Sources of silver in twelfth-century northern English and Scottish coins: a preliminary look

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Introduction

In 1136, at the beginning of The Anarchy, David I of Scotland (1124-53) took control of Carlisle and the surrounding North Pennine lead/silver mines focused on Alston (**Figure 1**). Thereafter, he began to mint the first native Scottish coins.[1] David I's desire to acquire silver from the 'mine of Carlisle' has been seen by historians as a major motivating factor in his territorial campaigns over disputed land in what is now northern England.[2] Although David's coinage was sporadic, Carlisle developed as a focus for royal power alongside Edinburgh and Roxburgh, while David's son, Henry, secured northern England for Scotland through his title as Earl of Northumbria.

There is widespread consensus that Alston silver provided the bullion for the first Scottish coins of David I and his son Henry, Earl of Northumbria (d. 1152), certainly from the mint of Carlisle, but also from mints at Edinburgh, Roxburgh, Newcastle and Corbridge.[3] Indeed, one scholar has claimed that 'Cumberland silver provided the liquid on which the "Davidian Revolution" in Scotland was floated'.[4] To date, however, there has been no direct, metallurgical evidence from the coinage itself that would help to confirm this (very reasonable) hypothesis, nor that could establish how widespread Alston silver was in the minting of the earliest Scottish coins.

Carlisle fell back under English control in 1157, but the impact of this loss on the silver supply to Scottish mints is unclear.[5] The later twelfth century is characterised by monetary expansion in both England and Scotland.[6] Results from Timothy Crafter's Electron Probe Microanalysis (EPMA) analyses of trace elements in the Crescents coinage (1170-95), produced in Scotland under William I (1165-1214), suggests that these coins did not utilise Alston silver. This is in contrast to northern English mints at the time, which, Crafter argues, did use Alston silver for the production of the Cross and Crosslets type (1158-80), minted under Henry II (1154-89). Thus, the actual source of silver in the Scottish Crescents coinage remains obscure. The occasionally high bismuth contents of the Crescents coinage revealed through EPMA analyses led Crafter to suggest the use of an old stock of Central Asian, Samanid dirham silver, potentially alongside Continental silver, a suggestion that we probe here.[7]

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1 Stewart 1967; Mattinson and Cherry 2013.

2 Fairburn 2017, 49; Oram 2011, 97

3 Fairburn 2017, 49; Mattinson and Cherry 2013; Blanchard 1996, 36; Blackburn 1994, 192

4 Oram 2011, 97

5 Crafter 2007; Britnell 1996, 105-15; Bolton 2012, 141-52; Allen 2012, 321-5; Savage forthcoming

6 Crafter 2007

7 Crafter 2007, 243-5

We thus sought to address two, related questions: 1) to what extent was the first native Scottish coinage based on silver from the 'mine of Carlisle'? And 2) what sources of silver fuelled monetary expansion in Scotland in the later twelfth century? Here, we present the combined lead isotope and trace element analysis of a small group of 8 coins, all from the collection of the Fitzwilliam Museum, Cambridge: three coins of David I and one of Henry of Northumberland, along with two coins of William I and two of Henry II (the latter included for comparative purposes) (**Figure 2; Table 1**). The coins come from the mints of Edinburgh, Berwick, Roxburgh, Carlisle and Newcastle (**Figure 1**). There are constraints on this, admittedly small, dataset, notably the absence of Carlisle coins of David I and any coins of David's successor Malcolm IV (1153-65). The analysis was designed as a first look at twelfth-century Scottish coins from a metallurgic perspective, and represents the first application of lead isotope analysis to any British coins of this period. It is our hope that it will form the basis for future research.

Methods

The eight coins were analysed by laser ablation inductively coupled plasma mass spectrometry (LA-ICPMS; Nexion 350D ICP-MS) at the department of Earth Sciences at the University of Cambridge.[8] The NWR193 LA system was set to 4.8J/cm^2 at 10Hz with a beam size of 80µ. During analysis, the samples and reference materials were ablated in three spots for 60 seconds each and Glitter software was used to capture time-resolved spectra. After the first 30 seconds, surface enrichment effects subsided and signal intensities/ablation behaviour became more consistent between individual ablations. For quantification, the average background-subtracted signal intensity for the final 20-30 seconds of the ablation were used.

The isotopes ^{53}Cr, ^{57}Fe, ^{59}Co, ^{60}Ni, ^{65}Cu, ^{66}Zn, ^{75}As, ^{77}Se, ^{105}Pd, ^{107}Ag, ^{111}Cd, ^{113}In, ^{118}Sn, ^{121}Sb, ^{125}Te, ^{195}Pt, ^{197}Au, ^{208}Pb and ^{209}Bi were selected for quantification. ^{57}Fe signal intensities were monitored but quantified values are not reported because the high background, isobaric interference with argon compounds and high variability make interpretations based on this element unreliable. Simple normalisation using ^{107}Ag intensities consistently indicated concentrations in the hundreds to low thousands of ppm in reference materials and samples.

