Aspects of Roman Republican coins found in late Iron Age Dacia

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1 Introduction

I first met Virgil in 1992 during my first trip to Romania when I visited Iaşi and he and his family were kind enough to look after me. The following year I spent some six months studying at the Institute of Archaeology there, and then in 1996 Virgil, Tim Sly and I organised the annual *Computer Applications and Quantitative Methods in Archaeology* conference (Lockyear *et al.* 2000). It is, therefore, a great pleasure to contribute this paper to my dear friend's *festschrift* both in thanks for all the help and friendship he has shown me over the years, and to wish him the best for the future.

Given Virgil's numismatic interests it seemed appropriate to examine the problem of Roman Republican *denarii* from late Iron Age Dacia. The finds of *denarii* in Dacia have been described as "One of the most remarkable phenomena within the pattern of monetary circulation in antiquity..." (Crawford 1977, 117). This pattern raises many problems in analysis and interpretation (see Lockyear 2004, pp. 65–67) but here I want to focus on two of the more basic problems: at what date did Roman Republican *denarii* start to arrive in Dacia in quantity and what proportion of the *denarii* found are locally made copies?

2 What date did Roman Republican *denarii* arrive in Dacia

There have been a remarkable number of papers written examining the problem of the supply of *denarii* to Dacia (for example, those by Babeş 1975; Chiţescu 1981; Crawford 1977; Macrea 1933–5; Mitrea 1958; Poenaru Bordea & Cojocărescu 1984; Preda 1971). A few years ago I published a statistical analysis of 217 Roman Republican coin hoards from across the ancient world (Lockyear 1995, 1996a). In this paper I argued that the strong similarity between hoards from Italy dating to the period 75–65 BC, using Crawford's 1974 chronology, with Romanian hoards closing at a wide variety of dates, clearly showed that the first major influx of these coins occurred at this date. I argued, along with Crawford, that earlier coins in Romania simply reflected the coins in circulation in Italy at the date that they were taken to Dacia. The various suggestions of earlier influxes of coins mistook variations in coin *production* with variations in coin *supply* to Dacia. Crawford preferred a slightly later date to allow for the coins to reach Dacia by a series of small down-the-line type movements (see also Davis 2006), whereas I feel that the lack of Republican coins from most of the regions between Italy and Dacia at this date makes it more likely that coinage was directly transported from Italy to Dacia for the purposes of trade.

More recently, however, Moisil & Depeyrot (2003) have presented an alternative pattern of supply. Their suggested pattern of supply is as follows:

Numismatic event	historical event
From 145 BC the area which now forms Romania received an abnormal number of *denarii*.	
Denarii of 135–125 AD arrive in great numbers.	
Denarii of 105–95 BC arrive in great numbers and are hoarded	In 109–106 BC M. Minucius Rufus repels the Dacians.
Denarii of 95–80 BC arrive in particularly large numbers, they are hoarded	
Denarii of the 70s BC arrive in great numbers and are hoarded, then around 70 BC supply stops.	In 74 BC C. Scribonius Curio, and in 71 BC Terentius Varro Lucullus attack the Dacians and enter Dobrogea
	In 69 Pompey defeats the Armenians
	In 69 Pompey defeats the pirates
Around 31 BC the area once again receives *denarii*	Fighting continues
	Around AD 62–66 Plautius Silvanus reinforces a buffer zone between the Dacians and the Romans and settles Dacians and the Roxolani on the south bank of the Danube[1]

This pattern of supply was deduced using a innovative method. Moisil and Depeyrot compared the total numbers of coins in the Romanian *corpus* with Michael Crawford's 1974 estimates of dies used to strike each issue of

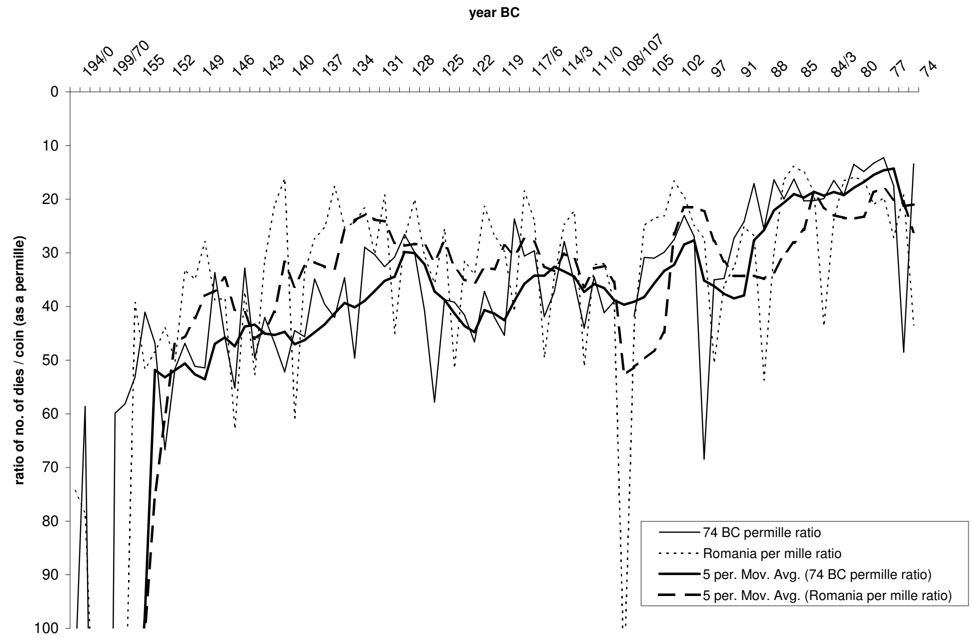

Figure 1: Coins to dies ratio for Romania v. Italian hoards closing in 74 BC. See text for details. The thicker lines are five year moving averages.

coinage. The graph they presented has two lines plotted on it. The first is the ratio of coins to dies by year. The second line unfortunately goes unexplained but would appear to be a five year moving average, the default trendline in Microsoft Excel.[2] Unfortunately, for this line to represent the pattern of coinage supply to Dacia we would have to argue that only *new* coin was exported to the region, rather than a mixture of coins as present in the circulation pool of the place of exportation, presumably Italy. To demonstrate this, I constructed Fig. 1. In this graph I have replotted their figures for the period up to 74 BC and then plotted on the same graph the figures for twenty hoards from Italy closing in 74 BC. To make them directly comparable I converted the figures for both Romania and the Italian hoards to permilles before calculating the ratios (see Appendix A below for details). As can be seen, the two sets of figures are very comparable and thus cannot support the pattern of supply suggested by Moisil and Depeyrot.

The next analysis presented by Moisil & Depeyrot (2003, pp. 6–7) is based on the weights of coins. The average weight of coins from three periods, 139–30 BC, L Piso Frugi (90 BC) and 89–80 BC was calculated, dividing the corpus into decades. One would expect the average weight of coins to fall over time as they became worn but the weights did not follow this pattern.

[2] Excel plots this incorrectly by placing the five year average at the end of the five year range instead of its midpoint.

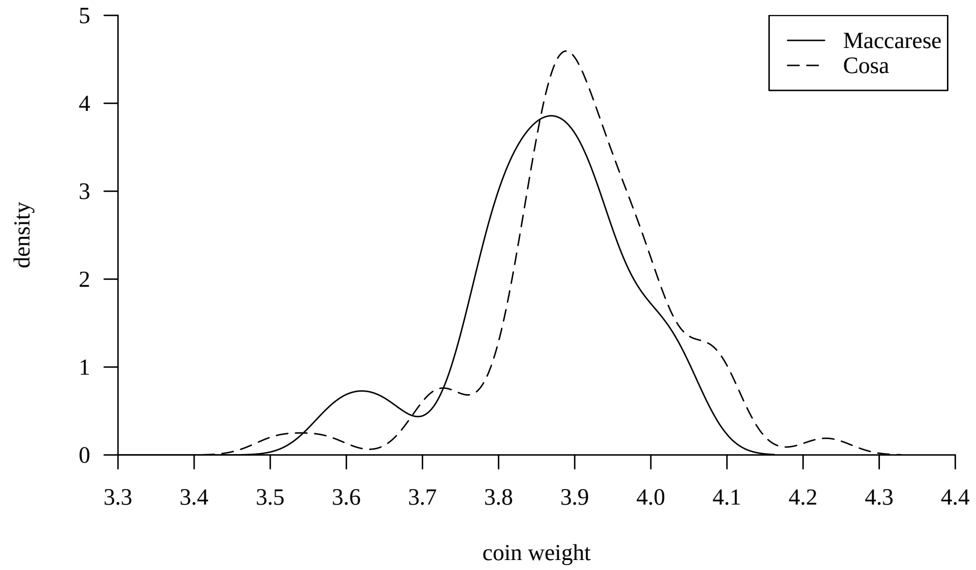

Figure 2: Weights of coins of L Piso Frugi compared. One very light-weight coin in the Maccarese hoard has been excluded. The graph is a plot of the kernal density estimates for the two hoards.

Moisil and Depeyrot interpret this as the result of changes in coin use and the speed of circulation. There are two problems, however. Firstly, Moisil and Depeyrot ignore the problem of Dacian copies. Known copies in, for example, the Poroschia hoard, are quite light, often *c.* 3.5g. The weights plotted by Moisil and Depeyrot for 29–20 bc are dominated by that hoard and metallurgical analysis (see below) suggests that about 48% of the coins from Poroschia are copies. Thus, taking the average weight of all coins is misleading.

Secondly, how much do we trust the published weights? An example will illustrate my point. The Maccarese and Cosa hoards have both been published including coin weights. Both hoards are large, come from central Italy and close in 74 bc. If we look at the weights of the coins of L Piso Frugi (RRC 340/1) in these hoards we find that the average for the Maccarese hoard is 3.86g. whereas for the Cosa hoard it is 3.91g. (Fig. 2). Comparison of these weights using the two-tailed two-sample t-test shows a statistically significant difference at the 0.05 level.[3] There is no numismatic or archaeological reason for this difference and we must therefore conclude that it is due either to differential corrosion/cleaning, or errors in recording. Indeed, simply subtracting 0.05g. from every coin in the Cosa sample results in an identical mean weight, and there is also no statistically significant dif-

[3] Maccarese: 41 coins, $\bar{x} = 3.86$g.$, s = 0.111$; Cosa: 64 coins, $\bar{x} = 3.91$g.$, s = 0.118$; $t = -2.06; P = 0.041$; therefore reject H_0 at the 0.05 level.

