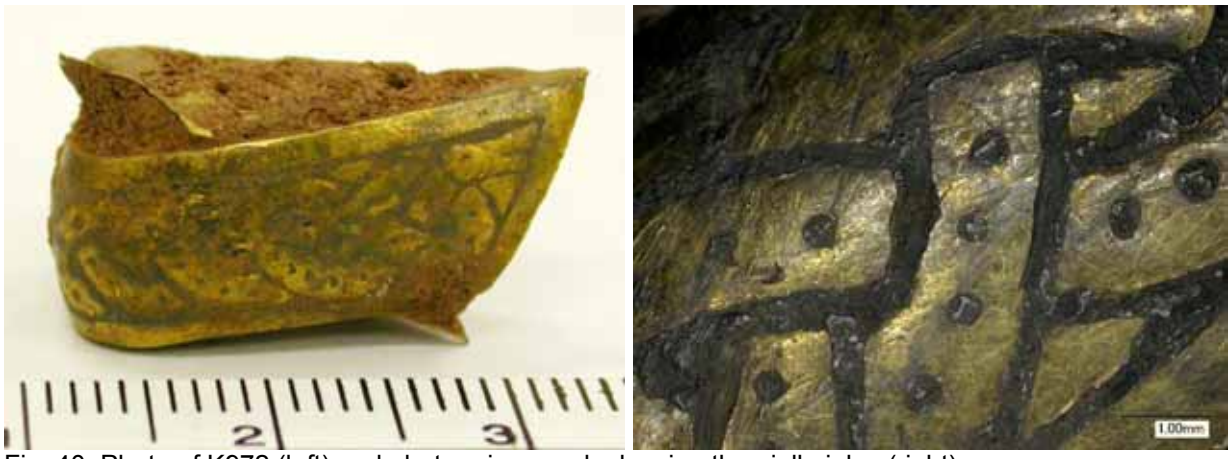

Fig. 40. Photo of K972 (left) and photo-micrograph showing the niello inlay (right).

K731[73] **and K1365**[74]

Small domes of niello form the eyes of the snake heads K731 and K1365. The niello in K731 is raised, but it is unknown whether this is the case with K1365 as no niello surface remains. Where the niello has fallen out there is a conical void. One niello eye in K731 has a clear void perhaps formed by escaping gas as the niello solidified. No samples were sent to the British Museum for XRD analysis. The XRF analysis of the niello inlay suggested that it is a silver sulphide, as there were only traces of copper detected.

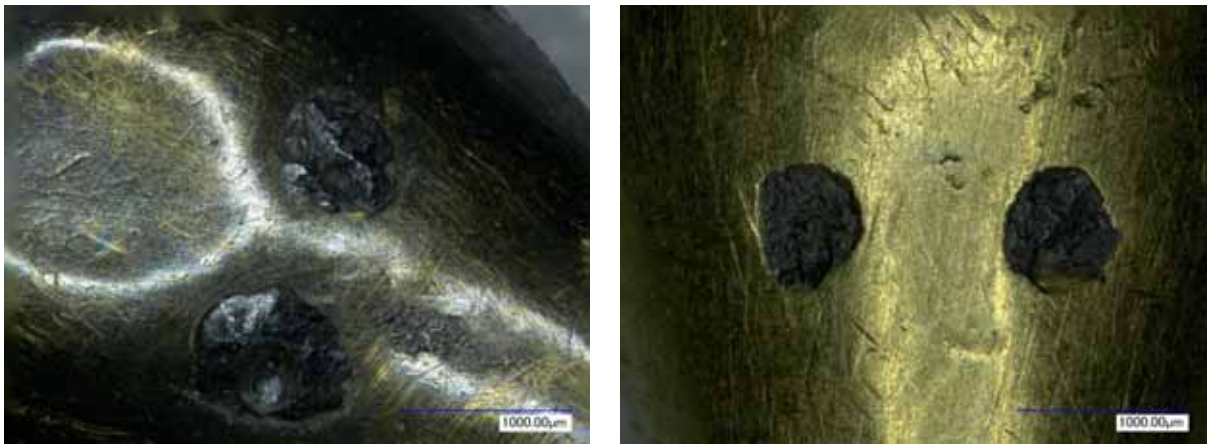
Fig. 41. Photo of K731 and K1365 (top) and photo-micrograph showing the niello inlay in K731 (left) and rounded holes in K1365 for the niello (right).

[72] Catalogue no. 412. Mount in gold from the tip of a hilt-guard, with serpent ornament in niello.
[73] Catalogue no. 532. Serpent mount cast in gold.
[74] Catalogue no. 531. Serpent mount cast in gold.

Possible niello objects

K298 *et al.*[75] and K181, K755, K1152 *et al.*[76]

K298 *et al.* form the majority of a hilt-collar. Fragments K181, K755, K1152 *et al.* are clearly fragments of what appears to be the pair of K298. The edges of the collar have a triangle punched design, similar to hilt-collars K369 and K19, K430, K537 *et al,* and also the helmet cheek pieces. The impressions may have originally held niello inlays but no remains were apparent for analysis, however the absence of gilding in these impressions may be an indication that niello was present.

Fig. 42. Photograph of K298 (right) and fragments K181, K755, K1152 *et al.* (left) which is the other hilt-collar pair.

Fig. 43. Photo-micrograph showing the triangle stamps of K528 (left) and K936 (right) which have no gilding suggesting they may have originally held niello inlays.

[75] Catalogue no. 182. Hilt-collar in cast silver, of high form, with gilded low relief decoration.
[76] Catalogue no. 183. Hilt-collar in cast silver, of high form, with gilded low relief decoration.

K1277[77]

This mount has wide silver bands which probably originally had a niello inlay within the v-shaped channel. No niello remains so analysis could not be carried out to determine the type.

Fig. 44. Photo of K1277 (left) and photo-micrograph showing the v-shaped channels for the niello (right).

K596[78]

Pommel K596 has an engraved design on the front. The channels are straight sided with a flat base. The channels are free from gilding which may suggest that there was originally a niello inlay present.

Fig. 45. Photo of K596 (left) and photo-micrograph showing the flat based channels for the niello (right).

