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Imitations of Roman Republican *Denarii*: New Metallurgical Data

Plate 34

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M. Schreiner,** M. Radtke and U. Reinholz****

This article presents the results of scientific analyses performed on nine ancient imitations of Roman Republican silver *denarii*, which are part of a group commonly referred to as "Geto-Dacian" imitations, and discusses the data in a broader context. The coins were dissected and analyzed for their composition in the core with synchrotron micro X-ray fluorescence analysis (μ-SRXRF); their microstructure was examined with a scanning electron microscope (SEM) using backscattered electrons. Micrographs of all the cross-sections are published. The majority of the coins were found to have a high standard of fineness of more than 93% silver, which is in good agreement with the few modern analyses of this class of coinage published up to now (performed with a different analytical method, *viz.* atomic absorption spectrometry, AAS). The coins were also analysed for their main impurities (Au, Pb, Bi), and this data was compared with trace metal signatures of published groups of Republican *denarius* imitations as well as official Roman *denarii*.

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1. Introduction

The study of contemporary imitations of ancient coinages has become an integral part of scholarly numismatic research for quite some time.[1] Work on copies of course yields information of a different quality, as compared to the study of the prototypes, at least to some extent. Since the typology of imitative coins is, by its very nature, derivative, and since their production often does not seem to have followed strict systems or straightforward work plans, studies of these coins are bound to have a different focus than studies of so-called 'official' or 'regular' coinages of the ancient world. In most cases, the issuing authority responsible for contemporary copies cannot be determined, and often even the broader geographical attribution of imitative series remains in doubt. Chronology is another notoriously problematic point. If the prototype(s) of an imitative coin can be identified with certainty, this provides no more than a *terminus post quem* for the production of the imitation—we shall return to this below. In some instances, even the function and purpose of imitative series is disputed: suffice it to cite here the 'fraud or necessity' debate recurring regularly in scholarship with regard to imitations of Roman Imperial bronze coins.[2]

It is therefore clear that research on imitative coinages is, methodologically, probably one of the greatest challenges in numismatics. From the economic historian's point of view, however, it is by all means one of the key fields of the discipline. In some periods of ancient history, imitative coinages make up a significant part of the coins used in given areas,[3] so that their proper evaluation is an essential prerequisite to understanding the economic realities of ancient coin circulation.

Imitations of Roman Republican *denarii* have always held a special place in the study of ancient copies, for various reasons. Although there are several different classes of contemporary imitations of Republican-type coins, among which the compact Eraviscan group from Pannonia may be singled out,[4] the bulk of these coins has traditionally—and correctly—been associated with Dacia: indeed, the majority of imitative coins of this kind seems to be found in modern Romania.[5] This coinage came to be known more thoroughly only through the study of some

1 The current volume of the *Survey of Numismatic Researc*h (covering the years 2002–2007) is the first to contain sections dedicated specifically to "Imitations of Greek Coinages" (Arnold-Biucchi 2009) as well as to "Imitations of Roman Coins" (Peter 2009).

2 See, most recently, Woytek 2010: 125–127.

3 An instructive example is provided by the material from Carnuntum (Lower Austria), where about 50% of the bronze coins of the emperors Septimius Severus and Caracalla which were studied are cast copies (so-called "Limesfalsa"); see Pfisterer 2007: 678–680 (with diagram 11.6).

4 See, most recently, Haupt and Nick 1997, Freeman 1998 and Kolniková 2005.

5 For a distribution map of *denarius* imitations from Romania (in hoards as well as isolated finds), see Chițescu 1981: Map 3 (to be used in conjunction with her listing, pp. 316–330).

important Romanian hoards.[6] To the west, Dacian imitations spread to Pannonia[7] and recently, attention has been drawn to the occurrence of specimens of this large group in Moesia and Thrace (modern Bulgaria) as well,[8] but this does not substantially change the overall picture. All the copies from these parts of Central and Eastern Europe are to be interpreted in the context of a most peculiar phenomenon, which has continuously been attracting scholarly attention at least since the 1970s, *viz.* the occurrence of large numbers of official Roman Republican *denarii* in Romania.[9] Since Dacia became part of the Roman Empire only under the emperor Trajan (in AD 106), we are dealing here with a remarkably early, massive penetration of non-Roman territory by Roman coinage. Despite repeated claims by distinguished scholars—mostly from Romania—that these silver coins were imported into the country already from the middle or the end of the second century BC onwards,[10] this is most probably not the case: no hoards of Roman Republican coins closing before 90 BC have been recorded in Dacia so far,[11] and Kris Lockyear was doubtless right in concluding, on the basis of the currently available hoard evidence, that "the principal period of import was around about 75–65 BC".[12] He thereby slightly modified the date of the "mid or late 60s BC" advocated by Michael Crawford,[13] who believed that the sudden influx of Roman

6 The Poroschia hoard (Moisil and Depeyrot 2003: no. 126; Chițescu 1980; Davis 2010) and the Breaza hoard (Moisil and Depeyrot 2003: no. 168; Poenaru Bordea and Știrbu 1971) may be singled out here, since they are of a particular methodological relevance. For the frequent occurrence of imitations in hoards of official *denarii* from Romania in general, see Chițescu 1981: 52, as well as Moisil and Depeyrot 2003, passim.

7 Two Republican *denarius* imitations (one of which neatly fits into the "Dacian" group) have come to light as far in the west as the area of Carnuntum in the modern province of Lower Austria (Woytek 2007: 520f.). See also Popović 1973–1974: 11 for the evidence from Hungary. A small hoard of seven Republican *denarii*, two of which are imitations, was discovered in archaeological excavations at Gomoglava, in the village of Hrtkovci in the Serbian province of Vojvodina (Borić-Brešković and Popović 2006: 37f.). Unfortunately, we do not have hard and fast evidence for the provenance of the hoard consisting exclusively of *denarius* imitations in the Belgrade National Museum. This hoard, which was originally published by Popović 1973–1974 (see now also Borić-Brešković and Popović 2006: 19 and 39, and cat. nos. 1659–1673), is presumed to have been unearthed in Vojvodina, too.

8 Davis and Paunov 2012.

9 A classic paper on the subject: Crawford 1977.

10 *Inter alios*, Chițescu 1981: 15–17, as well as Moisil and Depeyrot 2003: 5–9.

11 See Moisil and Depeyrot 2003: 27 (cat. nos. 1–3); the earliest hoard of which the contents are known closes with a Roman *denarius* dated to 89 BC by Crawford.

12 Lockyear 2008: 24. *Ibid.* he adds: "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". Lockyear thus confirms the position he had already adopted in his 1995 article. For typological observations regarding the chronology of the Roman prototypes, which tie in nicely with Lockyear's dating of the main period of influx, see Davis 2006: 322.

13 Crawford 1977: 121.

cash was caused by an upsurge in the slave trade between Rome and Dacia, which he connected with the elimination of the pirates in the eastern Mediterranean—an explanation which he restated later,[14] but which perhaps still is a bit too narrow.[15]

The role of the Republican coins in the economy of Late Iron Age Dacia has been the subject of considerable scholarly debate as well. In view of the fact that small denominations were apparently lacking, Crawford posited that the imported Roman silver coins did not primarily have the function of a means of exchange in a market economy, but were used "rather for exchange of gifts and for payments such as dowries, where the gift element is considerable" (1977: 118)—as a form of wealth, which was above all a means to enhance the status of the local aristocracy. This socio-anthropologically inspired view[16] was adopted and developed further by Lockyear,[17] who even tried to interpret the evidence provided by coin hoards in this perspective.[18] Both British scholars thus reject the model defended by Maria Chițescu and others, according to which Roman coins were simply needed to satisfy the considerable monetary needs of the Dacian state in the first century BC.[19]

In the debate on the function(s) performed by Roman Republican money in Dacian society of the first century BC, the above mentioned fact that *denarii* were locally imitated on a considerable scale doubtless must be taken into account. When copying started is, obviously, hard to ascertain, but Kris Lockyear may well be right in suspecting that it may have been a local response to a curtailment of the supply of official *denarii* in c. 65 BC.[20] While copies are usually made of solid silver flans,[21] there are also plated forgeries of "Dacian" *denarius* imitations[22]—a

14 Crawford 1985, chapter 15 "The Balkan Question" (esp. 232–234).

15 For a discussion of various models that have been proposed in order to explain the import of *denarii*, see Moisil and Depeyrot 2003: 11–13.

