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ORIGINAL ARTICLE

Quality from Kent: Preliminary results from the analysis of fifth- to seventh-century silver alloys

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Abstract

This paper explores early results from the chemical and lead isotope analysis of 30 silver-alloy objects from southeast England dating between the fifth and seventh centuries CE, presenting limited aspects of the three main analyses that were conducted. First, a comparison of the results gained from surface x-ray fluorescence (pXRF) values and drilled samples subjected to microwave-plasma atomic emission spectrometry (MP-AES) will be explored for their methodological implications. Second, proportions of silver, gold and lead derived from MP-AES will be investigated in order to model the basic characteristics of the bullion used to create these objects and the recycling practices to which it was subjected. Third, results from stable lead isotope analysis (LIA) will permit some comments on the most likely sources of the silver and the possibility of refinement processes. We offer some preliminary perspectives on the socio-economic implications of these results, insofar as the control and management of precious metals are concerned.

KEYWORDS

Anglo-Saxon, archaeology, economy, Kent, metallurgy, silver

INTRODUCTION

When it comes to understanding the post-Roman centuries in Britain, material decline and dislocation have always been foregrounded, from which has emerged the picture of an economically

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simple society composed of self-reliant households practicing subsistence agriculture, living under basic but relatively egalitarian conditions (Wickham, 2005, 307–14; Carver, 2019, 288; Fleming, 2021, 8, 185). Such conclusions have not been drawn without reason. Direct evidence for a formal economy servicing the ambitions of even modestly centralised political authorities has been elusive for the fifth and much of the sixth centuries. Yet, the historical record is strongly suggestive of the fact that a fledgling political class, variously described in historical texts and more recent scholarship as warlords and kings, survived the 'ruin' of Roman Britain, or else emerged as other regional and local leaders fell away (Halsall, 2013, 270–81; Gerrard, 2013, 251–5). But where is the archaeological evidence for the economic basis that sustained such an elite? We have worryingly scant evidence to satisfy that empirical requirement.

To be sure, the exit of the former provinces of Britain from the imperial taxation cycle in the early fifth century resulted in a rapid simplification of the economy, and no doubt a consequent flattening of political hierarchies. Settlement evidence in the fifth and sixth centuries shows precious little evidence for economic distinction (Hamerow, 2012), and disparities of grave wealth, once used as direct evidence for economic inequality (e.g. Arnold, 1980), have long been critiqued on theoretical grounds (Pader, 1982) or have since benefited from substantial contextual nuance (Sayer, 2020, 186–9). Persuasive evidence for distinction seems only to emerge in the later sixth and seventh centuries (Blair, 2018, 103–38; Carver, 2019, 641–5). There is still, however, the occasional glimmer of a precious metal economy in post-Roman Britain, though questions about who, if anyone, controlled it are moot. Summarily, the direct evidence includes the continued circulation of old issues of clipped *siliquae*, apparently still used as a form of currency, whilst its offcuts became bullion (Moorhead & Walton, 2014), and the deposition of substantial precious metal hoards including plate, coins, and hacksilver (Hobbs, 2006, 94–5; Johns, 2010; Hunter & Painter, 2013; Hobbs et al., 2016). Both seem to be limited to the fifth century. The rare occurrence of small sets of scales in graves in the south and east of England, most likely used for the weighing of small amounts of precious metal, appears to be a phenomenon of the fifth as well as sixth centuries (Scull, 1993). Careful analysis of the weights found with these scales, considered alongside the Old English terms used to describe payments in law codes of the seventh century, suggest the existence of a bimetallic bullion economy in which the value of silver was determined by weight quite precisely in relation to gold at least from the sixth century (Hines, 2010). However, this evidence for a bullion economy, though widely acknowledged, has been hard to integrate into economic models. Determining how long late Roman precious metal coins and plate were in circulation has proven difficult, and because they tend to occur in isolation or as stray finds, economic interpretation is limited. The result is that the kingdoms first reliably attested by the end of the sixth century are hard to connect in any way to the immediately post-Roman period and appear to spring from origins accounted for only by a pseudomythological—rather than an economic—history (Bassett, 1989; Yorke, 1997).

This paper suggests that a new category of evidence might be mobilised in the form of high-resolution metallurgical analyses of silver alloys. Such evidence can help inform debate over the nature of the economy and its sociopolitical implications from an empirical base. The advantage of the approach is that it engages directly with the very material on which political influence at least partly depended. The flow of precious metals through post-Roman society is unlikely to have been random, but instead it depended on the agency of human actors who variously stored or dispersed these potent resources as a means of achieving their ambitions. Chemical analysis also provides an unexpected window onto the difficult chronology of the fifth century. Inhering somewhere within the chemistry of later sixth- and seventh-century alloys is a history of their use in the fifth century.

Understanding how the flow of silver was or was not controlled has been compromised by the quality of available data, which up until now has largely been limited to nondestructive surface analysis. We present below preliminary results of subsurface microwave-plasma atomic emission spectrometry (MP-AES) analysis, as well as lead isotope analyses (LIA) of 30 silver alloys of the fifth to early seventh centuries from southeast England, predominantly from Kent. We assess methodological potentials and limitations, and provide some initial models for the flow and control of silver bullion and its most likely sources. The results indicate the presence of a mode of precious metal acquisition in sixth-century Kent that exceeds substantially what one might predict from ad hoc scavenging or bartering but implies a degree of centralised control.

THE ANALYSIS OF BRITISH FIFTH- TO SIXTH-CENTURY PRECIOUS METAL ALLOYS TO DATE

Virtually all knowledge of fifth- and sixth-century silver-alloy chemistry is based on surface analyses obtained using x-ray fluorescence or SEM-based energy-dispersive spectroscopy (XRF or SEM–EDX). Although these results have provided valuable insight into surface chemistry, knowledge of the core chemical compositions of silver alloys in this period has not progressed substantially since the introduction of these methods in the 1980s due to the lack of reliable, high-quality data pertaining to bulk major, minor, and trace elements, as well as lead isotopes, derived from drilled samples. Indeed, the very earliest analyses of this nature by Leigh and colleagues admitted that surface contamination rendered the results from their 25 objects unreliable (Leigh et al., 1984). With the exception of a small number of incidental surface analyses of silver alloys conducted in the meantime (Hines, 1985, 1997, 313–15; Mortimer, 1990, 365–70; Mortimer & Draper, 1997), and XRF analysis of drilled samples of just two items with substantial silver content (Brownsword & Hines, 1993, 2–3), the next major analysis by Nicholas (2016) subjected 68 silver-alloy artefacts from the Lakenheath cemeteries to surface XRF analysis. Nicholas used statistical analyses of bulk elements to suggest the use of different recipes to create alloys for different functions (for wire, casting and sheet), but he was candid concerning the limitations of surface analysis on silver alloys, stating plainly that the data it produces, although capable of broadly characterising alloy types, can tell us little that is reliable about original fineness and recycling practices, let alone provenance (ibid. 170–1, 245). Such repeated warnings similarly limit the reliability of a recent and extensive XRF study of post-Roman ‘Quoit Brooch Style’ objects, eight of which were of silver alloys (Swift, 2019, 27). Recent subsurface analysis from broken edges of items from the Staffordshire Hoard has improved our knowledge of silver alloys from the mid-seventh century onward (Blakelock & Fern, 2019, 128–9), but this material belongs to an immediately later phase than that considered here.

Existing knowledge of silver alloys from the fifth and sixth centuries appears to derive from the surface analysis of fewer than 100 artefacts, with significant limitations to the use such data can be put, and from the subsurface analysis of fewer than five items. Such limitations have been widely acknowledged within this period (Brownsword & Hines, 1993, 9–10; Nicholas, 2016; Mortimer & Draper, 1997) as well as beyond it (Klockenkämper et al., 1999; Condamin & Picon, 1964; Beck et al., 2004; Butcher & Ponting, 1995; Ponting, 2012). Surface enrichment itself has taphonomic causes, affecting different component elements in a manner that is not easily predicted, at depths that vary according to the alloy and taphonomic conditions. But it can also be intentional, and we know that at least by the seventh century goldsmiths were artificially enhancing the appearance of precious metal alloys using surface enrichment (Blakelock et al., 2016). The unfortunate outcome is that most analyses of fifth- to sixth-century English silver alloys, though they can tell us plenty about the current state of the surface metal and, in some cases, its deliberate treatments by ancient craftspeople, are unlikely to tell us much reliably about the core alloy in terms of bulk as well as trace elements. The evidence for the same period from the European continent is potentially even less well developed (a very small number of examples can be found in Riederer, 1975; Hines, 1985; Gohkle &

Neumayer, 1996; Istvánovits, 1993). There is therefore an urgent need for subsurface, high-resolution analysis of drilled samples, as well as for lead isotope analysis, which, when used in tandem with bulk and trace element analysis, has been shown to be a powerful tool for understanding early medieval recycling practices (Kershaw et al., 2024; Merkel, 2018).