Both MBH 133X-AGA1 and MBH 133X-AGA3 were measured as standards and MBH 133X-AGA3 was chosen to be the primary standard for all samples. Calibration and quantification were achieved by standard bracketing with AGA3 using the method described by Halter et al. 2002. The coin sample elemental compositions are found in **Table 2** and analyses of reference materials found in **Table 3**. AGA3 was chosen to be the calibrating standard because it most closely matches the expected concentrations of elements in the coins. The standard AGA1, used as a control, has a significantly different matrix with much higher concentrations of many of the elements, which means that errors occur due to extrapolation beyond the calibration range. Despite this, the analysis of AGA1 shows that silver was accurate within 5%, and gold and zinc within 10%. Other elements, such as copper, lead, bismuth, tin, arsenic and antimony were measured to be 10-26% lower than the given value. The precision (2SD) for these elements in AGA1 is roughly comparable to the accuracy. Since the calibration standard (AGA3) is much closer to the compositions of the coins, the analyses of the coins themselves are expected to have a significantly better accuracy than AGA1.

Each coin was then sampled by scalpel to inconspicuously remove approximately 1mg of silver from the coin edge. At the Vrije Universiteit Amsterdam (VU) the samples were dissolved in dilute nitric

8 The methods followed those of Kershaw et al. forthcoming.

acid. The lead was separated from the matrix following the procedure of Merkel et al. 2022. The purified lead was diluted with a 1% nitric acid solution to a concentration of 25 ppb. Samples and isotopic reference solutions were measured in 'dry-plasma' with an Aridus II desolvator coupled to a Thermo Neptune MC-ICP-MS. Sample measurements were bracketed with measurements of the NIST SRM 981 Pb isotope standard. An in-house Pb isotope reference solution (diluted from a CPI single-element Pb standard solution) was measured six times in each analytical session to estimate the repeatability of the measurements. Mercury concentrations were monitored and corrected. All Pb isotope ratios were normalised to the mean of the corresponding ratios for bracketing measurements of NIST SRM 981 using the values of Thirlwall 2002. The Pb isotope ratios obtained for the in-house CPI reference solution were within uncertainty of the long-term average of measurements of this solution in the VU laboratory, and the repeatability (2 RSD) for $^{206}Pb/^{204}Pb$, $^{207}Pb/^{204}Pb$, $^{208}Pb/^{204}Pb$, $^{207}Pb/^{206}Pb$, and $^{208}Pb/^{206}Pb$ was ~0.02%, 0.04%, 0.05%, 0.016%, and 0.025%, respectively. These uncertainties were quadratically added to the measurement uncertainties (2 SE) for each sample. The whole method blank was measured to be 110pg, which is negligible compared to the >1µg Pb in the samples. The Pb isotope ratios of the coin samples are found in **Table 4**.

Methodological Considerations

Elemental and lead isotope analyses of silver are well-established techniques to provenance metals and rely on a combination of source-related and technological factors.[9] Regarding elements, gold and bismuth are two important potential source indicators: gold is present in silver ore deposits in varying amounts and follows silver through all the metallurgical processes into the finished product, while bismuth is difficult to remove from silver without significant loss of silver. Bismuth, if present in the ore, tends to be present in the finished silver. Thus, levels of gold and bismuth observed in silver coinage can be used to discriminate between candidate silver sources. Lead also survives the cupellation process in minor or trace elements. Analysing the ratios of the isotopes of lead conveys information about the geological age of an ore deposit.[10]

Nevertheless, there are challenges to the interpretation of elemental and lead isotope data (Kershaw and Merkel 2021). Due to the need for coins to achieve a certain standard fineness, silver in coinage was often cupelled or refined. When this happens, lead is added to the silver so that, during high-temperature oxidation (cupellation), non-noble metals are selectively oxidized and removed. The final product is silver that is typically very pure, with small amounts of copper and lead (≤2%), the noble metals and bismuth. The lead remaining in the silver after refining reflects the lead used during cupellation, rather than lead associated with the source ore: importantly, it is this lead which imparts its isotope values onto the silver. If the lead added during cupellation originates from the same source ore as the silver, this is not problematic, but the lead may stem instead from a different source that may or may not have been local to that of the silver. In any study of coined silver provenance, it is thus essential to analyse potential lead sources alongside candidate silver ores. Additionally, silver may be alloyed or mixed, which also mixes the elemental and lead isotope signals. All these factors need to be considered when interpreting the elemental and isotope data.

