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ON CHEMICAL COMPOSITION OF ROMAN COPPER, BRONZE AND BRASS COINS MINTED IN THE 1st, 2nd and 3rd CENTURIES IN LOCAL BALKAN MINTS

Introduction

In the first, second and third centuries of the new era the territory of the Balkan Peninsula was entirely or in its greater part comprised within the frontiers of the Roman Empire. In this period coins were stamped in a large number of local mints in the Balkans[1] Until recently almost nothing has been known on the chemical composition of copper, bronze and brass coins from these mints.

In the course of the last ten years, we analysed the chemical composition of coins of copper and of its alloys, minted in several Balkan mints in the above mentioned period. The results are presented in the papers dealing with the composition of coins minted at Viminacium,[2,3] at Stobi,[4,5] of the coins of the Province of Dacia,[6] of the mine coins,[7] of the coins of Thessalonice[8] and a paper dealing

[1] Н. Мушмов: Античните монети на Балканскија полуостров и монетит на блгарскит царе, Софија, 1912.

[2] V. Simić: The chemical composition of coins minted from copper alloys which contain zinc in the roman colony of Viminacium, Archaeologia Iugoslavica, 12 (1971) 55—63.

[3] В. Симић: Резултати испитивања хемијског састава бронзаног новца кованог у Viminacijumu (The results of the examination of the chemical composition of bronze coins minted in Viminacium) Зборник Народног музеја у Београду, VII (1973) 197—205.

[4] V. M. Simić: Metallanalysen römischer Kolonialbronzen von Stobi, Jahrbuch für Numismatik und Geldgeschichte, 24 (1974) 99—108.

[5] V. M. Simić: Differences between coins from Stobi and other Balkan mints, Balcanica VII (1976) 45—59.

[6] В. М. Симић: Хемијски састав новца Провинције Дакије и његова сличност са новцем кованим у Viminacijumu (Chemical composition of coins of the Province of Dacia and the resemblance to the coins minted at Viminacium), Balcanica, VI (1975) 23—36.

[7] V. M. Simić, M. R. Vasić: La monnaie des mines romaines de L'Illyrie, Revue Numismatique, 6e serie, XIX (1977) 48—61.

[8] В. Симић: Хемијски састав новца из Тесалонике од I—IV века (in preparation for the print).

with the composition of coins from 8 mints of Moesia Inferior and Thracia.[9] Thus, we have so far analysed 766 samples, coined in 13 Balkan mints (Table 1).

It proved necessary to make a comparative analysis of the chemical composition of the coins stamped in these mints. To point out their similarities and their differences and to notice their common properties. Also, to make some comparisons with the mints situated outside the Balkans. Under the identical conditions as for the coins from Balkan mints, there was made an analysis of coin samples from two mints situated outside the Balkans — one in the East and the other in the West. These are the mints of Nicaea and Roma. The data concerning the chemical composition of coins from these mints are set forth in Table 2.

In order to make possible the comparison of compositions of coins from 13 Balkan mints and 2 mints situated outside the Balkans, there has been set up Table 3. In it are presented the compositions of main alloy components, whereas the impurities will be analysed separately.

Similarities and differences in the composition of coins from the analysed Balkan mints

COINS FROM VIMINACIUM AND FROM THE PROVINCE OF DACIA. As to the coins from Viminacium,[2,3] there have been analysed 138 bronze pieces and 67 samples containing Zn as one of the main components of the alloy. Among the copper-bronze coins, the least numerous are those of copper (Cu), and the most numerous those of the lead-tin bronze (CuSnPb). Small samples have been found only among the coins minted in the first two years of coining, and the great ones in all the years of coining. In the first years there were found few coins composed of CuSnPb, whereas in the later years they form a marked majority. The coins of small and great dimensions do not differ as to their chemical composition. Coins containing zinc existed in all the years of coinage, half of these samples having been made of brass. The brass samples were found in the first eleven years of coinage, whereas they do not occur in the years 11—16. However, there appear then the samples of complex composition (CuSnPbZn). Both with bronze coins and with those containing Zn there can be observed a gradual shortening of diameters in later years. Coins minted at Viminacium are typical coins of the middle of the 3rd century.

There have been analysed also 100 samples of coins of the Province of Dacia[6] — 88 bronze coins and 12 containing zinc. The bronze samples are made of tin bronze (25), of lead-tin bronze (45)

[9] В. Симић: Хемијски састав Римског новца кованог у осам ковница Доње Мезије и Тракије у II, III. веку, Старинар XXVIII—XXIX, 1977—1978, Београд, 1979, стр. 241—248.

and lead bronze (12) and there are also a few copper (Cu) samples — 6 pieces. A single coin is made of brass (CuZn), and 11 samples containing Zn are of complex composition. All of them are of large dimensions. The coins of the Province of Dacia, by their composition and their appearance, show a striking similarity with those of Viminacium, from the time when both these coins had been minted simultaneously. This points out the possibility that both mints used the same ore for making the alloys. It also suggests the assumption that the coins of the Province of Dacia had been minted in the area of Viminacium, or perhaps that they were coined somewhere else, but using the imported ore from Viminacium and that they were minted by the workers trained at Viminacium. This hypothesis is supported by the analysis of the contents of antimony as the impurity of alloys (Table 8).

COINS OF THESSALONICE. There have been analysed but 43 samples and it is exceptionally few for this mint[8]. This shortage is partly compensated by the great uniformity of chemical composition of the samples throughout the investigated period. The analysed samples were minted within a period of about 300 years in the course of the first three centuries of our era. No samples made of brass (CuZn) were found, but chiefly those of lead-tin bronze (CuSnPb — 26 pieces) and of lead bronze (CuPb — 10 pieces). The composition is identical both with small and large coins. A characteristic feature of the coins minted in Thessalonice is a great concentration of lead in the samples. By this feature they are similar to the coins minted at Viminacium and even more to the coins of the Province of Dacia. They differ essentially from the coins of all the analysed, territorially close mints. Considering the little number of analysed samples, it can be assumed that there are also coins from Thessalonice with different composition.