SAMPLE RATIONALE

The priority for sample selection was to limit all axes of variation besides chronology to produce a diachronic picture of how silver use developed between the fifth and early seventh centuries. All objects were selected from the British Museum's collection for reasons of expedience, this being one of few museums in the country where a sufficient chronological spread could be selected from a single collection. Several considerations led to restricting the sample to brooches, the main one being that their typochronological characteristics are well established, so that reliable phases could be assigned to all sampled objects. Due to the relative rarity of silver-alloy objects beyond Kent in this period, most objects came from within the bounds of the modern county, which aligns broadly with the distinct—and indeed distinctive—kingdom

FIGURE 1 The distribution of the sampled objects.

of Kent at least by the later sixth century (Brooks, 1989, 64–5; Brookes & Harrington 2010), with the exception of a small number of outliers selected for the sake of comparison (Figure 1). An attempt was made to select objects from as many sites as possible from this region, in order to minimise the influence of any very local idiosyncrasies. Bearing in mind Nicholas' findings that silver alloys were created according to their expected use, limiting the analyses to brooches of similar dimensions and thicknesses meant that the sample was also restricted to alloys created for the purpose of casting moderately large items with a similar desirability for tensile strength and the ability to hold cast relief ornament. Objects from known and reliably recorded contexts were included where possible in order to maximise the utility of the results for future studies. Finally, where possible, the ethical and aesthetic concerns of destructive sampling led us to prioritise incomplete and fragmented artefacts.

The sampled objects were categorised according to 'early' (fifth century), 'middle' (later fifth to later sixth century), and 'late' (mid-sixth to early seventh century) phases. The early phase included two square-headed brooches belonging to the Jutlandic brooch group (Bakka, 1959; Haseloff, 1981) and a Saxon equal-arm brooch (Böhme, 1974; Bruns, 2003; Evison, 1977). A number of early quoit brooches (Suzuki, 2000; Swift, 2019) were also examined for possible analysis but found to be too thin to be sampled without risk to the integrity of the object, as well as the reliability of any sample gained given that the chemical alteration of the surface may well have spread through the whole object. The middle phase was populated by Kentish square-headed brooches including a fragment of uncertain identification (Leigh, 1984; Brugmann, 1999; Parfitt & Brugmann, 1997, 35–9), a single great square-headed brooch (Hines, 1997), a single Continental square-headed brooch (Koch, 1998), and keystone garnet disc brooches belonging to Avent's classes 1 and 2 (Avent, 1975), or types BR2-b1 and BR2-b2 in the national chronological framework (Hines & Bayliss, 2013, 221–2). The latest group was populated exclusively by keystone garnet disc brooches of Avent's classes 3, 5 and 6, or types BR2-b3 and BR2-b4, as this is the only type known to span this transitional phase. These objects are summarised in Table 1 and visually represented in Figure 2.

Though all efforts were made to form a representative sample, two limitations were unavoidable. The first limitation concerns the latest group, which is composed of a single brooch type, meaning that an error in their typochronology could have implications for any chronological arguments developed here. This is partly mitigated by the high reliability of the dating of this particular brooch type thanks to its inclusion in the national chronological framework (Hines & Bayliss, 2013). The second limitation concerns the earliest group. Typical of most material that can be dated confidently to the fifth century, there is no reliable means of pinning down the geographical origins of items belonging to the equal-arm and Jutlandic brooch group series to either side of the North Sea, though both would appear to have been first used in northern Germany and southern Scandinavia, and adopted soon after in England (Haseloff, 1981, 25–26). Something similar is true of the single great square-headed brooch, deeply unusual for being silver among a series that was typically copper alloy. Silver versions of such brooches are far more common in Scandinavia, and its stylistic tendencies, though obviously closest to insular products, show considerable similarity with Scandinavian parallels (Hines, 1997, 27–32). The same applies to the Continental square-headed brooch, which is certainly related to *Typ Langweid* known from Alsace through Bavaria to northern Italy (Koch, 1998) but also found in a local variant form at King's Field in Kent (not sampled here, British Museum 0.1054-'70). The sampled item from Buckland is closer to its Continental than its Kentish cousins but not precisely paralleled anywhere. On this basis its 'Continental' pedigree might be called into question, even though this is the most likely scenario. As we will show, however, these uncertainties probably add to, rather than detract from, the potential of the analytical results, as they help to define the distinctive nature of the alloys used to create Kentish jewellery.

TABLE 1 The items subjected to pXRF and MP-AES analyses as part of this study, ordered by type and phase.

Site	Museum no.	Sample no.	Typology	Phase
Buckland	1963,1108.811	AS17	Jutlandic brooch group	Early
Martyr's field	1942,1008.10	AS27	Jutlandic brooch group	Early
Kempston	1876,0212.18	AS12	'Saxon' equal-arm brooch, type Wehden	Early
Buckland	1963,1108.806	AS6	Continental square-headed brooch (related to Koch VI.2 *Typ Langweid*)	Middle
Darenth Park	1954,1204.1	AS7	Great square-headed brooch, Hines group I	Middle
King's Field	0.1051.'70	AS14	Kentish keystone garnet disc brooch, BR2-b1	Middle
Buckland	1995,0102.546	AS3	Kentish keystone garnet disc brooch, BR2-b1	Middle
Howletts	1918,0708.49	AS22	Kentish keystone garnet disc brooch, BR2-b2	Middle
King's Field	0.1045.'70	AS13	Kentish keystone garnet disc brooch, BR2-b2	Middle
King's Field	0.1034.'70	AS24	Kentish keystone garnet disc brooch, BR2-b2	Middle
Ash	1862,0701.12	AS1	Kentish square-headed brooch, Leigh series 1	Middle
Ash	1862,0701.13	AS29	Kentish square-headed brooch, Leigh series 1	Middle
Buckland	1963,1108.776	AS28	Kentish square-headed brooch, Leigh series 1	Middle
Howletts	1918,0711.1	AS2	Kentish square-headed brooch, Leigh series 1	Middle
Buckland	1995,0102.669	AS11	Kentish square-headed brooch, Leigh series 2	Middle
Buckland	1995,0102.494	AS21	Kentish square-headed brooch, Leigh series 2	Middle
Buckland	1995,0102.668	AS25	Kentish square-headed brooch, Leigh series 2	Middle
King's Field	0.1083.'70	AS8	Kentish square-headed brooch, Leigh series 2	Middle
King's Field	.1083a.'70	AS23	Kentish square-headed brooch, Leigh series 2	Middle
Stodmarsh	1854,1202.4	AS5	Kentish square-headed brooch, Leigh series 2	Middle
Ash	1862,0701.14	AS18	Kentish square-headed brooch fragment (possible)	Middle
Buckland	1963,1108.2	AS4	Kentish keystone garnet disc brooch, BR2-b3	Late
Buckland	1963,1108.181	AS20	Kentish keystone garnet disc brooch, BR2-b3	Late
King's Field	0.1040.'70	AS9	Kentish keystone garnet disc brooch, BR2-b3	Late
King's Field	0.1041.'70	AS16	Kentish keystone garnet disc brooch, BR2-b3	Late
King's Field	0.1035.'70	AS19	Kentish keystone garnet disc brooch, BR2-b3	Late
King's Field	0.1039.'70	AS26	Kentish keystone garnet disc brooch, BR2-b3	Late
Howletts	1936,0511.29	AS30	Kentish keystone garnet disc brooch, BR2-b3	Late
King's Field	0.1031.'70	AS10	Kentish keystone garnet disc brooch, BR2-b4	Late
King's Field	0.1042.'70	AS15	Kentish keystone garnet disc brooch, BR2-b4	Late

The outcome of the methodical rationale was a group of 25 characteristically 'Kentish' items (Kentish square-headed brooches and keystone garnet disc brooches) analysed against a more heterogeneous brooch types of potentially quite diverse origin, including great and continental square-headed brooches, an equal-arm brooch, and members of the Jutlandic brooch group.

METHODOLOGY

A preliminary examination was undertaken using hand-held portable XRF (pXRF). This was to enable a direct comparison between the results of an unprepared surface analysis and the