[77] Catalogue no. 535. Mount in cast silver, of tongue-shaped form, with low relief interlace ornament.
[78] Catalogue no. 74. Pommel in cast silver, of round-back form, with incised and gilded decoration, and filigree mounts.

Discussion

The results from the XRD analysis carried out at the British Museum suggested that all the samples taken were silver sulphides, rather than silver-copper sulphides[79] (La Niece 2013). The XRF analysis of *in situ* niello on these pieces confirmed that this was the case in all cases, with the possible exception of pommel K347.

The analysis of the remaining objects suggested that the majority were silver sulphide niellos, the only possible exceptions are; the pair of hilt-collars K369 and K19, K430, K537 *et al.*, the hilt collar K34, K53, K993, K1026 *et al.* and the pommel K711. However XRD analysis is required to confirm that the copper is not due to corrosion products formed during deposition. As noted in the British Museum study,[80] the choice of silver sulphide niello for the majority of silver or silver-gilt Staffordshire Hoard objects is unusual as the silver-copper sulphide niello have previously been reported to be the more common type used on Anglo-Saxon silver alloys.[81] Comparison between the type of niello applied and the composition of the silver alloy (Fig. **46**) revealed no obvious relationship.[82] The choice to use a silver sulphide niello in the Hoard cannot be explained at this time as there are no visual differences between silver and silver-copper sulphide niello, and it would be harder to bond the silver sulphide niello to the objects.[83] Silver sulphide niello is more commonly applied to gold objects, so it is unsurprising that all the niello in the gold objects have no detectable copper. However further analysis of K347 [56] could be required as some copper was detected in the niello.

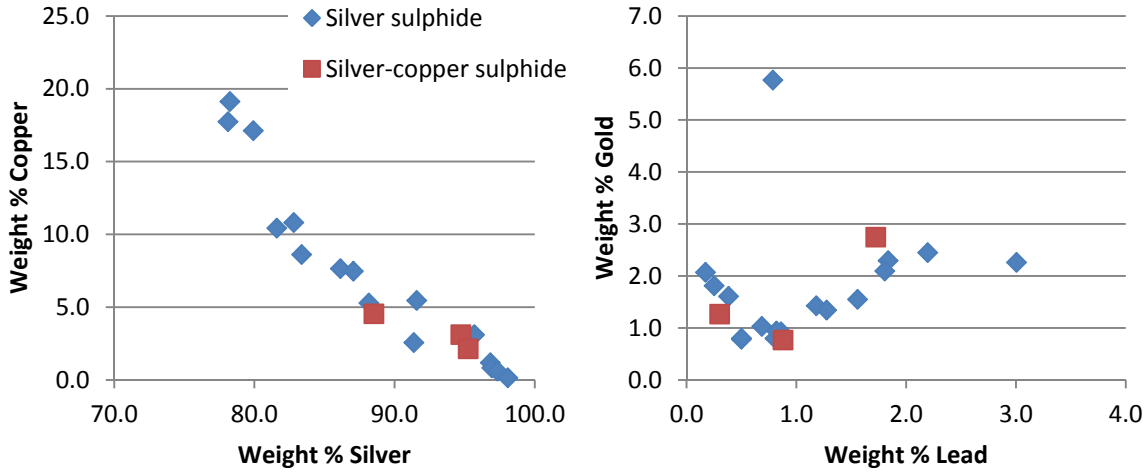

Fig. 46. Copper/silver and gold/lead bi-variate graphs showing the silver alloys plotted by the type of niello inlay used.

During this study it became clear that the niello inlays were either inset into channels or stamped impressions. The channels ranged in shape from very square sided and flat based to those that were more curved or even v-shaped. Classification of the channels was difficult as there were occasionally channels of different shapes on the same object as in K310, in addition there was a fine line between those that were v-shaped or those that had a curved

[79] La Niece 2013.
[80] La Niece 2013.
[81] La Niece 1983, 1988.
[82] Blakelock 2015.
[83] Newman *et al.* 1982.

base, they have thus been classified on the basis of the predominant shape. The stamped impressions were predominately triangular in shape, but there were also a number of conical impressions for niello domes that were also likely created by a stamp or punch.

On the niello pieces there was no obvious displaced metal to indicate that the channels were cut into the metal, however the polishing process would have removed these traces. There are however ragged edges and uneven surfaces within the channels themselves which suggests that they were cut, or at least widened, after the object was cast (Fig. 49, Fig. 50 and Fig. 52). K550 which appears to have channels cut into the sheet which is wrapped around a core (Fig. 47).

Fig. 47. 3D images of channels cut into the gold sheet of K550, so that the niello is applied onto the core, as the channels are not very deep the niello is raised from the surface.

The majority of the channels seen in the niello inlaid objects have sharp sides which result in a v-shaped channel (Fig. 48 and Fig. 49), in some cases this is a gentler curve but the base is still not flat (Fig. 50).

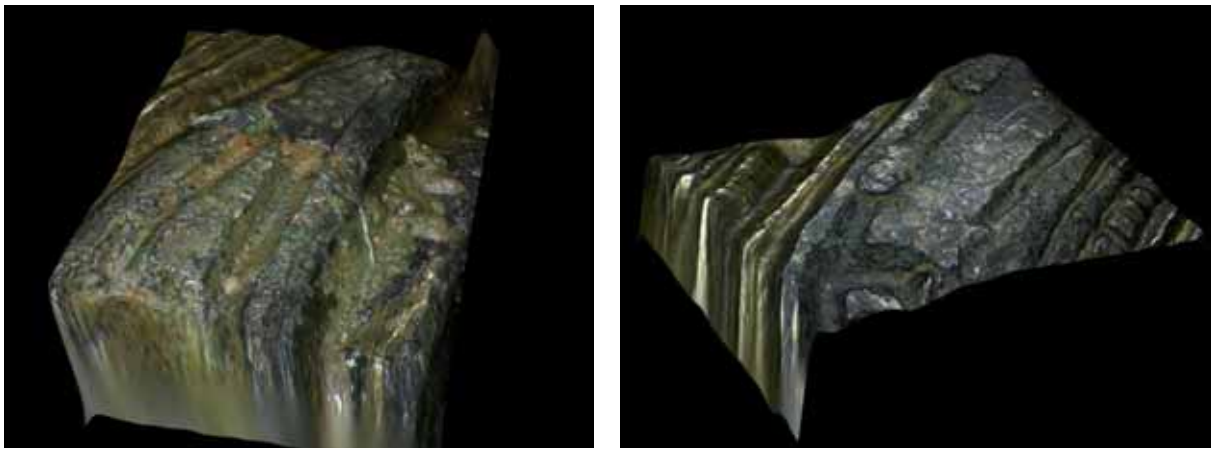

Fig. 48. 3D images of the v-shaped niello channels on the pommel ring from K242, K291, K301, K831 *et al.* (left) and hilt-collar K53 (right)