MINE COINS. The analysed samples of mine coins (23 pieces, coined in the 2nd century, bear the names of six different mines or mining areas: Pincum, Pannonia, Delmata, Metalla Aurelianis, Dardania and Ulpiana. Until recently, these names have been thought to denote the mint in which the coin in question had been minted. Our analyses[7] have shown that mine coins contain 4 types of alloys: copper (Cu), tin bronze (CuSn), brass (CuZn) and complex (CuSnZn). However, regardless of the enumerated principal components in the alloy and regardless of the name stamped on the coin (Pincum, Delmata, ...), all the analysed samples contain six elements (Cu, Sn, Pb, Zn, Ag and Sb) in concentrations over 0.1 p. c. Differences in composition among the samples of these coins are less than usual differences among the samples coined in some other Balkan mint. This points out the fact that all of them were made of the same ore. Thus uniform chemical composition of samples indicates that they were most probably also coined in the same place. The greatest number of samples were found on the Kosmaj mountain. They were probably even minted there, but

the ore concentrate might have been imported. The identity of the chemical composition of mine coins and of Roman quandrantes of the same dimensions, from the regular coinage of that period, indicates that the quadrantes, too, were minted of the same ore. This means that the mine coins could have bean minted outside Balkan (perhaps in Rome — Table 8) or at least of the imported ore. In relation to other local Balkan coins, they are rather specific and of exceptionally small dimensions.

COINS FROM 8 MINTS OF MOESIA INFERIOR AND THRACIA. There have been analysed the compositions of alloys used in three mints of Moesia Inferior and in five mints of Thracia[9]. They are territorially disposed in such a way that they include the entire territory of these two provinces. They can be used, with some exceptions, in judging the composition of local coins from these two provinces. The analysed coins were minted in the 2nd and 3rd centuries. Considered as a whole, there were found about 75 p. c. of brass (CuZn) samples, i. e. 80 p. c. of samples containing Zn. The remaining 20 p. c. of samples (64 pieces) of copper and bronze, are rather evenly distributed over all the mints. About 85 p. c. of them (54 pieces) are of small dimensions, and over a half of this number (30) are made of copper (Cu). The conclusion can be drawn that these are chiefly brass coins when they are of large dimensions, and of copper and bronze when they are of small dimensions. Such a uniformity of composition suggests the conclusion that other mints of this area, too, stamped probably the coins of the approximately identical composition of alloys. Finally, this refers to the hypothesis, that other mints from this territory, too, used the ore of the same proveninence. Obviously, the mints of these two provinces make a compact group, perhaps under the common firm control, and rather different from the neighbouring analysed Balkan local mints.

COINS OF STOBI. The mint at Stobi worked, with some interruptions, about 150 years in the 1st, 2nd and 3rd centuries. There have been analysed[4,5] 83 samples from all the periods of coinage. It has been established that the chemical composition of Stobi coins was changing in the course of time. One kind of alloy was replaced by another, or they were used both at the same time, one along with the other. The coins from the period Vespasian-Trajan were made of copper (Cu) or of tin bronze (CuSn). We proved that the pseudo-autonomous coins were of the same composition, which means that they had been minted also in the period Vespasian-Trajan. Since Marcus Aurelius we did not find such coins any more, but only the coins made of lead-tin bronze (Cu SnPb). In addition to the coins made of SuSnPb, from Septimius Severus on were found also the coins made of lead bronze (CuPb). Since the time of Julia Domna (Caracalla's reign), the coins were minted also from brass (CuZn) and even of complex alloys containing Zn.

The coins of Stobi are totally different from those of Thessalonice. It differs also considerably from the coins stamped in the mint of Moesia Inferior and of Thracia, until the period of Julia Domna. After that period, the coins of Stobi became nearer, by their composition, to those of their eastern neighbours. The possible reason of these differences in composition — different provenience of ores — has been given in Table 8.

COINS FROM THE MINTS OUTSIDE BALKAN. In order to compare the Balkan coins with those minted autside Balkan, there were analysed the coins from Nicaea and Rome. The chemical composition of the samples from these mints has been shown in Table 2. There were analysed 69 samples from Nicaea, minted in the course of 80 years in the 2nd and 3rd centuries. Almost all samples (63) contain Zn; the greatest number of samples (44) are made of brass. Many samples are of small dimensions (20). To this category belong all the samples made of copper and bronze (6) and many brass samples (11). There were analysed also 40 coins minted in Rome, in the course of 60 years in the 1st and 2nd centuries. Most samples contain Zn as one of the main components of the alloy (32). Among them are wery few samples of brass (CuZn), only 14. All the samples, even the copper ones (except one) are of large dimensions. The coins from Nicaea are rather near, by their composition, to those of Moesia Inferior and of Thracia. It may be even assumed that the respective mints were supplied with the ores from the same sources or from the sources of a very similar composition. The comparison of the contents of Sb as impurity (Table 8), refers also to this conclusion. The coins minted in Rome differ to a considerable extent from the analysed Balkan coins. However, the analysis of the contents of antimony as impurity (Table 8), points out their resemblance to the mine coins and the coins of Stobi.

Some common properties of the analysed Balkan coins

The analysed coins from Balkan mints and from those outside Balkan (875 samples) have diameters from 13.5 to 34.5 mm. In order to make obvious the relation between the chemical composition, mint and diameter of samples, there were set up two tables: one for the bronze coins and the other for those with zinc. On account of the lack of space, they are not presented here, but only a few conclusions drawn from them are quoted.

In literature the ancient coins are often referred to as little (up to 20 mm of diameter), medium sized (20—24 mm) and large ones (over 26—27 mm). Our tables do not point out such a sharp separation. It can be noticed but a certain difference between the „small" samples and the „big" ones at 19—21 mm.

In the analysed Balkan coins there were found 90 samples (12 p. c.) of small dimensions (Table 4). The smallest bronze samples have a diameter of 16 mm, the samples containing Zn have a diameter of 17 mm. Exceptionally, smaller samples were found only among the mine coins (bronze coins — 14 mm, those with Zn — 16.5 mm), all of which are of small dimensions. This indicates once more their specific origin and purpose. The bronze coins of Nicaea are also of such small dimensions.

