ADULTERATIONS IN FIRST CENTURY B. C.: THE CASE OF GREEK SILVER DRACHMAE ANALYSED BY X-RAY METHODS

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Abstract

For coins, chemical differences that occur during preparation affect the elemental composition and can be used to identify the producing technologies and workshops and to distinguish between originals and counterfeits. In this study, we focus our attention on some Thassos silver tetradrachmae and on an important number of Apollonia - Dyrrhachium silver drachmae emitted by these Greek cities under Pompejus authority during the First Roman Civil War. All the analyzed coins were found on the territory of present Romania (ancient Dacia). The important presence of Apollonia-Dyrrhachium drachmae here can be explained by the hypothesis that these coins were probably used by Pompejus as payment for Dacian mercenaries. To analyze the elemental composition we used: ^{241}Am gamma source based X-Ray Fluorescence (XRF) and in vacuum 3 MeV protons Particle Induced X-ray Emission (PIXE). The following main categories were found: original coins, local (Barbarian)

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imitations, debased coins with silver content down to 70%, official (original dies) counterfeits of bronze, official counterfeits of tin, and plated coins - a bronze core covered by a 0.2-0.5 mm silver layer.

Keywords: silver coins, adulterations, XRF, PIXE.

Introduction

The great number of Greek silver coins from the first century B.C. found in the Balkan – Carpathian region have aroused a sharp interest among numismatic researchers [1]. The problem is to classify these coins - tetradrachmae of Thasos (Greek island near Thessaloniki) and drachmae of Apollonia and Dyrrachium (ancient Greek commercial cities, now in Albania) into originals, copies and imitations, in relation to their provenance. Well-known are the Celtic Thasos tetradrachmae copies (good quality coins, closest to the originals), and also Barbarian imitations (absent or misspelled legend, disproportionate and simplified figures) [2, 3, 4]. Barbarians (non-Greek population), i.e. Thracians, Dacians and Celts used to "produce" the same type of coins. The dies used for coining were bought or stolen from the Greeks, while some local engravers manufactured their own dies. Apollonia and Dyrrachium drachmae, all emitted during the Roman civil wars, were also found in many hoards on the Romanian territory. The archaeological problem is to explain the large diversity of these coins – the differences in composition, weight and physical aspect.

Experimental

Visual examination, the first step of a numismatist's work, is insufficient to classify the coins. This is the reason why elemental analysis is required, e.g. the use of XRF (X-Ray Fluorescence) and PIXE (Proton Induced X-ray Emission) methods.

All the coins were analysed with XRF using a 30 mCi ^{241}Am annular source and a Hungarian ATOMKI Si(Li) detector (energy resolution 190 eV FWHM at 5.9 keV). The typical acquisition time was about one hour [5].

Some representative coins for each group found after XRF examination (see tables 1 and 2) were also PIXE analysed using in vacuum a 3 MeV proton beam from the Bucharest 8 MV FN Van de Graaff Tandem (High Voltage Engineering Corporation) accelerator impinging at 45° to the surface. A Canberra GL0110P – Low Energy Germanium Detector (100 mm^2 area, 10 mm thickness, 0.075 mm Be window thickness, energy resolution 160 eV FWHM at 5.9 keV, 500 eV FWHM at 122 keV), oriented perpendicularly to the proton beam direction recorded the X-ray spectrum emitted by the sample. We routinely used a 0.8 mm diameter beam and a constant proton dose, each acquisition taking roughly 20 min [6].

Pure thick metal foils and alloys (Goodfellow) of known composition were used as certified reference materials. They were irradiated (PIXE) or excited (XRF) under the same conditions as the samples to be analyzed. This approach has some drawbacks: because the reference material and the sample are not identical, but only similar, enhancement and absorption effects in the real sample introduce some uncertainties. Software designed in our laboratory was employed to determine the quantitative results.

Major elements are those contributing 10% to overall composition, minor elements 0.1-10% and trace elements less than 0.1%, down to detection limits. The overall uncertainty for XRF was 3% for major elements, 5-10% for minor elements and 20% for trace elements, while for the PIXE method the corresponding values were 5% for major elements, 5-10% for minor elements and 15% for trace elements. The uncertainties are not only statistical, but they also originate from the roughness of coin surface and from the chemical corrosion and/or wearing of the objects, altering the accuracy of the results.

281 pieces silver coins (36 Thasos tetradrachmae and 245 Apollonia and Dyrrachium drachmae, struck between 60 and 48 B.C., a very intense period of civil Roman wars), belonging to Ţării Crişurilor Museum in Oradea and to the Bucharest National Institute of Archaeology were analyzed. These pieces were found in various places on the Romanian territory, concentrated in the North-West of Transylvania and South-East of Muntenia regions.