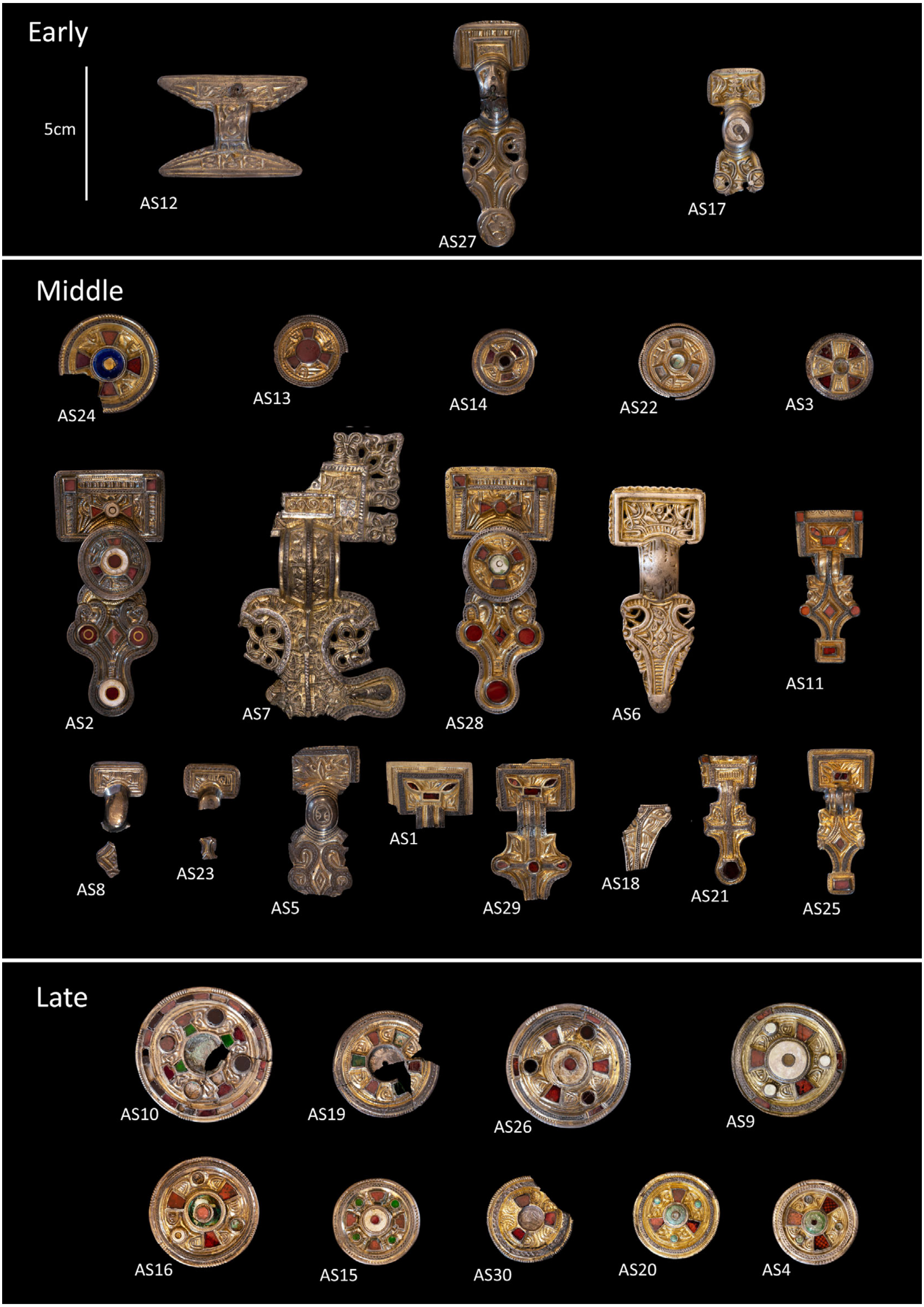

FIGURE 2 All objects sampled labelled by their sample number. Photography by T. Martin, reproduced courtesy of the trustees of the British Museum.

results from a drilled sample taken from subsurface metal to be made. The instrument used was a NITON GOLDD XRF unit with the precious metal calibration. The accuracy of the results was checked using a series of commercially available silver-alloy standards produced by MBH Ltd. (AGA1, AGA2 and AGA3) and found to be reliable when analysing the unprepared surfaces of the disks (Table 2).

A single drilled sample was then taken from each brooch where the fabric of the artefact was judged to be thick enough and in visually sound condition. A site was selected in as inconspicuous a position as possible, or from a broken edge, that was thick enough to allow the removal of a drilled sample without the drill breaching either surface. In all cases the first millimetre or so of material was discarded to exclude any metal altered by corrosion process, postexcavation cleaning, or by plating processes used during manufacture.

The drilled sample was weighed into a glass vial and digested using aqua regia (1:3), and made-up to either 5 ml or 10 ml depending on sample weight (5 or 10 mg), thereby ensuring a broadly consistent dilution factor. This method is similar to that reported in Butcher and Ponting (2015, 104–126). The solutions were then run through the MP-AES spectrometer that had been calibrated for arsenic, gold, bismuth, cobalt, chromium, copper, iron, manganese, nickel, lead, antimony, tin, and zinc. A quality control solution containing fixed levels of the same analytes was run every 10 sample solutions to monitor instrumental drift. Silver was not measured by this process because the digestion used aqua regia, necessary to ensure that gold and tin were dissolved but that results in the precipitation of the silver as silver chloride. This is removed from the sample solution by centrifuge and the supernatant liquid pipetted into clean vials for analysis. Silver was measured by energy dispersive spectrometry on a scanning electron microscope (SEM-EDS) using the remaining drilled sample mounted on a stub. Again, drillings from the MBH standards were used to ensure data quality for both the MP-AES and SEM-EDS analyses (Table 3).

ANALYSIS AND RESULTS

The results of the pXRF analyses are presented in Table 4, and the results of the MP-AES analysis are presented in Table 5. Comparison of the two data sets reveals that there is little agreement for the elements measured by both techniques.

The silver measurements (Figure 3) show widely differing values, especially where the bulk composition (by MP-AES) is low and the correlation (as expressed by the R^2 value) is weak, showing no strong relationship between the two sets of measurements. The values come closer as the bulk silver content increases, but with bulk values of 80% and above, the surface XRF values are consistently higher by 10% or more. Surprisingly, some brooches have lower surface silver contents than in the bulk. This is contrary to the standard understanding of depletion silvering (Butcher & Ponting, 2015) and environmental surface enrichment (Cronyn, 1990, 162–172). Closer examination, however, reveals that the lower silver values measured on the surfaces are because of layers of copper or iron corrosion that have built up on top of the original surface. An example of this is sample AS25, a Kentish square-headed brooch (marked in Figure 3), that gave a surface value of 50.4% silver, whereas the drilled sample gave 70.2% silver. Examination of the brooch itself reveals the reason for this, having had an iron pin that has corroded resulting in a layer of iron corrosion products overlaying the original surface that is barely visible in the area analysed (Figure 4). The iron content measured at the surface is 18% and only 2% in the bulk (also due to contamination). Another square-headed brooch, AS28 (marked in Figure 3) shows the results of expected surface effects on silver-copper alloys. The pXRF measurement gives 90% silver compared to the 80% silver measured in the subsurface drilled sample, and the graph also indicates that this brooch is one of a group displaying similar enrichment tendencies.

TABLE 2 Unprepared surface analysis (Wt.%) of MBH archaeological silver standards by Niton pXRF (precious metals config.). Error values are twice the instrumental standard deviations per reading (2 sigma).

Standard		*Sn*	*Ag*	*Pb*	*Au*	*Zn*	*Cu*	*Ni*	*Co*	*Fe*	*Mn*	*Cr*
AGA1	**Measured**	**0**	**73.4**	**0.235**	**1.388**	**0.280**	**23.95**	**0**	**0.052**	**0.165**	**0**	**0.012**
	Cert	***0.291***	*77.7*	***0.207***	***1.48***	***0.211***	***19.95***	***0.0118***	***0.0406***	***0.039***	***0.0061***	***0.002***
	Error	*0.01*		*0.007*	*0.03*	*0.005*	*0.21*	*0.0003*	*0.0007*	*0.001*	*0.0001*	*0.0002*
AGA2	**Measured**	**0.773**	**84.2**	**1.24**	**0.49**	**0.663**	**11.99**	**0**	**0.011**	**0.252**	**0.049**	**0.048**
	Cert	***0.52***	***87.3***	***1.02***	***0.507***	***0.502***	***10.00***	***0.0264***	***0.0163***	***0.027***	***0.0115***	***0.0076***
	Error	*0.015*		*0.04*	*0.001*	*0.006*	*0.15*	*0.0016*	*0.0027*	*0.003*	*0.0003*	*0.0012*
AGA3	**Measured**	**1.48**	**87.9**	**2.90**	**0.269**	**1.398**	**5.51**	**0.009**	**0.000**	**0.282**	**0.023**	**0.090**
	Cert	***0.92***	***91.1***	***1.89***	***0.258***	***0.816***	***4.91***	***0.045***	***0.005***	***0.015***	***0.0098***	***0.009***
	Error	*0.01*		*0.05*	*0.002*	*0.01*	*0.08*	*0.005*	*0.0001*		*0.0004*	*0.002*

TABLE 3 Limits of detection (LOD) and measured values compared with certificate values for the MBH archaeological silver-alloy standards (ppm, except where marked as %). Silver is the value reported by SEM-EDS analysis of drilled metal. Error values are twice the instrumental standard deviations (replicates) per reading (2 sigma).

Standard		Ag %	As	Au	Bi	Co	Cr	Cu %	Fe	Mn	Ni	Pb	Sb	Sn	Zn
LOD (ppm)			*0.300*	*0.009*	*0.076*	*0.004*	*0.001*	*0.705*	*0.013*	*0.0004*	*0.001*	*0.007*	*0.215*	*0.005*	*0.033*
AGA1	**Measured**	**78.3**	**299**	**14,627**	**1,567**	**363**	**19**	**19.74**	**370**	**65**	**97**	**1765**	**533**	**3,024**	**2,231**
	Cert.	*77.7*	*260*	*14,800*	*1940*	*410*	*20*	*19.95*	*390*	*61*	*118*	*2070*	*500*	*2,910*	*2,110*
AGA2	**Measured**	**87.9**	**141**	**5,030**	**1,096**	**66**	**43**	**10.05**	**130**	**115**	**199**	**9,645**	**1921**	**5,367**	**5,121**
	Cert.	*87.3*	*144*	*5,070*	*1,130*	*163*	*80*	*10.00*	*270*	*115*	*264*	*10,200*	*1920*	*5,200*	*5,020*

TABLE 4 Unprepared surface pXRF analyses of the brooches (Wt.%). Values that were below the limit of detection of the instrument are marked <LOD.