From the tables which are not presented here and from Table 4 it results that the small dimension samples are chiefly made of copper and of different kinds of bronze (70 out of 90 analysed ones). Among the samples containing Zn, two thirds are made of brass (CuZn). Almost half of the analysed samples (39) are made of copper (Cu). The small dimension samples were, in all probability, more frequently minted than the samples with other alloy compositions. Among the large dimension samples were found but 36 copper (Cu) coins, i. e. approximately 5 p. c. of the analysed ones. This indicates that the elementary copper was used, first of all, for the production of small coins. For the large samples, it seems, it was used but exceptionally.

The tin (CuSn), lead-tin (CuPbSn) and lead bronze (CuPb) also served as alloys for the production of small coin samples. These were the same compositions of alloys, which were used also for the production of large dimension samples. It is obvious that the same alloys were utilized and the coins were minted in small or in large dimensions according to the corresponding needs. The same criteria should be applied also to the coins samples containing zinc and among them also to brass samples. The little number of discovered small dimension samples, made of brass, is probably a consequence of the fact that they had been coined in small amounts.

From Table 5 a conclusion can be drawn that small dimension samples were minted in all the analysed periods. However, the largest percentage of them were found in the period Trajan-Elagabal (78 out of 416 analysed ones, i. e. 20 p. c.). This indicates that in this period were perhaps really more small dimension samples in circulation than in other periods. From Table 5 it is also to be seen that in the course of the entire observed period there were used, for the production of small dimension coins, the alloys of identical compositions.

The analysed coins were minted in a period of almost three centuries. In the course of time, the composition of alloys they were coined of, were changing. These changes were neither identical nor simultaneous in all the mints. The coins with the figure of a ruler was minted at the same time in several mints. Thus, for instance, we analysed 108 samples with Caracalla's figure, coined in 11 mints. The question arose, whether the coins minted for the same ruler should have the same composition, regardless of the

mint it had been coined in. Or should the composition depend on the mint and not on the ruler's figure. The analyses have shown that the composition depended on the mint. If the composition of alloys, used for the coins of the same ruler, is the same for the samples from several mints, then the composition of coins in these mints is similar or identical. It turned out that, in general, the coins minted for the same ruler in different mints can have entirely different composition. Two such examples, from quite different periods, are presented in Table 6.

The analysed elements are not equally represented in the alloys of investigated coin samples. Some elements are to be met with more and some other less frequently. Copper is always present with the concentration which is superior to that of all the other elements. According to the importance, there follow zink, tin and lead. Silver and antimony have considerably less importance. Nevertheless, the last one served us for the interesting hypothesis on the origin of ores used for the stamping of Balkan coins.

The alloys contain, in addition to copper, in most cases 1—2 other elements. Of the alloys containing zinc the most frequently occurring is the composition CuZn, ancient variant of brass. Of 450 samples containing Zn, 350 have the composition CuZn. The remaining ones, of a more complex composition, in addition to Cu and Zn, contain Sn or Pb resp. Sn and Pb. Of 875 analysed samples a total of about 450 contain Zn in the alloy. The remaining samples were made of copper or of tin bronze, lead-tin bronze and lead bronze.

The occurrence of Zn, Sn and Pb in the alloys of coins from individual mints is set forth in Table 7. Among the coins from the mints of Moesia Inferior and Thracia there are 248 samples containing Zn as one of main components of the alloy, and this is 80 p. c. The remaining 20 p. c. contain Zn as impurity or do not contain it at all. Tin and lead, as main components were found 7 times less than zinc. In most samples they were not found even as impurities.

To the second group of mints there belong Stobi and Viminacium. The coins stamped in them contain all these three elements (Zn, Sn and Pb) in a large number of samples as main components. The mine coins are close to this group. Among the coins minted in Thessalonice and among the coins of the Province of Dacia there are very few samples with zinc as one of main components of the alloy. On the contrary, the samples containing Sn and Pb are very numerous. The coins from the mints outside Balkan (comparable), may be classed into the first group if we consider Zn and Pb, whereas, by the occurrence of Sn, they differ from it. From a total of 875 analysed samples there were found equal numbers of samples containing Zn, Sn and Pb.

If we consider the coins according to the rulers, Zn was not found in the samples previous to Domitian's reign, nor in the

samples of the last analysed rulers, except Gallienus. The absence of Zn in the coins from Caesar to Titus is probably a consequence of the small number of analysed samples. The absence of Zn in the coins of the rulers from the middle of the 3rd century is a consequence of the fact, that at that time Zn gradually ceased to be used for minting the coins. The samples which contain tin resp. lead in the alloy, were minted for all the rulers, whose coins have been analysed.

Silver was found only as impurity. It occurs in the coins from all the mints and stamped for all the rulers, most frequently in concentrations from 0.1 to 0.3 p. c. In some instances it occurs also in concentrations above 1—2 p. c., but this is, probably, an accidental phenomenon. Antimony, too, is always impurity. In a few instances it was found in concentrations of about 1—4 p. c. In our opinion, it got into these samples casually, owing to the unrefined ore. Or, perhaps, it was put instead of tin.

On the origin of ores used for making alloys of Balkan coins

We have established that the coins of Stobi[5] differed from the coins which were stamped at the same time in 8 mints of Thracia and Moesia Inferior. The papers[4,9] give the details of this difference. The question arises therefore, where do these differences come from? Where do the ores, used in the mint of Stobi, originate from? In addition to what has been so far said on this subject, we based the analysis of the origin of the ores on the contents of antimony (Sb) which was found as impurity in the coins made by the investigated mints. The results of this analysis are set forth in Table 8. They should not be conceived as irrefutable facts which give a direct answer to the question of the origin of ores. Nevertheless, they can be taken as a basis for the hypothesis where the ores, used in making the coins in the Balkans, have to be looked for.

In Table 8 we notice three data. The coins of Stobi, mine coins and coins minted in Rome contain Sb in 50—80 p. c. of samples. The mints of Moesia Inferior, Thracia (a minor exception is Hadrianopolis), Thessalonice and Nicaea contain it in 10—20 p. c. of samples. The coins made by the mints of Viminacium, those in the Province of Dacia and of Pautalia do not contain it at all (i. e. in concentrations over 0.1 p. c.). This suggests the hypothesis that the *coins of Stobi were perhaps minted from the ores, used in the same period of time, also for minting the mine coins and the coins in Rome.* In the paper dealing with the mine coins[7] we inferred that it had been minted either on the Kosmaj mountain (perhaps from the imported ore) or, more likely, outside Balkan, in Rome. The results set forth in Table 8 confirm this, very close, connection with Rome.