All analyzed coins were gently chemically and, sometimes, mechanically cleaned by the curators to remove the earth and dirtiness traces and to give them a shining look. We tried to analyze in all cases the flat and bright regions of all coins, i.e. patina- free surfaces. For XRF we performed two measurements, one for each side of the coin. For PIXE, because of the smallness of the beam spot (only 0.8 mm diameter), 3 - 4 measurements were made for each side to test the homogeneity of the composition (the obtained results varied with ± 10% from a point to another) and to get an average result. For both methods we took into account the average values as working numbers.

The purpose of our study was to group the coins with similar composition, and not to get an accurate value for each element content. One must mention that the compositions we obtained is relevant only for a thin layer at the surface (tens of micrometers in depth), and not for the bulk. One should mention here the well known Ag enrichment – Cu depletion surface phenomena. For similarly cleaned silver coins, we obtained in [7] a decrease from 93% to 82% for Ag concentration and an increase from 6% to 17% for Cu if we compared the surface values and the concentrations from 100 microns deeper in the sample, measured after polishing.

In our study, iron concentrations were neglected, because this element originates mainly from the surface contamination or inclusions present in the sample (Fe does not appear either in Ag ore, or in the metallurgical processing of Ag) [8].

After completion of analyses, the coins can be grouped into several categories, taking into account their elemental composition. The groups were inferred using the simple presence/absence of certain elements (e. g. Br and/or Sn), or using the order of magnitude of Cu content (Cu is the main element which is added on purpose in debasement situations).

Results and discussion

Regarding the first group of Thasian tetradrachmae (table 1), they are similar in composition to the so-called Celtic imitations, e.g. the pieces found in Slovenia and Austria, reported by Smit et al [3]. They are good quality minted coins.

The coins from the second group (see figure 1) were probably deliberately alloyed with copper (0.7 - 5 %). The low concentration of copper may show that the alloying was made for hardening and not for debasement reasons. Hg traces presence could indicate an amalgamation procedure for silver metallurgy, but additional arguments are necessary.

The separation between this group of coins with relatively higher Cu concentrations and the first one (with lower Cu contents) can be observed in the Ag-Cu-Au diagram (figure 2).

The “fingerprint” of the third group of Thassian tetradrachmae is the bromine. The presence of this element in silver coins is mentioned in the literature in [9], where bromine is linked to marine spray, because the hoard was found near the seacoast. In our situation, the coins were found in a region, which is far away from the Black Sea coast (approx. 300 km). Taking into account the presence of bromine in silver ore from some Transylvania mines Rodna (embolite – Ag(Cl Br) and bromargirite - AgBr) and supposing an imperfect procedure of refinement (see also Cu and Pb high content), these coins could be attributed to local Barbarian (Dacian) workshops. To confirm this hypothesis are necessary further archaeological arguments, e.g. an analysis of a silver jewelry, definitely attributed to local craftsmen from this period.

The results for Apollonia and Dyrrachium drachmae are summarized in table 2, the classification being similar with the one for Thassian tetradrachmae.

Because of the high silver content and refined aspect of the coins belonging to the first group, one can assume that these drachmae are the original ones, minted of Macedonian silver.

The percentage of copper in the second group of coins (displaying imperfections in their design and execution) is higher than in the previous case. These drachmae were struck in Apollonia, using Dyrrachium dies belonging to MENISKOS and XENON magistrates, Pompejus and Caesar contemporary.

The separation between the first and second group of table 2 was made only on coins appearance grounds, and there is no clear distinction between the elemental compositions of the two groups.

However, it is clear that a continuous debasement is present, the copper content being increasingly higher (see figure 3). The conclusion is that copper was deliberately added to the alloy, reflecting a difficult economic situation during the civil wars.

The third group of drachmae is similar in composition to a category of the tetradrachmae table (the third one): again a relatively high content of bromine (possible use of Dacian local silver).

Another important group is bronze Dyrrachium drachmae, found in South-East of Romania (see figure 4). Some of these coins were covered with a thin (submicronic) layer of tin, which can be partly noticed by visual examination. The tin layer was strongly corroded. The Cu-Sn proportion is unbalanced, triggering a frailty process because of the high content of Sn. Moreover, the absence of Zn brings about a certain degree of porosity that can be noticed in some coins. The result of this alloying is a compound named "white bronze", which can easily be mistaken for silver. This was in fact, the intention of the manufacturer. This artifice was used in extreme situations, when silver resources were completely exhausted. This aspect is in agreement with Elder Pliny, which mentioned in his "Historia Naturalis" that Romans used for tinning two lead-tin alloys: argentarium (50% tin) and tertiarium (33% tin) [10]. The same alloys were used for coins, too, which were coated with a very thin layer of molten material.