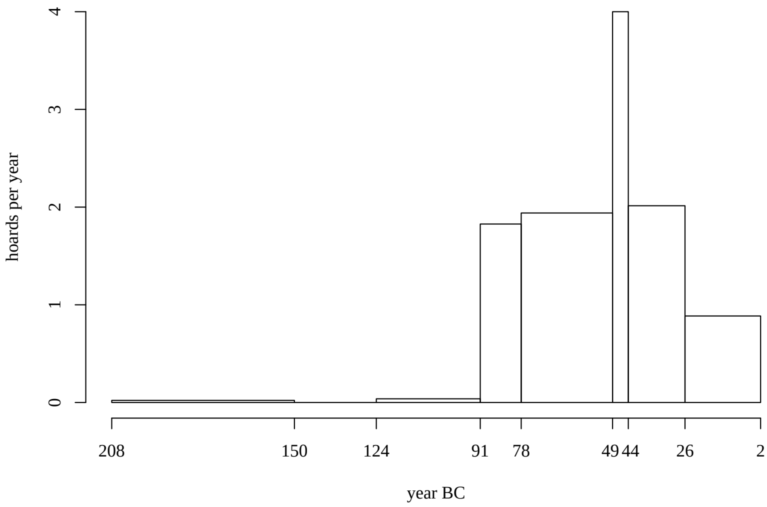

Figure 3: *Denarius* hoards *per annum* in the CHRR database from Romania.

ference in the variance between the two groups.[4] Thus, any attempt to use coin weights for examining variable speeds of coin circulation has to deal with this problem.

A third strand of evidence is the pattern of hoarding when plotted by closing date. We must acknowledge that the closing date of the hoards is only going to be a *terminus post quem* which, due to the presence of copies in the Dacian material, could be a long way removed from the actual closing date. In my database of Roman Republican coin hoards I only have two hoards from Romania closing before 91 BC and they only have four *denarii* between them. Moisil and Depeyrot do not list any hoards closing before 91 BC. Figure 3 plots the numbers of hoards per year from my database grouped according the the periods used by Crawford (1969).

From the above discussion we have to conclude that it seems extremely unlikely that any *denarii* were supplied to Dacia prior to *c.* 90 BC, and that the pattern of supply and hoarding suggested by Moisil and Depeyrot cannot, at present, be supported by the hoard data. The pattern discussed by Moisil and Depeyrot is a reflection of the coinage pool which was itself created by the pattern of coin manufacture, supply and loss.

Can we make any progress on this problem? Previously, on the basis of a cluster analysis of 217 hoards of Roman Republican coin hoards closing between 147–29 BC I concluded that there was a massive import of Roman Republican *denarii* into Dacia in the period 75–65 BC and that thereafter coinage supply was much lower and more erratic (Lockyear 1995, 1996a). I have recently rerun this cluster analysis with an expanded dataset of 294

[4]Cochran's C test for equality of variances: 0.53, P=0.62. Figures from Statgraphics.

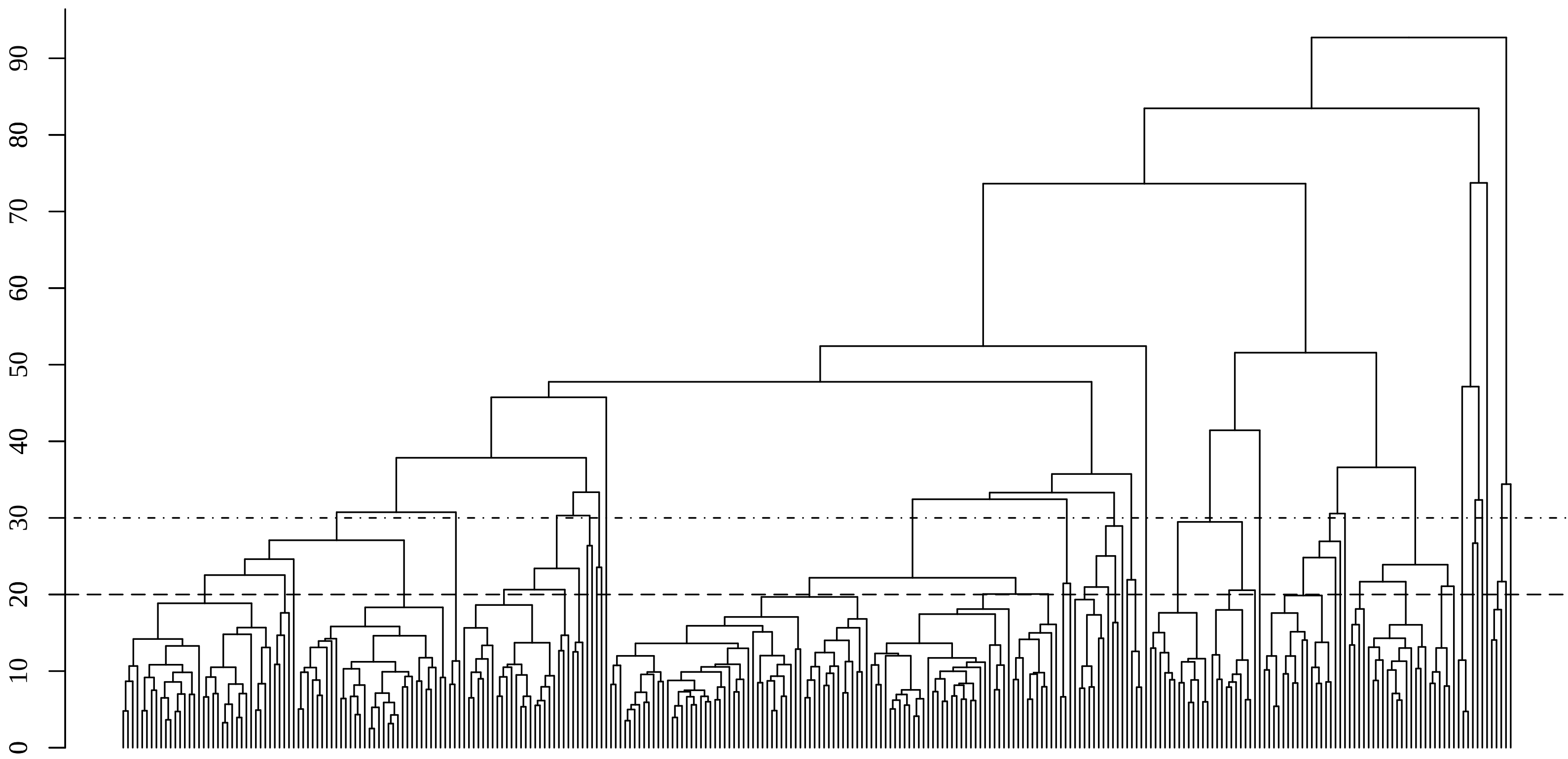

Figure 4: Dendrogram from cluster analysis using Dmax as a dissimilarity coefficient, and the average link agglomeration method. The dashed line shows the cut for the groups at 20%, the dot-dash line shows the cut for the supergroups at 30%.

		Italy *etc.*			Romania			Iberian penisula			Total		
sprgrp	gps.	tot.	range	med.	tot.	range	med.	tot.	range	med.	tot.	range	med.
Χ	σ–τ	3	147–141	146							4	147–141	146
Ω	υ	1		138							1		138
Ν	γ	1		136							1		136
Μ	z–β	16	130–86	113				5	109–101	104	23	130–86	118
Ξ	δ–ζ	6	103–83	100h				11	115–101	105	17	115–83	103
Ρ	θ–λ	19	101–48	92	1		41	2	100–100	100	23	101–41	92
Θ	q–r	2	89–87	88				1		74	3	89–74	87
Κ	w–x	3	87–82	87							4	87–82	86h
Ι	s–v	7	80–72	74	3	74–49	62				11	80–29	74
Λ	y	1		74							1		74
Η	n–p	29	82–49	74	47	79–32	49	9	78–46	74	95	82–29	71
Β	e	1		48							3	54–48	49
Φ	ρ	1		45							1		45
Δ	i–j	1		43				1		46	2	46–43	44h
Α	a–d	38	58–19	42h	11	42–2	15	6	51–29	45	69	58–2	42
Σ	μ	1		32							3	32–32	32
Γ	f–h	13	40–2	28	5	19–8	12	4	29–15	22	26	40–2	18h
Τ	ν–ξ	1		2							2	2–2	2
Π	η							1		113	1		113
Ζ	m										1		46
Ε	k–l										2	41–41	41
Υ	π										1		8

Table 1: Cluster analysis — date ranges and median ‘end date’ for super-groups by region. Where the median falls between two years, the notation ‘h’ has been used.

hoards closing 147–2 BC (Fig. 4). As before, I cut the dendrogram at two levels, 20% and 30% to create 45 groups (including 23 'singletons', *i.e.,* groups with a single member) and 22 'supergroups' of which seven are still singletons. As a detailed discussion of this analysis is to be published elsewhere (Lockyear forthcoming) I will present only the table of 'supergroups' here (Table 1). As can be seen from this, of the 67 Romanian hoards in this analysis, 47 (70%) were placed in supergroup H with 29 Italian hoards and 9 Iberian peninsula hoards. The Italian group had a median closing date of 74 BC. The Romanian hoards are, therefore, remarkably homogenous in terms of the coins they contain, and remarkably similar to what would be expected from an Italian hoard of *c.* 74 BC. It would appear, therefore, that the data available continue to confirm my original interpretation.