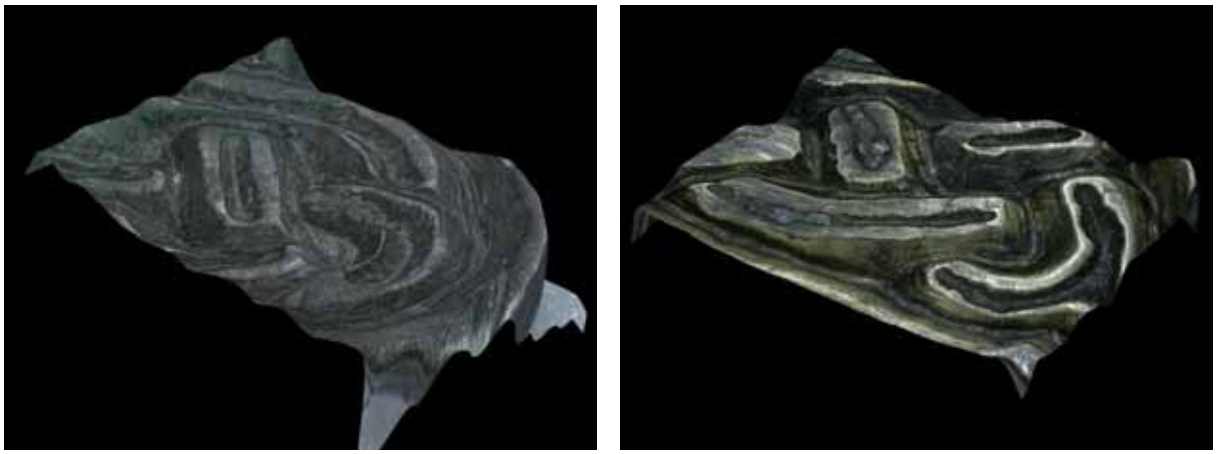

Fig. 49. 3D images of the v-shaped niello channels on K1106 (left) and K577 (right)

Fig. 50. 3D images of the slightly curved based niello channels on K1364 (left) and K304 (right)

The niello on pommels K20, K1112, K1185 *et al.* and K242, K291, K301, K831 *et al.* are different to most other pieces, the shape of the snake or the dots within the triangles are silver with large fields of niello (Fig. 51), which more closely resembles champlevé enamel working (Fern *pers comm*.).

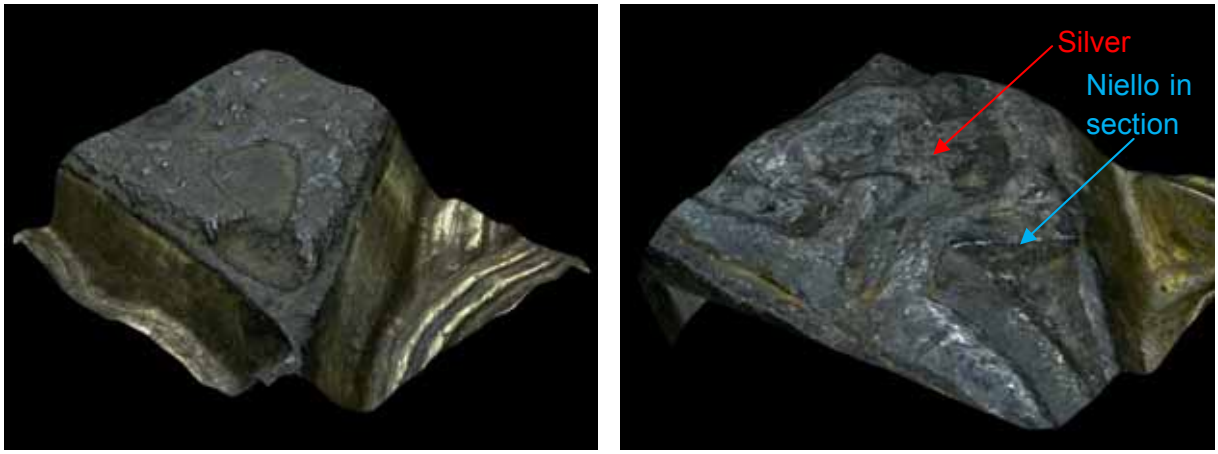

Fig. 51. 3D images of the inlaid neillo decoration on K20, K1112, K1185 *et al.* (left) and K242, K291, K301, K831 *et al.* (right)

All of the niello mounts, and pommel K596, in the Hoard had flat based channels (Fig. 52). In the case of the niello mounts most had a similar appearance, with a flat base and a slightly deeper central channel, presumably made by the tool used (Fig. 53).