Results

9 Merkel 2019.
10 Merkel 2016, 67-8.

Elemental analysis of the coins shows that all coins are made to the same silver standard with ca. 3-5.5% copper, except the three coins of David I: these are of notably lower quality, with around 10% copper, something we discuss in more detail below (**Figure 3**). With the exception of the David I coin from Edinburgh, all of the coins have very low zinc and tin contents, meaning they were alloyed with copper; the David I Edinburgh coin contains some brass. Regarding the source-related elements, gold and bismuth, two of the coins stand out. While most coins contain moderate levels of gold (0.26-0.43%) and low bismuth (<0.1%), two coins: a Henry, Earl of Northumbria, coin from Carlisle, and a Henry II coin from Newcastle, are significantly different, having extremely low gold contents (≤0.003%). The Earl Henry coin is also distinctive in having elevated bismuth (0.33%).

The lead isotope ratios divide into two clusters: one containing the coins of David I, Henry of Northumberland and Henry II of England, and a second group containing the two coins of William I (**Figure 5**). Geochemically, the model ages of the two groups are roughly similar (ca. 260-290 Ma), but there are major differences in the ratios of lead deriving from uranium and thorium, which point to very different tectonic environments. We argue below that these groups relate, in all but two cases, to the use of mined lead which was used in refining silver (cupellation), rather than the silver itself.

Discussion

David I

Three sterlings of David I were analysed from Edinburgh (Quadrilateral on Cross Fleury type) and Berwick and Roxburgh (Cross Fleury and Pellets types). The Quadrilateral on Cross Fleury type copies the English designs of Henry I and occurs early on in David I's reign, in the late 1130s, whereas the Cross Fleury and Pellets type is a much larger issue dating from the later 1140s and even after David I's death in 1153.[11]

Despite their different dates, the coins are elementally and isotopically similar. They share similar elemental compositions as well as lead isotope ratios, supporting the notion generated from studies of dies and moneyers that the mints were closely related.[12] The elemental results show that the coins are c. 85-87% fine (**Table 2; Figure 3**). They thus contain slightly less silver than contemporary issues of King Stephen from England,[13] and the issues of Earl Henry and the later Crescents and Cross and Crosslets coins analysed as part of this study, all of which have a silver fineness above c. 89% (**Figure 3**). This result is unexpected, as it has been postulated that the silver fineness of David's coinage was on par with contemporary English issues and that David struck coins to an acceptable international standard.[14] Although the coins are only marginally less fine, this pattern may point to a limited supply of silver at these mints, with copper being added to make the silver go further. All three coins contain c. 9-12% copper, suggesting a deliberate and controlled alloying process across mints. It would appear that silver was refined centrally, and re-alloyed with c. 10% copper.

The lead isotope ratios of the three David I coins plot with Alston Moor (specimens from the Smallcleugh Mine, Nentsberry Mine, Rotherhope Fell mine and Carr's Vein) (**Figure 5**). At first glance, this seems to point to the importance of silver from the 'mine of Carlisle' during this period.

11 Stewart 1971, 192; Mattinson and Cherry 2013, 102-8.
12 Blackburn 1994, 192-3.
13 Blackburn 1994, 173.
14 Stewart 1967, 2; Blackburn 1994, 193.

However, other patterns in the data allow us to rule out Alston silver as a significant silver source. All three David I coins have elevated gold, between 0.32 and 0.42 per 100 parts Ag. By contrast, Crafter has argued convincingly that unadulterated silver from Alston is low in gold, with low or moderate bismuth: later English Cross and Crosslets coins from Carlisle and other northern mints having very low levels of gold, typically at or below 0.1%, which could only be explained by the use of newly mined silver.[15] A contribution of small amounts of Alston silver is still possible. Nonetheless, the results suggest that, at these three mints, David I's coinage relied mainly on recycled coin stock.

Unfortunately, our sample did not include David I coins from Carlisle, but we note that the Carlisle coin of David's son, Earl Henry of Northumberland, appears to have been made with freshly mined Alston silver (see below). Presumably, the same is true for the Carlisle issues of David I and those issued by David and Henry in King Stephen's name. There is no documentary evidence for how the Scottish mints or the northern English mint of Carlisle operated during the twelfth century. The Carlisle moneyer Erebald struck coins at Carlisle, Edinburgh and Earl Henry's mint at Corbridge, potentially indicating a joint minting operation between these three mints.[16] The silver itself, however, appears not to have been shared.

The lead isotope ratios of the David I coins plot can be explained by the use of Alston lead in *refining* silver at the Berwick, Edinburgh and Roxburgh mints. Lead from the 'mine of Carlisle' was thus a valuable resource in its own right. The addition of lead to silver in the refining process obscures the source of the silver, and thus the provenance of the silver in the analysed David I coins remains uncertain. As mentioned above, silver might have been drawn from the southern English silver stock in the coinage coinage, which, broadly speaking, shares the same gold values as the coins of David I.