16 For which see also Crawford 1985: 229–230 ("Coinage in fact is to be envisaged as for the most part a fashionable form in which to hold and display wealth, alongside jewellery and other forms of mobile riches; the origin of the fashion perhaps lies in a perception of the power of money in the civilised and fascinating Greco-Macedonian Mediterranean world; there of course the power derived from a real economic function. Nor is there any reason to suppose that any change took place when Republican *denarii* replaced the assortment of Greek and native issues available earlier").

17 "perhaps we can see them [*sc.* the *denarii*] as one expression of competition between and within polities. The use of Roman coins was, perhaps, […] a symbol of power. […] possession of these coins […] could have formed a part of local power-relations" (Lockyear 2004: 70).

18 "No single explanation will do for all hoards, but the possibility that simple possession became an insufficient means of élite competition, which led to a phase of deliberate destruction by burial, could explain the extraordinary number of hoards in this region" (Lockyear 2004: 70).

19 Chițescu 1981: 9–25, especially 16ff. On the controversy, see also Davis 2006: 325f. (who remains agnostic) and the remarks in Davis 2010.

20 Lockyear 2004: 66. On the problem of date, see also Chițescu 1981: 20.

21 For a thorough discussion of metallurgical aspects, see below.

22 For illustrations, see, *e.g.*, the auction catalogue Gemini 9 (8 January 2012), lots 764–767.

fact that has not yet been fully appreciated in the discussion of the role of imitative *denarii* in the economy of Late Iron Age Dacia.

It was Maria Chițescu who, in her 1981 monograph, not only created the framework for the modern understanding of this class of imitative coinage in general, but also developed a pertinent nomenclature.[23] She distinguished between "monetary copies" (reproducing the images and inscriptions of the prototypes quite accurately) and "monetary imitations", which depart radically from the Roman models and display stylized, 'barbarous' images as well as blundered legends. Although clear at the extremes, this distinction becomes somewhat blurred in the middle, where there is a grey area;[24] hence, it can be difficult to apply Chițescu's terminology rigorously, and this is why it is not used in this article.

As far as production technology is concerned, the vast majority of the imitative coins were produced by striking.[25] While the specimens diverging radically from the prototypes were all struck from dies carved freehand, some of Chițescu's "monetary copies" were struck from dies produced mechanically by using genuine Roman coins as hubs—so-called "transfer dies,"[26] examples of which have been discovered in Romania.[27] The scale of the phenomenon of copying in ancient Dacia is hard to assess more precisely. While Crawford, working on the basis of the material available in the late 1970s, had the impression that the production of struck Dacian imitations was "relatively restricted,"[28] Lockyear presumes copying to have been "remarkably prevalent and widespread" and supposes copies to amount to c. 14–30% of the entire Dacian *denarius* population in the 'Republican' period.[29] Production of copies with Republican types, however, seems to have continued well into Imperial times in Dacia, perhaps even up to Trajan's conquest of the country at the beginning of the second century AD. This is indicated not only by hybrid imitations combining Imperial obverses with Republican reverses,[30] but also by an important find from Sarmizegetusa Regia, where a group of dies was discovered in a layer dated by the excavators to the period immediately prior

23 Chițescu 1981: especially 47–48.

24 See the comments by Davis 2006: 326f.

25 Cast copies were, however, contained in the Breaza hoard; see Poenaru Bordea and Știrbu 1971 (especially 281 and the references to the plates *ibid.*) as well as Crawford 1980: 51f. These cast copies should perhaps be regarded as an isolated phenomenon, see Davis 2006: 324.

26 On technical aspects, see especially Stannard 2011: 72f.; *cp.* also Crawford 1980: 51. Such "transfer dies" and barbarous dies carved freehand were used side by side in the workshops and were sometimes even coupled: see Gemini 9 (8 January 2012), lot 722.

27 See, *e.g.*, Lupu 1967 (Tilișca); Glodariu, Iaroslavschi and Rusu 1992 (Sarmizegetusa Regia). For systematic collections of the evidence provided by locally found dies, see Lockyear 2008: 8f. and 13 (with tabulation), as well as Malkmus 2007: 119–122 (Die Nos. V-12b to V-12zz).

28 Crawford 1980: 52.

29 Lockyear 2008: 24.

30 For some examples, see Gemini 9 (8 January 2012), lots 734–735 and 738.

to Trajan's Second Dacian War.[31] The three identifiable dies are all obverses; two show Republican coin types (*RRC* 266/1 and 407/2), whereas one reproduces a *denarius* obverse of Tiberius with the legend TI CAESAR DIVI AVG F AVGVSTVS.[32] Hence, it is important to bear in mind that a *denarius* imitation from Dacia copying a Republican type from say, the 70s BC, can *a priori* have been struck at any point in time between these years and the Trajanic period.

Recently, work on the *denarius* imitations from Dacia has gone in several different directions, and progress has been considerable. Phillip Davis paid particular attention to the numismatic objects themselves, meticulously studying individual coins and trying to arrive at refined structural, typological or geographical classifications of this difficult body of material.[33] One of the most important results of his efforts is the great increase in the number of images of *denarius* imitations (from various sources) now available for study, as compared to ten years ago.[34] Kris Lockyear, for his part, has not only studied the chronological aspect of the import of Roman Republican coins to Dacia repeatedly, but has also done a lot of work on the socio-economic embedding of this phenomenon.[35] Furthermore, as briefly mentioned above, he also approached an issue which has been raised repeatedly in the recent scholarly discussion, *viz.* the supposed difficulty in distinguishing Roman originals from Dacian copies of high quality.

In cooperation with Matthew Ponting, Lockyear conducted metallurgical analyses on, *inter alia*, coins from Romanian hoards—both on regular Republican pieces and clearly identifiable local copies (struck and cast)—and on comparative material from UK museum collections, in order to see whether a distinction between genuine (Roman) and copied *denarii* was possible on the basis of their metallurgical composition.[36] The analytical technique they used was atomic absorption spectrometry (AAS) on samples taken from the core of the coins by drilling—in order to circumvent the problems posed by "surface enrichment"—and the data they obtained were processed using statistical techniques such as principal components analysis (PCA). Lockyear and Ponting were not entirely happy with the results of the investigation, though: "The metallurgical results have proved a difficult data set to analyze with many problems and pitfalls." They acknowledged that "the exact proportion of copied coins in the hoards is still extremely unsure."[37] On

31 Glodariu, Iaroslavschi and Rusu 1992: 61.

32 Glodariu, Iaroslavschi and Rusu 1992: 62.

33 Apart from several minor contributions, his main article on the subject is Davis 2006 (largely superseding his earlier treatment Davis 2004).

34 The articles by Davis cited above are well illustrated, but the most important resource for images is his educational website "Imitations of Roman Republican Denarii" <http://rrimitations.ancients.info/> (last accessed on 17 November 2012). See also Gemini 9 (8 January 2012), lots 583–767.

35 Lockyear 1995, 2004 and 2008.

36 Lockyear 1999 and Lockyear 2008: 12–23.

37 Lockyear 2008: 23.

balance, they proposed that up to about a third of the material in Romania might consist of local copies—a hypothesis that did not meet with universal approval.[38]

Although Ponting and Lockyear were not able to achieve the goal they had set themselves, their project is of great significance in that it redirected scientific attention to the problem of the metallurgical composition of copies of Roman Republican *denarii* in general. As with many other aspects of the study of Dacian imitations, interest in their alloy goes back to Maria Chițescu. In her monograph, the Romanian scholar stated that the silver fineness of *denarius* imitations normally was significantly lower than the fineness of Roman Republican coins.[39] She did not have a comprehensive set of data at hand to support her statement, but merely pointed to analyses of coins in the Bonțesti hoard which purportedly all contained less than 75% of silver in their alloy.[40] The analyses done by Lockyear and Ponting did not confirm this, but showed a completely different picture. Among the coins they sampled successfully, there were ten specimens labelled "barbarous imitations."[41] One of these coins contained 12.75% Cu, but all the others just a little less than 5%.[42] Thus, it is not difficult to see the contradictions and inadequacy of the metallurgical documentation of Republican *denarius* imitations currently at our disposal. Apart from the fact that so few analyses have been performed in total,[43] the coins analyzed by Lockyear and Ponting were not illustrated in their article, and so far no metallographic analyses of Republican *denarius* imitations whatsoever have been published.[44]

38 *Cf.* Davis 2006: 325.

