

SMALL CHANGE(S):

TRENDS IN THE COMPOSITION OF COPPER-BASED COINS FROM ISTROS (I)
THE EARLY BYZANTINE COINS FROM THE ACS SECTOR (2013-2015)

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Abstract: This paper discusses the composition of 13 Early Byzantine copper-based coins (6th – beginning of 7th c. AD) recovered during archaeological excavations at Istros (Romania). The measurements were conducted using a non-destructive analytical technique, namely X-Ray fluorescence (XRF). The main aim of this study is to determine the compositional clusters and the alloying materials used in the case of these coins, and to compare them with data obtained on similar items from other parts of the Early Byzantine Empire.

Rezumat: Acest articol discută compoziția a 13 monede bizantine timpurii realizate din cupru sau aliaje ale cuprului (sec. VI-VII p.Chr.), descoperite în cursul cercetărilor arheologice de la Istros (România). Analiza a fost realizată folosind o tehnică analitică non-distructivă, și anume fluorescența de raze X (XRF). Principalul scop al acestui studiu este să determine grupările compoziționale și aliajele utilizate în cazul acestor monede, și să le compare cu date obținute despre monede similare din alte părți ale Imperiului Bizantin timpuriu.

Keywords: Early Byzantine coins, copper/copper alloys, XRF analysis, Istros/Histria

Cuvinte cheie: monede bizantine timpurii, cupru/aliaje ale cuprului, analiză XRF, Istros/Histria

INTRODUCTION

This paper discusses the composition of 13 Early Byzantine copper-based coins (6th – beginning of 7th c. AD) recovered during archaeological excavations at Istros (Romania). The measurements were conducted using a non-destructive analytical technique, namely X-Ray fluorescence (XRF). The main aim of this study is to determine the compositional clusters and the alloying materials used in the case of these coins, and to compare them with data obtained on similar items from other parts of the Early Byzantine Empire.

THE EARLY BYZANTINE COINS AT ISTROS

The research conducted on Early Byzantine coins recovered from Istros, from the beginning of the excavations in the ancient city to the present day, brought important information regarding the evolution of the city during the 6th – 7th c. AD. The numerous archaeological campaigns conducted in the area of the city starting with 1914 led to the discovery of a rich numismatic material dated to the 6th c. AD and the first decades of the 7th c. AD. The publications dedicated to this topic cover the finds recorded before 1970 and an important batch recovered from the Episcopal Basilica. Other finds, less numerous, come from the various archaeological sectors of the site, including also several gold issues, which come to complete the image of the monetary circulation in connection with Istros¹.

The archaeological excavations conducted on the new Acropolis Centre-South Sector, starting with 2013, resulted, as expected, also in the discovery of a number of Early Byzantine coins. There were found folles issued by Justinian I, Justin II, Tiberius II Constantine, Mauricius, but also subdivisions, such as a 10 nummia coin from Justinian I, a rarer presence at Istros, and a 20 nummia coin from Phocas, attesting the continuation of the monetary circulation in the first decade of the 7th c. AD. Although the number of Early Byzantine coins found so far on this sector is not large, it can be noticed that in general they follow the trends of the already known numismatic material, from the point of view of both issuing authority and represented mints².

The analysis of more recent finds, corroborated with the interpretation of older finds, indicates that the monetary circulation at Istros ceased at the beginning of the reign of Heraclius.³

The latest issues from the city, found in the Sacred Area Sector, are a follis issued in 613 and one issued in 613/614. Together with a half-follis issued by Thessalonica in 613/614, found in the area of the Sinoe commune (Constanța county), they indicate the ceasing of the activity at Istros during the second decade of the 7th c. AD. Single finds from the vicinity of the city, such as a gold solidus from Constantine IV, issued in 674-681, recovered from the territory of the Istria commune (Constanța county), do not seem to have connections with the Byzantine administration anymore, and could be rather connected with newcomers in this region⁴.

¹ Preda, Nubar 1973, 198-233; Poenaru Bordea, Dima 2007, 153-193. For the Byzantine gold coins from Istros, see Vîlcu et al. 2006.

² See also, in completion to the above-mentioned works, the batch discussed by Poenaru Bordea et al. 1997, 143-145, Tables 9-13.

³ Vîlcu, Țârlea 2016, 162.

⁴ Vîlcu et al. 2006, 169, cat. no. 564.