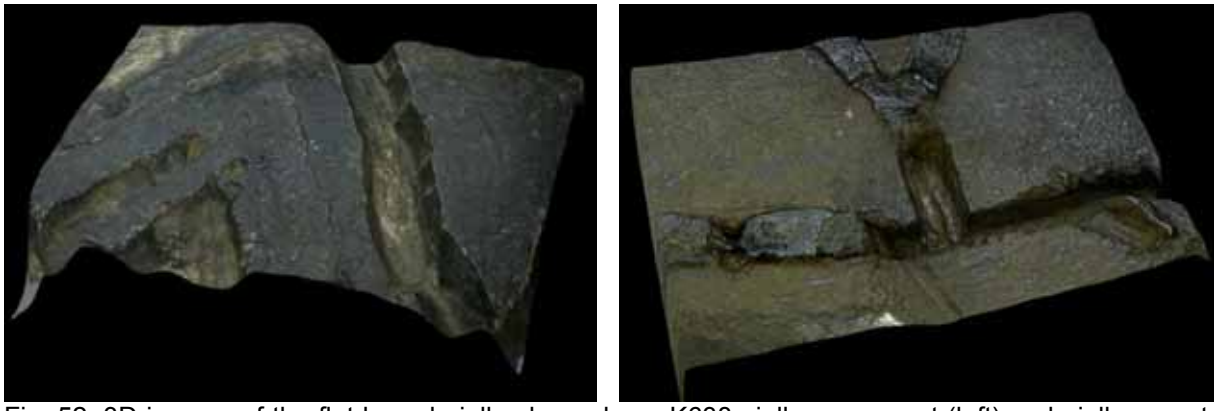

Fig. 52. 3D images of the flat based niello channels on K638 niello eye mount (left) and niello mount K1192 (right).

Fig. 53. Tool mark, flat with central groove K310 (left) and right K592 (right)

The final group are the objects with stamped decoration which were then filled in with niello. The majority of the stamps were triangular in shape, and the niello was raised (Fig. 54). In the case of the helmet cheek pieces (K453 and K5004) and related strip K97 the stamps are joined together to form a zig-zag of silver (Fig. 55). When the goldsmith wanted to create domes of niello, for the eyes in pommel K711 or the gold snakes K731 and K1365, a concave indentation was made. It is likely that some of the pieces that used stamped impressions, such as the cheek pieces, used laying out marks to ensure the design was even. On K5004 there are two thin lines cut into the top and bottom of the row and adjoining each triangular punch (Fig. 54 left), the punch appears to have been aligned to these lines which has resulted in a design which is more regular than the stamps seen on K369 (Fig. 54 right).


Fig. 54. Triangular punched marks for the niello in K5004 (left) and K369 (right), the red arrow indicates the thin laying out line.

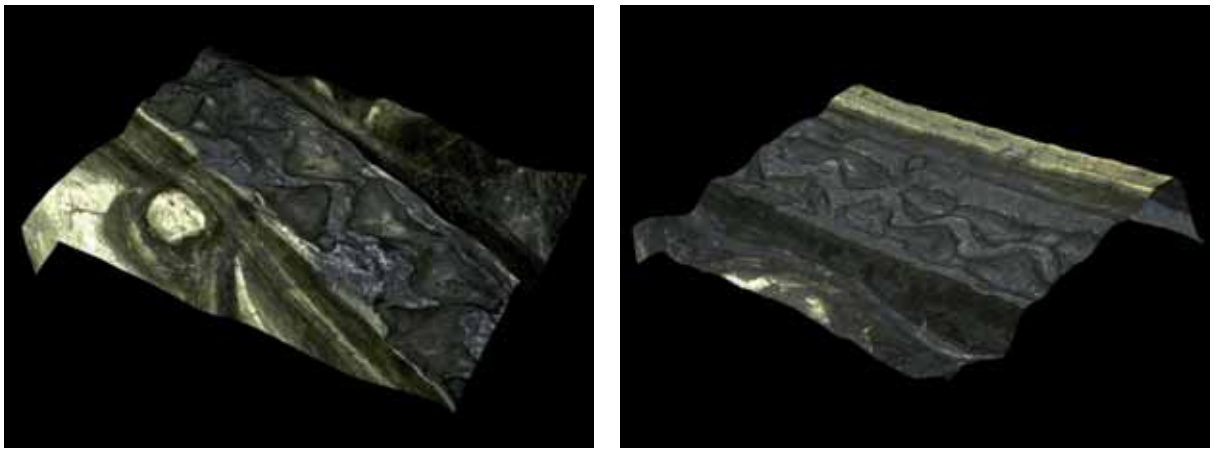
Fig. 55. 3D images of the punched niello channels on K5004 (left) and K97 (right)

The niello in the Hoard objects was either slightly raised from the surface or flush with the edges of the channels where it was placed. The differences may indicate where the goldsmith made a choice between applying a ground niello within the channels or as a solid strip, or more likely is related to the final polishing process.

It is not known how the niello in these pieces was applied. There are some instances where the small lumps of niello appear to overlap, and they have clearly been applied in short lengths (Fig. 52), which suggests that in these cases the niello was applied as a strip or bar into the channels (Fig. 8 right). However there are no historical texts that describe such a method, instead most recipes involving silver or silver-copper sulphides apply the niello as a powder then heat the object and push it into place, or rub a bar of niello across the hot object.[84] It is clear however that the niello in the Staffordshire Hoard was unlikely to have been applied as a molten liquid. This is because the silver sulphide niello would decompose to metallic silver before reaching its melting temperature of 861°C, unless it was melted in a reducing environment.[85] Instead it may have been softened and pushed into the channels at around 600°C.[86] Even so the *Mappae Clavicula*[87] does describe a silver-copper sulphide

[84] Hawthorne and Smith 1979, 108.
[85] Newman *et al.* 1982; Oddy *et al.* 1983.
[86] La Niece 1983.
[87] Smith and Hawthorne 1974, 57.

that would melt at c. 650°C[88] (Northover and La Niece 2009) but this could be due the presence of borax and soda.

The niello which is flush with the surface of the object most likely represents where it has been polished into place. Probably in a similar method to that described by Theophilius, who describes the polishing process as follows

‘ *Hold the work in the same cloth and with a scraping tool carefully scrape all the places which have been blackened with niello. After this you should have a soft black stone of the kind that can be easily cut and almost scratched with a fingernail. Wet the niello with saliva and rub it all over with a stone, carefully and evenly, until all the engravings are clearly visible and it is completely smooth. You should also have a piece of wood from a linden tree, as thick and as long as the middle finger, dry and cut smooth. On this put the moist powder that comes of the stone and the saliva in the course of rubbing and lightly rub the niello for a very long time with this wood and powder. Continuously add saliva so that it stays moist until it shines brightly all over. Then take some wax from your ear-hole and after wiping the niello smear the wax all over it with a fine linen cloth and gently rub with a goatskin or a buckskin until it is entirely bright*’.[89]

There appears to be distinct groupings when the silver alloy data[90] are plotted based on the profile of the niello, either raised or flush, or the shape of the channel. It is possible that a purer silver alloy was selectively used to create niello objects with raised niello (Fig. **56**). The only exception to this group was pommel K39/K1007 which had a higher copper content. Purer silver was also used to create the range of niello mounts (K310, K620 *et al*. K64 *et al*., K161 *et al*. and K82 *et al*.), and these all share similar flat based channels, but the silver objects with niello inlaid into stamped impressions also tended to be purer silver, potentially from the same workshop (Fig. **57**).