39 "Another way to distinguish the copied coins from the genuine ones […] is to determine the fineness of the silver they are made of" (Chițescu 1981: 51).

40 "the fineness of the silver of all the coins in the hoard (sc. the Bonțesti hoard, in the collection of the Museum in Focșani, Vrancea district) has been found to be less than 75.0%" (Chițescu 1981: 52). See also Chițescu 1971: 255 ("le titre des pièces d'argent véritables étant de 900‰–980‰, alors que certaines pièces de Dacie, bien que reproduisant avec fidelité le prototype, n'en marquent que 750‰—ce qui incite l'auteur à les considérer des simples copies").

41 As well as five "cast copies" from the Breaza hoard and six "struck copies" from the Poroschia hoard.

42 For a more detailed discussion of their results, see below, pp. 143–147.

43 Mention must be made here of the recent attempt by Davis 2009 to obtain metallurgical data for a total of 35 imitations of Roman Republican *denarii* by measuring their specific gravity with a newly developed device ("Archime-De") and then extrapolating the silver fineness from these values. This method, however, fails to take into account the internal inhomogeneity of some of the coins (see below); apart from this obvious deficiency, its overall reliability has not been ascertained independently so far.

44 This situation is all the more surprising since some work on metallurgical aspects of official Roman Republican silver coins has been done recently: see, *e.g.*, Walker 1980, Zwicker 1993 and Hollstein 2000.

2. The Material

In this project, nine imitations of Roman Republican *denarii* from private collections were subjected to metallurgical and metallographic analyses. Since the coins had kindly been donated especially for this purpose, they could be dissected, so that it was possible not only to analyze the chemical composition of their core metal on the cross sections, but also to examine their internal homogeneity/heterogeneity in the scanning electron microscope.

No.	Obverse	Reverse	Prototype(s) and Date	Weight	Die Axis	Comment
1	Head r., behind ATAON	Dioscuri riding r., below P. PAE	Rev. *RRC* 233/1 (138 BC)	3.31 g	2 h	Serratus; pitting on surfaces
2	Helmeted head of Roma r., before X, behind C K	Jupiter in quadriga r., holding sceptre and thunderbolt; below ANTE (in ligature), in exergue MOM	Obv. and rev. *RRC* 238/1 (136 BC)	4.32 g	12 h	
3	Head of Apollo r., behind control symbol	Dioscuri standing front between horses	Obv. *cf. RRC* 340/1 (90 BC), 346/2a (88 BC), 408/1 (67 BC); rev. *RRC* 304/1 (109/8 BC)	4.09 g	12 h	Serratus
4	Head of Jupiter (wreathed, bearded) r., behind C and retrograde S	Victory in quadriga r., holding palm-branch, in exergue NFOA	Obv. and rev. *RRC* 364/1 (83/2 BC)	3.38 g	9 h	Serratus
5	Head of Jupiter (wreathed, bearded) r.	Figure in triga r., in exergue ATANAV	Obv. and rev. *cf. RRC* 364/1 (83/2 BC) *etc.*	3.37 g	6 h	Reportedly found in Bulgaria.
6	Head r., behind lyre	Pegasus r. on base	Obv. *RRC* 494/23 (42 BC). Rev. *RRC* 341/1–2 (90 BC)	2.21 g	9 h	Serratus.
7	Female head r., pearls in hair	Figure in stylized triga r.		3.98 g	5 h	
8	Helmeted head of Roma r.	Figure in stylized biga r., in exergue VAAH … AV		3.23 g	9 h	ex Lanz 97 (22 May 2000), no. 28
9	Helmeted head of Roma r.	Figure in biga r., in exergue blundered legend		2.64 g	3 h	

3. Experimental analyses

Scientific investigations on objects of art and archaeology represent a challenge for modern analytical techniques. In the case of the analysis of coins, which are often objects of high value, investigations should generally be non-destructive: this means that no material should be removed and the object itself should not be modified in any way during examination. When, in fact, some sampling can be done due to the nature of the objects to be examined (or when it is inevitable for scientific reasons), non-destructive techniques have the advantage of allowing sample conservation for several measurements.[45]

One of the most important and best documented problems in the analysis of coins concerns the phenomenon of surface enrichment. In coins manufactured from a silver/copper alloy, copper tends to deplete and hence silver to apparently enrich in the surface areas of the object. This surface enrichment may be accidental or intended and can have been caused by: 1) segregation during casting or annealing; 2) deliberate thermal and/or chemical post-treatment as, for example, pickling in acids or blanching; 3) wear and 4) corrosion.[46]

For most of the non-destructive X-ray based techniques, the zone analyzed extends only from a few micrometers up to a few tens of micrometers into the object. In coins affected by surface enrichment phenomena, this corroded/enriched surface layer may be very thick, compared with the penetration depth of the analytical beam. The phenomenon of surface enrichment can therefore give an erroneous impression of the bulk composition of the coins. Thus, strictly non-destructive analysis almost never yields meaningful results in numismatics.[47]

In order to avoid these problems in our analyses, and in order to be able to determinate the chemical composition of the cores of the *denarius* imitations, it was decided to prepare cross-sections of the coins and analyze their true core-metal with X-ray based surface techniques. The nine *denarii* were dissected in the upper third, through the head, which is the thickest part of the coin; there, minimal analysis problems were expected. The smaller part of each coin was then embedded in synthetic resin, ground and polished with SiC-paper up to 2400 mesh. Shortly before the measurements, all samples were also polished with SiC-paper of 4000 mesh to remove any corrosion products which could have possibly developed (fig. 1, below).

Compositional analysis was carried out at the BAM*line* for hard X-rays at the electron storage ring Bessy II in Berlin using synchrotron micro X-ray fluorescence analysis (μ-SRXRF).[48] An excitation energy of 23 keV was used and the emitted fluorescence radiation was detected with a HPGe-semiconductor detec-

45 Pernicka 1986.
46 Beck *et al.* 2008.
47 Beck *et al.* 2004, Linke *et al.* 2003 and 2004
48 Görner *et al.* 2001, Riesemeier *et al.* 2005.

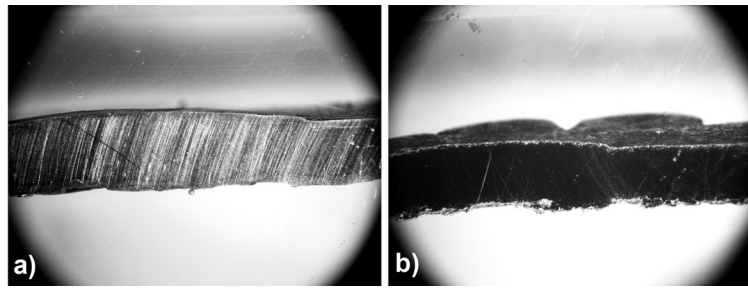

Figure 1. Examples of cross-sections used for analysis: coins no. a) 2 and b) 5, stereo microscope, 40x magnification.

tor. An X-ray beam of approximately 100 µm width and height was achieved and two spot analyses were performed in each cross-section for 60 seconds. The detected elements included the major components Ag and Cu as well as some of the minor and trace elements—Au, Pb, Bi, Fe and Mn. The peak's assignment was performed with Axil® software,[49] and quantitative analysis was carried out with the package NRLXRF.[50] Copper and the minor and trace elements were quantified with reference to pure element standards provided by the BAM*line*,[51] whereas silver was accepted as a difference to 100 %.

As for metallographic aspects, the microstructure of all the coins was investigated by examining the polished cross-sections with a Quanta 200 Mk2 Scanning Electron Microscope (SEM), using backscattered electrons (BSE). The chemical composition was determined with an energy dispersive X-ray (EDX) spectrometer coupled to the SEM, producing a 20 keV beam. The elements quantified in the coins included only the main components Ag and Cu. Spectra evaluation was performed with the system EDAX®, which uses ZAF matrix effect corrections to determine the concentrations (atomic number, absorption and fluorescence). Backscattered electron (BSE) images, with magnifications between 60x and 400x, were also collected and used for interpretations. During the analyses with both techniques, the reproducibility of our measurements as well as the stability of the instruments was monitored by periodic testing of silver-copper standards made by ÖGUSSA (Österreichische Gold- und Silberscheideanstalt) with the following Ag/Cu compositions in wt%: 100/0, 95/5, 92.5/7.5, 90/10 and 80/20. The results in table I (see appendix) show a good agreement between the two different methods used.