There is limited numismatic evidence for the make-up of the circulating medium in Scotland during the reign of David I: only one hoard (Bute, discovered in 1863) is recorded for the early to mid-twelfth century from Scotland, deposited at the end of David's reign, and it contained mostly coins of David I, a sterling of Earl Henry and one of Stephen, along with two gold rings, a torc, three gold bands and a silver bar.[17] The single-find evidence is composed primarily of coins of David I, with three coins of Stephen and one of Earl Henry.[18] It seems, then, that coins of David made up the bulk of the circulating currency in Scotland prior to c.1170/74. This may reflect a decreased supply of English coins to Scotland during the Anarchy, as royal control over coinage in England broke down. Alternatively, it may be an indication that foreign (English) coin was melted down on arrival in Scotland, potentially for political as well as economic reasons.[19] Did its silver fuel the nascent Scottish coinage at Scottish mints?

Henry of Northumberland

We analysed one coin minted in the name of Earl Henry, from the Carlisle mint (as Henry I type 15).[20] It is finer than David's coinage, with a silver content of c. 93%, and plots isotopically with Alston Moor (**Table 2; Figures 3 and 5**). Its bismuth levels are quite high (0.32%) and its gold contents are extremely low (0.03%) (**Figure 4**). Alston silver-bearing veins can be associated with bismuth-rich

15 Crafter 2007, 240.
16 Stewart 1971; Allen and Savage 2023, 256.
17 Thompson 1956, 21, no. 63.
18 Savage, Freeman and Paul 2021, 143-74; 2022, 163-86.
19 Savage forthcoming.
20 Mattinson and Cherry 2013, 102.

minerals,[21] and a subset of EPMA-analysed coins linked to Alston silver have moderate bismuth (c. 0.3%).[22] The low gold is also consistent with an Alston source. Thus, the Early Henry coin seems very likely to have been made with new silver mined at Alston, reinforcing the association - in this instance - between the 'mine of Carlisle' and the Carlisle mint.

William I

In 1157 Carlisle fell back under English control after a period of just 21 years. What was the impact of this loss on Scottish coinage? We analysed four coins from the later twelfth century, including two Crescent Class C coins of William I of Scotland (his second coinage), from the Roxburgh and Edinburgh mints.[23] The two coins are very similar geochemically. Both are fine silver (93% and 94%) (**Table 2; Figure 3**). Isotopically, they plot not with Alston, but with the Leadhills-Wanlockhead orefield in the southern uplands of Scotland (**Figures 1 and 5**). These ore fields are not particularly silver rich, with silver to lead ratios of about 85 g/t based on modern mining records.[24] They are thus unlikely to have been a source of fresh silver: instead, the lead isotope signature likely relates to lead added to the silver during refining. Indeed, the gold contents of the coins are somewhat elevated at 0.26%. As with the David I coins discussed above, these gold levels are not low or distinctive enough to suggest newly mined silver and more likely reflect the use of mixed, recycled sources.

This result is interesting for a couple of reasons. First, it indicates that William I, like his grandfather David I, did not have access to the same freshly-mined silver from the 'mines of Carlisle' used for the coinage of Earl Henry of Northumberland. Second, William I's acquisition of locally-available lead from Scotland makes sense in the context of England's recovery from Scotland of Cumberland and Northumbria in 1157. Whereas David I had refined silver using Alston (i.e. Cumbrian) lead, William I used lead from Scotland, presumably after having lost access to resources further south.

There are other hints that lead was mined in Scotland during William I's reign, as lead is included among the duties payable to the king,[25] but documentary sources for lead mining at Leadhills-Wanlockhead specifically date only from the 1230s.[26] There is a radiocarbon date obtained from alder charcoal associated with a slag scatter from a potential lead smelting site at Glennkin, Leadhills, which provided a calibrated date range of 1005 ± 45 BP (Lab code AA-43412).[27] Given that alder is a relatively short-lived species, we are probably safe in dating lead smelting at Leadhills from the eleventh century. The new data provided by our analyses, coupled with the early radiocarbon date, thus signal earlier lead mining at Leadhills than indicated by the written sources.

What, then, *was* the source of silver used in coins of William I? The very need for refining hints at the use of a varied silver stock requiring cupellation to achieve a uniform standard. The lack of adequately recorded coin hoards from late twelfth-century Scotland means that the composition of the circulating currency for this period, from which silver for new coins might be drawn, is unclear.[28] A hoard from Dyke Churchyard, Elgin (Moray) deposited c.1180s is said to have contained a mixture of

21 Ixer et al. 1996; Fairbairn et al. 2020.
22 Crafter 2007, 239 fig. 6.5 (data for: England, northern mints).
23 Crafter 2007, 156.
24 Brandes and Brandes 2021.
25 Harvey 1997, 124.
26 Pickin 2010, 81.
27 Pickin 2010, 83.
28 Crafter 2007, 242.