3 The problem of copies

As noted above, the second big problem facing us is how many coins from Iron Age Dacia are contemporary copies of Republican *denarii*. There are two main schools of thought on this topic. The first, as represented primarily by Chiţescu and Preda, is that a large proportion of the Republican *denarii* found in Romania are locally produced copies which form a class of coinage called 'Geto-Dacian coins of the Roman Republican type' (Preda 1973, pp. 345–352). The second school of thought is that of Crawford (1980) who, whilst acknowledging that there is remarkable evidence for the copying of *denarii*, has no doubt that the majority of them are genuine. This view is based on his personal examination of some of the coins. He believes that if a large proportion of the coins are copies, there should be a higher proportion of hybrid coins, as the Geto-Dacians would not be concerned to match obverses and reverses.

The evidence for the copying of *denarii* in late Iron Age Dacia has come in two main forms: coins dies and cast coins.

Prior to 1961, four coin dies were known, one each from Poiana (Galaţi), Braşov, Ludeşti (near Costeşti) and Pecica (Chiţescu 1981, p. 316; Preda 1973, p. 347; Stoicovici & Winkler 1971). It is impossible to identify which issues were struck with the Poiana and Pecica dies; the Ludeşti die is for the reverse of C. Marius C.f. Capito (Stoicovici & Winkler 1971, pp. 78–9) and the Braşov die for "Caesar" (Chiţescu 1981, p. 316). The Ludeşti example is 'die-linked' to a coin in Paris (A12480 Crawford 1980, n. 5).

During excavations on the large hill-top settlement of Tilişca in the summer of 1961, a further set of fourteen dies were discovered (Lupu 1967, 1989). These dies were found in an earthernware vessel along with three mounts. The dies were made of copper alloy (bronze?), the mounts were made of iron. Ten of these dies had clear designs and would have struck coins identical to Republican issues dating from 148–74 BC. The remaining four dies had no visible design. These dies appear to have been made by some form of hubbing process. Die 9, the reverse of a coin of C. Naevius Balbus (RRC 382/1a, 79 BC), shows a clear impression of serrations around the edge of the design. The serrations on some issues of *denarii* would have been applied to the flan of the coin by the Roman mint, not to the die surface. Crawford (1980, n. 4) also notes a 'die-link' between the design on die 7, an obverse of the same issue, and a coin from the Maccarese hoard (see also RRC plate LXV). We can assume, therefore, that these dies were made by some mechanical process from original coins.

In 1988 during excavation and conservation work at Sarmizegtusa Regia a further three dies were found (Mihăilescu-Bîrliba 1990, p. 98, Glodariu *et al.* 1992). The designs on these dies date to issues from 126 BC (RRC 266/1), 68 BC (RRC 407/2) and to Tiberius (AD 14–37). The dies were found in a context beneath two layers of Roman date and the excavators suggest that they date to immediately prior to the second Dacian war (AD 105–6).

The Breaza hoard was found in 1967 after a storm. It is currently in two lots: one of 10 coins in Sibiu (Lupu 1969) and second of 122 coins in the Severeanu Museum, Bucureşti (Poenaru Bordea & Ştirbu 1971). Differences between the reports accompanying the acquisition of these two lots make it unsure whether they represent one or two hoards (Poenaru Bordea & Ştirbu 1971, p. 265). During the preparation of the publication of the Bucureşti lot it was noticed that some coins are identical to each other — not only is the type identical, as might be explained by the use of the same dies, but the shape of the flan, the position of the design and the position of countermarks are also identical (Poenaru Bordea & Ştirbu 1971). There is only one possible explanation: these coins must have been cast, almost certainly using a genuine coin to make the moulds. Five separate issues were cast with a total of 11 coins being identified. The dates of the issues copied range from 85–41 BC (Crawford's chronology).

The Poroschia hoard, found in 1964, forms the last major piece of evidence for the copying of *denarii*. In her original interim publication, Chiţescu (1965) published a photograph of a *denarius* of L. Satvrn which she believed was an imitation of a *denarius*, a suggestion not universally accepted (Crawford 1969, p. 124). Subsequently, Chiţescu developed her classification of imitations and copies (Chiţescu 1971), and in the full publication of the Poroschia hoard (Chiţescu 1980) identified 55 of the 552 coins as copies of *denarii*, and 9 as imitations.

Chiţescu based the classification of copies on a number of criteria:

1. coin weights
2. diameter
3. style

4. errors in the design and/or legend
5. errors in serration
6. lack of cuts on the coins
7. metallurgy

As regards weight, Chiţescu discusses the weight distribution of coins in hoards from Italy, such as Morrovalle in comparison to Romanian hoards including Poroschia, Gura Padinii and others (pp. 54–58, 60–63). She concludes that there is a larger proportion of light-weight coins (*c.* 3.4–3.6g.) in Romanian hoards than in Italian, and that this is one indicator that these coins are copies.

The second criterion, diameter, is hard to assess. Chiţescu states that the diameter of Republican *denarii* is 20–22mm, whereas the coins identified by her as copies are only 17.5–19mm (p. 60). Unfortunately, comparative data from outside Romania is lacking.

Style is a difficult criterion to examine as it relies upon the expert knowledge of a numismatist who has handled large numbers of coins. In the context of the copies in the Poroschia hoard Chiţescu states:

> The 55 silver coins which total 7 types are sharply detached from the other coins in the hoard and even from the types of coins issued by the same moneyer magistrates that appear in the hoard. All the specimens are distinguished from the originals in style and execution. There are elements — such as the rendering of the figures, the hair, the horses, the flames — that are not identical with those on the original coins. The effigy of Roma on the coin of L. Appuleius Saturninus, for example, is closer to an eastern rendering than to a hellenistic one; the pelt on the held of Juno on this coin seems more like a head of hair with ringlets; the torch flames on the coins of P. Clodius are spirals; the effigy of Apollo on the coins of C. Piso L.f. L.n. Frugi is in flattened relief, not modelled as on the original coins. These are only a few of the distinct elements that patently separate the copied coins from the original Roman coins found in all the catalogs of the speciality field. (Chiţescu 1980, p. 60; H. Bartlett Wells unpublished translation in the British Museum, p. 24)

Chiţescu also believed that errors in the legend on the coins may be an indication that they were copies (p. 60). This criterion will vary between issues as some, *e.g.,* the issue of M. SCAVR (RRC 422/1a–b, 58 BC) has many blundered legends, whereas other issues, such as those of MVSA (RRC 410/1–10b, 66 BC) appear to have been more carefully struck. One group of coins in the Poroschia hoard, that of L. Procilius (397/2), has the legend

PROCII I instead of PROCILI; it appears that the bottom bar of the L has somehow been accidently omitted although the space has been preserved.

For a small number of coins, the incomplete serration, or serration of an issue not normally serrated, also led Chiţescu to suggest they were copies. She also makes the extremely interesting observation that only 1 of the 55 coins she identified as copies has any form of cut or counter-mark on the surface. Many Republican *denarii* are 'cut', usually with a punch, presumably by money-changers or possibly even the state, to test whether the coin is solid silver or a plated coin (Crawford 1968). It is difficult to assess the usefulness of Chiţescu's observation without collecting comparative data. The final criterion, metallurgical analysis, was unavailable to her, although she did note that two coins of M. Fourius Philus and C. Cassius 'appear to be alloyed with much bronze' (p. 60).

We have, therefore, a series of criteria and observations that led Chiţescu to believe that at least 55 of the Poroschia coins were copies. Each of these observations by themselves would not be enough to identify with absolute confidence that these coins were copies. Chiţescu did, however, either fail to mention, or did not notice, one further aspect of these coins which in my view confirms the attribution of many of them as copies.

During a short visit to Alexandria in 1992 to take samples for the metallurgical analyses discussed below, I observed a high number of die-links in the issues of C. Piso Frugi. I was able to return briefly in 1993 and carefully examined and photographed all the putative copies. Initially, I examined the 24 coins of L. Procilius (RRC 379/2). Chiţescu believed that 23 of the coins were copies, and only one genuine (no. 401), which appeared to be die-linked to an example in Naples (Chiţescu 1980, p. 59). To my great astonishment, I found that 21 of the 24 coins had complete die-links, that is both the obverse and reverse die in each case was identical.[5] This is extremely unusual (Crawford 1980, p. 52) although high levels of die-linking can sometimes be seen between copies in later hoards in Roman Britain (R. Bland, *pers. comm.*). The die-linked coins varied in weight from 3.04–4.26g with a mean of 3.51g and a median of 3.51g. The remaining three coins had weights of 3.79g, 3.82g and 3.91g. I believe that these 21 coins can be confidently identified as copies.

Following this I then examined the 17 coins of C. Piso Frugi (RRC 408/1a–b). Of these 17 coins, Chiţescu had identified 12 as copies. All 12 had complete obverse and reverse die links. Similarly, she had identified 4 of 8 anonymous coins (RRC 350A/2) and 6 of 10 coins of L. Saturnius as copies: all were completly die linked. The remaining two coins she identified as copies were on the basis that they were serrate, whereas the originals

[5] The identification of the obverse die-link was made easier by virtue of a small fault on the die surface just below the legend SC. Coin numbers 398, 401 and 420 were struck with different dies from each other and the 21 other coins.

were not. The mean weight of most these groups of die-linked coins was low (3.4–3.52g) with the exception of the anonymous issue 350A/2 (3.84g). As a result, I believe that we can safely accept that at least 51 of the 55 coins identified by Chiţescu are copies.[6] An important point, also noted by Chiţescu, is that all these coins are copies made by striking.

The style of the copied coins did not appear to me as substantially different from the genuine coins. I suspect, but cannot prove, that the Poroschia coins were struck from dies made in a mechanical way from original coins (*cf.* the Tilişca and Ludeşti dies) and thus the style criterion is a red herring. The errors in the legends could easily have occurred by damaged coins being used or other problems in the manufacture of the dies. The flatness of the design is almost certainly due to the hubbing process. Another important consequence of the Poroschia data is that we can no longer "suppose *a priori*" that a Dacian mint would not be concerned to match obverse and reverse (*cf.* Crawford 1980).

I have summarised the evidence for Dacian copies in Table 2. In addition to these coins Davis (2006) lists possible Dacian copies in US private collections. As he himself notes (Davis 2006, footnote 24) these coins are all unprovenanced and thus they are of no scientific value, whatever the legal and ethical problems involved in using that material.