ARCHAEOLOGICAL BACKGROUND

The archaeological excavations conducted by the team from the University of Bucharest (Romania) at Istros/Histria, one of the most important sites on the western coast of the Black Sea for the Greek and Roman period (7th c. BC – 7th c. AD), started in 2013 and are still continuing⁵. The research on the Acropolis Centre-South Sector led to the uncovering of a Late Antique *insula* (second half of the 6th – beginning of the 7th c. AD), representing the last inhabitation phase of the ancient city. The building offered rich archaeological materials⁶, an important part being represented by the numismatic finds⁷.

The coins found so far in the Late Antique *insula* reflect the entire monetary history of Istros, from the 5th c. BC to the beginning of the 7th c. AD, to which even earlier arrowhead-shaped tokens can be added. The coinage ranges from wheel-type coins representing the earliest copper-based issue of the city during the autonomy period, going through River god type coins and Apollo type coins issued by Istros, Hellenistic coins issued by other Greek centres, and continuing with Roman Imperial coins, Roman Provincial coins, and Early Byzantine coins⁸. This situation, with important amounts of archaeological material removed from its original context, is not surprising on a site characterized by uninterrupted habitation for almost fourteen centuries. Nor are the coins the only items that “travelled” both vertically and horizontally, due to ulterior human interventions and environmental impact. Still, for some of the coins, as for other categories of small and/or precious items, alternative explanations for their presence in a later context than that of their production/use could be put forward, for example their transformation into heirlooms⁹. Even more, in the case of both Greek and Roman coins, there are still many uncertainties regarding their real “lifespan”, meaning that some issues could have continued into circulation (or at least possession) for longer periods¹⁰.

The strategy of the team from the beginning of the project was to adopt an interdisciplinary approach to the archaeological research. This translated also into an interest in archaeometry and its potential in raising the quantity and quality of information regarding both various categories of archaeological material and their

⁵ Bottez et al. 2015; Bottez et al. 2018; Bottez 2022.

⁶ Bottez et al. 2015; Bottez et al. 2018; Bottez 2022; Iliescu, Bottez 2021; Țârlea et al. 2022; Țârlea, Cliante 2020; Țârlea, Cliante 2023 ; Iliescu, Achim 2025.

⁷ Vilcu, Țârlea 2016; Țârlea et al. 2018.

⁸ Vilcu, Țârlea 2016; Țârlea et al. 2018.

⁹ Stoner 2019.

¹⁰ For example, in the case of the heavier coins reflecting Justinian’s reform of 538, it was determined that they were still in circulation at the end of the century (Gândilă 2012).

historical context. Inside this theoretical framework, several batches of finds made of different materials were already analyzed¹¹, while others are waiting for their turn.

THE NUMISMATIC MATERIAL

The first three archaeological campaigns on the Acropolis Centre-South Sector (2013-2015) brought to light more than 90 coins and coin-shaped objects. Among these, the composition of 21 coins, representing issues of Istros from the Greek (autonomous) period, Hellenistic, and Roman Provincial coins, was already published elsewhere¹². The other coins of this batch, representing Roman Imperial coins and Early Byzantine coins (end of 1st c. BC – beginning of 7th c. AD), as well as unidentified/undetermined coins, are summing 75 items. The 13 identified Early Byzantine coins (6th – beginning of 7th c. AD) represent the topic of the present paper. The rest of the batch, represented by the Roman coins (1st c. BC – 5th c. AD), will form the core of a future paper discussing their metal composition.

It should be emphasized that the state of preservation of copper-based objects in general tends to be poor on the site of Istros. The soil conditions seem to play the most important role. As until present no soil analyses were conducted on this site in connection with its effects on various archaeological materials, this observation is an empirical one. In addition, in many cases the items also show signs of exposure to heat, a normal situation in a city that experienced during its history numerous events implicating fire. The coins are ones of the main sufferers in this situation, due to their reduced thickness, especially already worn items or issues that from the start were small and thin. Also at this moment an empirical observation in case of this site, but not an unexpected one, the metal composition seems to play a role in the chances of better preservation of a coin against unfavourable soil conditions, and/or against exposure to heat.

Due to this situation, some of the items that were collected from the excavation under the preliminary label of “coin” based on shape, dimensions, and weight, remained undetermined even after the cleaning/removal of patina, due to their advanced state of degradation (12% of the 75 items). Other items were identified as coins belonging to a certain chronological framework, mainly 4th c. AD and 4th – 5th c. AD, but in most cases without the possibility of further refining their characterization (24% of the 75 items). In general, the coins dated to the last habitation phase of the city are better preserved than older ones.