In 8 mints of Moesia Inferior and Thracia[9] the coins were obviously minted from one ore or several ores, very similar to one another. The resemblance in composition of alloys used in these mints to those of Nicaea points out the fact that all these 9 mints might hawe been supplied with the ore from the same source as well as other mints in the Eastern Balkan and in Asia Minor. The quoted papers[2-9] and the data from Table 8 suggest the following, rather probable, conclusion. Eight mints in the Eastern Balkan and Nicaea were, perhaps, supplied with the ore from a cominon source. Stobi, the mint which made the mine coins and Rome were probably also supplied with the ore from a common source. *These two sources of supply were, most probably, far from each other.* It may be assumed, therefore, that this distance could be the cause of difference in chemical composition of alloys used at Stobi and those in the coins of its eastern neighbours.

The data presented in Table 8 point out once more (in addition to what has been already quoted) that Viminacium and Province of Dacia used the same or similar ores for the alloys used in coinage. This fact shows that this ore came from some „third" source, perhaps from wider surroundings of Viminacium.

According to all these facts, it seems that a further study of the origin of ores from which the coins were minted in the Balkans, would be an exceptionally interesting task.

Conclusions

A comparative analysis has been made of the chemical composition of 766 samples of coins from 13 Balkan mints and of 109 samples of coins from two mints situated outside Balkan. As a result, the author pointed out their similarities and differences as well as some properties they have in common.

It was noticed that there existed five groups of coins of a more or less different composition. The coins from Viminacium and those from the Province of Dacia are almost identical, in the period of simultaneous minting. They partly remind of the coins minted in Thessalonice, but they differ from the latter by the absence of antimony. The analysed coins from Thessalonice did not almost change their composition in the course of three centuries. By their composition they differ strikingly from the coins of their neighbours: Stobi, Moesia Inferior and Thracia. It has been established that the mine coins differed by their composition (and dimensions) from all the analysed Balkan coins. Judging by the identity of composition with the Roman quandrantes from regular coinage, they might have been minted outside the Balkan Peninsula, perhaps in Rome. This assumption is corroborated also by the antimony contents in the mine coins and those minted in Rome.

The coins from eight mints of Moesia Inferior and Thracia are identical in the analysed period of about a hundred years. They differ essentially from the coins of their neighbours in the north (Viminacium, Province of Dacia), in the west (Stobi, mine coins) and in the south-west (Thessalonice); they are similar to the coins minted in the south-east (Nicaea). The coins of Stobi changed their composition in the course of time, but they differed almost always from the coins of all the neighbours. The contents of antimony makes them, to a certain degree, similar to the coins minted in Rome and to the mine coins. It results therefrom that there existed at least four sources which supplied the ore for making the alloys. These are: the area of Viminacium, the territory supplying Thessalonice, the area of Bulgaria and Asia Minor and the territory which, perhaps, supplied Stobi, Mine mint and Rome with the ore.

By comparing the characteristics, such as chemical composition — diameter of samples — mint — ruler, it has been noticed that the Balkan coins had several common features. Among the total of analysed coins there were found an eigth of small dimensions. From this number about 45 p. c. are made of copper — Cu (among the large samples only 5 p. c.) and over 30 p. c. of bronze, which makes over 75 p. c. Among the small coins containing zinc, two thirds are made of brass (CuZn). Small coins were minted in all the periods and their composition did not change essentially in the course of time.

The analysed coins, stamped for the same ruler in several mints could have had very different compositions of alloys. This means that the mint is of essential importance for the composition, not the ruler's figure, both for large and small samples. After copper (Cu), the most important elements in alloys are Zn, Sn and Pb, whereas Ag and Sb, which are always impurities are less important. However, antimony helped us to presume the possible origin of ores used in making alloys for Balkan coins. The occurrence of Zn, Sn and Pb varies very strongly from one mint to the other. Thus, for instance, in Thessalonice there predominates lead, in the mints of Moesia Inferior and Thracia zinc, at Stobi are represented all of them, etc. Taking things altogether, there was found an equal number of samples containing Zn, Sn or Pb in the alloy.

In addition to a large number of samples made of brass (CuZn), there was found also a considerable number of samples (77 out of 766) made of complex alloys containing zinc (Cu Sn Zn, CuPbZn, CuSnPbZn). It can be assumed that they are all obtained from alloys made by melting old coins, among which might have been also some samples of brass.

The present paper offers no complete picture of the composition and the characteristics of Balkan coins of this period, but it gave a considerable insight into them. Further researches will complete it.

Table 1

NUMBER OF EXAMINED SAMPLES-ACCORDING TO PROVINCIA AND MINT

Provincia	Mint	Number of examined samples	
Moesia Superior	Viminacium	205	205
Moesia Inferior	Dionysopolis	7	
	Marcianopolis	69	
	Nicopolis ad Istrum	62	138
Thracia	Augusta Traiana	21	
	Hadrianopolis	46	
	Pautalia	50	
	Philippopolis	33	
	Serdica	24	174
Macedonia	Stobi	83	
	Thessalonice	43	126
Unidentified	Provincia Dacia	100	
	Mine Coins	23	123
Balkan Mints — Total			766
Outside Balkan (comparable)	Nicaea	69	
	Roma	40	109
		Total	875

Table 2

CHEMICAL COMPOSITION OF ALLOYS IN EXAMINED COINS MINTED IN OUTSIDE THE BALKAN (COMPARABLE) PROVINCES

Mint: R O M A

No	Ruler	Sample	Diameter (mm)	Chemical composition Cu	Sn	Pb	Ag	Zn	Sb
1.	Domitianus	g—9		Cu	+	—	+	Zn	+
2.	„	g—4		Cu	+	—	+	Zn	—
3.	„	g—3		Cu	+	—	—	—	+
4.	„	g—2		Cu	+	—	+	—	+
5.	„	h—4		Cu	+	+	—	—	+
6.	„	h—2		Cu	Sn	—	+	Zn	—
7.	„	h—3		Cu	Sn	Pb	+	Zn	—
8.	„	g—8		Cu	+	Pb	+	Zn	+
9.	„	g—6		Cu	+	—	—	Zn	—
10.	„	g—10		Cu	+	—	—	Zn	+
11.	N e r v a	a—9		Cu	Sn	Pb	+	Zn	—
12.	„	a—6		Cu	Sn	+	+	Zn	—
13.	„	a—3		Cu	Sn	+	+	Zn	+
14.	Traianus	h—6	24	Cu	Sn	+	+	Zn	—
15.	„	h—5	24	Cu	Sn	Pb	+	Zn	—
16.	„	f—5	27	Cu	—	—	+	Zn	—
17.	„	c—6	26,5	Cu	Sn	+	+	—	+
18.	„	h—8	33,5	Cu	+	—	+	Zn	—