The problem with this evidence is that it is not amenable to calculating an estimate of how many coins from Dacia are copies. I, therefore, instigated a programme of archaeometallurgical analysis. Metallurgical analysis of coins has usually been employed to determine the fineness or composition of issues in order to plot the pattern of debasements or changes in composition (*e.g.,* Walker 1976). In this case, we hoped to be able to distinguish between genuine *denarii* and copied *denarii* on the basis of their metallurgical composition. To do this, *denarii* from Romanian hoards, along with some imitations, some tetradrachms and the Stăncuţa silver bars, were sampled and analysed, and compared to coins from the British Museum and the Ashmolean Museum, Oxford. Table 3 provides a summary.

The technique chosen for this analysis was atomic absorption spectometry on samples taken from the core of the coins by drilling. This method avoids the problem of surface enrichment/depletion (Ponting 1994).

It was decided to obtain samples from 10% of coins in a selection of Romanian hoards. This proportion was chosen because we estimated that we would be able to sample 150 coins in the time available, and the hoards we originally wished to examine contained approximately 1,500 coins. The analyst, Dr. Matt Ponting, and I attempted to sample, and photographed 178 coins and objects during May 1992. Subsequently during 1994 further samples were taken from museum specimens in Britain.

[6] Davis (2006, pp. 323–3) discusses these die links without reference to my work which originally identified them.

origin	evidence	RRC	date of original
Tilişca	coin dies (obv. & rev.)	216/1	148 BC
Tilişca	coin die	245/1	134 BC
Tilişca	coin die	256/1	130 BC
Sarmizegetusa	coin die	266/1	126 BC
Poroschia	die-linked struck coins (6 ex.)	317/3b	104 BC
Tilişca	coin die	324/1	101 BC
Tilişca	coin die	350A/2/1	86 BC
Poroschia	die-linked struck coins (4 ex.)	350A/2	86 BC
Breaza	cast coin (2 ex.)	353/1	85 BC
Ludeşti	coin die	378/1a	81 BC
Poroschia	die-linked struck coins (21 ex.)	379/2	80 BC
Tilişca	coin die	382/1a	79 BC
Tilişca	coin dies (obv. & rev.)	382/1b	79 BC
Breaza	cast coin (2 ex.)	390/2	76 BC
Tilişca	coin die	396/1a	74 BC
Sarmizegetusa	coin die	407/2	68 BC
Poroschia	die-linked struck coins (21 ex.)	408/1a-b	67 BC
Breaza	cast coin (2 ex.)	433/1	54 BC
Breaza	cast coin (2 ex.)	452/2	48–47 BC
Braşov	coin die	'Caesar'	before 44 BC
Poroschia	die-linked struck coins (8 ex.)	494/23	42 BC
Breaza	cast coin (3 ex.)	517/5	41 BC
Sarmizegetusa	coin die	Tiberius, RIC $1^{(2)}$ pp. 93–95	AD 14–37

Table 2: Evidence for copies of coins from Romania. The rows are in order of date of the original issue.

type	no.	sample nos.
barbarous imitations	10	29, (30), 31, 32, (33), 34, 66, 70, 71, 72, 73, 186
tetradrachms of Thasos	5	35, 36, (37), 63, 64, 65
cast copies (Breaza)	5	38, 39, 40, 41, 42
struck copies (Poroschia)	6	81, 82, 98, 99, 111, 122
silver bars (Stăncuţa)	2	61, 62
British Museum and Ashmolean	24	179–185, 187–190, (191), 192–203
other *denarii* from Romania	165	all others

Table 3: Objects sampled for metallurgical analysis. Sample numbers in brackets were too small to be analysed, or those analyses which should not be relied upon.

The hoards analysed were chosen on numismatic and pragmatic grounds; details are given in Table 4. A formal method of random selection was not possible as the requirements for drilling precluded this — each flan had to be thick enough in least one area, it had to be reasonably flat, and could not be too brittle. Instead, the most suitable coin nearest to every tenth coin was selected, where the order of the coins was that in which they were stored or catalogued. Additionally, four cast coins were deliberately chosen from the Breaza hoard to ensure that some comparative data from known copies were available, and some deliberate imitations both unprovenanced and from hoards were examined. At this time, the die-linking of the Poroschia coins had not been observed and therefore no deliberate selection of them was undertaken. Some of these coins were, however, selected by the process described above and thus provide more comparative data.

The samples were taken from the cylindrical edge of the coins using a high-speed twist drill and a 0.6 or 0.8mm drill-bit. The initial surface material was discarded, and then the remaining drillings stored in small sample tubes until analysis. The samples were analysed in batches: the first 30 were analysed in late 1992 (Lockyear & Ponting 1993), the remainder, including comparative material from British museums, was analysed in the summer of 1994. The first batch of coins was analysed using a single solution method where the sample was partially dissolved in concentrated nitric acid to digest the silver and most of the other elements. Concentrated hydrochloric acid was then added to form aqua regia which should dissolve any tin and gold remaining (Lockyear & Ponting 1993, p. 9). This highly acidic solution was then diluted to 25ml (48% acid) for analysis by AAS.

The results from these first analyses were highly encouraging. However, there were some problems and the analyst changed technique slightly for the remainder of the coins. The second method required the use of two solutions: nitric acid for most elements, and a ‘high acid’ solution (aqua regia) for tin and gold. Smaller quantities of sample were used for the high acid analyses

hoard	no.	sampled	reference	reason
Zătreni	41	6	Chiţescu 1981, no. 215	early hoard in Muntenia
Poiana	152	20	Chiţescu 1981, no. 148	hoard from major settlement in Moldavia
imitations	—	6	Chiţescu 1981, nos. 11, 28, 84, 67, 165, 239	unprovenanced, for comparison to hoard material
Popeşti	?	3	in preparation	3 tetradrachms of Thasos, by request of Poenaru Bordea
Breaza	122†	19	Poenaru Bordea & Ştirbu 1971; Chiţescu 1981, no. 29	contains cast copies
Stăncuţa	34	9	Preda 1958; Chiţescu 1981, no. 188	mixed hoard of tetradrachms, *denarii* and silver bars
Voineşti	94	3	Ştirbu 1978, p. 90, no. 4;	by request of C. Ştirbu
Poroschia	552	66	PRS; Chiţescu 1980; Chiţescu 1981, no. 154	contained possible copies
Şeica Mică	348	44	Floca 1956; Chiţescu 1981, no. 193	hoard from Transylvania, used by Crawford in RRC

Table 4: Romanian hoards sampled May 1992. † Bucureşti lot.

than the nitric acid analyses. The results, mainly for the quantity of silver contained in these coins, are believed to be more reliable. Some samples from the first batch using a single solution were re-analysed using the two solution method to provide a comparison.

In the first batch twelve elements were measured: silver (Ag), copper (Cu), lead (Pb), gold (Au), zinc (Zn), antimony (Sb), cobalt (Co), bismuth (Bi), arsenic (As), nickel (Ni), tin (Sn) and iron (Fe). The last three elements (Ni, Fe and Sn) were consistently below the detection limit. For the second set of analyses arsenic was dropped as the analyst believed the results to be unreliable.

In analysing the data provision has to be made for elements where the concentration was sometimes below the detection limit. To say there is none of that element is incorrect, and some of the statistical techniques cannot cope with zero values. One method is to use a value calculated from half the detection limit. In AAS this limit varies from batch to batch which, along with the variable sample sizes available, created some problems with mechanically applying this method. As a result, these low values were calculated and assigned carefully using a variety of methods designed to prevent the statistical analyses erroneously highlighting coins because of these estimated values (Lockyear 1996b, 411–4).

The first stage was to 'clean' the data: after the removal of those coins too brittle to sample and those samples too small for analysis, 193 were left for analysis. Of these, sample 191 is considered unreliable and no particular interpretation should be placed upon it. Furthermore, three coins analysed in the pilot study were reanalysed with the later batches using the two solution method (samples 6, 41 and 56). This left 196 analyses on 193 objects: 191 coins and 2 silver bars. The coins from Romania are sample numbers 1–178, samples 179–203 are from UK museum collections.

The data were then subjected to univariate, bivariate and multivariate statistical analyses. In each case it was often very difficult to declare that an individual coin was a copy or genuine. Therefore, at each stage a list of coins was constructed about which we might be 'suspicious'. A formal method of dividing the probably genuine from the possible copies did not seem appropriate in the light of the data to be presented, and a exploratory approach was adopted.

The first stage of analysis was an examination of univariate dot-plots — a simple form of barchart — as recommended by Baxter (1994, pp. 28–30). Each element was plotted and the distribution examined and coins which had unusual amounts of an element noted (Lockyear 1996b, pp. 415–21). Table 5 presents the results of this examination. For any one element, the majority of the coins with 'suspicious' quantities are from Romania although it is interesting to note that even with known copies they do not necessarily show up in more than one element. Thus samples 38–42, all cast coins from Breaza, have unusually high levels of copper but only sample 39 has unusually high levels of zinc and bismuth, and sample 38 has high levels of iron. Apart from the five known cast copies from Breaza, three further coins are clearly copies principally based on their copper content (coins 47, 51 and 52).[7]

The four elements (apart from silver) which were recorded consistently enough across the samples were also plotted against date to check for any temporal variation (Lockyear 1996b, Figs. 14.18–19). None was clearly visible although there is a possibility that the quantity of copper in genuine coins increased after 80 BC, but only to between 0.5–1.0%.