Scottish and English coins,[29] and the Baddinsgill (Peeblesshire) hoard deposited c. 1180-95 contained Crescent coins and one English Short Cross coin of Henry II. The presence in Scotland of ten single finds of contemporaneous English coins points to a possible bullion source.[30] A small number of Crescent sterlings overstruck on *Pfennige* also provide evidence for the import of Rhineland silver into late twelfth-century Scotland: it is possible that German silver in this or other forms also entered the melting pot.[31] Crafter speculates that earlier Scottish coins of David I, Earl Henry and Malcolm IV continued to circulate into William I's reign in Scotland and northern England, meaning that they could have been a third potential source of bullion.[32]

More controversially, Crafter posits that older stocks of Islamic silver, circulating in Scotland since the Viking Age, constituted a significant source of silver for the Crescent coinage.[33] His argument is based on the substantial levels of bismuth observed in some of the twenty Crescent coins analysed by EPMA, which, he argues, reflects a contribution from low-gold, high-bismuth Samanid silver. Unfortunately, neither of the Crescent-type coins we analysed have high bismuth, meaning we cannot test the hypothesis directly using Pb-isotope analysis. However, two arguments can be put forth to dismiss this suggestion.

First, the Samanid silver stock in Scandinavia was quickly replaced by European silver in the latter tenth century, to the point that there is little trace of it in coinage of the eleventh century.[34] This makes it highly unlikely that Samanid silver provided the basis for European coinage in the later twelfth century. Second, contemporary Continental coinage, for example the Habsburg Löwenpfennig minted in the Upper Rhine and associated with silver mining in the Black Forest area, can have equivalent gold and bismuth levels.[35] The much higher variation of silver compositions in Scotland during the reign of William I detected by Crafter reflects an influx of silver that is unrelated to the 'Carlisle mine' and recycled English silver.[36] It probably signals new silver coming from the Continent, which has not been previously homogenised through large-scale mixing and recycling.

Henry II

Our final analysis concerns two Cross and Crosslets coins of Henry II from northern English mints, broadly contemporary with those of William I: one class A2 from Carlisle and one class E3 from Newcastle.[37] Both coins plot isotopically with ore from Alston Moor (**Figure 5**). However, elementally, they are different (**Table 2, Figure 3**). The Newcastle coin is low in gold and likely reflects the use of fresh, 'Carlisle-mine' silver. It is in keeping with the elemental results obtained by Crafter is his analysis of Cross and Crosslets types from the northern mints of Newcastle, Carlisle and Durham (**Figure 4**).[38]

The coin from Carlisle has a much higher level of gold, which is consistent with the broader silver stock used at mints in the rest of England (Bristol, Canterbury, Exeter, Ipswich, London.

29 Allen 2017, 83.
30 Crafter 2007, 207; Savage, Freeman and Paul 2021, 143-74; 2022, 163-86.
31 Stewart 1971.
32 Crafter 2007, 242; 2017, 224.
33 Crafter 2007, 243-5.
34 Merkel 2016.
35 Ilisch et al. 2003, 183-4.
36 Crafter 2007, 239 figs. 6.4 and 6.5.
37 Allen 1951.
38 Crafter 2007, 239 fig. 6.5.

Northampton, York) (**Figure 4**).[39] This is notable, since Crafter used the distinctive elemental profiles of coins from northern English mints and mints from the rest of England to argue that only the northern English mints were supplied with freshly mined Alston silver, with the other English mints likely relying on metal from other sources.[40] Our data shows that even at Carlisle not all coins were made using freshly-mined Alston silver. This result adds weight to the argument, already made by Martin Allen,[41] that the significance of Alston silver for the expansion of coinage in the late twelfth century has been overstated: not only is Alston silver unrecorded in southern English Cross and Crosslets coins,[42] it is not found in all northern English issues, including Carlisle itself.[43]

A wider look at English and Scottish silver supply from a wider European perspective continues to be an attractive topic for future research. The silver supply of the British Isles was not a closed system, and it is expected that the discovery of silver in the Saxon Ore Mountains contributed to the broader European metal supply in the later twelfth century. While coinage from some regions of the Continent have been characterised by XRF,[44] major research gaps remain. The use of modern analytical techniques may reveal unseen patterns in the supply and flow of silver on a much larger scale.

Conclusions

The combined lead isotope and trace element analysis of this small group of coins has yielded some unexpected results, which add nuance to the picture of minting in Scotland and northern England in the twelfth century. A major result is that silver from the ‘mine of Carlisle’/Alston is not widespread: it is not detectable in the coins of David I from Edinburgh, Berwick and Roxburgh, which may indicate that its use was limited to Carlisle during the early stages of Scottish minting. We do detect Alston silver in the Earl Henry coin from Carlisle and Henry II’s Newcastle example. However, other mints on both sides of the border drew their silver from a much larger stock of circulating metal or re-minted imported silver at ports of entry. Even at Carlisle in the later twelfth century, the use of ‘mine of Carlisle’ silver was not guaranteed, as demonstrated by the results relating to Henry II’s Carlisle Cross and Crosslets coin.