¹¹ Bugoi et al. 2022a; Bugoi et al. 2022b; Bugoi et al. 2022c; Bugoi et al. 2023; Bugoi et al. 2024.

¹² Țârlea et al. 2018.

The repartition of the Roman and Early Byzantine identifiable coins from the analyzed batch on century shows a predominance of the 4th c. AD coins, followed by those issued during the 6th c. AD (Fig. 1).

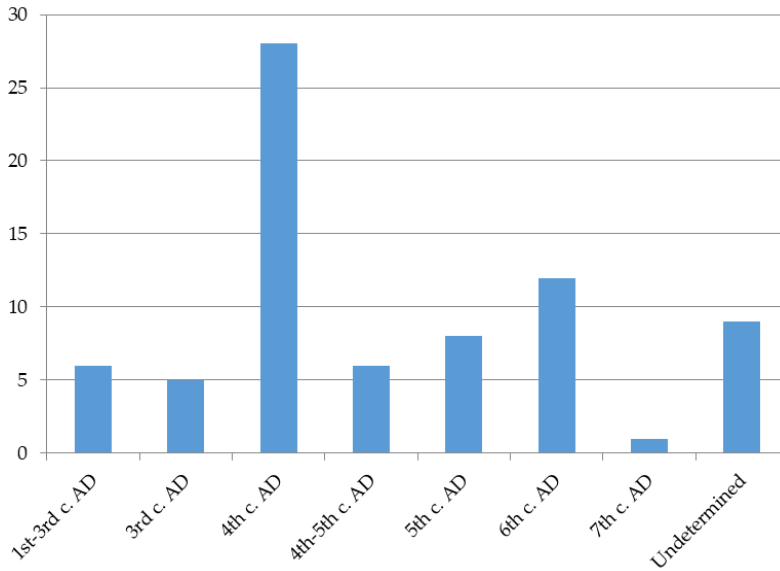


Fig. 1. The chronological repartition of the analysed coins

The identified coins are as follows:

- six coins dated to the 1st c. BC – 2nd c. AD;
- six coins dated to the 3rd c. AD (five Roman imperial coins and a Roman provincial coin, identified, due to its extremely poor state of preservation, too late to be discussed in the previous paper on Greek and Roman provincial coins from Istros);
- 28 coins dated to the 4th c. AD;
- six coins dated to the 4th-5th c. AD;
- eight coins dated to the 5th c. AD;
- 12 coins dated to the 6th c. AD;
- one coin dated to the 7th c. AD.
- nine items are too damaged to be identified, and there are doubts that several of them are coins at all.

This situation, which could be perceived as rather unusual, given the fact that the archaeological context is clearly dated to the second half of the 6th c. AD and

beginning of the 7th c. AD¹³, is explained, as already mentioned above, by the peculiarities of multi-layered sites. In addition, this situation should be judged against the background offered by the numismatic finds for which the issuing authority could be determined (Fig. 2). The graph clearly shows the predominance of coins issued during the reign of Justin II, matching well the dating of the habitation phase the coins were recovered from. Nevertheless, it should be kept in mind that these graphs present a very incomplete (and most probably biased) image of the general numismatic situation of the Acropolis Centre-South Sector, as they are based only on the finds from the first three campaigns.