No	Ruler	Sample	Diameter (mm)	Chemical composition					
				Cu	Sn	Pb	Ag	Zn	Sb
19.	„	i—9	28	Cu	+	—	+	Zn	+
20.	„	g—7	27	Cu	Sn	—	+	Zn	—
21.	„	d—8	27,5	Cu	+	—	+	—	+
22.	„	e—6	27	Cu	Sn	—	+	Zn	—
23.	„	c—10	27	Cu	+	Pb	+	Zn	+
24.	„	f—1	27,5	Cu	+	Pb	+	Zn	+
25.	„	i—3	32,5	Cu	Sn	—	+	Zn	+
26.	„	f—10	32	Cu	—	—	+	Zn	—
27.	„	e—2	33	Cu	+	—	+	Zn	+
28.	„	i—5	26	Cu	Sn	—	+	Zn	+
29.	„	g—10	26,5	Cu	+	—	+	Zn	+
30.	Hadrianus	e—1	27	Cu	+	+	+	+	+
31.	„	g—3	26,5	Cu	+	—	+	Zn	+
32.	„	c—3	33,5	Cu	Sn	Pb	+	Zn	+
33.	„	f—4	26	Cu	—	—	+	+	+
34.	„	d—2	32,5	Cu	Sn	Pb	+	Zn	—
35.	„	d—9	32,5	Cu	+	+	+	Zn	+
36.	„	f—6	27,5	Cu	+	—	+	Zn	+
37.	„	e—9	32	Cu	—	—	+	Zn	+
38.	„	e—6	32	Cu	+	Pb	+	Zn	+
39.	„	c—10	27	Cu	Sn	Pb	+	+	—
40.	„	c—5	33,5	Cu	Sn	Pb	+	Zn	—
Mint: NICAEA									
1.	Commodus	1150	29	Cu	+	—	+	Zn	—
2.	Julia Domna	1151	21,5	Cu	+	—	—	Zn	—
3.	Caracalla	1152	30	Cu	—	—	+	Zn	—
4.	„	1153	23,5	Cu	+	—	+	Zn	—
5.	„	1154	30	Cu	—	—	—	Zn	—
6.	„	1155	27	Cu	—	—	—	Zn	—
7.	„	1156	23	Cu	Sn	+	+	Zn	—
8.	„	1157	22	Cu	+	+	+	Zn	—
9.	„	1158	22	Cu	—	—	+	Zn	—
10.	„	1159	23,5	Cu	+	—	+	Zn	—
11.	„	1160	23	Cu	—	—	+	Zn	—
12.	„	1169	15,5	Cu	Sn	+	—	+	—
13.	„	1170	15	Cu	Sn	+	+	—	—
14.	Geta	1177	26,5	Cu	+	+	—	Zn	+
15.	„	1178	18	Cu	+	—	+	Zn	—
16.	„	1179	15,5	Cu	Sn	Pb	—	—	—
17.	„	1180	14,5	Cu	Sn	—	+	—	—
18.	„	1181	13,5	Cu	Sn	+	+	—	—
19.	Elagabalus	1182	22	Cu	Sn	+	+	Zn	—
20.	„	1183	23	Cu	+	Pb	+	Zn	—
21.	„	1184	24,5	Cu	+	—	+	Zn	—
22.	„	1185	23	Cu	Sn	Pb	+	Zn	—
23.	„	1186	23	Cu	—	—	+	Zn	—
24.	„	1187	23	Cu	—	—	+	Zn	—
25.	„	1188	22	Cu	—	—	—	Zn	—
26.	„	1189	23	Cu	—	+	+	Zn	—
27.	„	1190	21	Cu	—	—	—	Zn	—
28.	„	1191	22	Cu	+	—	+	Zn	—

No	Ruler	Sample	Diameter (mm)	Chemical composition					
				Cu	Sn	Pb	Ag	Zn	Sb
29.	Alexander Severus	1200	21,5	Cu	+	—	+	Zn	—
30.	„	1201	19,5	Cu	Sn	Pb	+	Zn	—
31.	,	1202	23	Cu	+	+	+	Zn	—
32.	„	1203	20	Cu	Sn	+	+	Zn	—
33.	„	1204	20	Cu	+	—	+	Zn	—
34.	„	1205	19,5	Cu	Sn	—	—	Zn	—
35.	„	1206	21	Cu	+	—	+	Zn	—
36.	„	1207	21,5	Cu	Sn	+	+	Zn	—
37.	„	1208	20,5	Cu	—	+	+	Zn	—
38.	„	1209	21,5	Cu	+	—	+	Zn	—
39.	„	1210	22	Cu	Sn	+	+	Zn	—
40.	„	1211	21	Cu	+	+	+	Zn	+
41.	„	1212	20	Cu	+	—	+	Zn	—
42.	„	1213	21	Cu	+	—	+	Zn	+
43.	„	1214	18,5	Cu	+	—	+	Zn	—
44.	„	1215	20	Cu	Sn	+	+	Zn	—
45.	„	1216	21	Cu	+	—	+	Zn	—
46.	Julia Mamea	1378	21	Cu	+	—	+	Zn	—
47.	„	1379	14	Cu	+	—	+	—	+
48.	„	1380	20	Cu	Sn	+	+	Zn	—
49.	„	1381	20	Cu	Sn	+	+	Zn	—
50.	„	1382	20,5	Cu	Sn	—	+	Zn	—
51.	„	1383	22,5	Cu	Sn	Pb	Ag	Zn	+
52.	„	1384	20,5	Cu	Sn	+	+	Zn	+
53.	„	1385	21,5	Cu	+	+	+	Zn	—
54.	„	1386	22	Cu	Sn	+	+	Zn	—
55.	„	1387	23,5	Cu	+	—	+	Zn	—
56.	Gordianus III	1388	19,5	Cu	+	—	+	Zn	—
57.	„	1389	19	Cu	+	—	+	Zn	—
58.	„	1390	21	Cu	+	Pb	+	Zn	—
59.	„	1391	18,5	Cu	—	—	+	Zn	—
60.	„	1392	20	Cu	+	—	+	Zn	—
61.	„	1393	20,5	Cu	Sn	+	+	Zn	—
62.	„	1394	19	Cu	+	—	+	Zn	—
63.	„	1395	20,5	Cu	—	—	+	Zn	—
64.	„	1396	18	Cu	+	Pb	+	Zn	—
65.	„	1397	18	Cu	+	—	+	Zn	—
66.	Herennia Etruscilla	1470	18	Cu	—	—	+	Zn	—
67.	„	1471	18	Cu	—	+	+	Zn	+
68.	Gallienus	1472	17,5	Cu	—	+	—	Zn	—
69.	„	1473	17	Cu	+	+	+	Zn	—