The final stage of analysis was to look at the data either as a series of bivariate scattergrams or via a multivariate statistical technique. For this stage of the analysis we have only have five elements with sufficient data: silver, copper, gold, bismuth and lead. One problem in the analysis of this type of compositional data is known by statisticians as 'closure.' In data which is expressed as a percentage or a proportion the various values are not independent of each other. If, for example, silver forms 95% of the composition of a coin, the other elements cannot sum to more than the remaining 5%. If, however, silver is only 90% they can form 10%. If, for example, copper and lead were present in equal quantities in both coins, they

[7]The Principal Components Analysis of the first batch of 30 coins clearly separated these eight coins from the remainder of the samples (Lockyear & Ponting 1993).

	reason	n	samples (*denarii*)	samples (copies *etc.*)
Cu	$\geqslant$4%	33	10, 13, 22, 47, 51, 52, 57, 69, 77, 80, 84, 90, 91, 94 115, 116, 133, 152, 153, 154, 178, 200	29[1], 34[1], 38[2], 39[2], 40[2], 41[2], 42[2], 66[1], 70[1], 71[1], 186[1]
Pb	$\geqslant$0.85%	41	1, 18, 47, 49, 51, 52, 69, 74, 78, 80, 85, 86, 91, 110 115, 116, 129, 130, 131, 145, 154, 155, 160, 161, 163, 164, 166, 168, 171, 173, 174, 177, 181, 201	31[1], 32[1], 81[3], 98[3], 99[3], 111[3], 122[3]
Au	$\geqslant$0.72%	17	55, 56, 58, 77, 89, 107, 112, 119, 142, 150, 194, 195	62[4], 64[5], 66[1], 81[3]
Zn	$\geqslant$0.035%	7	8, 23, 47, 105, 202	39[2], 186[1]
Sb	AML, not batch 1	2	80, 83	
Co	AML, not batch 1	0		
Bi	$\geqslant$0.325%	15	1, 2, 3, 57, 59, 67, 68, 74, 154, 189	32[1], 34[1], 39[2], 62[4], 63[5]
Fe	AML	8	12, 19, 20, 109, 118, 138, 188	38[2]
Ni	AML	3	83, 86, 123	
Sn	AML	8	118, 119, 120, 121, 125, 127, 133, 134	

Table 5: Samples which appear to have extreme values based on the univariate analysis. AML= above maximum (worst) detection limit. [1]Imitations, [2]Breaza cast copies, [3]Poroschia struck copies, [4]silver bars, [5]tetradracms of Thasos.

	Axis			
	1	2	3	4
Eigenvalue	0.316	0.275	0.24	0.169
Perc. Var. Expl.	31.6	59.1	83.1	100

Table 6: Eigenvalues *etc.* from PCA of full metallurgical data set.

could form only 2.5% each in the first coin but 5% in the second. Dealing with this problem has proved controversial. Aitchison (1986) developed a method using log-ratios which was criticised by Tangri & Wright (1993). This critique in turn was rebuffed by Aitchison *et al.* (2002). A detailed comparative analysis was undertaken by Baxter (1992, 1995) and despite the criticisms, it appears that the simple expedient of omitting the major element, in this case silver, 'works' in the majority of cases where 'works' is defined as producing archaeologically intelligible patterns.

A Principal Components Analysis was therefore performed on four elements: copper, lead, gold and silver. The data were standardized before analysis resulting in the analysis of a correlation matrix (Table 6). The first two axes accounted for 59.1% of the variance in the data, not particularly high given that we are only dealing with four variables. Figure 5 is the biplot from this analysis. The points represent the samples, the arrows the contribution of each element to the plot and the correlation between elements and the axes. Close examination of the biplot reveals that the first axis is mainly representing the variation in the copper and lead levels of the samples, and then second axis appears to be representing the variation in the gold and bismuth concentrations. All four arrows are pointing to the right-hand side of the biplot — this is because the samples on the left-hand side of the plot are associated with the missing element silver, *i.e.,* they are very fine coins. Looking at the plot symbols we can see that the majority of the UK museum coins are in the top-left quadrant, the majority of the cast and struck copies are in the bottom right quadrant. The three points at the top of the biplot are three objects from the Stăncuţa hoard, all with high gold levels. Although the copies are clearly grouped in the biplot, there is no simple clear division in the remaining coins from Romania between genuine coins and copies.

The visualisation of distributions in crowded point patterns such as these is difficult. One solution is to use *kernel density estimates* (KDE Baxter & Beardah 1995; Bowman & Foster 1993; Lockyear 1999). When applied to bivariate data, KDEs can be used to produce a percentage contour plot. The 'contour' lines enclose a set proportion of the points, whilst minimising the area within which these points are contained. It is therefore possible to 'contour' separate bivariate point distributions and compare their distribu-

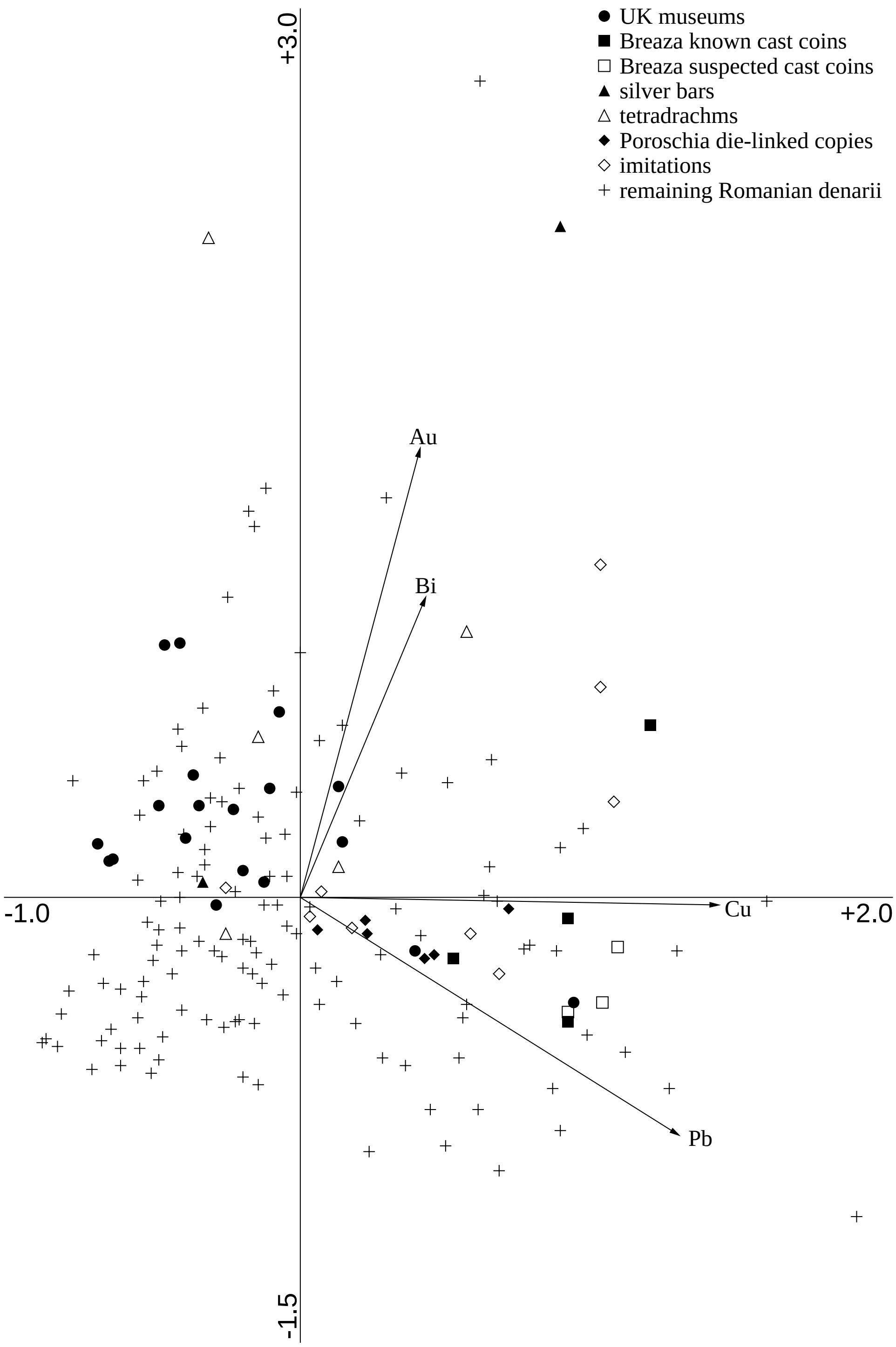

Figure 5: Biplot from PCA of full metallurgical data set omitting sample 191. 1st and 2nd principal axes.

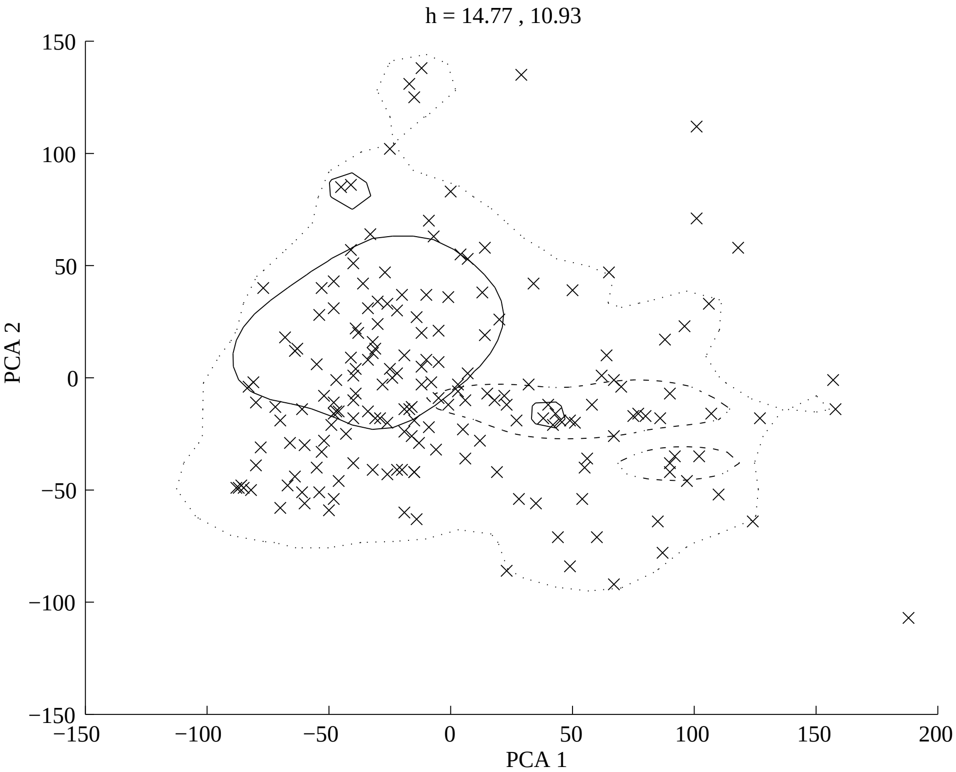

Figure 6: Bivariate Kernel Density Estimate contour plot. All lines are 95%; all *denarii* (dotted line), UK museums (solid line) and cast/struck copies (dashed line). Samples 58 & 191 omitted. NB: the scores on the principal axes have been multiplied by 100.

tions not via crowded point maps, but via the contour maps. Fig. 6 presents the 95% contours for all *denarii*, the cast and struck copies, and the UK museum coins.[8] As can be seen, the copies and the UK museum coins form two almost completely distinct groups. Sample 58 was omitted from this map as it was such an extreme outlier it distorted the map.