[88] Northover and La Niece 2009.
[89] Hawthorne and Smith 1979, 115.
[90] Blakelock 2015.

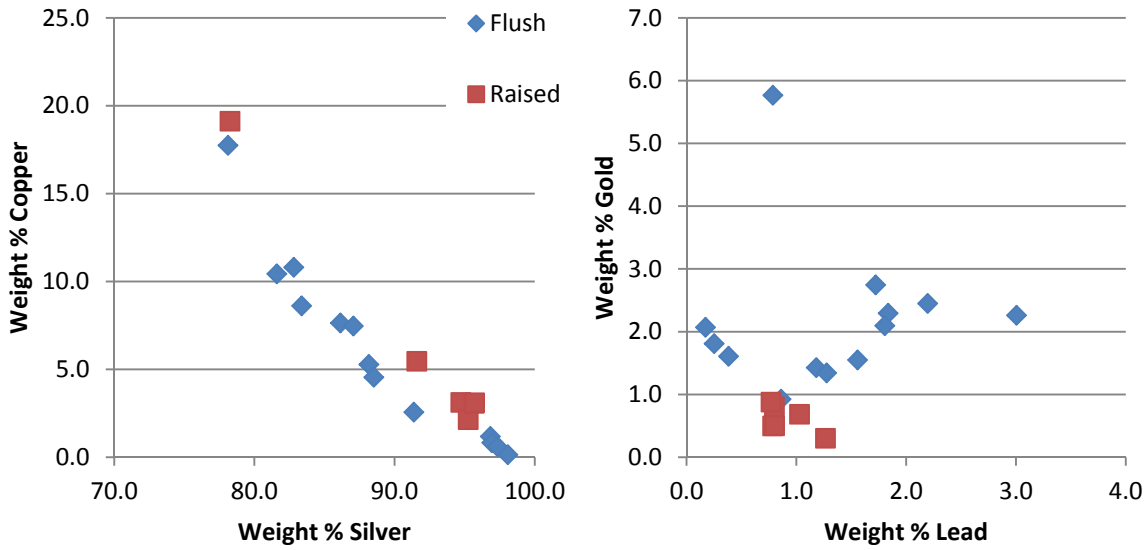

Fig. 56. Copper/silver and gold/lead bi-variate graphs showing the silver alloys plotted by the profile of the niello applied.

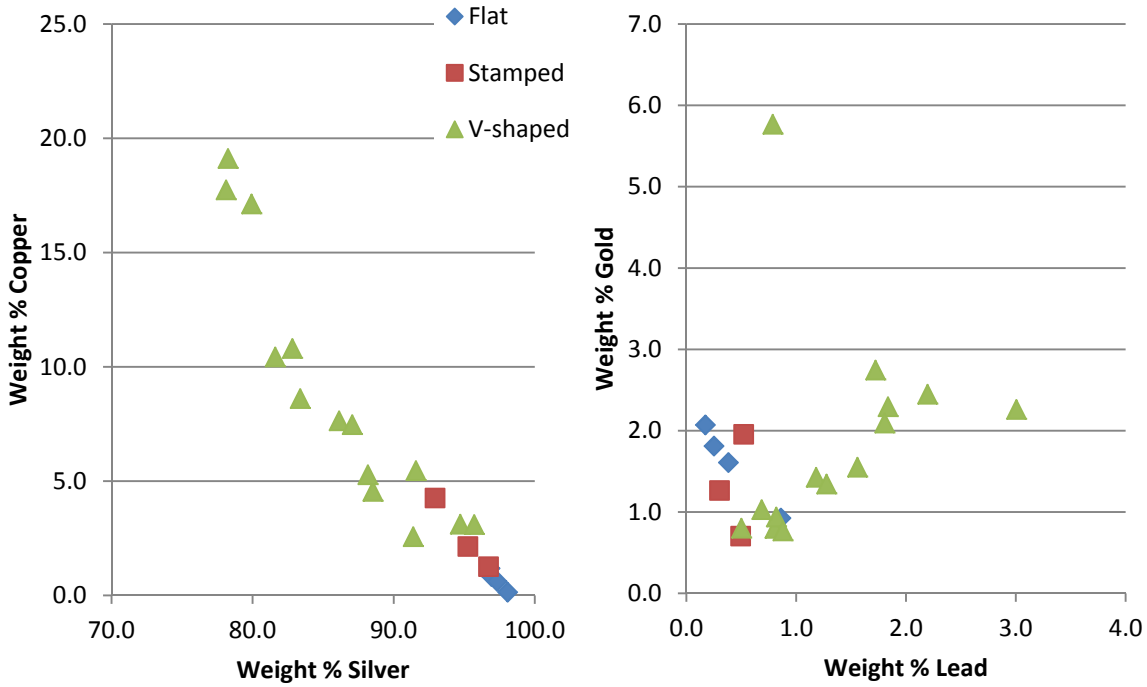

Fig. 57. Copper/silver and gold/lead bi-variate graphs showing the silver alloys plotted by the shape of the indentation or channel into which the niello was laid.