Only one sample (listed at the end of table 2), with low weight and strongly oxidized, differs in composition from the above ones. One could assume this Dyrrachium drachma bearing the inscription XENON was minted using Illyrian tin.

A special case was the plated drachmae. Almost since the invention of coinage, imitation silver coins have been manufactured by attaching a silver layer, with the same composition as the contemporary official coinage, onto the surface of a base metal core [11, 12]. A similar technique was to use a thick plate covering a bronze or copper core [13]. In the case of copper (bronze) cores, this process could be carried out by coating the surface of the core with a layer of solder consisting of a silver-copper alloy, or by attaching a layer of silver foil to the surface, either by soldering or by heating to form a layer of eutectic at the interface of the silver and copper. This latter technique is, in effect, a self-soldering process, known today as Sheffield plating. In the Republican and early Imperial periods, a common technique of manufacturing silver plated forgeries was the application of silver foil. To try if the coins were plated, a test cut or punchmark on the surface were made. Another procedure was to drop the coin on a stone surface and to listen if the coin 'rings' like a normal one. The latter method left no indication on the coin, but the results of test cuts and punches are to be seen on many surviving ancient silver coins, which is the case for a few samples studied by us.

Another way of plating was described in [14]: in Roman coinage the covering was produced using silvering pastes or by dipping the blanks in molten silver chloride. We did not find in our cases any indication for using such technique.

Some of the analyzed coins had a crust broken in some areas, especially on the edge, making the core visible. For six of these coins we used a proper collimation in PIXE, obtaining in this way compositional information about their bronze cores.

Our results indicate the use of the following plating system: a 0.3-0.5 mm thick crust made of high purity silver (95-97%), broken in some areas, bearing an inside core (0.2-0.3 mm), made of bronze (90-97% Cu, 3-10% Sn) and a very thin (a few microns) tin-lead layer between crust and core used as soldering interface. No evidence of Sheffield plating was found.

As a possible economic and political explanation for these last categories of coins, one can assume that during the Roman civil wars (1^{st} century B.C.) - Caesar versus Pompejus, and Octavianus versus Brutus - the connection with Macedonian silver mines was often interrupted. Therefore, the local administration started to mint plated coins just with a silver skin. After ingot exhaustion, the coins were only made of bronze, and the silver was reduced to a thin covering; sometimes even this silver covering was replaced with a tin one. These coins have a very elaborate aspect; one can conclude that they were struck using the original dies. Historically, all these aspects are in agreement with the fact that many Dacians participated in the Roman civil wars as mercenaries, on Pompeius and Brutus side.

Conclusions

The present study allowed a classification of Thassian tetradrachmae and Apollonia – Dyrrachium drachmae found on Romanian territory, and connections between the coins composition and historical aspects of the corresponding minting period were drawn. Hard economical and political times were characterized by debasement, reflected in our study by the increased content of Cu of drachamae. In the case of Apollonia and Dyrrachium drachmae, the plating procedure was revealed as a solution for the Roman civil war times.

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Figure captions

Figure 1 – A typical PIXE spectrum of a Thassian coin belonging to the second group of table 1 (high Cu content).

Figure 2 - 3d diagram Ag – Cu - Au concentrations of Thassian coins.

Figure 3 - 3d diagram Ag – Cu - Au concentrations for drachmae, illustrating the debasement process.

Figure 4 – A typical XRF spectrum of a tinned (bronze core covered with argentarium) drachma coin.

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Table 1 – Classification of Thassian tetradrachmae using the determined elemental composition

Group no.	Ag(%)	Cu(%)	Au(%)	Pb(%)	Br(%)	Bi(%)	Trace elements
I	97…98	0.1…0.7	0.1…0.9	0.2…0.5	-	0.05-0.15	Fe, Sn, Hg
II	94…98	0.7…5	0.1…0.9	0.2…0.5	-	0.1…0.15	Fe, Sn, Hg
III	95…97	2…3.5	0.5…0.8	0.5…0.8	0.1…0.3	traces	Fe, Sn, Hg

Table 2 – Classification of Apollonia and Dyrrachium drachmae using the determined elemental composition.