Sample ref.	Sn	Ag	Pb	Au	Zn	Cu	Fe	Total
AS1	5.20	24.6	1.21	4.10	3.80	3.87	3.72	46.5
AS2	1.10	91.3	0.89	1.79	1.76	3.15	< LOD	100.0
AS3	19.06	38.1	2.66	0.26	1.54	33.93	4.31	99.9
AS4	1.20	82.3	1.35	2.70	0.51	11.46	0.16	99.7
AS5	4.16	91.1	1.21	1.27	0.65	0.68	0.44	99.5
AS6	10.05	58.7	3.89	0.69	2.37	24.03	0.11	99.8
AS7	3.83	55.4	1.95	0.94	1.65	36.06	0.17	100.0
AS8	3.48	82.4	0.79	3.80	0.89	1.85	2.00	95.2
AS9	0.92	73.5	0.30	0.17	4.50	11.30	8.51	99.2
AS10	1.99	87.6	3.44	1.68	1.42	3.65	0.15	99.9
AS11	0.49	44.5	0.30	0.39	0.63	52.85	0.77	99.9
AS12	12.49	26.4	12.40	0.12	1.47	45.95	0.38	99.2
AS13	2.64	74.7	0.67	1.49	0.97	2.87	3.84	87.2
AS14	0.88	83.7	0.62	6.63	2.06	4.14	0.39	98.5
AS15	2.21	66.6	0.71	4.70	1.42	2.19	11.48	89.3
AS16	1.43	89.5	1.03	3.82	1.08	3.04	< LOD	99.9
AS17	6.60	9.3	1.00	3.75	1.80	2.60	10.61	35.7
AS18	2.72	90.6	0.72	2.99	0.60	2.22	0.08	99.9
AS19	3.68	80.4	1.79	1.49	0.46	1.48	10.08	99.3
AS20	1.96	38.6	0.66	25.42	1.15	14.22	2.54	84.5
AS21	0.81	34.9	0.64	0.61	1.01	60.46	1.52	99.9
AS22	6.22	10.0	1.32	2.91	4.50	5.47	7.54	38.0
AS23	1.83	76.8	0.97	13.66	2.84	2.88	0.75	99.8
AS24	0.91	87.0	0.79	2.05	0.28	8.54	0.25	99.8
AS25	< LOD	50.4	0.55	1.95	2.87	41.88	2.30	99.9
AS26	2.21	88.8	2.14	2.73	1.01	3.00	0.15	100.0
AS27	2.43	66.2	1.11	1.33	1.01	27.74	0.19	100.0
AS28	1.36	89.3	1.03	1.50	0.64	5.68	< LOD	99.5
AS29	1.53	88.2	0.48	2.26	2.06	1.39	0.84	96.7
AS30	3.70	87.0	1.02	3.76	1.22	1.88	0.81	99.4

The other element that shows significant differences between the surface and bulk compositions is gold. The plot (Figure 5) shows how two brooches (AS20 and AS23) have considerably higher levels of gold on their surfaces than in their bulk metal. This is, of course, the result of gilding, as is clearly apparent on the fronts of many of the brooches. Although the pXRF analysis was done on the apparently ungilded backs of the brooches, it seems that these two had significant amounts of gold smeared on their backs as well. A number of other brooches also have somewhat higher levels of gold measured on the surfaces of the brooch backs, with 13 of the 28 brooches having surface gold levels above 2%. Only nine brooches have over 2% gold in their bulk compositions, although this figure is in itself worthy of comment because it is considerably higher than the levels that would normally be expected in a silver-copper alloy and must reflect the recycling of silver-gilt objects. Gold is often a naturally occurring impurity in silver ores, but the levels are usually below 0.5%, higher levels can be found in the products of specific

TABLE 5 MP-AES analyses of the drilled samples taken from the brooches (ppm, unless marked). Where values were below the limit of detection of the instrument, a value equivalent to half the limit of detection has been used. The silver percentage is the value measured by SEM-EDS of drilled metal.

Sample ref.	Ag %	As	Au	Bi	Co	Cr	Cu %	Fe	Mn	Ni	Pb	Sb	Sn	Zn
AS1	89.0	125	6700	351	2	4	6.67	118	14	4	4,795	232	2,789	28,157
AS2	90.0	323	36,306	193	2	3	4.23	106	3	9	4,970	110	3,216	12,384
AS3	71.0	350	8935	253	3	3	23.6	1,359	2	88	9,150	127	6,792	27,189
AS4	85.2	293	10,160	301	2	2	11.9	187	1	82	8,521	204	5,419	4,277
AS5	89.7	276	6024	162	2	4	5.61	90	102	15	15,394	401	13,557	10,965
AS6	56.1	369	1843	40	2	5	36.8	324	5	92	13,690	305	32,502	21,773
AS7	39.2	472	4826	148	3	2	50.2	1135	3	207	17,656	353	26,294	54,832
AS8	91.1	307	11,567	230	2	2	5.01	410	1	3	7710	111	12,414	5,812
AS9	82.9	354	12,933	895	6	10	9.21	125	6	8	12,145	709	14,048	37,163
AS10	81.2	198	14,615	608	3	7	9.79	189	3	5	37,661	444	15,818	20,862
AS11	88.9	149	10,136	284	3	2	7.44	9,019	4	1	5875	35	3820	7,649
AS12	7.15	399	3316	212	5	5	80.8	1543	6	257	13,462	147	47,397	53,679
AS13	93.7	104	4716	232	2	7	4.10	108	2	8	4882	88	1508	10,119
AS14	80.8	210	27,361	318	4	7	10.8	234	5	3	9141	177	5785	40,308
AS15	90.6	144	18,207	344	2	5	5.68	735	2	8	7706	122	7,197	3211

TABLE 5 (Continued)

Sample ref.	Ag %	As	Au	Bi	Co	Cr	Cu %	Fe	Mn	Ni	Pb	Sb	Sn	Zn
AS16	88.1	343	23,835	382	3	6	5.70	300	3	12	10,214	134	10,235	16,113
AS17	46.7	384	24,019	584	3	5	47.5	3178	5	130	10,407	297	17,428	1224
AS18	94.6	107	8440	178	2	2	3.05	129	1	3	4,917	90	5629	4280
AS19	91.6	155	5261	1,020	3	5	4.22	64	3	7	18,286	131	13,517	3193
AS20	54.5	408	37,148	321	3	7	37.1	1057	4	183	9977	345	11,983	21,731
AS21	74.4	129	13,097	391	2	5	21.1	1087	7	82	14,875	263	9444	6031
AS22	79.0	166	22,911	413	3	6	11.9	872	6	17	21,491	327	29,345	15,527
AS23	90.2	138	23,971	362	2	4	5.06	202	2	3	10,034	116	9901	2757
AS24	89.4	104	9711	421	2	2	8.45	79	2	9	5,168	745	3179	1732
AS25	70.2	178	57,816	272	3	11	18.6	17,612	8	1	5362	150	2223	28,873
AS26	75.7	188	31,316	763	3	7	13.3	1350	5	18	31,060	513	25,614	18,824
AS27	62.0	117	7,123	249	2	2	32.9	373	2	93	8280	99	16,778	17,927
AS28	80.5	124	13,439	362	2	6	15.8	193	3	80	6860	105	7,050	8454
AS29	90.6	100	6101	206	2	5	5.56	119	3	5	4527	84	3243	24,138
AS30	96.3	47	8,719	187	3	6	1.25	294	3	1	4024	128	8039	3413

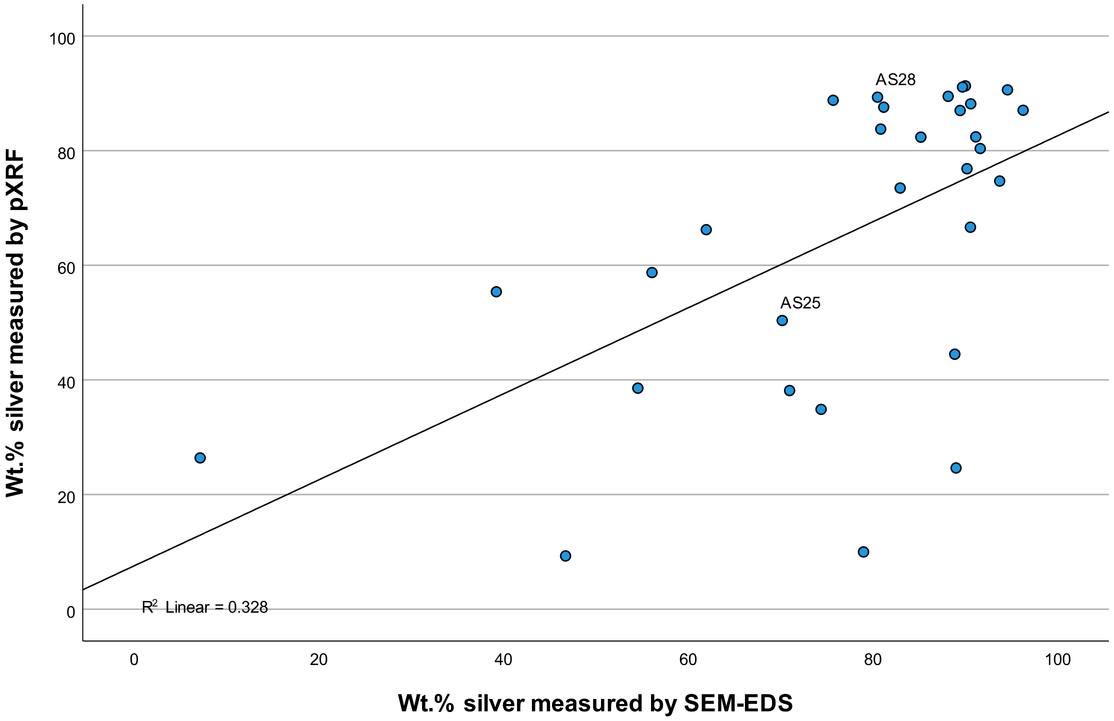

FIGURE 3 Scatterplot comparing silver contents measured on the surface by pXRF and of drilled samples by SEM-EDS.