This analysis has also confirmed that the niello was most likely applied to the piece before the gilding took place. This is probably due to three reasons, which are not mutually exclusive. The first is that the process of applying niello would have most likely left residues on the surface of the object, which would potentially cover any gilding. Secondly the process of polishing or cleaning the niello after application could potentially damage any gilding present. Finally the heat required to soften the niello so that it could be pushed into channels would have been well above the boiling temperature of the mercury,[91] resulting in a total loss

[91] Northover and Arnheuser 2000.

of this metal from the surface; chemical analyses revealed that mercury was still present on the surface.[92] In addition the high temperatures could have resulted in silver diffusing into the gold in the gilding layer.[93]

Conclusion

XRD analysis carried out at the British Museum indicated that all the samples analysed were silver sulphides, rather than silver-copper sulphides.[94] The survey of the remaining objects by XRF suggested that many were silver sulphide niello with the exception of hilt-collars K369, K19 *et al.*, K34 *et al.* and pommel K711 which may be silver-copper sulphide.

Examination of the objects showed that the niello was inlaid into sharp, curved or flat based channels, or into stamped impressions, often triangular in shape. There seemed to be no consistent finish to the niello, with eight raised from the surface while twelve had been polished smooth.

Further work

XRD analysis, alongside SEM-EDX analysis, of the remaining niello objects in the hoard is required to accurately identify the type of niello present. This is particularly important for those objects potentially identified as silver-copper sulphides to confirm the XRF results. It would also be useful to re analyse a sample from K347 as the XRF analysis suggested a silver-copper sulphide but the XRD revealed a silver sulphide, but is unknown where this sample was taken from.

It would also be beneficial in the future to look at silver working instruments and the marks they leave on the object. This may help identify different workshop groups. This analysis might also reveal more about the tools of the goldsmith, as their forms do not appear to have changed through time.

[92] Blakelock 2015.
[93] Northover and Arnheuser 2000.
[94] La Niece 2013.

References

Ashbee, C.R. 1967. *The treatises of Benvenuto Cellini on Goldsmithing and Sculpture*, Dover publications, New York

Blakelock, E.S. 2015. *XRF study of silver objects from the Staffordshire Hoard*, Staffordhsire Hoard Research Report 19, Archaeological Data Service, York

Caley, E.R. and Jensen, W.B. 2008. *The Leyden and Stockholm Papyri: Greco-Egyptian chemical documents from the early 4th century AD*, The Oesper Collections, Cincinnati

Cool, H.E.M. 2015. *Contextualising Metal-detected Discoveries: Staffordshire Anglo-Saxon Hoard. Stage 2 Project Design*. Barbican Research Associates, Nottingham

Hawthorne, J.G. and Smith, C.S. 1979. *Theophilus On Divers Arts: The foremost medieval treatise on painting, glassmaking and metalwork*, Dover Publications, New York

La Niece, S. 1983. 'Niello: an historical and technological survey', *Antiquaries Journal,* **63**, 279-297

La Niece, S. 1988. 'White inlays in Anglo-Saxon jewellery', in E.A. Slater and J.O. Tait (eds), *Science and Archaeology, Proceedings of a Conference on the Applications of Scientific Techniques to Archaeology, Glasgow, September 1987*, 235-46, BAR British Series 196, B.A.R., Oxford

La Niece, S. 2013. *The Scientific Analysis of Niello Inlays from the Staffordshire Hoard*, Staffordshire Hoard Research Report 4, Archaeological Data Service, York

Newman, R., Dennis, J.R. and Farrell, E. 1982. 'A technical note on niello', *Journal of the American Institute for Conservation*, **21**, 80-85.

Northover, P. and Anheuser, K. 2000. 'Gilding in Britain: Celtic, Roman and Saxon', in T. Drayman-Weisser (ed.), *Gilded Metals: History, Technology and Conservation*, 109-22, on, Archetype Publications, London

Northover, P. and La Niece, S. 2009. 'New thoughts on niello', in A.J. Shortland, I.C. Freestone and T. Rehren (eds), *From Mine to Microscope: Advances in the Study of Ancient technology*, 145-54, Oxbow Books, Oxford

Oddy, A., Bimson, M. and La Niece, S. 1983. 'The composition of niello decoration on gold, silver and bronze in the Antique and Mediaeval Periods', *Studies in Conservation*, **28**, 29-35.

Rackham, H. 1952. *Pliny Natural History: Books 33-35*, Harvard University Press, Cambridge Massachusetts and London

Smith, C.S. and Gnudi, M.T. 1990. *The pirotechnia of Vannoccio Biringuccio: the classic sixteenth-century treatise on metals and metallurgy*, Dover Publications, New York

Smith, C.S. and Hawthorne, J.G. 1974. 'Mappae Clavicula', *Transaction of the American Philosophical Society,* **64**, 3-76

Wolters, J., 2006. On the Noble and Illustrious Art of the Goldsmith: an 11th century text, *Historical Metallurgy Journal*, **40**, 68-88

Appendix

Objects	Metal	Analysis (sulphide type)		Shape	Profile
		BM XRD	BMAG XRF		
K310 and (K620, K638, K1021 *et al.*)	Silver	Silver	Silver	Flat and v-shaped	Flush
K64, K592, K641, 1235, K1168 *et al.*	Silver	Silver	Silver	Flat	Flush
K161, K241, K639 *et al.*	Silver	Silver	Silver	Flat	Flush
K82, K83, K168, K182, K251, K1700 *et al.*	Silver	Silver	Silver	Flat	Flush
K369 and (K19, K430, K537 *et al.*)	Silver		Silver-copper	Stamped	Raised
K34, K53, K993, K1026 *et al.*	Silver		Silver-copper	V-shaped	Flush
K304, (K160, K595, K186 et al) and (K39 and K1007)	Silver	Silver	Silver	V-shaped	Raised
K242, K291, K301, K831 *et al.*	Silver	Silver	Silver	V-shaped	Flush
K20, K1112, K1185 *et al.*	Silver	Silver	Silver	V-shaped	Raised
K711	Silver		Silver-copper	Cone and v-shaped	Raised
K825	Silver		Silver	V-shaped	Flush
K358 and K27	Gold		Silver	V-shaped	Flush
K347	Gold	Silver	Silver	V-shaped	Raised
K550	Gold		Silver	Flat	Raised
K972	Gold		Silver	unknown	Flush
K731	Gold		Silver	Cone	Raised
K1365	Gold		Silver	Cone	Unknown no original surface
K63, K137, K529 *et al.*	Silver	Silver	Silver	V-shaped	Flush
K97, K453 and K5004	Silver		Silver	Stamped	Raised
K577	Silver		Silver	V-shaped	Flush
K1106	Silver		Silver	V-shaped	Flush
K298 and K181, K755, K1152 etc	Silver			Stamped	No niello remains
K1277	Silver			V-shaped	No niello remains
K596	Silver			Flat	No niello remains