Group no.	Ag(%)	Cu(%)	Au(%)	Pb(%)	Br(%)	Sn(%)	Fe(%)	Trace elements
I	96…98	0.5…2	0.2…0.8	0.2…0.7	-	traces	traces	Bi
II	78…92	4…20	0.2…0.8	2…4	-	traces	traces	Bi
III	95…97	0.5…1	0.7…1	0.5…1.0	0.1…0.2	traces	traces	Bi
IV	-	67…72	-	0.1...0.4	-	28…33	0.5…1.5	Sb
V (one coin)	-	7	-	0.1	-	90	3	Ni, Sb

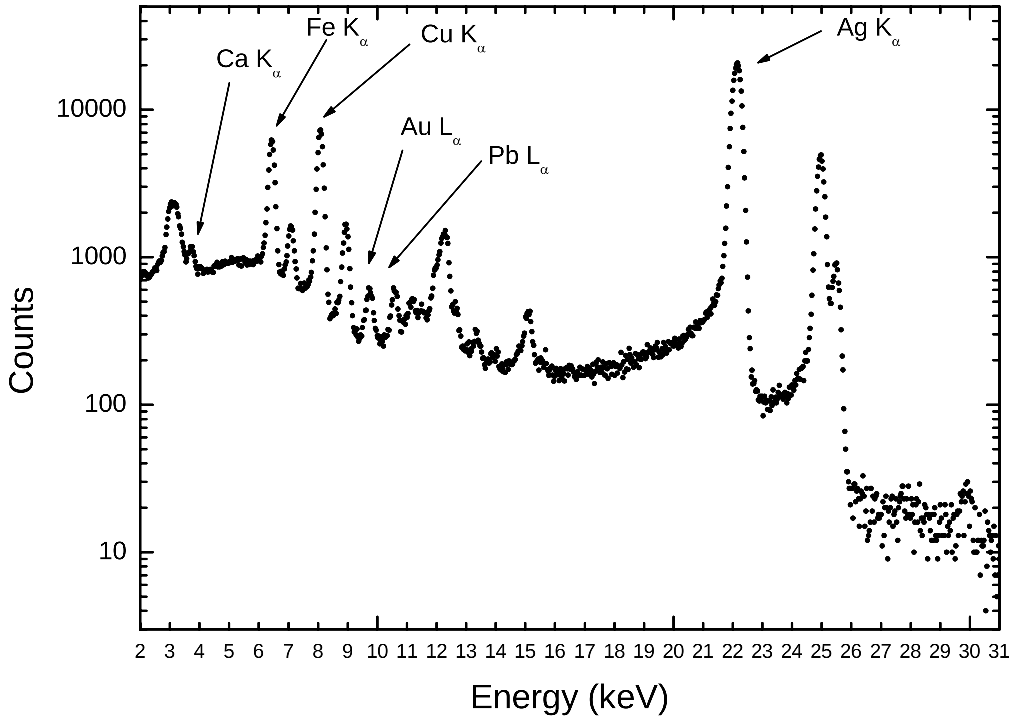
Counts
10000
1000
100
10
Ca K$_\alpha$
Fe K$_\alpha$
Cu K$_\alpha$
Au L$_\alpha$
Pb L$_\alpha$
Ag K$_\alpha$
2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Energy (keV)