FIGURE 4 Iron staining on a Kentish square-headed brooch sample (sample number AS25).

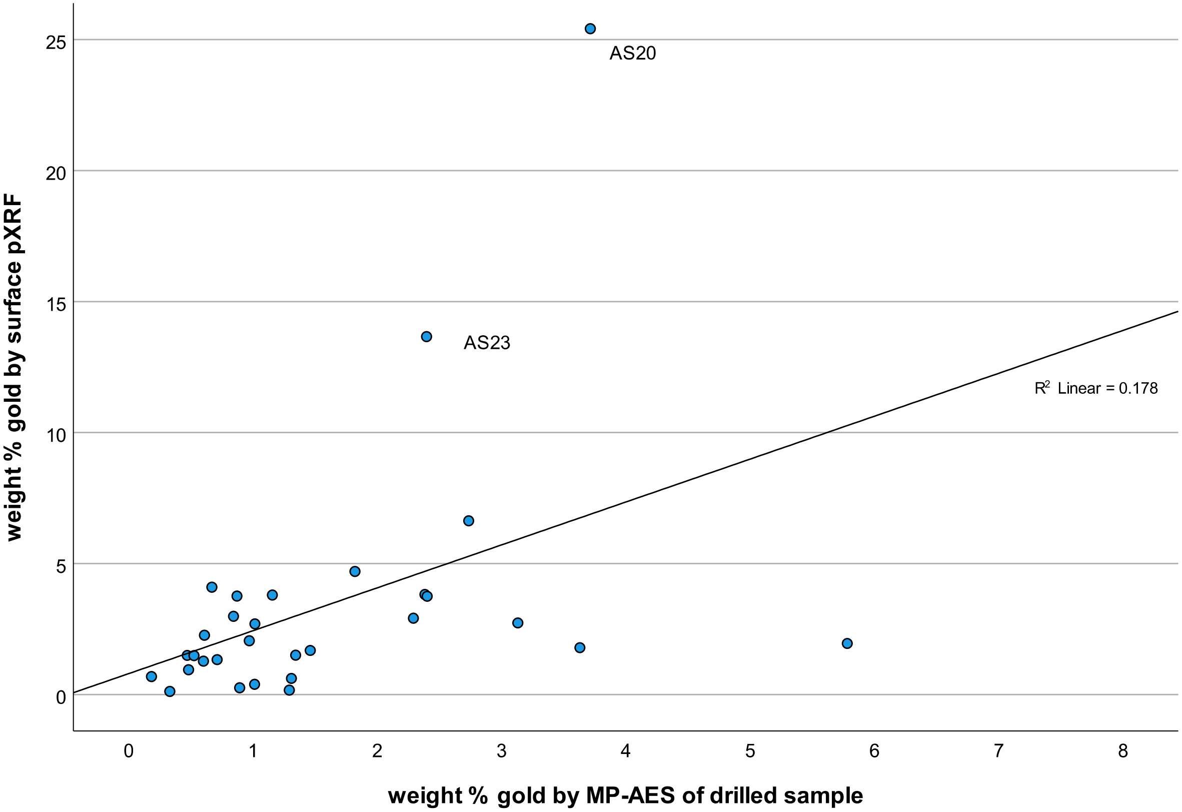

FIGURE 5 Surface pXRF measurement of gold compared with MP-AES measurement of gold in drilled samples.

ore types, but amounts above 2% are very rare (Craddock, 1995, 213; Meyers, 2003). This observation suggests quite strongly that the source of the silver used to produce the alloys was not primary, freshly extracted silver but recycled silver objects (cf. Blakelock & Fern, 2019, 128).

If we accept that the MP-AES and SEM-EDS analyses of the drilled samples provide a more accurate estimation of the original alloy from which the brooches were made, we can now turn to these results alone.

The elemental silver content is presented by type and by phase in Figure 6. The Kentish keystone disc brooches have quite a wide range of silver contents, from as low as about 70% up to over 95%, with a single very low silver example (AS20) containing only 54.5% silver. The Kentish square-headed brooches for the most part have a much tighter distribution between about 85% and 95% silver, but with three examples having lower silver contents, ranging from about 80% down to 70%. Typologically speaking, these are all distinctively Kentish products. The remaining five brooches comprise other types that are not Kentish but are more typical of wider southeast England and the North Sea area. They are all quite base in composition ranging from just over 56% silver to a mere 7% in the case of the equal-arm brooch.

Turning to silver by phase, it is unsurprisingly apparent that type and phase are related, with the BR2-b3 and BR2-b4 keystone disc brooches being later than the BR2-b1 and BR2-b2 keystone disc brooches and the Kentish square-headed brooches. It is therefore interesting that the baser brooches of different types are the earliest, and the baser brooches belonging to the middle phase are the non-Kentish great and continental square-headed brooches. It is therefore apparent that the silver content of brooches increases between the early and middle phases, and even the late group, forms a tighter and slightly elevated group with a single outlier (AS20, discussed below). The main distinction, however, lies between the non-Kentish and the Kentish brooches, with the latter types forming a relatively homogeneous cluster in terms of their fineness.

But silver as measured by the instrumentation employed is just the abundance of the chemical element we call silver. The metal that was extracted, refined, mixed, and alloyed in the past was not simply the element silver; indeed, few elements exist in their pure elemental state in nature. Silver was extracted from a variety of ores, combinations of elements that achieve a stable state in nature, and to do this a considerable amount of energy is required, mainly in the form of heat. The processes that were developed to do this in the past were efficient but less than perfect from a modern chemical perspective. The silver produced would always contain contaminating elements from the original ore or from the processes used in its extraction. Gold is a standard contaminant in silver, existing in varying amounts depending on the type of ore, and is a very unreactive element, meaning that the levels in the ores will pass almost unchanged by the processes used in extraction from ore to artefact. The levels of gold found in Roman silver coins and plate are generally less than 1% (0.36% is the average for over 1,000 analyses of Roman silver coins [Ponting, unpublished data] and 0.71% average for Late Roman plate hoards [Doračić et al., 2015: 91]). Thus, levels of 2% and above are significantly higher than would be expected. Bismuth is another element associated with silver ores, but the levels of this can change depending on the extraction and refining processes undergone. Lead is also commonly associated with silver, largely because some lead ores can contain economical amounts of silver that can be extracted, but the silver will always retain a trace of the original lead.

Consequently, it is common to calculate the amount of silver 'bullion' in an alloy as the sum of the elemental silver, gold, bismuth, and lead, a figure more representative of the silver metal being used in the past. There are, however, some important issues that make this approach unsuitable for the brooches under scrutiny here. The elevated levels of gold observed in several of the brooches and the fact that the brooches themselves are frequently gilded makes the levels of gold in the alloy more an indicator of the frequency that silver-gilt objects were recycled than anything to do with metal source or character. What to do with the lead and

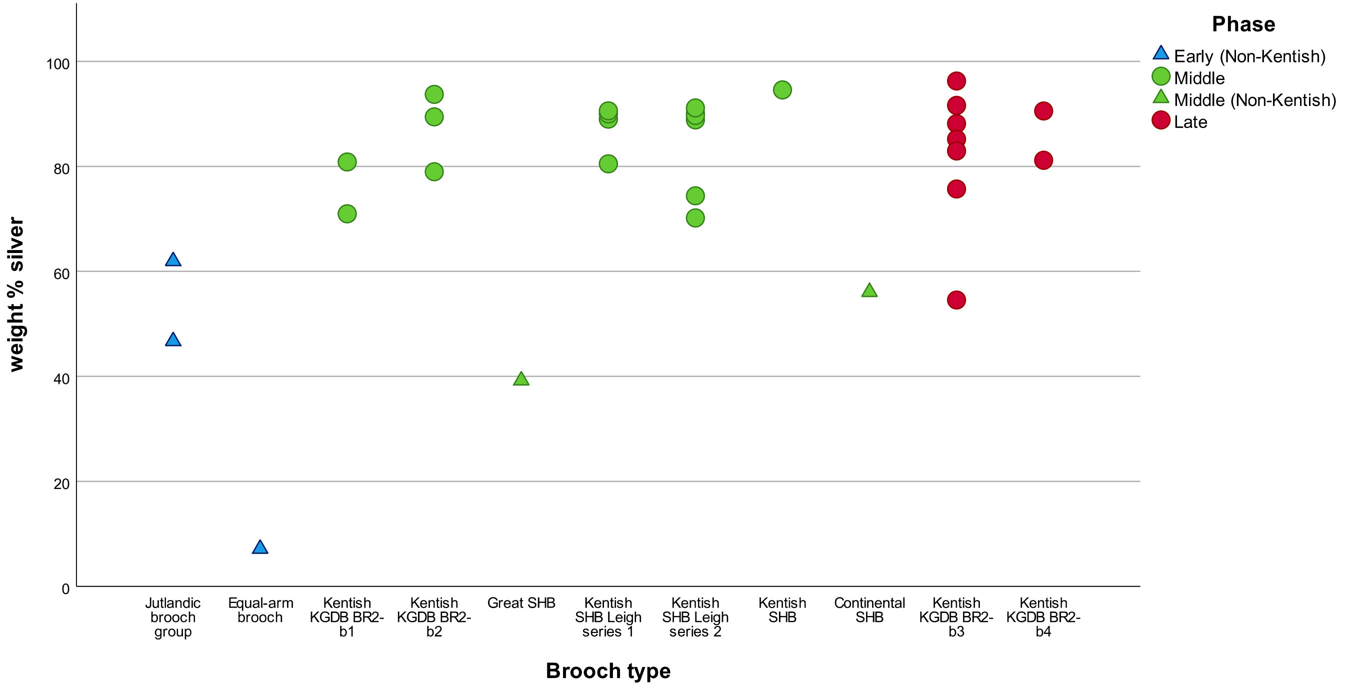

FIGURE 6 Silver content by brooch type and phase (‘Kentish KGDB’ = Kentish keystone garnet disc brooches; ‘Kentish SHB’ = Kentish square-headed brooches; ‘great SHB’ = great square-headed brooch, ‘continental SHB’ = continental square-headed brooch).