Text	Date	Niello		Reference
		Recipe	Application	
Pliny the Elder 'Natural History'	77-79 AD	Silver, copper and sulphur melted in vessel pg 99	Could be surface treatment as no description of application to channels pg 99	(Rackham 1952)
Leyden (or Leiden) Papyri	3rd-4th century AD	Asem 2 parts [tin, pitch and mercury?] and lead 4 parts, placed and melted with triple the weight of sulphur pg 27	When removed from furnace beat or cast to shape pg 27	(Caley and Jensen 2008)
Mappae Clavicula	9th century	• Silver, copper and lead pg 36 • Silver pg 36 • Silver 2 parts and copper 1 pg 57	• Applied on surface, perhaps as treatment pg36 • Rubbed in engraved channels pg57	(Smith and Hawthorne 1974)
Greek manuscript ' On the noble and illustrious art of the goldsmith'	11th century	• Silver pg 72 • Silver, copper and lead pg 75 • Another silver, copper and lead pg 80	Surface has borax and soda flux, niello is crushed and applied pg 72	(Wolters 2006)
Theophilus ' On Divers Arts'	12th century, but possibly earlier i.e. 10th century	Pure silver and 1 part copper, 1/2 part lead pg104	• Melted with borax pg104-105 • Rubbed into channel when hot pg 108 • Details on finishing pg 115	(Hawthorne and Smith 1979)
Benvenuto Cellini 'Goldsmithing and sculpture'	c. 1568	Silver, copper and lead pg 7	Clean, borax, heat but not too hot so as to protect metal of object pg 7-9	(Ashbee 1967)
Vannoccio Biringuccio 'treatise on metals and metallurgy'	16th century	Silver 1 part, 2 parts copper, 3 parts lead pg 365-366	Pg 365-366	(Smith and Gnudi 1990)

Table 1. Table of historical sources that mention niello recipes.

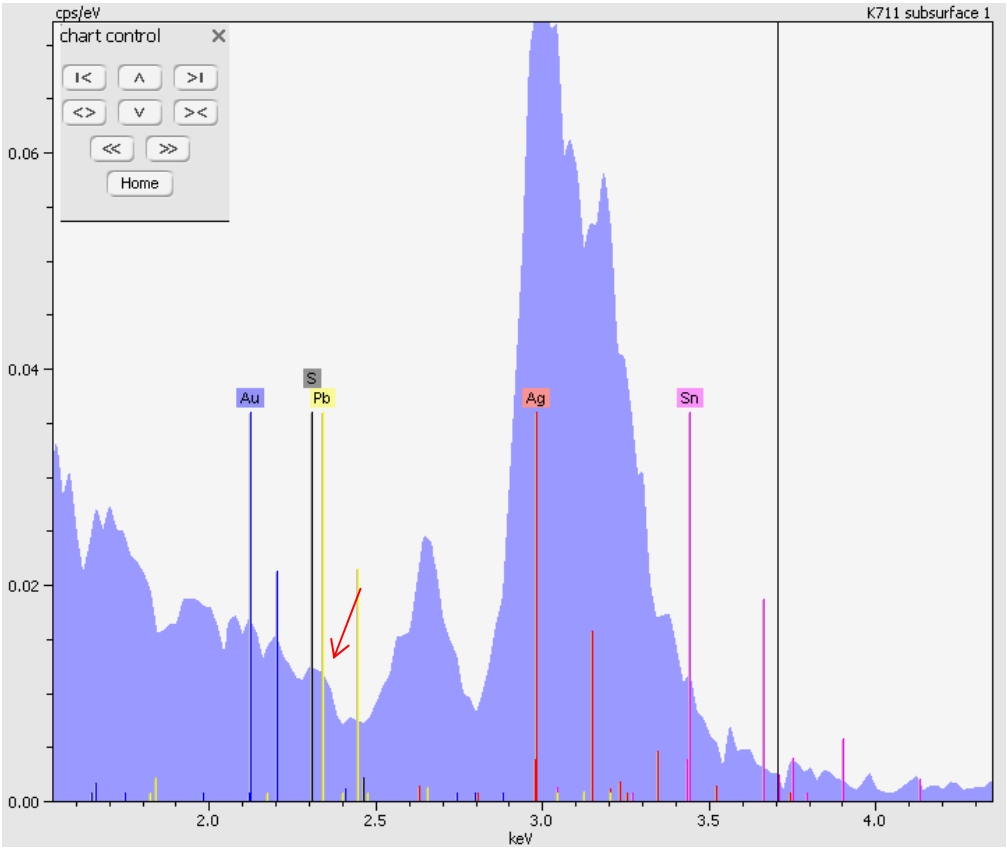

Fig. 58. Spectra showing the k alpha sulphur peak.