Figure 1

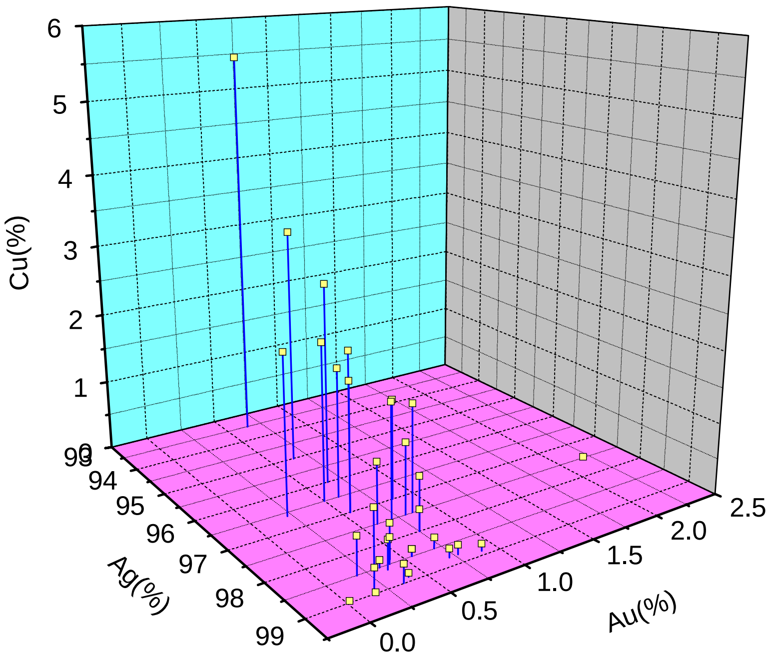

Figure 2

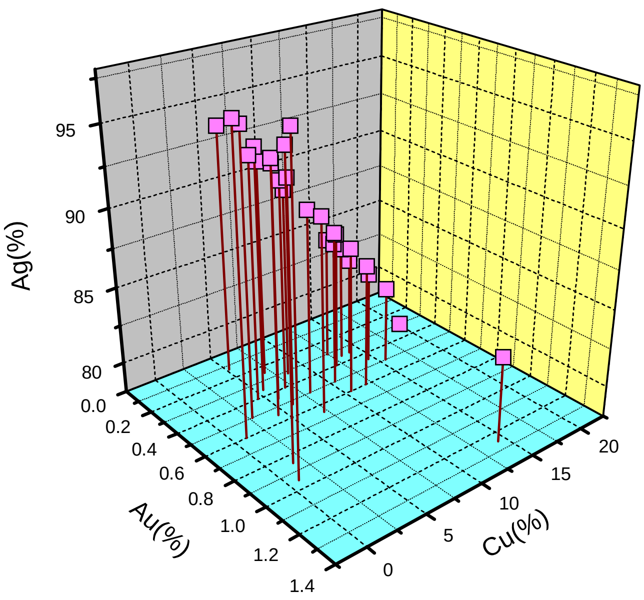

Figure 3

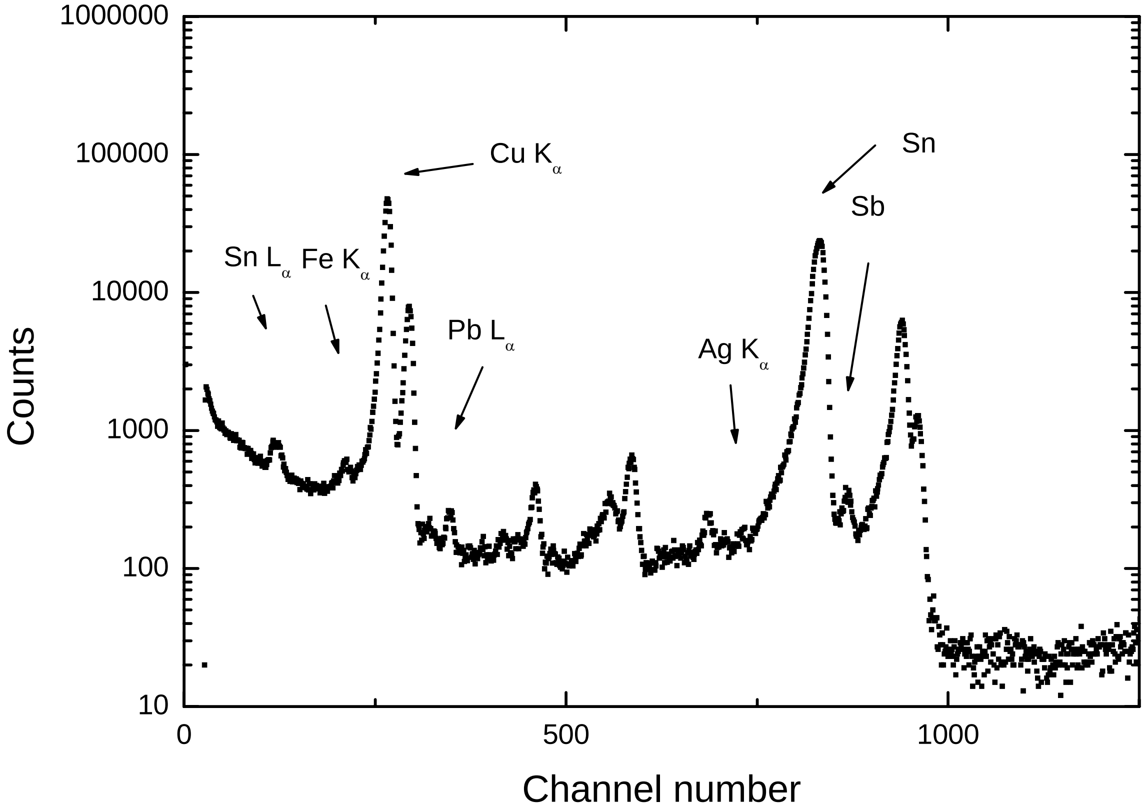
1000000
100000
10000
1000
100
10
Counts
0
500
1000
Channel number
Cu Kα
Sn
Sb
Sn Lα
Fe Kα
Pb Lα
Ag Kα

Figure 4