49 Espen *et al.* 1986.
50 Criss *et al.* 1978.
51 Radtke *et al.* 2010.

4. Results and Discussion

a) Compositional Analyses

The results of the compositional analyses of the nine imitations of Roman Republican *denarii* presumably struck in Dacia are presented in detail in table II (see appendix). The analyses show that all coins are made of a silver-copper alloy. The silver content of the imitations we analyzed is in general very high, with concentrations of c. 90% or more. Six of the coins were found to contain even more than 93% silver in their core material, the highest value we observed is 97.98% (coin no. 4). The two exceptions are coins no. 2 and 6, with silver concentrations of 57.9% and 86.3% respectively (fig. 2, below). On the whole, this confirms the results reported in the recent article by Ponting and Lockyear already referred to several times,[52] in which a set of data of metallurgical analyses on—*inter alia*—ten imitations of Roman Republican *denarii* was published.[53] Nine of the ten imitations sampled by Lockyear and Ponting show concentrations of more than 90% of silver. It is thus clear that the pattern postulated by Chițescu, according to which the alloy of "Dacian" imitations of Roman Republican *denarii* was always drastically baser than the alloy of the prototypes, has no factual basis whatsoever.

Comparison with the fineness of official Roman Republican *denarii* is a little difficult insofar as the majority of analyses performed up to now on this class of coins were done with XRF on the surfaces, so that the data cannot *a priori* be regarded as completely reliable, due to possible corrosion phenomena.[54] Still, what evidence we have indicates that the fineness of Republican *denarii* was extremely high, and in a remarkably consistent way: Walker calculated an average of 97.7% Ag for 504 silver coins of the period 169–101 BC which he had analyzed, and this trend was confirmed by Hollstein.[55] After a transitional period in the first two decades of the first century, stability returned in post-Sullan times (until the outbreak of hostilities between Caesar and the senate): for 391 silver coins of the periods 78–62 BC and 61–49 BC, Walker reports averages of 95.9 and 97% silver respectively.[56] It is reassuring to see these results tie in well with data obtained in the project conducted by Lockyear and Ponting,[57] in which 157 Roman Republican *denarii* from Romania were analyzed using AAS. According to our calculations based on the data provided in their publication, these coins were found to contain 97.053% silver on average.[58] We may therefore conclude that the fineness

52 Lockyear 2008.

53 Lockyear 2008: nos. 29, 31, 32, 34, 66, 70–73, 186 with table 3 on p. 14. Two more imitations were sampled and analyzed by Ponting in the course of Lockyear's project, but the results obtained for these two coins were considered unreliable by Lockyear and Ponting.

54 See especially Walker 1980 and Hollstein 2000.

55 Walker 1980: 61 and Hollstein 2000: 115.

56 Walker 1980: 65.

57 Lockyear 2008.

58 Range: 99.576% (max.)–88.687% (min.). On these coins, see also below (with note 50).

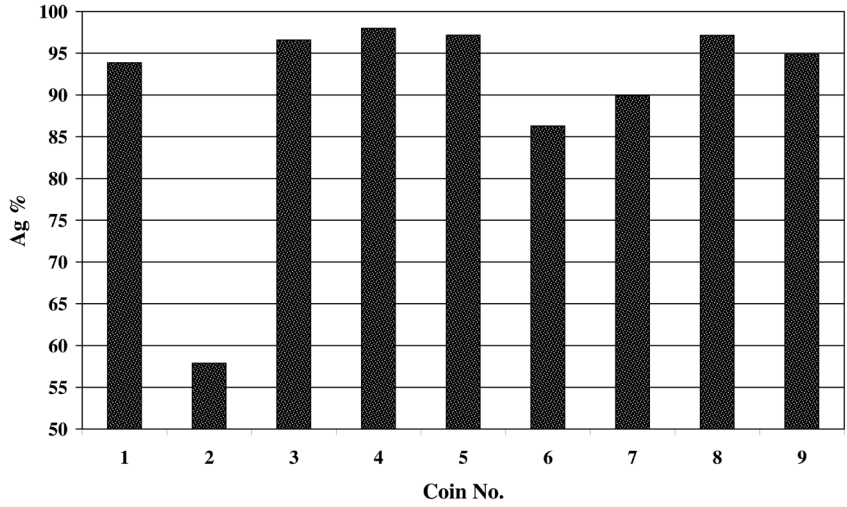

Figure 2. Ag content (in weight percent) of the *denarius* imitations.

of *denarius* imitations of the type analyzed here is decidedly less uniform than the silver standard of the prototypes, with a certain percentage of outliers of wildly differing fineness, but that the majority of copies display silver values very nearly approaching the official Roman silver coins of the Republican period.

Attempting to establish the provenance of ancient silver is an especially difficult task. The quantitative relations between the trace elements present in ancient alloys are a result of the geo-chemistry of the original ores, the smelting and refining technologies and the degree of mixing and recycling.[59] Concerning the silver refining process, as most trace elements are easily separated from this metal, their concentration may not be representative of the ore.[60] The correlation between the silver ore and the metal extracted from it to produce coins is determined by, on one hand, the type of the ore and the nature of the impurities, and, on the other hand, by the precise conditions of smelting. Cupellation was the process most widely used in antiquity to extract silver from the lead ore galena. The first step in this process was the smelting of the ore in order to produce silver-rich lead, followed by oxidation to remove most of the lead (as lead oxide) and by concentrating the silver in the remaining lead. The silver would then be extracted in small vessels (cupels) containing bone ash.[61] In this process, most of the lead was removed, but some inevitably remained and can be used as an indication of the effectiveness of the procedure. In high-quality silver produced by this process, the lead concentrations were reduced to around 0.5%, and therefore a low lead content

59 Gitler and Ponting 2003: 35.
60 Guerra 2000.
61 Butcher and Ponting 1995: 69.

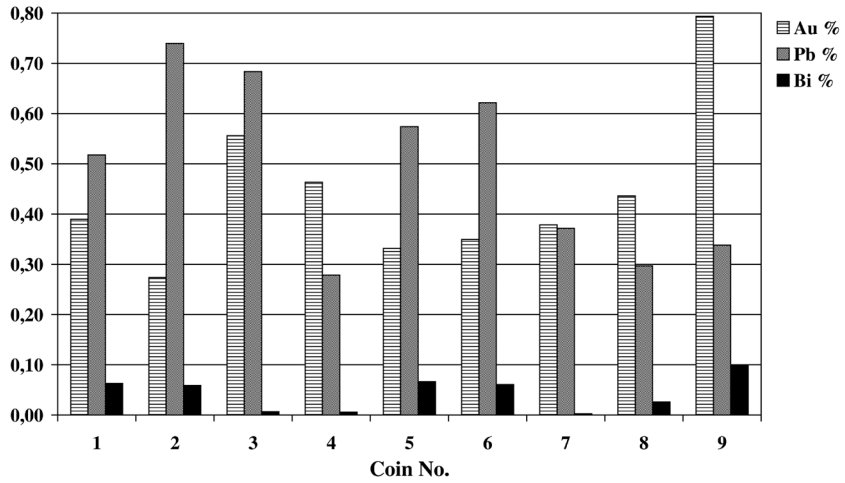

Figure 3. Au, Pb, and Bi content (in weight percent) of the *denarius* imitations.

is an indication of good smelting. Bismuth was also reduced during this process, but it is accepted that its concentration in metallic silver reflects to some extent that of the parent ore. The gold concentration, on the other hand, was not affected by the cupellation process.

Besides the main group of elements which are related with the silver ores and metallurgy (Ag, Cu, Au, Pb and Bi), we have detected manganese and iron in the imitations of the Roman Republican *denarii* (see table II in the appendix). These elements do not appear to be very instructive for the determination of the provenance of the silver ore—iron could originate both from the silver or the copper ore, and manganese is actually easily oxidized during the smelting process of the ores, so it will be removed efficiently into the slag, independently of the initial concentrations.[62] Consequently, bismuth and gold are the most important elements related with the original type of the ore. Although repeated recycling will gradually homogenize any groupings that may have once existed, it is worthwhile to observe the trace element signature of our coins more closely.