Despite the limited impact of its silver, the ‘mine of Carlisle’ was valued for its lead, which is widely distributed and seems to have been employed for refining processes across the surveyed mints. The exceptions are the two coins of William I, from Roxburgh and Edinburgh, which were instead refined using southern Scottish lead from Leadhills/Wanlockhead. These coins were minted following the loss of the ‘Carlisle mine’ to the English. This loss does, then, appear to have had a tangible impact on mineral resources available to the Scottish kings, albeit concerning lead, rather than silver.

The alternative sources of silver available in the twelfth century are less clear. The widespread practice of refining points to mixed stocks of potentially varying age, geographic background and fineness. We postulate on the basis of similar gold levels that recycled coins from southern England were used as a bullion source for David I coins produced at mints other than Carlisle. By the reign of William I, the influx of Continental silver to Scotland is very likely, alongside the recycling of English coins and older Scottish issues still in circulation. A further, potential source of silver for the Scottish Crescents coinage, namely Central Asian, Samanid, silver can be ruled out.

39 Crafter 2007, 239, fig. 6.5.
40 Crafter 2007, 240-1.
41 Allen 2011.
42 Crafter 2007, 240-1.
43 For the wider debate, see Blanchard 2001, 583–685; Claughton 2003, 148–9; Allen 2011, 121–4.
44 Ilisch et al. 2003.

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[Excel Tables in separate folder]

Table captions

Table 1. List of analysed coins.

Table 2 Elemental concentrations of analysed coins measured by LA-ICP-MS. The uncertainties given are 2SD of three measurement spots. Four elements were all below detection in all samples (Co, Cd <0.5ppb, and Cr, Se <5ppm).

Table 3 Analyses of the secondary standard MBH-133X-AGA1 compared to the given values.

Table 4 Pb isotope ratios of the analysed coins. The 2SD uncertainties of the secondary standard were quadratically added to the measurement uncertainties (2SE) for each sample.