It was decided to divide the *denarii* in these analyses into four categories the first two of which were: 'far-out' samples which had PCA scores of >0.5 on the x-axis, and >1.15 or <-0.35 on the y-axis and 'core' coins which were within the 95% contour of the UK museum material. An examination of the three samples for which there were two sets of analyses showed that there was a 0.25–0.31 difference in their co-ordinates on the PCA biplot, mainly on the x-axis. The coins that were left were therefore divided into those outside the 95% contour of UK museum coins but within a band 0.31 units from the contour ('penumbra' samples), and those outside this band ('outside' samples). Table 7 lists all the coins by these four categories along with their scores on the first two principal axes and the quantities used in the analysis.

Various observations should be highlighted. Firstly, only a single UK museum coin lies in the far-out category, and a further coin in the outside category. In the case of the former (coin no. 181) it seems a distinct possibility that this represents a further copy within the Ashmolean coin collection. Secondly, of the cast coins from Breaza, all lie in the 'far-out' category, but the struck coins from Poroschia mainly lie in the penumbra or outside categories. The imitations occur in most groups including the core group. Thirdly, Table 7 also indicates coins highlighted by the univariate plots and as can be seen, the majority of the coins in the far-out category were highlighted at that stage of the analysis. Fourthly, some samples with apparently high copper levels occur in the core group. These samples usually have very low quantities of the other elements, *i.e.,* they are still relatively fine. The fact that all the elements are represented on the right-hand of the ordination diagram (Fig. 5), which means that the left-hand side represents 'lack' of elements (*i.e.,* purer silver), suggests that the process of omitting the silver from the analyses has not entirely solved the problem of closure. The results did, however, seem to make archaeological sense and are therefore of use.

The final stage, therefore, is to estimate how many copies were in each hoard. To do this I decided to use the number of coins in the far-out category as the total number of copies identified. No doubt some of the coins in this category are in fact genuine, but there is also a likelihood that some of the coins in the core category are copies as shown by the fact that some of the

[8] These plots were produced using MATLAB and the KDEDEMO2 macros written by Christian Beardah and available over the internet from Nottingham Trent University (Beardah & Baxter 1996). They were produced using the *normal* kernel density estimate routine and the *solve the equation 2* method of determining 'h'. The latter was chosen as it did not appear to oversmooth the contour lines.

imitations have the same metallurgical composition to the main mass of points.

For the Breaza hoard I suggested above that a further three coins were copies on the basis of their high copper levels on a par with the five cast copies deliberately sampled. A further two coins appear in the far out-category. The first, no. 43 appeared odd in the the pilot analyses mainly due to the presence of minor trace elements (Lockyear & Ponting 1993). These elements have been omitted from this analysis but the coin still appears to be unusual because it is too pure! The second coin is in the far-out category because it has high levels of gold. If we accept all five coins as copies we can estimate of the proportion of copies in the hoard by a simple scaling:

$$p = x/n$$

where x is the number of copies in the sample, and n is the sample size. Obviously, this can be converted to a percentage by multiplying by 100. For the Breaza hoard 14 coins not known to be copies were sampled which gives us:

$$p = (5/14) = 0.36$$

To obtain an estimate of the total number of copies:

$$X = pN$$

where N is the size of the hoard. Therefore, in the Breaza example:

$$X = 0.36 \times 111 = 39.6$$

where 111 is the total population available in the Breaza hoard. This figure is only an estimate of the number of copies in the hoard and an indication of the range of likely figures is needed. We can do this by calculating confidence limits. As our sample sizes are small the method outlined by Shennan (1988, pp. 310–313) is inappropriate. The 95% and 99% confidence limits for proportions of small samples can be obtained from Table P of Rohlf & Sokal (1995). For Breaza this gives us a lower limit of 15.2% and and upper limit of 62.9% at the 95% confidence level. Thus there is a 95% probability, or 19 in 20 chances, that the number of copied coins in the remaining 111 of the Breaza hoard is between 17–70. To this we should add the 11 already identified coins giving us 28–87 coins out of 122, or between 25–78% of the hoard. It should be noted that these estimates do not take into account the finite size of the hoard (Shennan 1988, p. 303f.).

For the Poroschia hoard we find that of the 66 coins sampled, 4 were known imitations which leaves us with 62 samples. Unlike Breaza, where cast coins were deliberately chosen, the struck coins were chosen by the usual process and so they can be included in the calculations. Of the 62 samples, 30 were in the far-out category which gives us a mean estimate of 48%. Calculating the 95% confidence limits, this time using the formula given by Shennan (1988, p. 311) and using the finite correction factor, we get 95% limits of ± 11%, or between 205–327 coins! If we use an ultra-conservative estimate of only coins with more than 3% copper we get 10 coins which gives us a mean estimate of 16% ± 8%, or between 44 and 132 coins in total.

As Davis (2006, p. 325) argues, however, these figures may be unusually high because I have deliberately sampled hoards with known copies. The results from the Şeica Mică hoard are therefore of great importance because until now there had been no proof that this hoard contained any copies. If we count the samples which are 'far-out' in this hoard we get 16 coins from 44, or 36.36% with 95% limits of 36.3% ± 12.4% or between 83 and 169 of the total hoard. This figure seems very high. If we take an ultra-conservative line and only accept those 6 coins with very high copper levels as copies we still get 13.6% ± 8.8%, or 17–78 coins. These figures are in line with those from Poroschia and Breaza.

For the Poiana hoard, we only have 15 samples in total of which there are 6 far-out samples which gives us a mean estimate of 40%. Using Table P in Rohlf & Sokal (1995) we get 95% limits of 19–67%, which translates to 29–101 coins. If we were to restrict ourselves to coins with >3% copper we would have only 1 coin which gives a mean estimate of 6.6% and 95% limits of 0.3%–30%, or 0.5–45 coins.

For the Stăncuţa hoard we have 9 samples, but of those we only have 4 *denarii*. Of those 4 *denarii*, two are far-out. One of those has >5% copper, as well as a low weight, and the other has high levels of gold. This last is particularly suggestive as the only other objects in the assemblage with high levels of gold are one of the silver bars and one of the tetradrachms. If we accept both of these coins as copies we get a mean estimate of 50%, but confidence limits of 9–90%.

Zătreni seems to have one or two copies out of the six samples. Due to the very small number of samples this gives us a wide range at the 95% level: either 0.8–59% or 6–73%. The three coins from the Voineşti hoard were sampled at the request of the curator. One was a known imitation leaving us with a sample of two from which no useful limits can be derived.

The metallurgical results have proved a difficult data set to analyse with many problems and pitfalls. The above estimates all have rather wide confidence limits and thus the exact proportion of copied coins in the hoards is still extremely unsure. It has been suggested that any further work would be more profitably done using inductively coupled plasma spectrometry (ICPS). Any further work would, however, benefit from a large scale analysis of *denarii* from outside Romania, preferably Italy, to replace the results produced by (Walker 1980) using x-ray fluorescence.

We can be confident that there were more copies in the Breaza and

Poroschia hoards than Chiţescu or Crawford had allowed for, and there is good reason to believe that there are copies in the Poiana, Stăncuţa and Şeica Mică hoards; the Zătreni hoard remains a marginal case. It would appear that the level of copying is around 30% taking a cautious line, or about 14% taking an ultra-conservative line. Obviously, extrapolating to the entire Dacian corpus from a small number of hoards is not ideal, and a further programme of analysis is needed to improve upon our estimates.

4 Conclusions

We have been able to answer two of the basic, but vital, questions regarding Roman Republican *denarii* in Iron Age Dacia. Firstly, the principal period of import was around about 75–65 BC, with perhaps a secondary peak during the late 40s BC although this is more difficult to be certain about because of the increased levels of coin production within the Roman state at that time. Secondly, we can see that copying of *denarii* seems to have been remarkably prevalent and widespread. The challenge now is to situate these observations within a wide-ranging reinterpretation of Dacian society prior to the Trajanic invasions.

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A Constructing Figure 1.

In constructing Figure 1 a variety of difficulties was encountered which it would be instructive to note here. Firstly, the die counts listed by Moisil and Depeyrot did not always agree with those I had in my database. Comparing these to RRC I found that in a few cases I had an error, in a few cases Moisil and Depeyrot were in error but in most cases it was because I had taken my data from Table L in RRC vol 2, and Moisil and Depeyrot had taken it from the main catalogue. Table L lists Crawford's 'corrected' die counts, the main catalogue the actual die counts. For purposes of comparison the graph was constructed using the counts from the main catalogue but with the corrections noted below. The second problem concerned dates. Where Crawford gives a date range for an issue, I have used the start of the date range in my previous work (although both dates are stored in my database). On the whole, Moisil and Depeyrot lists these issues separately, but in the years 84–74 BC Moisil and Depeyrot lump issues together where they are given date ranges, but not consistently under the start or end dates. In the end I had to extract the data from my database by issue and add it up in Excel by the groups used by Moisil and Depeyrot. Because the two data sets were of different sizes I first converted them to permilles before calculating the ratios so that they would be directly comparable. One should also note that Crawford concentrated his die analysis on the period 157–50 BC and therefore the data Moisil and Depeyrot use outside this date range should be treated with even more caution.