Figure 3 shows the content of the elements gold, lead, and bismuth in the imitations of Roman Republican *denarii*. The coins are characterized by moderate quantities of gold and lead, 0.27–0.79% and 0.28–0.74%, respectively; bismuth is usually present in very low concentrations (<0.1%).

In order to check if the trace element signatures of the *denarius* imitations analyzed in the frame of this project and the signatures of the coins sampled by Lockyear and Ponting are related,[63] the ratios of gold to silver and bismuth to

62 Schubinger *et al.* 1977.
63 Lockyear 2008.

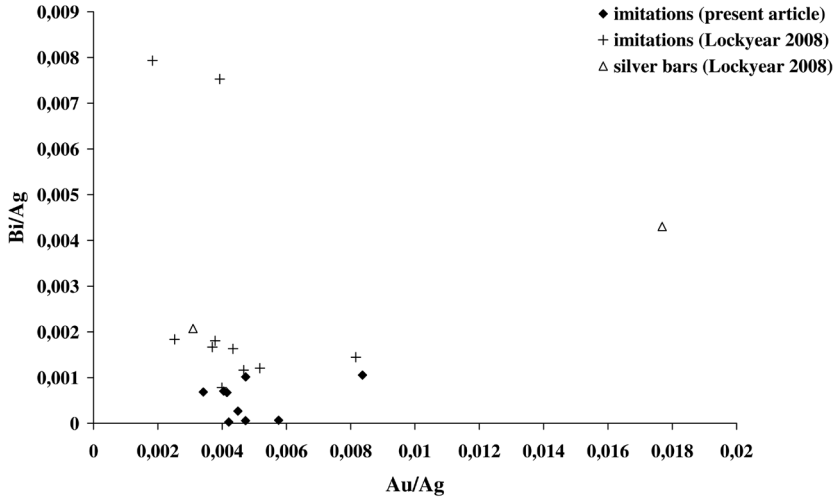

Figure 4. Ratios of gold to silver and bismuth to silver in the imitations of Roman Republican *denarii* and in the Stăncuța silver bars

silver (fig. 4) as well as gold to silver and lead to silver (fig. 5, below) in the alloy of these coins were compared. Apart from the two sets of *denarius* imitations, the graphs contain data for the two silver bars from the Stăncuța hoard[64] sampled by Lockyear and Ponting.[65]

It is interesting to observe that figures 4 and 5 present, in general, a coherent picture. When the trace element contents are scaled to the silver, the two assemblages cluster in the same region of the plot. In figure 4, only two coins stand out, with higher contents in bismuth. The cluster plotted in figure 5 is a little more scattered than the one in figure 4; this could, however, be attributed to the fact that the lead content is related in great extent to the efficiency of the refining process of the silver bullion. As for the two Stăncuța silver bars, their trace metal signatures are quite diverse between themselves: while one of them fits in nicely with the imitative coins, the other ingot has a markedly different fingerprint.

Thus, the imitative coins analyzed in the two independently launched projects seem to display a somewhat similar trend concerning their trace element signatures, which may be thought to point to the use of related silver ore sources. This is quite remarkable, since the provenance of the coins which were available for analysis is heterogeneous. While Lockyear's imitations (nos. 70–73) came from the Poroschia hoard[66] and no. 66 from the Voinești hoard,[67] no provenance is indicated

64 Preda 1958 (bars depicted on p. 248); Crawford 1969: no. 331; Moisil and Depeyrot 2003: no. 77.

65 Lockyear and Ponting 2008: nos. 61–62.

66 Chițescu 1980.

67 Știrbu 1978: 90 (hoard no. 4).

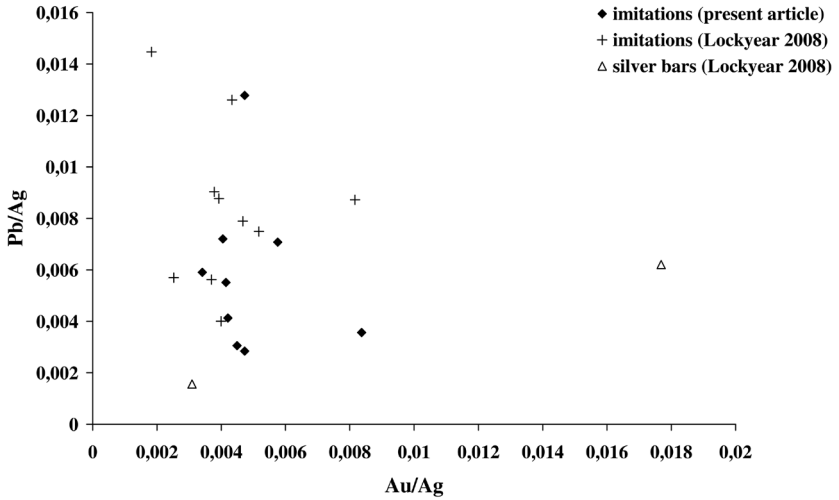

Figure 5. Ratios of gold to silver and lead to silver in the imitations of Roman Republican *denarii* and in the Stăncuța silver bars.

for the rest of the imitations sampled by Lockyear and Ponting; similarly, all the material analyzed here comes from private collections. *A priori*, we therefore can by no means be sure that all the pieces originated from the same coin-producing environment. Still, the silver used for the Roman Republican *denarius* imitations analyzed has trace metal signatures not widely differing from each other.

b) Scanning Electron Microscopy

Backscattered electron images (BSE) obtained with the scanning electron microscope were used to investigate the microstructure of all the imitations of Roman Republican *denarii* analyzed in this project. Silver/copper alloys with a silver content higher than 90% will generally solidify as a single homogeneous phase. Below this content, the alloy will separate in two distinct phases—a bright silver-rich α-phase and a dark copper-rich β-phase. In the BSE images of coins no. 1, 3, 4, 5, 7 and 8, a completely homogeneous structure is to be observed, and all the coins are constituted by a single metal phase (fig. 6, below). This is not surprising, since for all these coins the silver content is well above 90%.

As can be seen on the BSE micrographs in figure 7 (below), coin no. 9 has a homogeneous core structure as well and is constituted by a single metal phase structure. It has, however, thick corrosion layers of a depth of 100 to 200 μm in the near surface regions (on both obverse and reverse). Since the coin has an extremely shiny appearance, it cannot be excluded that this phenomenon may be due to modern overcleaning.

The SEM/EDX analyses provided most important background information on the coins no. 2 and 6, characterized by a somewhat lower fineness in silver. Coin

no. 2 displays a homogeneous core with two distinct silver-rich and copper-rich phases with an average silver content of 63.3%. The near surface layers of the coin, with a thickness of approximately 100 μm in depth on the obverse and approximately 200 μm in depth on the reverse, contain two sub-layers. The innermost is a silver-rich layer, with a silver content of around 90%, and the outermost is a copper richer layer, of around 70% silver on the obverse and 87% silver on the reverse (figure 8, below). At first sight, the overall structure of the coin might be thought to be down to a deliberate treatment of the flan in the course of the production process, as it is known for Roman imperial issues from the second half of the first century AD onwards. However, the big difference in fineness between the core and the near surface layers as well as the fact that blanching has not been attested for coinages of the first century BC so far—the most likely date for the production of the imitation—make this highly unlikely.

Figure 9 (below) shows two BSE micrographs of coin no. 6, doubtless the most peculiar one in our lot, metallurgy-wise. This coin has a completely inhomogeneous microstructure, with several silver-rich and copper-rich phases' layers of different average silver contents ranging from 69.1% to 92.3%. An enrichment of silver—hence depletion of copper—could also be observed in the near surface areas of the coin; it is approximately 100 to 200 μm in thickness.

5. Comparison between the trace metal signature of the imitations of Roman Republican *denarii* and of the *denarii* of Trajan (AD 98–117)

As mentioned in the introduction, imitations of Roman Republican *denarii* were apparently produced well into the early Imperial period, and perhaps even up to Trajan's Dacian Wars (AD 101/2 and 105/6), in Dacia—although more evidence on the latter problem is badly needed. Since one of our literary sources reports that the booty in gold and silver which the Romans obtained in Dacia at that time was exceptional,[68] potential repercussions of an influx of Dacian silver on the metallurgical composition of the Trajanic silver coins struck in Rome have been discussed repeatedly in scholarly research.[69] Hence, it was deemed necessary to take advantage of the program of scientific analysis of imitations of Roman Republican *denarii* presented here to examine this very problem.