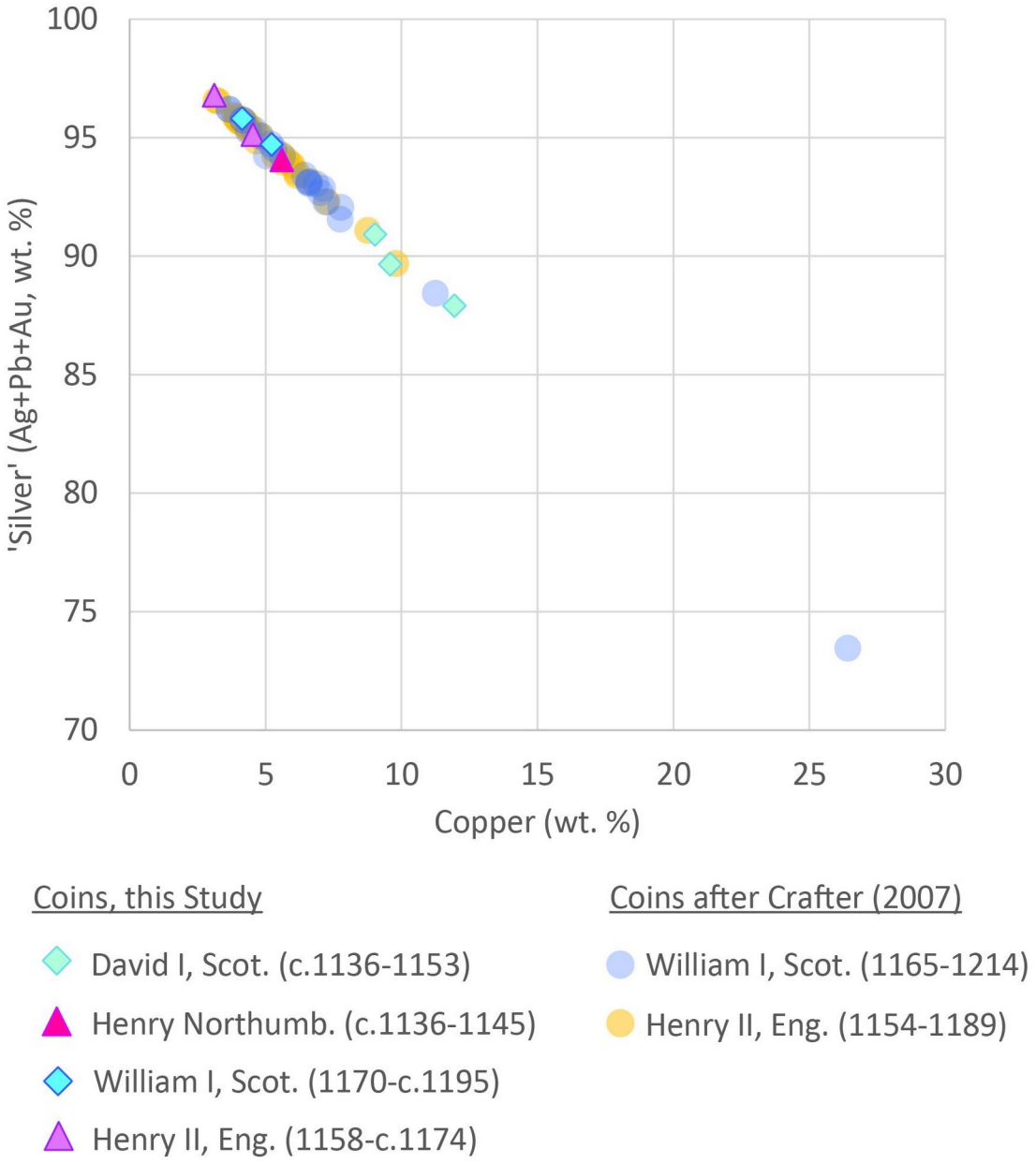

Figure 3. Comparing the silver and copper in the coins from this study with those analysed by Crafter (2007), it is clear that the coinage was generally of sterling quality and varied little during the 12th century. However the present analyses show that the coins of David I are lower in silver fineness compared to the other issues (ca. 90% rather than 95%). (Date in brackets refers to the coinage)

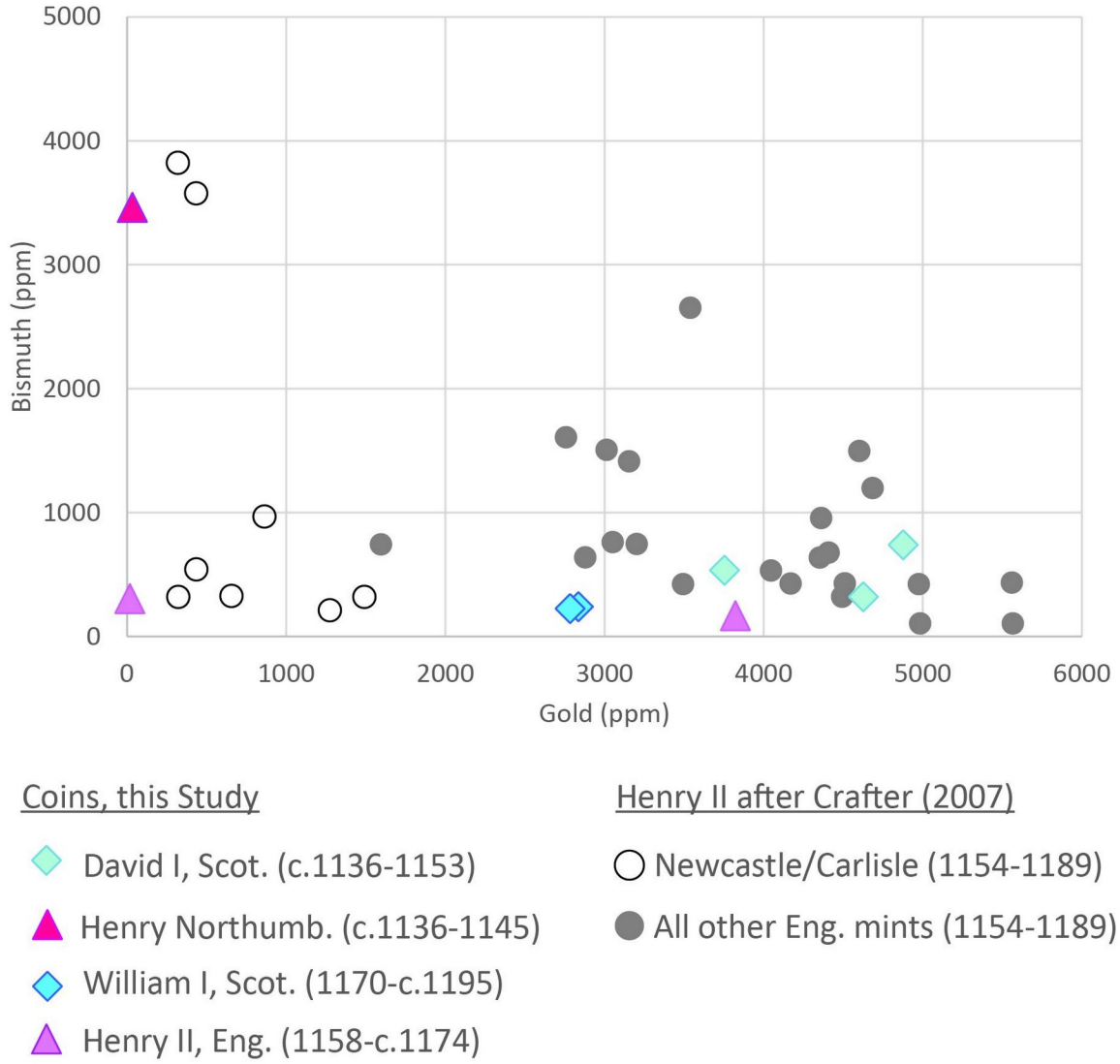

Figure 4. The source-related elements gold and bismuth indicate that a different silver source was used at the mints of Carlisle and Newcastle compared to the rest of England. This source is characterised by very low gold contents and moderate to low bismuth, which Crafter (2007) suggests is freshly mined from Alston in the North Pennines. Two of the coins in the present study (Henry Earl of Northumbria, Carlisle and Henry II, Newcastle) are consistent with this source. The other six coins are more similar to the silver stock circulating in England more broadly in the 12th century and are likely to have been made from a recycled silver stock.