bismuth, however, is less clear cut. Both elements have a chemical affinity for each other, with bismuth often being a byproduct of lead smelting in modern industry. Therefore, any bismuth in a silver alloy could originate from the silver ores or from the lead that may have been added to aid the refining of the silver. Furthermore, some of the lead may originate from the silver ore, but it may also have been added during many recycling episodes or, indeed, may have come into the alloy with the copper that was alloyed to the silver. It is therefore impossible to predict with any degree of reliability how much gold, bismuth, or lead may have been in the ores smelted and what proportion of these elements came into the alloy through various anthropogenic processes. What we can say with a degree of certainty is that the silver was heavily recycled, as this is indicated by the high levels of gold observed. Some brooches have less gold than others, confirming, if such confirmation were needed, that the brooches were made from silver alloys of quite variable minor and trace element composition and that, beyond an interest in maintaining a level of fineness, recycling was a rather ad hoc affair.

Given that the relationships between the main silver-related elements is unclear, discussion will only be of element pairs rather than scaled to silver (that assumes that the majority of the element originates with the silver) or as logged ratios (that retains relational variation between known components such as lead and bismuth, where they can be supported).

The lead values (Figure 7) are quite tight for the Kentish square-headed brooches and for many of the keystone disc brooches, and, indeed the earlier types are not that different, suggesting that the bullion itself had been refined by a broadly consistent technology and that any subsequent mixing had not involved re-refining. This would be consistent with taking reasonably well refined silver bullion and simply remelting and re-alloying it to form the brooches. The levels of lead and bismuth are quite consistent with published analyses of Roman silver plate and siliquae (Hours et al., 1985; Minnitt & Ponting, 2013: 287), although it worth noting that the levels of both do vary between different plate hoards (Hours et al., 1985: 46). It is

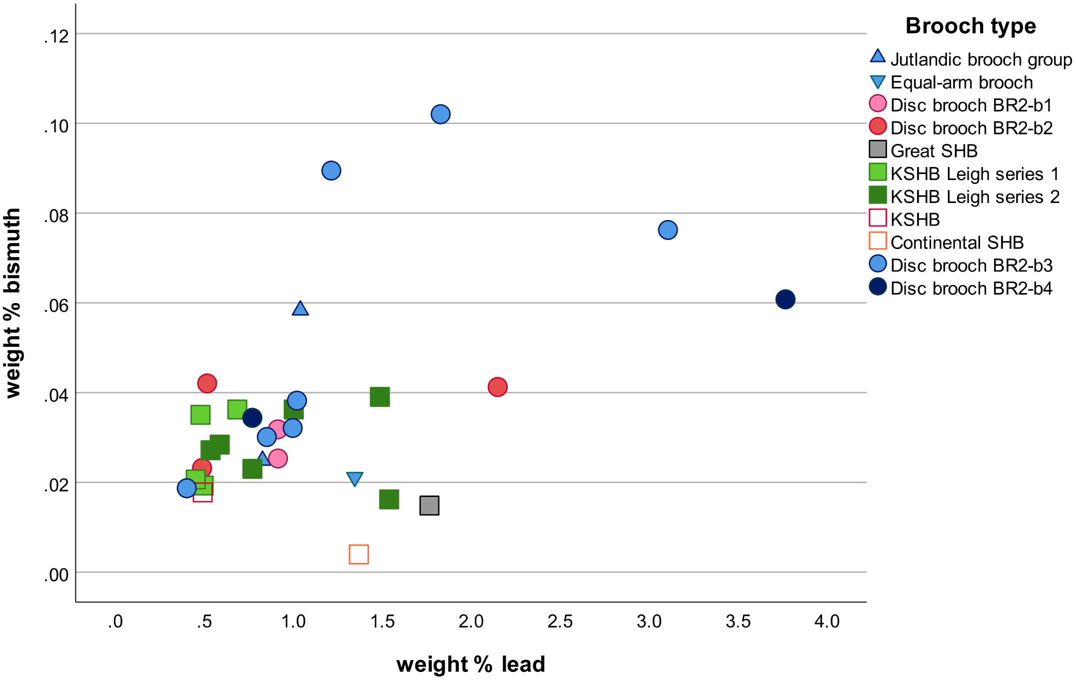

FIGURE 7 Simple biplot of lead against bismuth (MP-AES analysis of bulk samples).

therefore of interest that five keystone disc brooches, nearly all of the late group, contain higher levels of bismuth and/or lead.

The lead isotope measurements (Table 6) support the views expressed above. Standard biplots are presented in Figures 8 and 9. The brooches cluster along what can be described as a mixing line but generally present a fairly homogeneous group isotopically. This mixing line position is similar to those observed for Roman silver coins, generally showing the mixing of Spanish, Sardinian, and Gallic silver over several centuries with admixing of Balkan silver in the later periods. It is no surprise therefore that the published data for the Marengo Hoard (Angelini et al., 2019) overlaps with the brooches, as does some of the Roman silver denarii (Butcher & Ponting, 2015). In short, the lead isotopes confirm that the silver in the brooches is heavily mixed and bears close similarities to Late Roman silver plate and coin.

DISCUSSION

The obvious methodological implication of this research is that MP-AES analysis of a drilled sample is the more reliable method for ascertaining an accurate image of the original alloy. As a result, the utility of all existing data obtained from surface analyses from this period should be read discerningly and with critical knowledge of the variation revealed by this study. We are not the first to warn of the limitations of surface XRF analysis when it comes to understanding silver alloys of the fifth to seventh centuries (Leigh et al., 1984; Nicholas, 2016), but our analyses are the first to demonstrate their unpredictability empirically and quantitatively insofar as they might pertain to the chemical character of the core alloy. It is nevertheless important to recognise that the combination of surface analysis together with drilled samples can provide a powerful toolset with which to holistically understand ancient jewellery in terms of its deliberate alloy selection and surface treatments.

Relatively high gold content, averaging 1.6% but frequently 2–4%, represents our first intriguing finding, which we argue is most likely to derive from the recycling of silver gilt objects. One anomalous result inconsistent with this theory should be noted, however, which is the high level of gold (5.8%) for the brooch from Buckland (AS25) given its modest (70.2%) silver content. The fact that a large proportion of the recycled objects were probably gilded, however, does not aid their identification much further, as gilding was common on late as well as post-Roman silver-alloy objects. So much so, in fact, that the colour and therefore fineness of most silver-alloy objects was often hidden beneath gilding, which is nearly always the case on the Kentish objects. The perception of fineness in this period is a significant question to which we will return briefly below. Further light can be shed on the sources of the bullion from the lead, bismuth, and lead isotope ratios, which are all consistent with values observed for late Roman coin and plate. This strongly suggests that fifth-century clippings from *siliquae* and the kinds of objects that were being deposited in fifth-century hoards were ultimately finding their way into jewellery. It is perhaps notable that evidence for such stockpiling vanishes in the sixth century when most of these brooches were probably made, perhaps precisely because this jewellery was becoming a new mode of wealth storage, hacked, reworked, and measured by the kinds of scales that occur in graves in this period rather than retained as plate or coin.

Our most important finding is the link between fineness and object style, which is a first for this period, where the relationship between chemistry and object type has either been identified as random (Brownsword & Hines, 1993, 2), largely a result of chronology (Mortimer, 1990, 379) or as a result of the intended function of the alloy as sheet, wire, or for casting (Nicholas, 2016, 440–1). The results show a marked contrast between two groups: a relatively fine 'Kentish' assemblage of Kentish square-headed and keystone garnet disc brooches, and a baser, more heterogeneous assortment of Continental and great square-headed brooches, the equal-arm brooch, and the Jutlandic brooch group. No doubt, this distinction is a result of

TABLE 6 Lead isotope data for the sampled objects (insufficient sample available for AS13).