The imitations analyzed here may, with all due caution, be presumed to have been produced in the Dacian area. We do not have any external evidence for the provenance of the silver used to strike these coins, but basically two possibilities

68 John Lydus, *de magistratibus populi Romani* 2.28. Although widely regarded as unreliable concerning the precise figures he gives (5 million pounds of gold and 10 million pounds of silver), it is generally acknowledged that Lydus—who quotes Crito on this point—provides valuable evidence that the Roman booty in precious metals was substantial; see, most recently, Strobel 2010: 283.

69 See, for example, Butcher and Ponting 1998: 317, as well as Uhlir *et al.* 2007: 96.

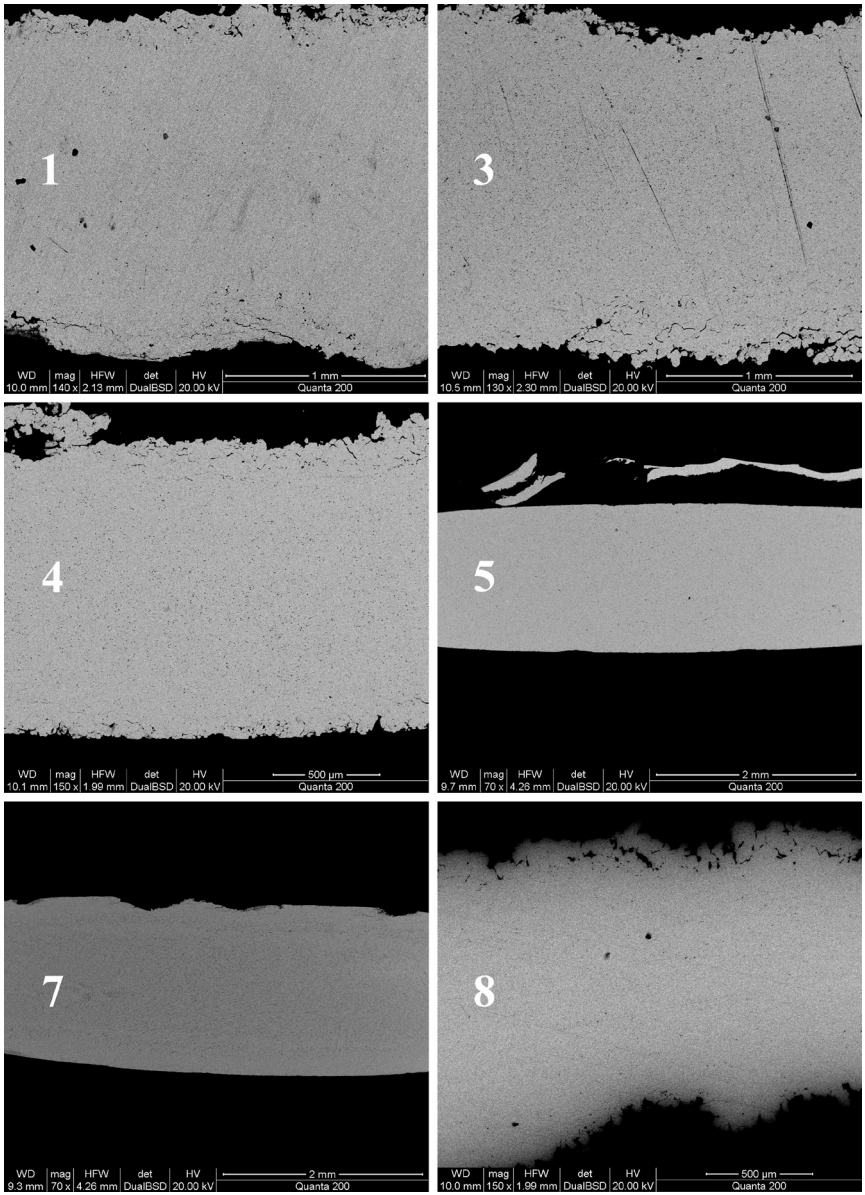

Figure 6. Scanning electron micrographs of the cross-sections of coins no. 1, 3, 4, 5, 7, and 8.

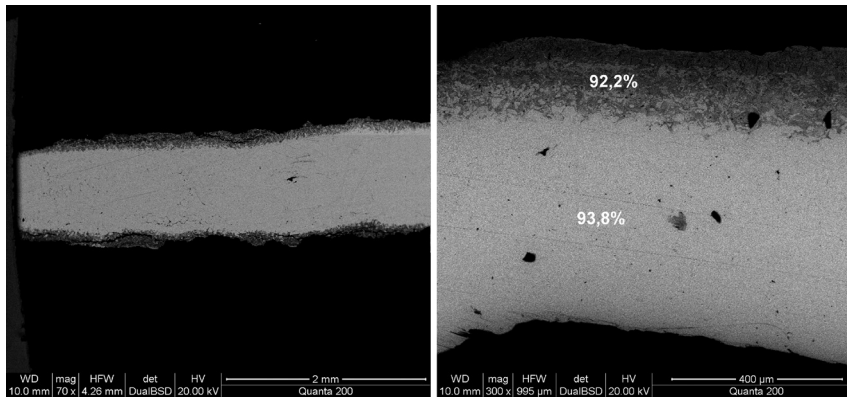

Figure 7. Scanning electron micrographs of the cross-section of coin no. 9.

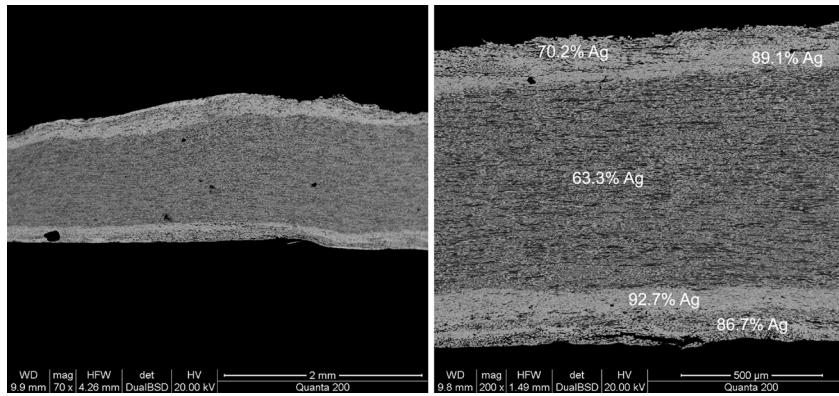

Figure 8. Scanning electron micrographs of the cross-section of coin no. 2.

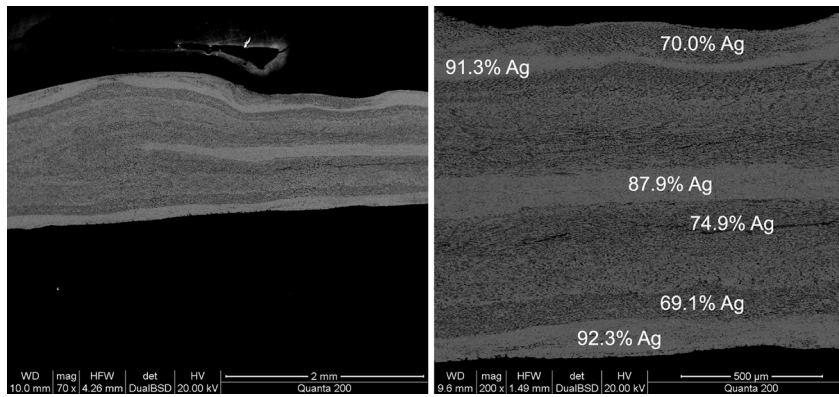

Figure 9. Scanning electron micrographs of the cross-section of coin no. 6.