The errors in Moisil & Depeyrot (2003, Annexe, p. 17–18) are: RRC 226–8, 155 dies not 151; RRC 306–8 445 not 325; RRC 309 omitted; RRC 314 & 316 487 not 455; RRC 319–20 345 not 253; RRC 335 343 not 255; RRC 348–9 (347 no known dies) 476 not 409; RRC 360–372 1667 not 1646.

B The metallurgical data

Table 7: Results from metallurgical analysis. Starred coins were highlighted by univariate analyses. [1]Imitations, [2]Breaza cast copies, [3]Poroschia struck copies, [4]silver bars, [5]tetradracms of Thasos. PCA values ×100.

No.	hrd.	ref.	date	wght.	PCA1	PCA2	Cu	Pb	Au	Bi
'Core' samples										
2*	ZAT	362/1	82	3.79	−5	21	0.710	0.710	0.154	0.398
6	ZAT	367/5	82	3.89	3	−3	1.690	0.800	0.465	0.131
6a	ZAT	367/5	82	3.89	−12	20	1.566	0.597	0.534	0.145
7	1PO	200/1	155	3.61	−29	−18	2.540	0.387	0.242	0.100
8*	1PO	273/1	124	3.74	−83	−4	0.274	0.152	0.237	0.107
23*	1PO	336/1a–c	92	3.51	−5	7	2.326	0.580	0.417	0.154
28	1PO	380/1	80	3.80	−5	−9	1.088	0.822	0.385	0.154
35[5]	POP	—	0	0.00	13	11	3.417	0.580	0.446	0.154

Table 7 continued from previous page...

No.	hrd.	ref.	date	wght.	PCA1	PCA2	Cu	Pb	Au	Bi
36[5]	POP	—	0	0.00	−25	−12	1.360	0.580	0.270	0.154
44	BRZ	337/3	91	3.90	−39	22	0.920	0.420	0.498	0.132
45	BRZ	340/1	90	3.70	−32	11	0.730	0.530	0.366	0.189
46	BRZ	344/1b	89	3.90	−47	−1	1.750	0.310	0.476	0.019
48	BRZ	405/3b	69	3.95	−8	−2	0.700	0.830	0.433	0.159
50	BRZ	444/1a	49	3.75	−31	13	0.980	0.510	0.445	0.143
53	BRZ	517/2	41	3.80	−22	2	1.420	0.560	0.372	0.152
54	BRZ	RIC 1[(2)], Augustus 272	29	3.75	−53	40	0.590	0.260	0.474	0.188
59*	STN	342/5b	90	3.86	−14	27	1.360	0.580	0.566	0.154
60	STN	274/1	123	3.77	7	53	3.459	0.356	0.507	0.253
61[4]	STN	—	0	0.00	−33	6	3.333	0.150	0.297	0.119
65[5]	STN	—	0	14.51	−14	54	3.681	0.158	0.682	0.110
70[1]*	PRS	*cf.* 317/3a	104	3.99	3	−6	4.519	0.379	0.378	0.074
72[1]	PRS	*cf.* 372/1	81	4.89	−25	4	1.232	0.549	0.361	0.163
73[1]	PRS	*cf.* 379/2	80	3.47	7	2	2.387	0.721	0.498	0.116
74**	PRS	220/1	145	3.57	−12	−3	2.030	0.580	0.342	0.154
79	PRS	412/1	64	4.02	−48	−16	0.850	0.470	0.373	0.050
87	PRS	324/1	101	3.80	−30	34	1.081	0.439	0.537	0.166
88	PRS	326/1	101	3.74	−48	−11	0.666	0.489	0.415	0.052
89*	PRS	341/2	90	3.74	−1	36	3.820	0.344	0.727	0.045
96	PRS	421/1	59	3.95	−47	−15	1.269	0.414	0.368	0.045
97	PRS	431/1	55	3.90	−46	−15	1.334	0.408	0.366	0.046
107*	PRS	299/1b	111	3.91	−40	51	0.706	0.396	0.865	0.043
108	PRS	313/1c	106	3.92	−34	−15	0.839	0.613	0.443	0.048
112*	PRS	319/1	103	3.96	−41	57	0.593	0.383	0.892	0.048
117	PRS	248/1	133	3.80	−52	−8	0.128	0.470	0.162	0.208
118**	PRS	243/1	134	3.79	−26	33	0.464	0.546	0.414	0.258
120*	PRS	281/1	119	3.83	−54	28	0.125	0.330	0.319	0.244
121*	PRS	203/1b	153	3.56	−32	16	0.656	0.510	0.318	0.234
123*	PRS	317/3a	104	3.84	−41	9	0.570	0.480	0.371	0.163
125*	PRS	337/3	91	3.90	−48	43	0.379	0.346	0.606	0.145
126	PRS	340/1	90	3.90	−20	37	1.089	0.514	0.505	0.216
127*	PRS	378/1b	81	3.91	−19	−14	0.531	0.761	0.257	0.194
128	PRS	372/2	81	3.93	−17	−14	1.092	0.709	0.290	0.161
137	SEI	273/1	124	3.70	−55	6	0.360	0.364	0.236	0.202
140	SEI	300/1	110	3.86	−61	−14	0.319	0.415	0.370	0.047
143	SEI	324/1	101	3.77	−24	0	1.123	0.634	0.565	0.044
144	SEI	316/1	105	3.96	−34	8	0.488	0.588	0.533	0.087
146	SEI	340/1	90	3.80	−40	1	0.644	0.505	0.359	0.139
148	SEI	337/3	91	3.98	−27	47	0.744	0.493	0.676	0.157
149	SEI	344/2a	89	3.87	20	26	2.942	0.690	0.628	0.138
150*	SEI	342/5b	90	3.77	4	55	3.391	0.380	0.726	0.137
151	SEI	342/5b	90	3.94	−10	8	2.708	0.472	0.411	0.134
156	SEI	354/1	84	3.77	−15	−19	1.358	0.704	0.277	0.149
157	SEI	350A/2	86	3.80	−26	−20	1.520	0.561	0.213	0.148
158	SEI	363/1d	82	3.65	−40	−10	0.676	0.525	0.271	0.149
159	SEI	364/1d	83	3.77	−16	−13	1.349	0.678	0.312	0.145
165	SEI	407/2	68	3.71	−30	24	0.886	0.508	0.549	0.133
167	SEI	422/1b	58	3.87	−80	−11	0.568	0.174	0.303	0.044
175	SEI	511/3a	42	3.88	−39	−7	1.944	0.343	0.264	0.124

Table 7 continued from previous page...

No.	hrd.	ref.	date	wght.	PCA1	PCA2	Cu	Pb	Au	Bi
176	SEI	517/2	41	4.05	−40	−18	1.487	0.442	0.277	0.093
179	—	379/1	80	3.81	−39	4	1.229	0.417	0.343	0.145
180	—	379/1	80	3.89	14	19	1.496	0.839	0.439	0.252
182	—	340/1	90	3.82	−38	20	0.824	0.421	0.380	0.195
183	—	340/1	90	3.88	−64	12	0.097	0.278	0.186	0.239
184	—	340/1	90	3.98	−48	31	0.561	0.325	0.356	0.235
185	—	408/1a–b	67	3.96	−28	−3	0.602	0.580	0.059	0.318
187	—	408/1a–b	67	3.90	−31	−18	1.089	0.580	0.222	0.154
188*	—	342/5b	90	3.99	−7	63	2.754	0.319	0.660	0.197
189*	—	352/1c	85	0.00	13	38	1.625	0.690	0.209	0.435
190	—	RIC $1^{(2)}$ 1, Augustus 543a	31	4.00	−68	18	0.524	0.142	0.130	0.268
192	—	200/1	155	4.06	−10	37	2.851	0.333	0.402	0.237
193	—	275/1	123	3.84	−63	13	0.147	0.278	0.175	0.251
196	—	337/3	91	3.97	−34	31	0.922	0.413	0.424	0.216
197	—	342/5b	90	3.99	−36	42	1.087	0.370	0.639	0.127
198	—	344/1a	89	3.87	−22	30	0.971	0.564	0.637	0.121
199	—	350A/2	86	4.11	−12	5	1.780	0.577	0.319	0.201
201*	—	494/23	42	4.04	38	−18	2.662	1.039	0.411	0.153
202*	—	517/2	41	3.47	−19	10	1.360	0.580	0.432	0.154
203	—	RIC $1^{(2)}$ 1, Augustus 272	29	3.73	−81	−2	0.429	0.145	0.258	0.102
'Penumbra' samples										
5*	ZAT	275/1	123	3.59	−60	−30	0.220	0.450	0.098	0.142
10*	1PO	342/4a–5b	90	3.51	34	42	4.262	0.580	0.685	0.154
15	1PO	382/1b	79	3.56	−1	−12	1.970	0.716	0.280	0.181
19*	1PO	139/1	189	3.34	−78	−31	0.282	0.297	0.203	0.042
21	1PO	291/1	114	4.31	14	58	3.224	0.438	0.480	0.310
29[1]*	—	*cf.* 238/1	136	3.24	18	−10	4.280	0.540	0.239	0.174
49*	BRZ	442/1a	49	3.75	12	−28	1.200	1.030	0.340	0.146
56*	BRZ	RIC $1^{(2)}$ 1, Augustus 174	12	3.90	−9	70	1.230	0.550	0.926	0.126
56a	BRZ	RIC $1^{(2)}$ 1, Augustus 174	12	3.90	−33	64	0.981	0.360	0.809	0.123
67*	VOI	340/1	90	3.80	0	83	1.500	0.440	0.379	0.477
82[3]	PRS	408/1a–b	67	3.48	6	−10	1.940	0.840	0.573	0.044
83**	PRS	415/1	62	4.02	−43	−25	0.838	0.525	0.200	0.123
84*	PRS	463/1a	46	4.27	15	−7	4.095	0.551	0.365	0.117
93	PRS	340/1	90	3.86	−19	−24	1.019	0.759	0.437	0.045
94*	PRS	344/3	89	3.97	27	−19	5.129	0.575	0.405	0.047
99[3]*	PRS	379/2	80	3.46	22	−8	2.800	0.850	0.560	0.067
103	PRS	277/1	122	3.88	−77	40	0.053	0.150	0.673	0.047
109*	PRS	362/1	82	3.73	−49	−21	0.407	0.540	0.371	0.045
122[3]*	PRS	317/3b	104	3.51	23	−12	2.820	0.870	0.544	0.062
129*	PRS	383/1	79	4.05	32	−3	2.258	0.979	0.384	0.218
134*	PRS	350A/2	86	3.85	−9	−22	1.930	0.688	0.284	0.125
135	SEI	275/1	123	3.60	−66	−29	0.055	0.420	0.132	0.122
136	SEI	271/1	125	3.55	−72	−13	0.055	0.304	0.144	0.156
147	SEI	337/3	91	3.78	−70	−19	0.198	0.338	0.205	0.105
152*	SEI	345/1	88	3.95	75	−17	6.798	0.764	0.325	0.148

Table 7 continued from previous page. . .