Sample	$^{206}Pb/^{204}Pb$	2SE%	$^{207}Pb/^{204}Pb$	2SE%	$^{208}Pb/^{204}Pb$	2SE%	$^{207}Pb/^{206}Pb$	2SE%	$^{208}Pb/^{206}Pb$	2SE%
AS1	18.5486	*0.006*	15.6731	*0.009*	38.666	*0.008*	0.84497	*0.007*	2.0846	*0.006*
AS2	18.6422	*0.007*	15.6729	*0.010*	38.747	*0.009*	0.84076	*0.007*	2.0785	*0.006*
AS3	18.4816	*0.006*	15.6537	*0.009*	38.540	*0.009*	0.84699	*0.007*	2.0853	*0.007*
AS4	18.4960	*0.007*	15.6553	*0.010*	38.557	*0.009*	0.84643	*0.007*	2.0846	*0.006*
AS5	18.4983	*0.007*	15.6427	*0.010*	38.557	*0.010*	0.84564	*0.007*	2.0844	*0.006*
AS6	18.4987	*0.007*	15.6628	*0.010*	38.655	*0.009*	0.84670	*0.007*	2.0896	*0.006*
AS7	18.4674	*0.007*	15.6497	*0.010*	38.509	*0.009*	0.84743	*0.007*	2.0853	*0.006*
AS8	18.4615	*0.006*	15.6363	*0.009*	38.497	*0.008*	0.84697	*0.007*	2.0853	*0.006*
AS9	18.5985	*0.006*	15.6692	*0.009*	38.713	*0.008*	0.84251	*0.007*	2.0815	*0.006*
AS10	18.5111	*0.006*	15.6619	*0.009*	38.584	*0.009*	0.84608	*0.007*	2.0844	*0.006*
AS11	18.4967	*0.006*	15.6619	*0.009*	38.595	*0.009*	0.84673	*0.007*	2.0866	*0.006*
AS12	18.4700	*0.006*	15.6499	*0.009*	38.498	*0.009*	0.84731	*0.007*	2.0844	*0.006*
AS14	18.5074	*0.007*	15.6613	*0.009*	38.625	*0.009*	0.84622	*0.007*	2.0870	*0.006*
AS15	18.5106	*0.006*	15.6600	*0.009*	38.603	*0.009*	0.84600	*0.007*	2.0855	*0.007*
AS16	18.6009	*0.007*	15.6662	*0.010*	38.692	*0.010*	0.84223	*0.007*	2.0801	*0.007*
AS17	18.4952	*0.007*	15.6575	*0.010*	38.570	*0.009*	0.84658	*0.007*	2.0854	*0.006*

(Continues)

TABLE 6 (Continued)

Sample	$^{206}Pb/^{204}Pb$	2SE%	$^{207}Pb/^{204}Pb$	2SE%	$^{208}Pb/^{204}Pb$	2SE%	$^{207}Pb/^{206}Pb$	2SE%	$^{208}Pb/^{206}Pb$	2SE%
AS18	18.5161	*0.006*	15.6608	*0.010*	38.609	*0.009*	0.84578	*0.007*	2.0851	*0.007*
AS19	18.4541	*0.006*	15.6468	*0.009*	38.513	*0.008*	0.84787	*0.007*	2.0869	*0.006*
AS20	18.5277	*0.007*	15.6615	*0.010*	38.614	*0.010*	0.84529	*0.007*	2.0841	*0.007*
AS21	18.4593	*0.007*	15.6510	*0.010*	38.517	*0.010*	0.84787	*0.007*	2.0866	*0.007*
AS22	18.5389	*0.007*	15.6617	*0.009*	38.641	*0.009*	0.84481	*0.007*	2.0843	*0.006*
AS23	18.4621	*0.007*	15.6481	*0.010*	38.513	*0.010*	0.84759	*0.007*	2.0861	*0.006*
AS24	18.4816	*0.007*	15.6589	*0.009*	38.584	*0.009*	0.84726	*0.007*	2.0877	*0.006*
AS25	18.4872	*0.007*	15.6596	*0.010*	38.578	*0.009*	0.84706	*0.007*	2.0867	*0.006*
AS26	18.5620	*0.007*	15.6645	*0.009*	38.648	*0.009*	0.84392	*0.007*	2.0822	*0.006*
AS27	18.4694	*0.006*	15.6525	*0.009*	38.528	*0.009*	0.84748	*0.007*	2.0861	*0.006*
AS28	18.5344	*0.007*	15.6648	*0.009*	38.626	*0.009*	0.84518	*0.007*	2.0841	*0.006*
AS29	18.5741	*0.007*	15.6652	*0.010*	38.675	*0.010*	0.84336	*0.007*	2.0822	*0.007*
AS30	18.5035	*0.007*	15.6499	*0.010*	38.569	*0.009*	0.84578	*0.007*	2.0844	*0.006*

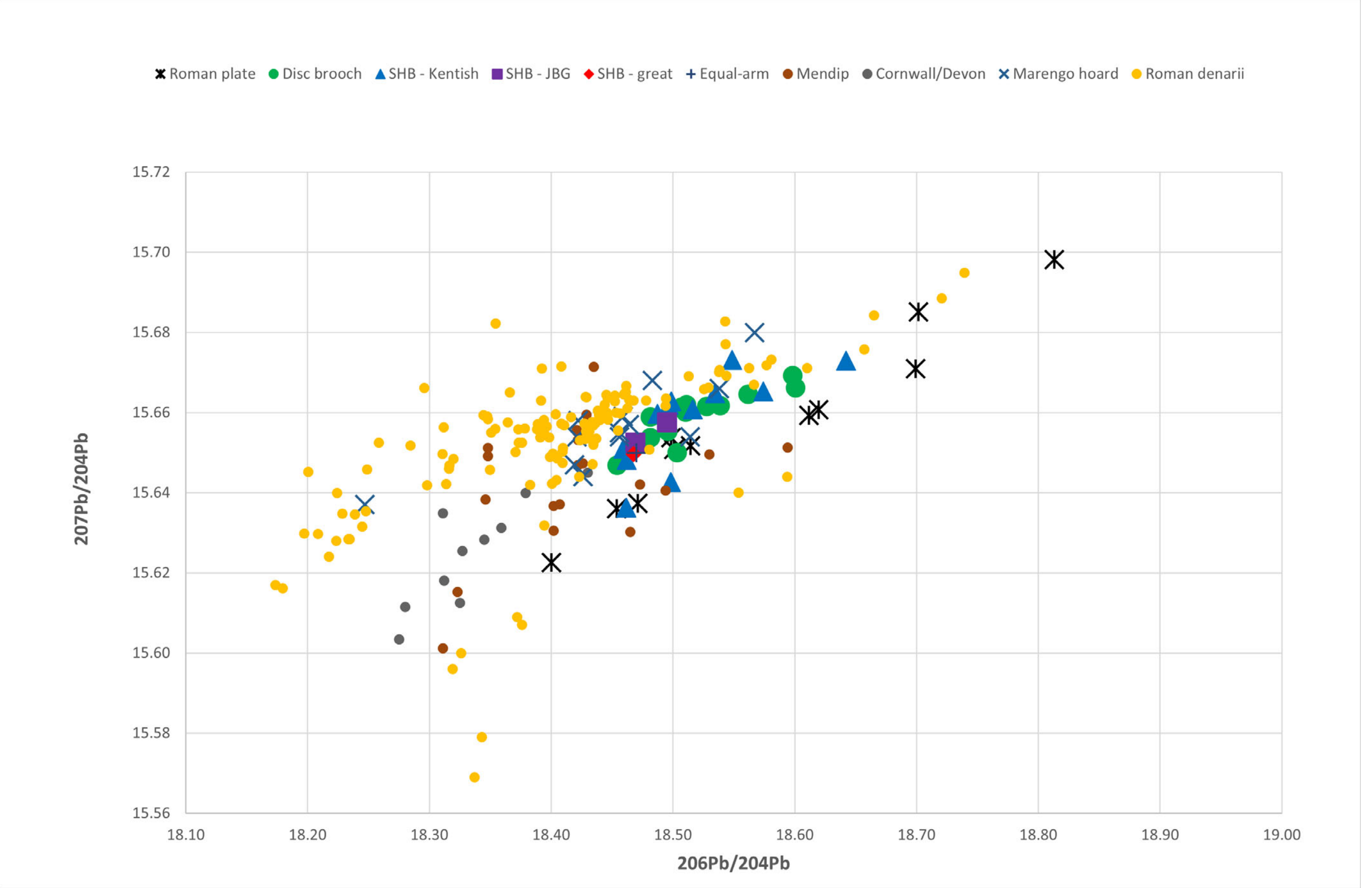

FIGURE 8 Plot of Pb207/204 against Pb206/204. Comparative data from Rohl, 1996 (Britain), Angelini et al., 2019 (Marengo hoard) and Butcher & Ponting, 2015 (Roman coins).