suggest themselves: either they were struck from silver obtained by remelting precious metal objects[70] and older coins—one might principally think of Hellenistic silver coinages and Roman Republican *denarii*—or they were produced from locally sourced silver, which would probably have been supplied by the famous mines of the Apuseni Mountains in the Western Carpathians. Of course, these two possibilities are not necessarily mutually exclusive, and different solutions, based on the form in which metal was momentarily available, are possible. The problem we are dealing with here is directly related to a longstanding debate in Romanian scholarship regarding the provenance of the metal used to manufacture silver plate or items of jewellery found in Geto-Dacian contexts. Constantin Preda repeatedly contributed to this discussion when he studied the silver bars from the Stăncuța hoard mentioned above. His conclusion was that the various silver coinages circulating in the Dacian territory were among the prime sources for locally produced silverware; he regarded the Stăncuța bars as evidence for an intermediary stage of this transformation of foreign coins into Dacian silver objects.[71] What are the implications of this for our question regarding the source of silver for the imitations of Roman Republican *denarii*? Since the fineness of the majority of the imitations is elevated, as has been demonstrated above, and is often identical to that of the prototypes, systematic remelting of imported Roman coins does not seem extremely likely at first glance; at least, it is not easy to see that this operation would have made much sense economically. Still, a comparison between the trace metal signatures of the *denarius* imitations analyzed here and Roman Republican *denarii* found in Romania and sampled by Lockyear and Ponting may provide a salutary warning against judgements taken too rashly in that regard (figs. 10 and 11, below). If the latter coins may be taken to be official mainstream issues of the Roman Republic,[72] then these diagrams reveal the trace metal signature of Roman Republican silver coinage to be very similar to the signature of the *denarius* imitations analyzed here. Thus, it has to be stressed that we do not, currently, possess valid evidence for the provenance of the silver used to produce the *denarius* imitations from Dacia. While the possibility of the use of Dacian silver for the production of the imitative coinage cannot be ruled out, it is far from proven, and it is also conceivable that *denarius* imitations were one of several classes of locally manufactured silver objects which were produced from melted down imported coins—Hellenistic silver or even official Roman *denarii*.

Therefore, the data obtained in our project is of limited significance in regard to the problem of the potential presence of imported "Dacian" silver in the *denarii*

70 On the distribution of finds of silver work from Late Iron Age contexts in Romania, see Lockyear 2004: 67–69. "Precious metals were relatively plentiful, within Dacia" (68).

71 Preda 1957: 120f. and 123f.; Preda 1958: 247–249 and esp. 251.

72 This obviously has to be the default assumption, although it is not possible to check if it is really the case, since the publication (Lockyear 2008) does not contain images of the coins analyzed.

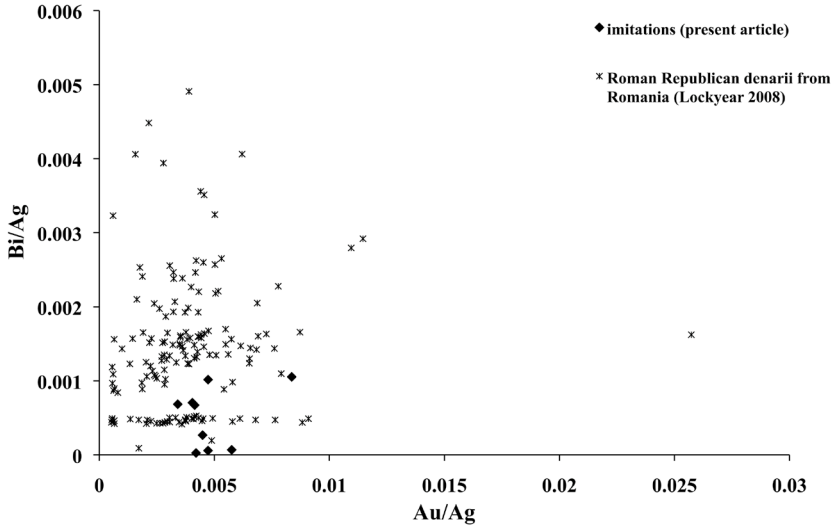

Figure 10. Ratios of gold to silver and bismuth to silver in the imitations of Roman Republican *denarii* and in the Roman Republican *denarii* from Romania (Lockyear 2008).

of Trajan. Still, it seemed reasonable to evaluate our data set by comparing it to Trajanic silver. Comparative data was provided by the analyses of 65 *denarii* of Trajan, evenly distributed over the entire span of his rule, and of 3 coins from the short reign of his predecessor, the emperor Nerva (AD 96–98), all produced in the Roman mint.

Analyses of the Roman coins were first conducted with laboratory energy dispersive X-ray fluorescence analysis (EDXRF), using the self-built instrument COPRA[73] available at the Institute of Science and Technology in Art, Academy of Fine Arts Vienna, equipped with a polycapillary for focusing the X-ray beam to a diameter of approximately 100–150 μm.[74] The data used for comparison here were, however, provided by further measurements of the Roman coins performed with μ-SRXRF, under the same conditions as previously described on pp. 147–148. This microanalytical method is much more adequate for analyzing elements at the trace-level, and thus it was possible to gain precise information not just on the major elements silver and copper, but also on some of the minor and trace elements, *viz.* gold, bismuth and lead.[75] For our purposes, a closer look at the main impurities of the precious metals was taken. Figure 12 (below) shows the average content of the elements gold, lead, and bismuth in the coins of Nerva and Trajan (consulates II to VI).

73 COPRA—A Compact Röntgen Analyser EU Project No. STM4-CT98-2237. Coordinator: Prof. Dr. K. Janssens, University of Antwerp, Belgium.

74 Woytek *et al.* 2007; Uhlir *et al.* 2007.

75 Rodrigues *et al.* 2011.

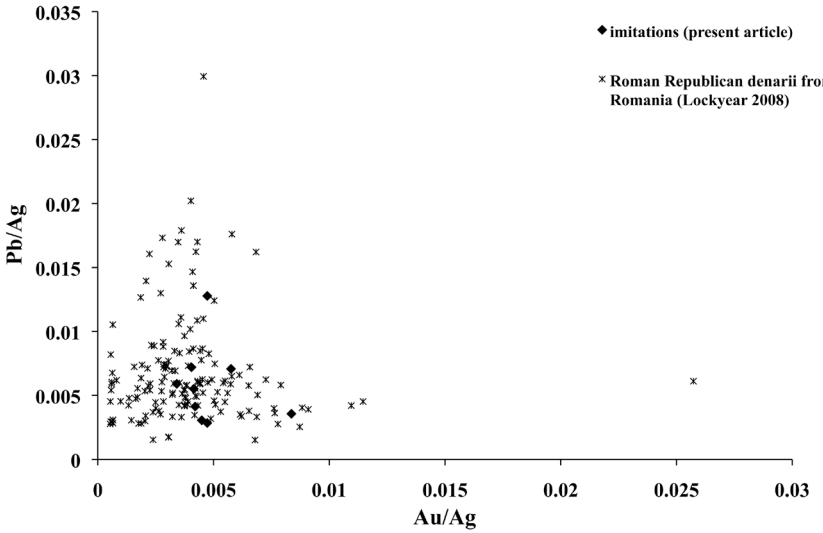

Figure 11. Ratios of gold to silver and lead to silver in the imitations of Roman Republican *denarii* and in the Roman Republican *denarii* from Romania (Lockyear 2008).

The average gold content of the coins minted by Nerva and during Trajan's rule varies between 0.05% and 0.25%, whereas the average lead content is usually higher than 0.50% and the bismuth content is very low (<0.1%). In order to study the relation between the trace element patterns of the Roman *denarii* of Nerva and Trajan on the one hand and the imitations of Roman Republican *denarii* analyzed in our project on the other, the ratios of gold to silver and bismuth to silver (fig. 13, below), as well as of gold to silver and lead to silver (fig. 14, below) were compared.

The coins struck during Trajan's consulates II to III (AD 98–100), thus before the First Dacian War, contain the highest quantities of gold, whereas bismuth is particularly low in this period. Subsequently, a marked decrease in the gold content and a corresponding increase in the percentage of bismuth may be observed. The turning point is in Trajan's long COS V period (AD 103–111), when a change in the source (or sources) of metals for producing the Roman *denarii* seems to have occurred (fig. 13, below).