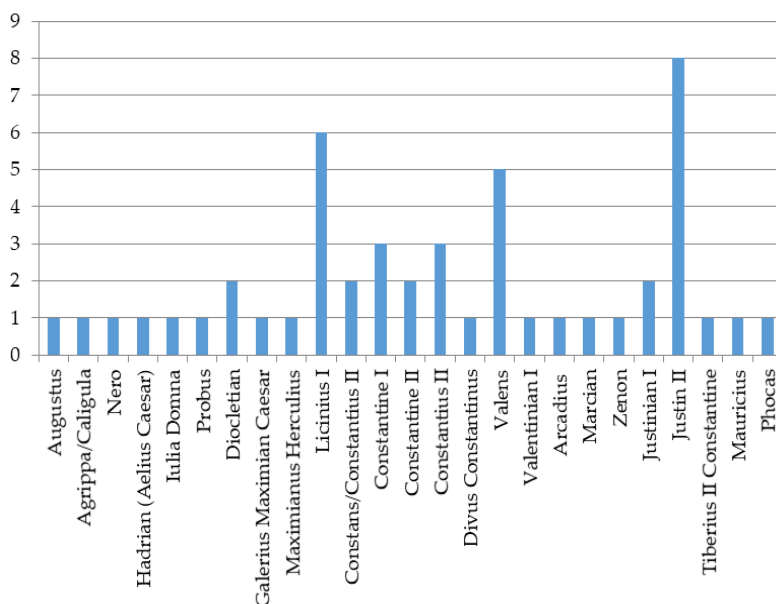


Fig. 2. The repartition of coins based on issuing authority

METHOD

The XRF analysis was conducted using a handheld spectrometer Innov-X Systems Alpha Series, with W anticathode tube, SiPIN diode, Peltier cooling effect, and work parameters 40kV tension, 35 μ A intensity, acquisition time 2 minutes¹⁴.

This technique was employed because of its non-intrusive character, which allows measuring the composition without damaging the object¹⁵, and thus being

¹³ Iliescu, Bottez 2021; Bottez 2022.

¹⁴ Țârlea et al. 2018. The analysis was conducted in the laboratory of the National History Museum of Romania by Dr. Migdonia Georgescu.

¹⁵ Padfield 1972, 219.

ideal for archaeological and heritage artefacts in general. On the less bright side, this technique, used only by itself, could produce less than accurate results, since the surface of a coin is chemically altered by corrosion, and as a result bulk and surface composition might present different concentrations of the same element¹⁶.

All the coins underwent cleaning in the laboratory of the “Vasile Pârvan” Institute of Archaeology in Bucharest before measurements, and in all the cases where the state of preservation allowed, the patina was removed, using a combination of chemical and mechanical interventions¹⁷. Still, on one hand, an important part of the coins were too damaged to allow proper/complete removal of patina, as already mentioned; on the other hand, even in the case of thoroughly cleaned coins the enrichment of the surface in case of tin bronzes or leaded copper/bronze can still be present, influencing the result of the measurement.

THE EARLY BYZANTINE COINS

The 13 Early Byzantine coins (6th – beginning of 7th c. AD) recovered during the archaeological campaigns from 2013-2015 on the Acropolis Centre-South Sector represent the issuing activity of five emperors: Justinian I (two coins); Justin II (eight coins); Tiberius II Constantine (one coin); Mauricius (one coin); Phocas (one coin) (Fig. 2).

They represent the mints of Antioch (1), Constantinople (3), Kyzikos (1), Nicomedia (4), and Thessalonica (3). In one case, the mint remained undetermined. The details of the coins are presented below and can be also consulted in Table 1. **Justinian I.** There are two coins issued during his reign: one follis issued by Antioch (554/555, officine G) and one 10 nummia coin issued by Nicomedia (561/562) (Fig. 3).



Fig. 3. Justinian – follis, Antioch, 554/555 (after Vilcu, Țârlea 2016, fig. 3/19)

¹⁶ Padfield 1972, 219; Vadrucchi et al. 2018, 8.

¹⁷ The authors would like to express their thanks to Mrs. Georgiana Mureșan (“Vasile Pârvan” Institute of Archaeology) for her work on the restoration and conservation of the coins.

Justin II. There are eight coins issued during his reign: four folles and four half-folles. The four folles are: two issued by Constantinople in 570/571 (one in officine B and one in officine E); two issued by Nicomedia, both in officine A (one in 570/571 and one in 577/578). The four half-folles were issued: three by Thessalonica (568/569; 569/570; 569/570-577/578) and one by Kyzikos (574/575) (Fig. 4).



Fig. 4. Justin II – follis, Constantinople, 570/571 (after Vîlcu, Țârlea 2016, fig. 3/20)

Tiberius II Constantine. It was recovered one follis issued by the mint in Nicomedia (578) (Fig. 5).



Fig. 5. Tiberius II Constantine – follis, Nicomedia, 578 (after Vîlcu, Țârlea 2016, fig. 3/21)

Mauricius. There is a half-follis (582-602), mint undetermined.

Phocas. It was found one 20 nummia coin from the Constantinopolitan mint (603-610, officine B) (Fig. 6).