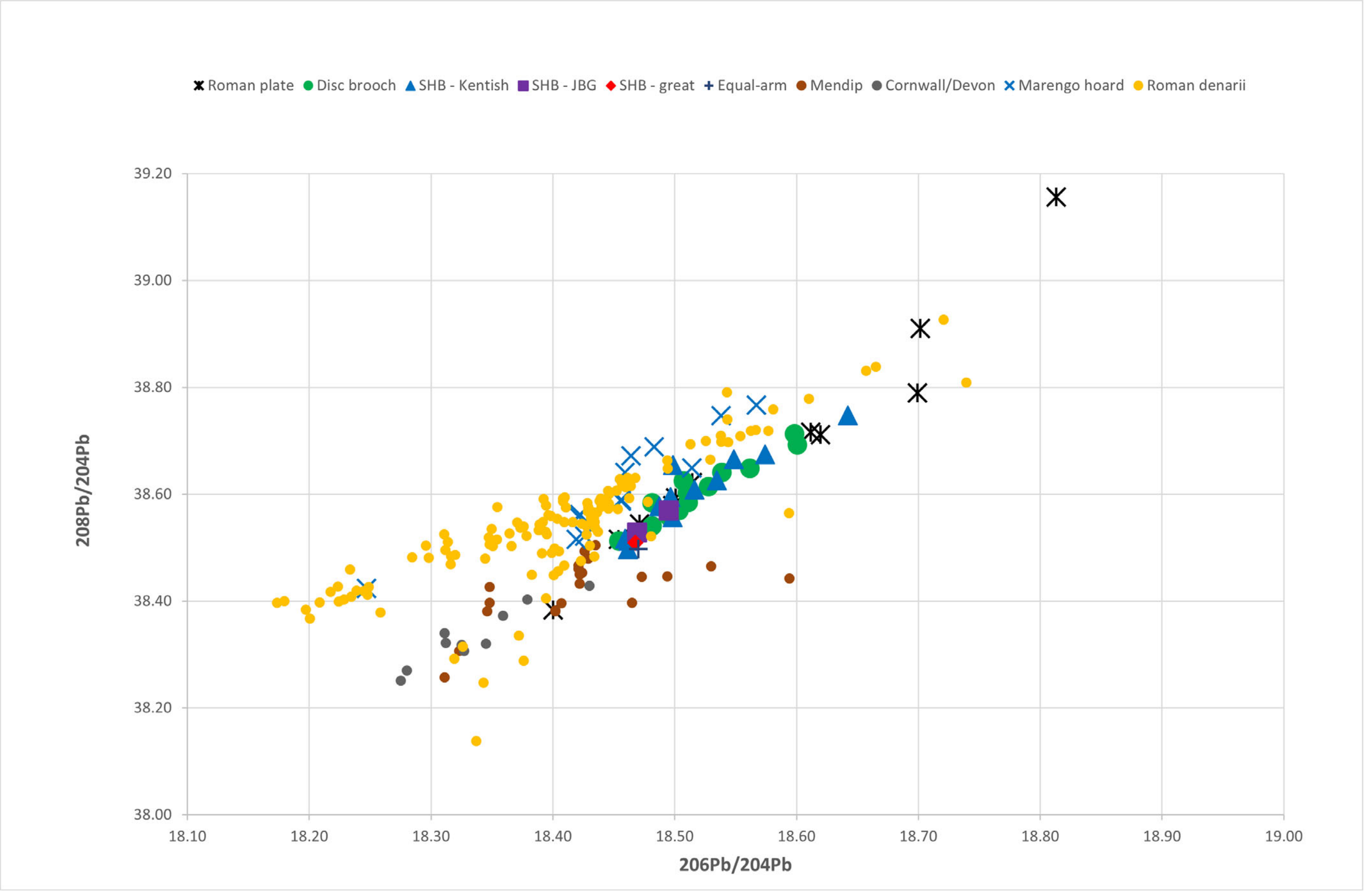

FIGURE 9 Plot of Pb208/204 against Pb206/204. Comparative data from Rohl, 1996 (Britain), Angelini et al., 2019 (Marengo hoard) and Butcher & Ponting, 2015 (Roman coins).

deliberately targeting a comparison between a strikingly homogeneous 'Kentish' assemblage of brooches against a more heterogeneous spread of silver alloys of potentially quite diverse origins, and more research is required on those latter types. However, the 'Kentish' items are all of a highly characteristic style, long observed and extensively documented (e.g. Leeds, 1936, 41–58; Bakka, 1959; Leigh, 1984; Suzuki, 2008, 284–90), and now found to be, with just one outlier, more than 70% silver. The single outlier, a late keystone disc brooch from Buckland (AS20) is not just unusual for this reason. The gold foils that line the base of its cloisons are stamped with a very unusual circular die consisting of a ring within a square, found only once in survey of 500 foils from 181 objects, and outside this sample only from three examples from Lyminge in Kent and Abingdon in Oxfordshire, though similar designs are known from the Continent (Avent & Leigh, 1977, 28–9 citing Arrhenius, 1971, 118–19). If there is an object among the stylistically 'Kentish' material from a distinct workshop, this item would be the strongest candidate.

Furthermore, fineness within the Kentish group appears to increase from the later sixth century, with the latest keystone garnet disc brooches of type BR2-b3 and BR2-b4 being on average finer than both the earlier types BR2-b1 and BR2-b2, and their contemporary Kentish square-headed brooches, which most likely belong to the first half of the sixth century. This runs counter to accepted understandings of the ad hoc mode of metal recycling generally thought to dominate this period (Mortimer, 1991; Brownsword & Hines, 1993, 2, 9; Fleming, 2012), in which one might expect fineness to decline over time, as indeed appears to be the case for copper alloys, which became more mixed over the course of the fifth and sixth centuries, perhaps due to successive recycling events (Mortimer, 1990, 377–80). This is perhaps because such models have been largely derived from work on copper rather than silver alloys (e.g. Pollard et al., 2015). On reflection, one would fully expect precious metals to be treated differently. There is also a distinctive increase in the bismuth and lead content of a disproportionate number of the latest brooches, presumably due to a change in the silver supply or its refinement process, though this remains to be explained.

The ambition to adhere to a specific fineness among a closely stylistically linked group of artefacts, which we now call 'Kentish', is therefore clearly observable from the analytical results. These are evidently not debased alloys where an element of silver has been added to lighten the metal for the sake of appearance, which is the kind of strategy that has been suggested elsewhere for copper alloys (Baker, 2013). Although it was understandable for Nicholas (2016, 244, 263) to raise questions over whether silver fineness necessarily mattered in this period based on an East Anglian assemblage of quite a different character (more similar to the non-Kentish outliers in the current sample), we can say that with regard to the Kentish assemblage analysed here fineness mattered. The question is why?

We opened this paper by querying the place of silver in a precious metal economy known to be present in the fifth and sixth centuries but poorly understood and barely integrated into economic models of the post-Roman period. Aspects of this economy start to emerge with a little more clarity in the earlier seventh century when it is clear that gold and exotic materials were moving long distances, almost certainly moved through royal networks (Scull, 2012 for a summary), with a silver monetary economy emerging by the later seventh century (Kershaw et al., 2024; Naylor, 2012). For the earlier centuries we are somewhat more in the dark, but the analyses reported here begin to shed some light.

The focus of scholarship on decorative metalwork of this period on style and cultural resonances has led to the neglect of their material properties. A reader of the scholarship on Kentish jewellery could be forgiven for missing the fact that these items are exceptional in the period for being so consistently made from precious metal alloys and, as we have shown, relatively fine ones. It is perhaps more widely acknowledged that in terms of their craft and technical complexities, these Kentish products are among the most accomplished in Europe, but even this sometimes takes a backseat when it comes to the dense typological and iconographic analysis that dominates the literature. In this context, it is worth emphasising the very restricted geographical spread of these objects, largely in Kent and the south coast, with outliers in northern France (Martin, 2020, 867), as well as their highly restricted technical and stylistic repertoire (Leigh, 1980). These characteristics led David Leigh to conclude that their quality and homogeneity was consistent with them all being the products of a single workshop that was clearly pre-eminent within Kent, but also beyond it, and this has never seriously been challenged.

Putting materiality centre stage helps to align these multiple strands of contextual evidence from distribution and typochronology, which all point to a degree of centralisation behind the production of Kentish jewellery, with potential intergenerational control of a precious metal supply and control of crafting skill to fix this metal flow into a highly characteristic and immediately recognisable form of personal adornment. These items were iconic in terms of their style and distinctive in terms of their quality. Given the small scale of the incipient kingdoms of the sixth century, which is the focal point of the Kentish sample considered here, a direct royal link is not as fanciful a suggestion as it might initially seem. Could it be that the hegemonic style that we call 'Kentish' also acted to guarantee the fineness of the metal from which it was crafted? The fact that the colour of a brooch, which would be the normal indicator of an item's fineness, was hidden beneath various forms of high artistry suggests that the precious metal content of a brooch could have been more of an economic than an aesthetic concern, and in this cultural context, exceptional artistry and iconic design could have been more of a reliable indicator of fineness, guaranteed by reputation, than colour. This proposition contributes a significant and principally economic facet to the interpretation of these particular brooches, the study of which has tended to focus on their artistic and cultural associations (e.g. Leigh, 1984), their role as a component of social identity (e.g. Stoodley, 2020), and more recently their entanglement in social networks (Martin, 2020). In this preliminary paper we would merely like to pose that question, which we will explore in more detail elsewhere in the light of the full suite of results from this research. The high-resolution analysis of post-Roman silver alloys is in its infancy, which means that the most significant current limitation is the sparsity of reliable data. The sample analysed here is pioneering, but as a consequence it is isolated and partial. Nevertheless, it hints at what could be productive sampling strategies. Although this study gives good indications of the kinds of variation across silver alloys used in Kent, similar patterns are yet to be explored elsewhere in England beyond surface analysis. Further, although the bulk of Kentish objects from the middle phase analysed here provides a picture of limited variation, the possible increase in fineness in the late phase deserves further probing, as does the earlier end of the chronology in the immediately post-Roman fifth century. The use and reuse of silver alloys have much to tell us about the place of silver bullion in post-Roman economies, but further enlightenment will depend on the ability to obtain more data in a strategically guided manner.

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DATA AVAILABILITY STATEMENT

The data that supports the findings of this study are available in the supplementary material of this article.

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