The data obtained during our analyses do not, however, provide any evidence that it could have been a change to silver imported from Dacia. The gold content of the imitations of Roman Republican *denarii*, which may be presumed to have been struck in the Dacian area, is very distinct from Trajan's fifth consulate issues, in that it is manifestly much higher. On the evidence currently available, a relation between the silver bullion used to produce these two groups of issues therefore cannot be postulated. The occurrence of two subsets with alloys of different trace metal signatures within the Trajanic *denarii* should nevertheless be attributed either to the use of silver ores with different origins or to the dilution of the silver

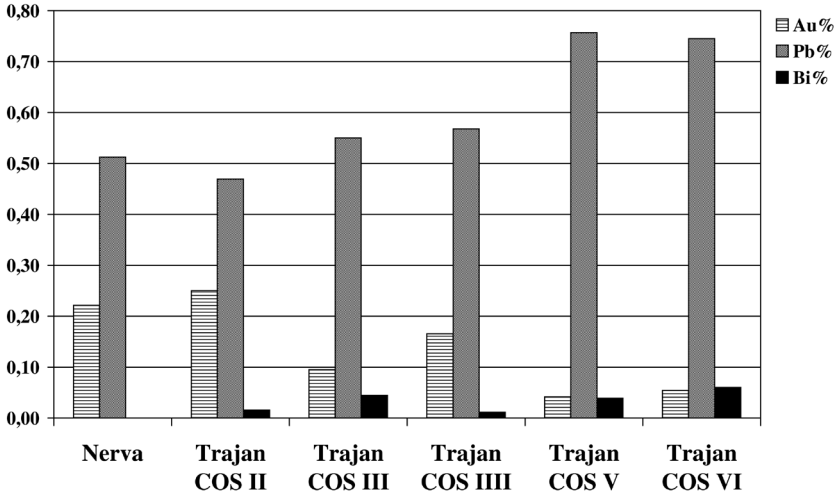

Figure 12. Average content of Au, Pb and Bi (*denarii* of Nerva and Trajan).

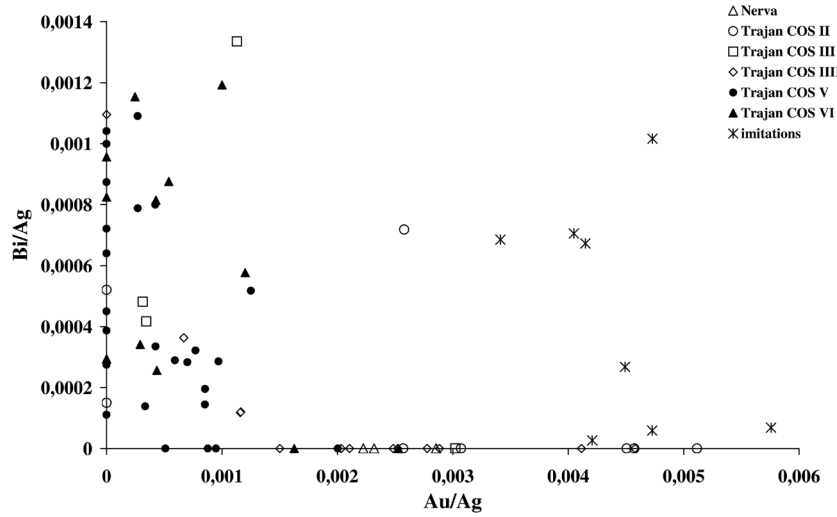

Figure 13. Ratios of gold to silver and bismuth to silver of the Roman *denarii* of Nerva and Trajan and of the imitations of Roman Republican *denarii*.

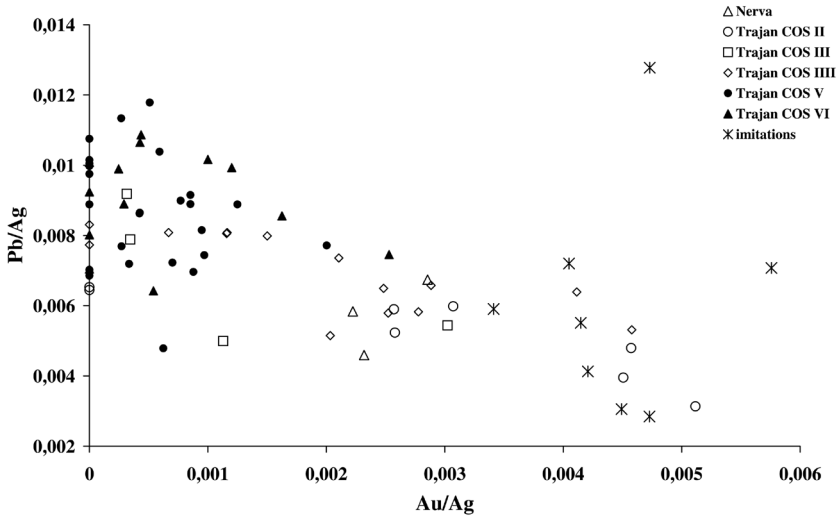

Figure 14. Ratios of gold to silver and lead to silver of the Roman *denarii* of Nerva and Trajan and of the imitations of Roman Republican *denarii*.

with another type of silver ore through re-melting and re-minting. For the moment, this problem is best left open.

Figure 14 corroborates the conclusion that there was a marked change in trace metal signatures from Trajan's COS IIII- to his COS V-issues. It illustrates that the most significant trace element switched from being gold to lead, at that time. This observation confirms the hypothesis of the possible use of a different source (or sources) of metal, but also suggests that this change was accompanied by a less efficient refining process for the silver bullion supplied to the mint of Rome, so that the coins' silver retained more lead. In comparison with the Trajanic issues, the imitations of Roman Republican *denarii* were found to contain lower amounts of lead, which indicates more effective smelting and refining processes.

6. Conclusions

The results of the synchrotron micro X-ray fluorescence analyses published here provide important evidence that the silver content of imitations of Roman Republican *denarii* of the "Geto-Dacian" group is, for the majority of these coins, very high (above 90%), and in some cases identical with the elevated silver content of the Roman prototypes. Therefore, it does not come as a surprise that our metallographic analyses revealed most of the coins to have a completely homogeneous internal structure. Among the coins sampled, there were, however, some exceptions. Two of the coins presented an intriguingly heterogeneous core structure as well as phenomena of surface enrichment.

Comparison with the data of analyses on comparable imitative material from Dacia conducted by Lockyear and Ponting with a different analytical technique (atomic absorption spectrometry) proved very rewarding. The trace metal signatures of the two groups of coins, which were selected randomly, are not unlike each other, which suggests that the imitations analyzed by Lockyear and Ponting and in this project may have been produced from silver with a similar origin. Whether it was locally sourced Dacian silver cannot be proven on the evidence currently available. Be that as it may, our analyses show the chemical composition of the silver used to strike *denarii* of Trajan (AD 98–117) to be markedly distinct from the silver used for the *denarius* imitations of the "Geto-Dacian" group; the hypothesis recently expressed that large quantities of imported Dacian silver may have been used for the production of Roman silver issues after Trajan's Dacian Wars thus does not find support in the scientific data published here.

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Appendix

Table I. Results obtained for the ÖGUSSA standards

	μ-SRXRF		SEM/EDX	
	Ag %	**Cu %**	**Ag %**	**Cu %**
Ag80	80.63	19.37	79.90	20.10
Ag90	89.27	10.73	90.00	10.00
Ag92.5	92.89	7.11	92.55	7.45
Ag95	95.26	4.74	95.10	4.90
Ag99.9	99.98	0.02	99.90	0.10

Table II. Chemical composition of the nine imitations of Roman Republican *denarii* analyzed by μ-SRXRF[76]

No.	**Ag %**	**Cu %**	**Au %**	**Pb %**	**Bi %**	**Mn ppm**	**Fe ppm**	**Rodrigues *et al.* 2011**
1	93.87	5.15	0.39	0.52	0.06	97	57	D9
2	57.88	40.82	0.27	0.74	0.06	513	1777	D3
3	96.57	2.16	0.56	0.68	0.01	105	68	D4
4	97.98	1.25	0.46	0.28	0.01	92	93	D5
5	97.16	1.86	0.33	0.57	0.07	55	35	D6
6	86.29	12.66	0.35	0.62	0.06	82	153	D8
7	89.92	9.31	0.38	0.37	0.00	81	94	D7
8	97.13	2.09	0.44	0.30	0.03	104	62	D1
9	94.84	3.91	0.79	0.34	0.10	104	76	D2

76 For a description of the coins, see section 2 above; note that the numbering system used here differs from the system utilized in the publication by Rodrigues *et al.* 2011—for a concordance see the last column of this table.

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Imitations of Roman Republican Denarii