Table 3.

COMPOSITION OF MAIN COMPONENTS IN ANALYSED COINS MINTED IN EXAMINED BALKAN AND OUTISIDE BALKAN MINTS

Provincia	Mint	Composition of Alloy / Ruler	Cu	Cu Sn	Cu Pb	Cu Sn Pb	Cu Zn	Cu Sn Zn	Cu Pb Zn	Cu Sn Pb Zn	Total
			Number of analysed samples								
Moesia Superior	Viminacium	Gordianus III	5	9	12	21	17	2	10	—	76
		Philippus Pater	1	7	4	26	4	3	7	—	52
		Otacilia Severa	—	1	2	1	—	—	—	—	4
		Philippus Filius	—	2	—	3	6	—	—	—	11
		Decius Traianus	—	1	—	7	5	1	1	—	15
		Herennia Etruscilla	—	—	1	6	—	—	—	2	9
		Herennius Etruscus	—	—	—	—	—	—	1	—	1
		Hostilianus	—	—	—	2	—	—	—	—	2
		Trebonianus Gallus	—	—	—	4	—	—	2	1	7
		Volusianus	—	—	—	2	—	—	—	—	2
		Aemilianus	—	2	1	2	—	—	—	—	5
		Valerianus	—	1	—	8	—	—	—	—	9
		Mariniana	—	—	—	3	—	—	—	—	3
		Gallienus	—	—	—	4	—	2	—	3	9
		Total	6	23	20	89	32	8	21	6	205
Moesia Inferior	Dionysopolis	Septimius Severus	—	—	—	—	1	—	—	—	1
		Caracalla	—	—	—	—	1	—	—	—	1
		Gordianus III	—	—	—	—	3	—	2	—	5
		Total	—	—	—	—	5	—	2	—	7
	Marcianopolis	Septimius Severus	1	—	1	—	11	—	—	—	13
		Caracalla	1	—	—	—	10	—	—	—	11
		Geta	4	—	—	—	—	—	—	—	4
		Macrinus	—	—	—	—	3	—	—	—	3
		Diadumenianus	1	—	—	—	2	—	—	—	3
		Elagabalus	3	2	1	1	10	—	1	—	18
		Alexander Severus	—	—	—	—	11	—	1	—	12
		Gordianus III	—	—	—	—	4	—	—	—	4
		Philippus Pater	—	—	—	—	1	—	—	—	1
		Total	10	2	2	1	52	—	2	—	69
	Nicopolis ad Istrum	Marcus Aurelius	—	—	—	—	1	—	—	—	1
		Commodus	1	—	—	1	1	—	—	—	3
		Septimius Severus	4	—	—	3	7	—	1	—	15
		Julia Domna	—	—	1	—	3	—	—	1	5
		Caracalla	—	—	—	—	5	—	—	—	5
		Geta	1	—	—	—	4	—	—	—	5
		Macrinus	—	—	—	—	8	—	—	—	8
		Elagabalus	2	—	—	—	5	—	—	—	7
		Diadumenianus	3	—	—	—	2	—	—	—	5
		Gordianus III	—	—	—	—	7	—	1	—	8
		Total	11	—	1	4	43	—	2	1	62

Thracia	Traiana Augusta	Faustina II	—	—	—	—	4	—	—	—	4
		Septimius Severus	—	—	—	—	2	—	—	—	2
		Julia Domna	—	—	—	—	1	—	—	—	1
		Caracalla	—	—	—	—	7	—	—	—	7
		Geta	—	—	—	—	2	2	1	—	5
		Gallienus	—	—	—	2	—	—	—	—	2
		Total	—	—	—	2	16	2	1	—	21
	Hadrianopolis	Sabina	—	—	—	1	—	—	—	—	1
		Marcus Aurelius	—	—	—	—	1	—	—	—	1
		Faustina II	—	—	—	—	1	1	—	—	2
		Lucius Verus	—	—	—	—	1	—	—	—	1
		Commodus	—	1	—	—	1	—	—	—	2
		Septimius Severus	—	1	—	—	6	—	—	—	7
		Caracalla	4	—	—	—	12	—	—	—	16
		Geta	—	—	—	—	1	—	—	—	1
		Gordianus III	—	—	—	—	11	1	3	—	15
		Total	4	2	—	1	34	2	3	—	46
	Pautalia	Marcus Aurelius	—	—	—	1	4	—	1	—	6
		Faustina II	—	—	—	—	7	1	—	—	8
		Commodus	2	—	—	1	1	—	—	—	4
		Septimius Severus	4	1	—	—	2	1	—	—	8
		Julia Domna	—	—	—	—	4	—	—	—	4
		Caracalla	—	—	—	—	13	—	—	—	13
		Geta	1	—	—	—	3	—	—	2	6
		Elagabalus	—	—	—	—	1	—	—	—	1
		Total	7	1	—	2	35	2	1	2	50
	Philippopolis	Antoninus Pius	1	1	—	1	5	—	—	—	8
		Marcus Aurelius	—	1	—	—	1	—	—	—	2
		Faustina II	—	—	—	—	1	—	—	—	1
		Commodus	—	1	—	1	5	—	—	—	7
		Crispina	—	—	—	—	1	—	—	—	1
		Septimius Severus	1	—	—	—	1	—	—	—	2
		Caracalla	1	—	—	—	7	—	—	—	8
		Elagabalus	1	—	—	—	3	—	—	—	4
		Total	4	3	—	2	24	—	—	—	33
	Serdica	Marcus Aurelius	—	1	—	—	1	1	—	—	3
		Julia Domna	—	—	—	—	2	—	—	—	2
		Caracalla	1	—	—	—	10	—	—	—	11
		Geta	—	—	—	—	5	—	—	—	5
		Gallienus	—	—	—	3	—	—	—	—	3
		Total	1	1	—	3	18	1	—	—	24