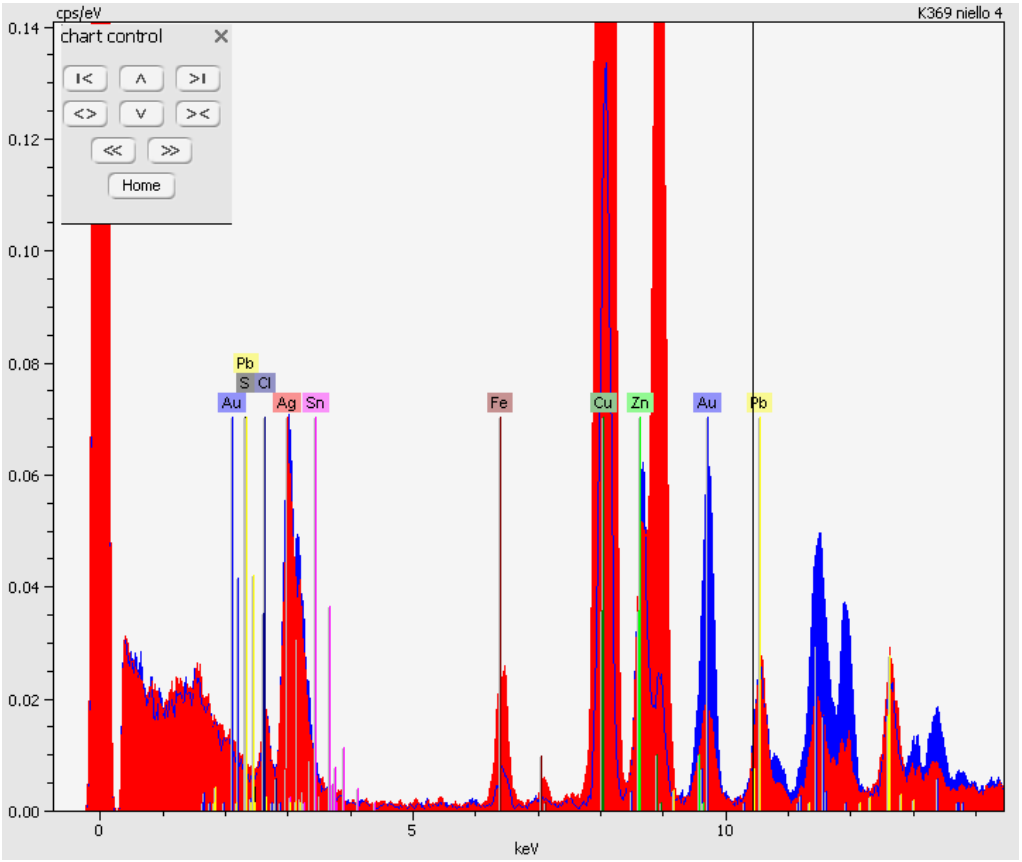

Fig. 59. Spectra of K369 showing the niello spectra (red) compared to the metal (blue) which shows more copper present in the niello than in the metal itself.

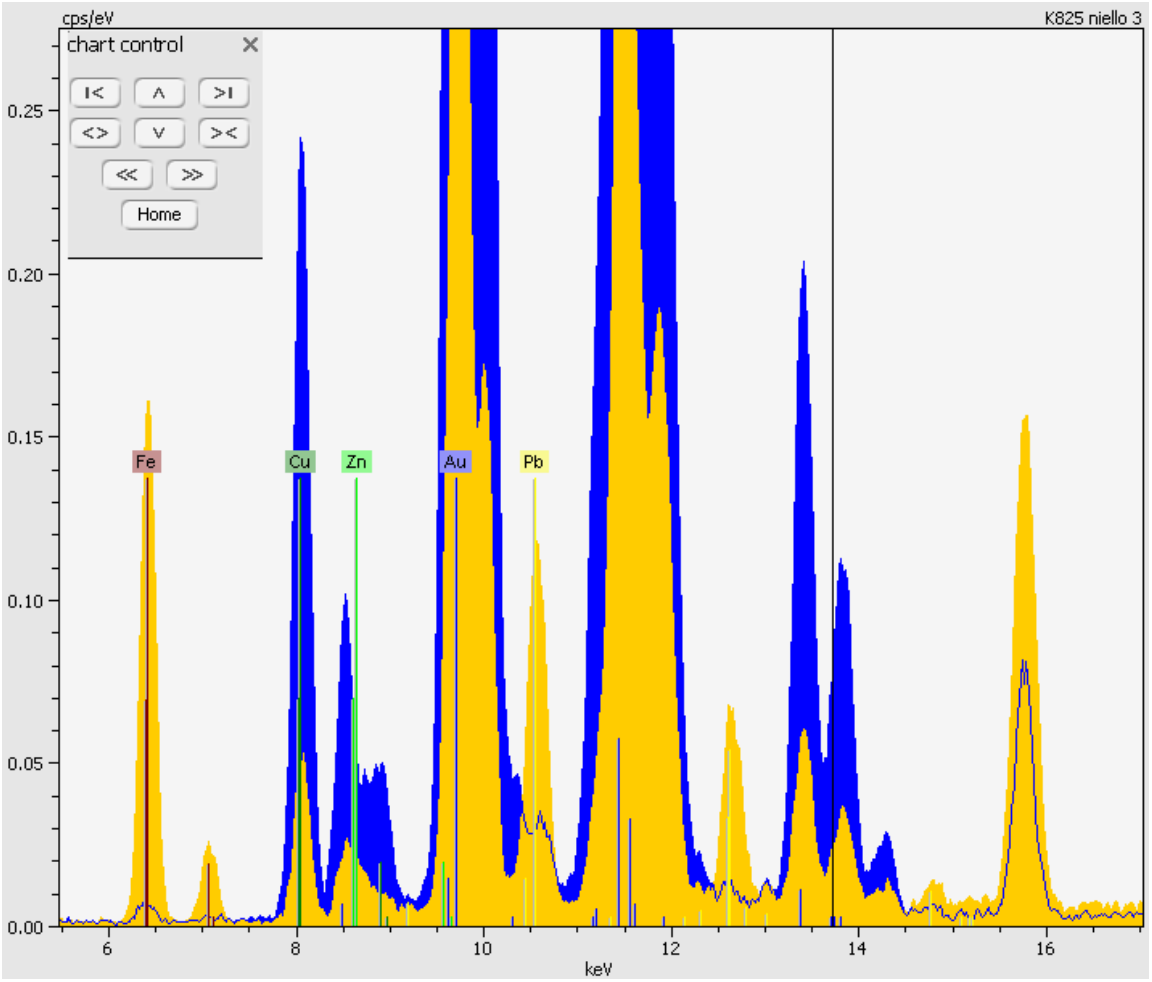

Fig. 60. Spectra of K825 showing the niello spectra (yellow) compared to the metal (blue) which shows a little copper present in the niello but this probably derives from the copper in the metal itself.

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.

The Staffordshire Hoard research project was conducted by Barbican Research Associates Ltd and funded by Historic England and the owners.

The work in this report was funded by a grant from the Esmée Fairbairn Collections Fund.

Historic England

Birmingham City Council

City of Stoke-on-Trent

Barbican RA

Birmingham Museums

The Potteries museum & art gallery