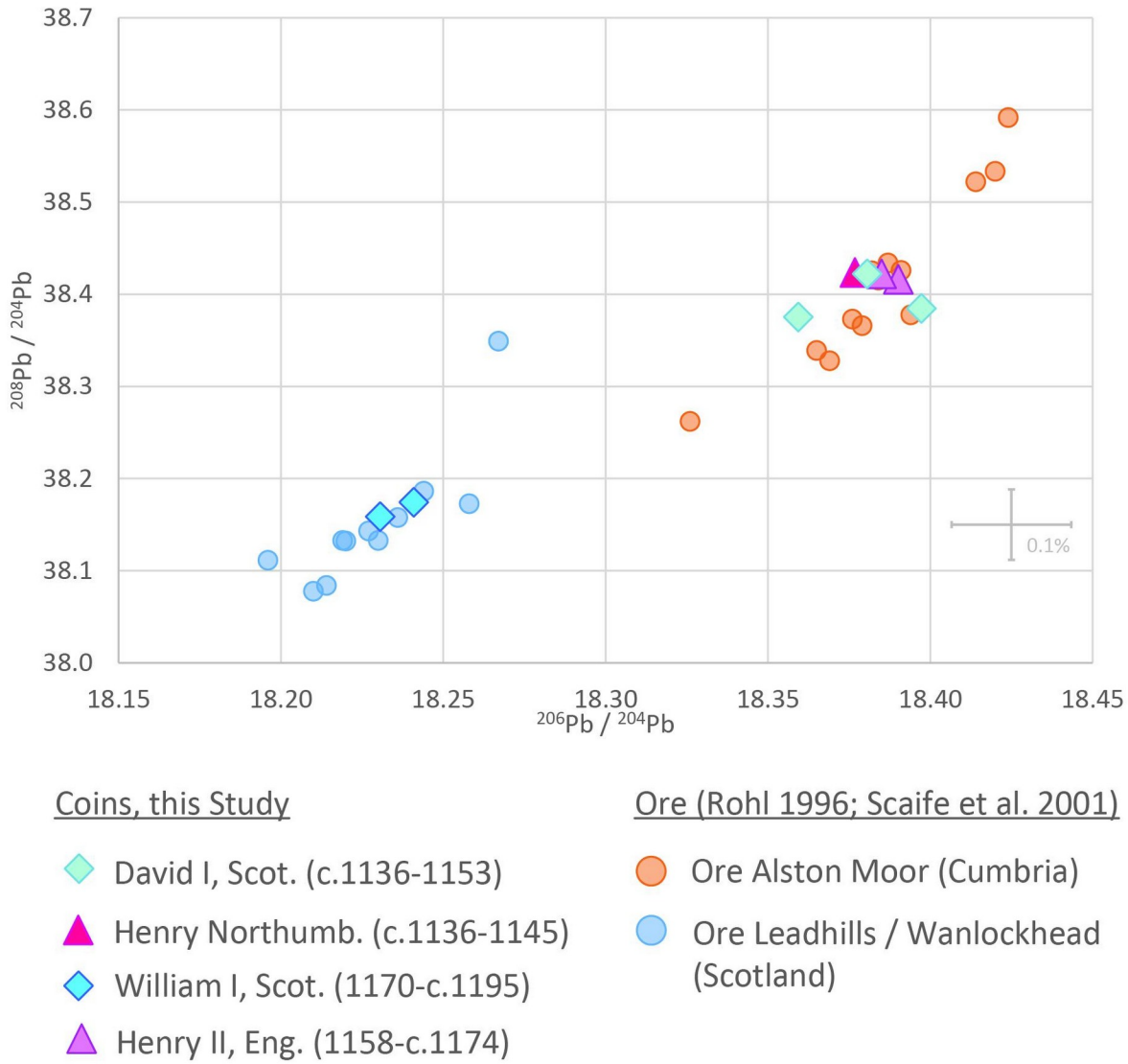

Figure 5. The lead isotope ratios of the coins from this study divide into two groups. Most are isotopically consistent with the lead ore from the Alston area, particularly Alston Moor, Nenthead and the Nentsberry and Rotherhoper Fell mines. In these cases, the lead in the silver originates from Alston, either as an impurity in silver mined at Alston or as lead added to the silver during refining and recycling. The two coins of William I, however, are consistent with lead ore from the Leadhills and the Wanlockhead deposits in southern Scotland. This suggests active lead mining at this time and that Scottish lead was used for refining silver at the Edinburgh and Roxburgh mints.