Macedonia	Thessalonice	Julius Caesar	—	—	—	2	—	—	—	—	2
		Marcus Antonius	1	1	—	2	—	—	—	—	4
		Augustus	—	—	—	7	—	—	—	—	7
		Tiberius	—	—	—	5	—	—	—	—	5
		Caligula	—	—	—	2	—	—	—	—	2
		Claudius	—	—	—	2	—	—	—	—	2
		Nero	1	—	—	—	—	—	—	—	1
		Vespasianus	1	—	—	—	—	—	—	—	1
		Domitianus	—	—	—	1	—	—	—	—	1
		Nerva	—	—	—	1	—	—	—	—	1
		Traianus	—	—	—	2	—	—	—	—	2
		Septimius Severus	—	—	1	—	—	—	—	—	1
		Julia Domna	—	—	1	—	—	1	—	—	2
		Caracalla	—	—	—	—	—	—	—	2	2
		Julia Mamea	—	—	—	1	—	—	—	—	1
		Gordianus III	—	—	5	—	—	—	—	—	5
		Philippus I	—	—	3	—	—	—	—	—	3
		Valerianus	—	—	—	1	—	—	—	—	1
		Total	3	1	10	26	—	1	—	2	43
	Stobi	Pseudo autonomous	1	2	—	—	—	—	—	—	3
		Vespasianus	1	5	—	—	—	—	—	—	6
		Titus	2	—	—	—	—	—	—	—	2
		Titus et Domitianus	—	3	—	—	—	—	—	—	3
		Traianus	5	1	—	—	—	—	—	—	6
		Marcus Aurelius	—	—	—	4	—	—	—	—	4
		Faustina II	—	—	—	1	—	—	—	—	1
		Septimius Severus	—	—	11	10	—	—	—	—	21
		Julia Domna	—	—	3	—	4	1	—	—	8
		Antoninus	—	—	1	5	14	2	—	1	23
		Geta	—	—	1	5	—	—	—	—	6
		Total	9	11	16	25	18	3	—	1	83
Unidentified	Provincia Dacia	Philippus Pater	1	8	2	14	—	3	1	2	31
		Otacilia Severa	—	3	—	—	—	—	—	—	3
		Philippus Filius	—	3	—	1	1	—	1	—	6
		Decius Traianus	—	1	2	5	—	—	—	1	9
		Herennia Etruscilla	—	—	1	3	—	—	—	—	4
		Herennius Etruscus	—	1	1	1	—	—	—	—	3
		Hostilianus	2	—	2	—	—	—	—	—	4
		Trebonianus Gallus	—	2	2	5	—	—	—	1	10
		Volusianus	1	1	2	8	—	—	—	—	12
		Aemilianus	1	—	1	4	—	—	—	—	6
		Valerianus	—	2	—	—	—	—	—	—	2
		Gallienus	1	3	—	4	—	—	—	2	10
		Total	6	24	13	45	1	3	2	6	100
	Minc-coins	Traianus	4	4	—	—	1	1	—	—	10
		Hadrianus	2	1	—	—	3	—	—	—	6
		Others	2	2	—	—	1	2	—	—	7
		Total	8	7	—	—	5	3	—	—	23

Outside Balkan comparable	Nicaea	Commodus	—	—	—	—	1	—	—	—	1
		Julia Domna	—	—	—	—	1	—	—	—	1
		Caracalla	—	2	—	—	8	1	—	—	11
		Geta	—	2	—	1	2	—	—	—	5
		Elagabalus	—	—	—	—	7	1	1	1	10
		Alexander Severus	—	—	—	—	11	5	—	1	17
		Julia Mamea	1	—	—	—	3	5	—	1	10
		Gordianus III	—	—	—	—	7	1	2	—	10
		Herennia Etruscilla	—	—	—	—	2	—	—	—	2
		Gallienus	—	—	—	—	2	—	—	—	2
		Total	1	4	—	1	44	13	3	3	69
	Roma	Domitianus	3	—	—	—	4	1	1	1	10
		Nerva	—	—	—	—	—	2	—	1	3
		Traianus	1	1	—	—	6	5	2	1	16
		Hadrianus	2	—	—	1	4	—	1	3	11
		Total	6	1	—	1	14	8	4	6	40

Remark: By the name of Antoninus in the coins minted at Stobi are comprised the samples which, in the literature, have so far been attributed both to Caracalla and to Elagabalus, for there is no reliable criterion for their distinction.

* Antoninus = Geta or Elagabalus.

Table 4.