No.	hrd.	ref.	date	wght.	PCA1	PCA2	Cu	Pb	Au	Bi
155*	SEI	352/1a	85	3.75	5	−23	1.307	0.938	0.364	0.130
161*	SEI	382/1b	79	4.05	−6	−32	1.004	0.895	0.276	0.132
162	SEI	383/1	79	4.11	−13	−29	1.534	0.719	0.186	0.161
169	SEI	443/1	49	3.83	−52	−28	1.418	0.370	0.259	0.042
170	SEI	449/1b	48	3.83	−16	−26	2.025	0.625	0.279	0.099
172	SEI	444/1b	49	3.86	−53	−33	1.021	0.438	0.245	0.042
194*	—	299/1b	111	3.86	−45	85	0.392	0.250	0.858	0.163
195*	—	317/3a	104	3.40	−41	86	0.418	0.272	0.765	0.224
Outside samples										
3*	ZAT	299/1b	111	3.61	−25	102	0.430	0.330	0.610	0.399
22*	1PO	290/1	114	3.71	40	−12	5.840	0.580	0.459	0.046
41a*	BRZ	390/2	76	3.55	49	−19	5.977	0.643	0.311	0.116
98[3]*	PRS	379/2	80	3.42	42	−21	3.360	1.010	0.546	0.055
111[3]*	PRS	408/1b	67	3.51	45	−19	3.420	1.020	0.545	0.066
200*	—	463/1a	46	4.02	43	−16	4.421	0.815	0.389	0.123
'Far-out' samples										
1**	ZAT	385/1	78	4.07	86	−18	1.260	1.670	0.269	0.380
4	ZAT	284/1a	117	3.59	−60	−56	0.330	0.550	0.170	0.009
12*	1PO	340/1	90	3.78	−40	−38	0.996	0.593	0.272	0.042
13*	1PO	348/2	87	3.95	77	−16	7.607	0.668	0.356	0.112
14	1PO	362/1	82	3.44	−55	−40	0.441	0.535	0.222	0.045
16	1PO	382/1a–b	79	3.83	−19	−60	1.231	0.801	0.055	0.116
18*	1PO	450/2	48	3.91	188	−107	2.692	2.811	0.429	0.154
20*	1PO	289/1	115	3.47	−82	−50	0.298	0.305	0.065	0.042
31[1]*	—	*cf.* 340/1	90	4.16	67	−26	3.692	1.192	0.410	0.154
32[1]**	—	*cf.* 389/1	76	3.95	101	71	1.600	1.390	0.176	0.762
34[1]**	—	*cf.* 319/1 & 280/1	103	3.91	101	112	4.630	0.820	0.367	0.704
38[2]**	BRZ	517/5a	41	3.60	51	−20	6.013	0.687	0.443	0.045
39[2]*	BRZ	517/5a	41	3.90	118	58	7.490	0.790	0.434	0.424
40[2]*	BRZ	517/5a	41	3.00	90	−7	7.450	0.800	0.476	0.113
41[2]*	BRZ	390/2	76	3.55	80	−17	7.120	0.770	0.383	0.115
42[2]*	BRZ	390/2	76	3.35	90	−42	7.980	0.840	0.371	0.029
43*	BRZ	289/1	115	3.80	−50	−59	0.120	0.670	0.062	0.086
47([2])***	BRZ	382/1b	79	3.50	107	−16	7.610	0.960	0.408	0.148
51([2])**	BRZ	463/3	46	4.10	102	−35	8.040	0.930	0.448	0.036
52([2])**	BRZ	494/24	42	3.40	90	−38	7.370	0.920	0.397	0.047
55*	BRZ	RIC 1[(2)] 1, Augustus 410	13	4.05	−15	125	0.760	0.360	1.052	0.252
57**	STN	348/3	87	3.57	65	47	5.970	0.546	0.409	0.330
58*	STN	344/1a–c	89	3.86	61	275	1.923	0.580	2.442	0.154
62[4]**	STN	—	0	0.00	87	226	3.951	0.580	1.652	0.402
63[5]*	STN	—	0	15.71	56	90	3.478	0.701	0.618	0.429
64[5]*	STN	—	0	16.02	−31	223	0.085	0.106	1.991	0.074
66*	VOI	—	211	0.00	106	33	7.770	0.790	0.739	0.131
68[1]*	VOI	RIC 1[(2)] 1, Augustus 134a	18	3.79	29	135	0.450	0.710	0.621	0.626
69**	PRS	517/2	41	2.50	127	−18	5.571	1.494	0.630	0.131
71[1]*	PRS	*cf.* 392/1b	75	5.01	58	−12	4.997	0.846	0.354	0.169

Table 7 continued from previous page...

No.	hrd.	ref.	date	wght.	PCA1	PCA2	Cu	Pb	Au	Bi
75	PRS	336/1c	92	3.83	−48	−54	0.580	0.610	0.080	0.083
76	PRS	340/1	90	3.86	−32	−41	1.290	0.622	0.183	0.087
77**	PRS	341/2	90	3.90	50	39	5.690	0.540	0.735	0.102
78*	PRS	391/3	75	3.90	56	−36	2.490	1.300	0.395	0.142
80***	PRS	342/5a–b	90	3.64	110	−52	4.981	1.509	0.394	0.123
81[3]**	PRS	379/2	80	3.53	70	−4	3.171	1.283	0.782	0.054
85*	PRS	494/28	42	3.89	35	−56	1.635	1.312	0.399	0.050
86**	PRS	321/1	102	3.83	−15	−42	0.724	0.875	0.227	0.111
90*	PRS	345/1	88	3.73	67	−1	7.192	0.604	0.560	0.045
91**	PRS	354/1	84	3.92	124	−64	7.417	1.332	0.372	0.044
92	PRS	337/3	91	3.83	−22	−41	1.457	0.716	0.288	0.044
95	PRS	354/1	84	3.99	−26	−43	1.148	0.729	0.279	0.043
100	PRS	268/1a	126	3.74	−70	−58	0.268	0.449	0.054	0.047
101	PRS	259/1	129	3.60	−86	−48	0.143	0.282	0.065	0.046
102	PRS	275/1	123	3.81	−67	−48	0.145	0.475	0.134	0.048
104	PRS	282/1	118	3.82	−85	−49	0.155	0.293	0.056	0.049
105	PRS	285/2	116	3.70	−80	−39	0.102	0.307	0.065	0.089
106	PRS	291/1	114	3.88	−87	−49	0.052	0.293	0.061	0.045
110*	PRS	366/4	82	3.93	67	−92	0.156	1.969	0.392	0.048
113	PRS	350A/2	86	4.18	19	−42	3.492	0.808	0.316	0.048
114	PRS	350A/2	86	3.66	−20	−41	1.302	0.751	0.298	0.049
115**	PRS	480/6	44	3.87	54	−54	4.511	1.044	0.338	0.039
116**	PRS	528/3	39	3.86	157	−1	9.538	1.101	0.446	0.228
119**	PRS	241/1a	135	3.71	−12	138	0.170	0.443	1.123	0.286
124	PRS	297/1a	112	3.85	−88	−49	0.051	0.276	0.053	0.044
130*	PRS	384/1	79	3.91	−15	−42	0.830	0.869	0.239	0.104
131*	PRS	386/1	78	3.62	60	−71	0.834	1.699	0.301	0.132
132	PRS	329/1a	100	3.80	−64	−44	0.235	0.482	0.170	0.047
133**	PRS	348/2	87	3.28	64	10	6.899	0.553	0.437	0.154
138	SEI	289/1	115	3.62	−54	−51	0.123	0.599	0.060	0.108
139	SEI	286/1	116	3.57	−61	−51	0.110	0.537	0.057	0.096
141	SEI	299/1a	111	3.66	−46	−46	0.000	0.686	0.135	0.103
142*	SEI	317/3a	104	3.71	−17	131	0.176	0.412	1.074	0.274
145*	SEI	334/1	97	3.63	−14	−63	0.050	1.039	0.064	0.154
153*	SEI	345/1	88	3.74	88	17	7.417	0.682	0.461	0.199
154**	SEI	348/3	87	3.59	96	23	5.393	1.021	0.423	0.326
160*	SEI	366/4	82	3.96	55	−40	0.126	1.659	0.420	0.188
163*	SEI	374/1	81	4.01	44	−71	3.004	1.209	0.177	0.093
164*	SEI	387/1	77	3.88	28	−54	1.246	1.262	0.264	0.129
166*	SEI	429/2b	55	3.90	23	−86	1.093	1.357	0.203	0.046
168	SEI	442/1a	49	3.84	49	−84	0.874	1.649	0.337	0.043
171*	SEI	449/1a	48	3.72	97	−46	3.101	1.665	0.548	0.093
173*	SEI	453/1a	47	3.87	87	−78	3.989	1.512	0.210	0.113
174*	SEI	467/1a	46	3.73	6	−36	2.169	0.852	0.273	0.111
177*	SEI	494/23	42	3.93	85	−64	2.289	1.709	0.345	0.140
178*	SEI	348/1	87	3.80	62	1	7.446	0.464	0.295	0.177
181*	—	379/2	80	3.92	92	−35	3.735	1.440	0.289	0.241
186[1]**	—	408/1a–b	67	3.39	158	−14	12.75	0.679	0.402	0.100

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