RELATIONSHIP BETWEEN MINT AND COMPOSITION OF ALLOY, FOR SAMPLES WITH SMALL DIAMETERS

Provincia	Mint \ Composition of Alloy	Cu	Cu Sn	Cu Pb	Cu Sn Pb	Cu Zn	Cu Sn Zn	Cu Pb Zn	Cu Sn Pb Zn	Total
		Number of analysed samples								
Moesia Superior	Viminacium	1	1	2	1	1	—	—	—	6
Moesia Inferior	Marcianopolis	9	2	2	1	—	—	—	—	14
	Nicopolis ad Istrum	11	—	1	3	1	—	—	—	16
Thracia	Augusta Traiana	—	—	—	—	1	2	—	—	3
	Hadrianopolis	4	2	—	—	1	—	—	—	7
	Pautalia	3	—	—	—	3	—	—	2	8
	Philippopolis	3	2	—	1	—	—	—	—	6
Macedonia	Stobi	—	2	—	—	1	—	—	—	3
	Thessalonice	—	—	—	4	—	—	—	—	4
Unidentified	Mines Coins	8	7	—	—	5	3	—	—	23
Balkan Mints — Total		39	16	5	10	13	5	—	2	90
Outside Balkan	Nicaea	1	4	—	1	11	1	1	1	20
	Roma	1	—	—	—	—	—	—	—	1
Outside Balkan Mints — Total		2	4	—	1	11	1	1	1	21

Table 5.
RELATIONSHIP BETWEEN THE RULER FOR WHOM THE COIN WAS MINTED AND COMPOSITION OF ALLOY, FOR SAMPLES WITH SMALL DIAMETERS

Ruler \ Composition of Alloy	Cu	Cu Sn	Cu Pb	Cu Sn Pb	Cu Zn	Cu Sn Zn	Cu Pb Zn	Cu Sn Pb Zn	Total
	Number of analysed samples								
Julius Caesar	—	—	—	1	—	—	—	—	1
Augustus	—	—	—	2	—	—	—	—	2
Tiberius	—	—	—	1	—	—	—	—	1
Stobi — Pseudo autonomous	—	2	—	—	—	—	—	—	2
Traianus	4	4	—	—	1	1	—	—	10
Hadrianus	2	1	—	—	3	—	—	—	6
Others Mines coins	2	2	—	—	1	2	—	—	7
Antoninus Pius	1	1	—	—	—	—	—	—	2
Lucius Verus	—	—	—	—	1	—	—	—	1
Commodus	2	2	—	1	—	—	—	—	5
Septimius Severus	5	1	1	3	—	—	—	—	10
Julia Domna	—	—	1	—	—	—	—	—	1
Caracalla	6	—	—	—	4	—	—	—	10
Geta	6	—	—	—	1	2	—	2	11
Diadumenianus	4	—	—	—	1	—	—	—	5
Elagabalus	6	2	1	1	—	—	—	—	10
Gordianus III	1	—	1	2	—	—	—	—	4
Philippus Filius	—	1	—	—	1	—	—	—	2
Total	39	16	4	11	13	5	—	2	90

Table 6.

COMPARISON OF THE COMPOSITION OF COINS MINTED IN DIFFERENT MINTS FOR THE SAME RULER

Ruler	Mint \ Composition of Alloy	Cu	Cu Sn	Cu Pb	Cu Sn Pb	Cu Zn	Cu Sn Zn	Cu Pb Zn	Cu Sn Pb Zn	Total
		Number of analysed samples								
Traianus	Stobi	5	1	—	—	—	—	—	—	6
	Thessalonice	—	—	—	2	—	—	—	—	2
	Mine coins	4	4	—	—	1	1	—	—	10
	Roma	1	1	—	—	6	5	2	1	16
	Total	10	6	—	2	7	6	2	1	34
Gordianus III	Viminacium	5	9	12	21	17	2	10	—	76
	Dionysopolis	—	—	—	—	3	—	2	—	5
	Marcianopolis	—	—	—	—	4	—	—	—	4
	Nicopolis ad Istrum	—	—	—	—	7	—	1	—	8
	Hadrianopolis	—	—	—	—	11	1	3	—	15
	Thessalonice	—	—	5	—	—	—	—	—	5
	Nicaea	—	—	—	—	7	1	2	—	10
	Total	5	9	17	21	49	4	18	—	123

Table 7.

NUMBER OF IDENTIFIED SAMPLES WHICH CONTAIN ZINC, TIN OR LEAD IN ANALYSED COINS

Provincia	Number of analysed samples / Mint	Zn					Sn			Pb			Total
		Main component			Impurity	Not found	Main component	Impurity	Not found	Main component	Impurity	Not found	
		CuZn	Other alloys	Total									
Moesia Inferior	Dionysopolis	5	2	7	—	—	—	2	5	2	5	—	7
	Marcianopolis	52	2	54	1	14	3	25	41	5	25	39	69
	Nicopolis ad Istrum	43	3	46	2	14	5	30	27	8	31	23	62
Thracia	Augusta Traiana	16	3	19	—	2	4	5	12	3	4	14	21
	Hadrianopolis	34	5	39	2	5	5	20	31	4	18	24	46
	Pautalia	35	5	40	—	10	7	11	32	5	9	36	50
	Philippopolis	24	—	24	1	8	5	16	12	2	6	25	33
	Serdica	18	1	19	—	5	5	11	8	3	3	18	24
Macedonia	Stobi	18	4	22	11	50	40	29	14	42	12	29	83
	Thessalonice	—	3	3	1	39	30	8	5	38	2	3	43
Moesia Superior	Viminacium	32	35	67	35	103	126	35	44	136	60	9	205
Unidentified	Provincia Dacia	1	11	12	2	86	78	19	3	66	29	5	100
	Mine coins	5	3	8	13	2	10	13	—	—	23	—	23
Balkan Mints — Total		283	77	360	68	338	318	224	224	314	227	225	766
Outside Balkan	Nicaea	44	19	63	1	5	21	33	15	7	24	38	69
	Roma	14	18	32	3	5	16	20	4	11	7	22	40
Outside Balkan Mints — Total		58	37	95	4	10	37	53	19	18	31	60	109
Total		341	114	455	72	348	355	277	243	332	250	285	875

Table 8

NUMBER OF SAMPLES WHICH CONTAIN Sb IN EXAMINED MINTS

Provincia	M i n t	Total number of analysed samples	Number of samples which contain Sb	Percent of total number of analysed samples
Moesia Inferior	Dionysopolis	7	1	14
	Marcianopolis	69	10	15
	Nicopolis ad Istrum	62	12	19
Thracia	Augusta Traiana	21	2	10
	Hadrianopolis	46	13	28
	Pautalia	50	0	0
	Philippopolis	33	4	12
	Sedica	24	5	20
Macedonia	Thessalonice	43	4	9
	S T O B I	83	39	47
Moesia Superior	Viminacium	205	0	0
Unidentified	Provincia Dacia	100	0	0
	MINE COINS	23	20	87
Outside Balkan	R O M A	40	24	60
	Nicaea	69	7	10