Fig. 6. Phocas – 20 nummia, Constantinople, 603-610 (after Vîlcu, Țârlea 2016, fig. 3/22)

As it can be noticed, all the Early Byzantine coins at our disposal for now for compositional analysis are dated after Justinian's monetary reform of 538, which operated changes in the weight of the follis¹⁸.

THE METAL COMPOSITION OF THE EARLY BYZANTINE COINS

The XRF analysis of the composition of this batch of Early Byzantine coins brought both expected and unexpected results. In the first category enters the composition of the folles, most of the half-folles, and the 20 nummia coin. In the category of unexpected results can be included two outliers: the 10 nummia coin issued for Justinian I by the mint from Nicomedia and the half-follis issued by Kyzikos for Justin II (Fig. 7).

As an overview, 11 of the 13 coins were made of copper with impurities (Fig. 7, Table 1), matching well from this perspective the general image created by previous analyses¹⁹. The 10 folles and half-folles are characterised by values of copper between 98.24% and 99.61%. The most constant minor or trace elements are Fe, Ni, and Pb. Other minor or trace elements present in some cases are Zn, Sb, Au, and As. In all the cases, Ag could be identified as a very weak trace in the spectra. The 20 nummia coin from the reign of Phocas is made also of copper, with several minor or trace elements: Fe, Ni, Ag, Sn, Au, Pb, As.

The 10 nummia coin issued by the mint of Nicomedia and the half-follis issued by the mint of Kyzikos are made of tin bronze, relatively small amounts of tin being added to copper with impurities.

¹⁸ Gândilă 2012, 363-365.

¹⁹ Padfield 1972; King et al. 1995.

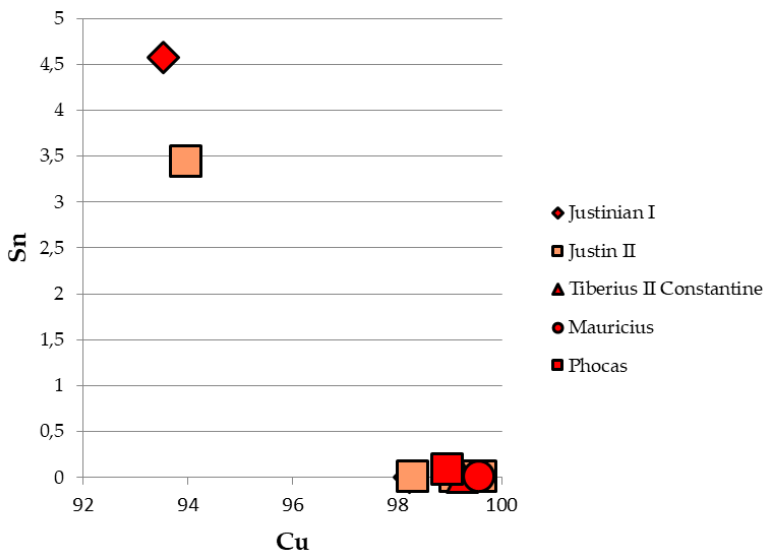


Fig. 7. The Cu-Sn ratio in the metal composition of the Early Byzantine coins

The small number of items at our disposal for the moment hampers reaching very reliable statistical conclusions. Still, these results will be briefly discussed in more detail, in order to determine possible hints regarding a relation between compositional characteristics, on one hand, and denomination, issuing authority / chronological framework, or mint. Most of the major and minor elements can be consulted in the table (Table 1).

Composition versus monetary value/nominal

An overview of the compositions against the background of the value/nominal of the coins leads to several observations.

The homogeneity of the **folles**, independent of their issue date, is very high, with the values of copper between 98.24% and 99.61%. In all the cases, there are minor elements or trace elements associated with copper: Fe, Ni, and Pb represent a constant, as well as the faint traces of Ag; Sb, Au, and As, as well as Zn, are present in some cases and absent in others.

The same pattern can be noticed in the case of the **half-folles**, across the entire time span, with the notable exception of the coin issued by Kyzikos. The copper has values between 98.31% and 99.57%, matching very well the values measured in the case of the higher denomination coins. The same minor/trace elements could be identified in their case.

TIN	Emperor	Mint / Officine	Year	Value	Fe	Ni	Cu	Sn	Sb	Au	Pb	As
351/2014	Justinian I	Antioch / G	554/555	follis	0.03	0.32	98.24	0		ND	1.31	
770/2015	Justinian I	Nicomedia	561/562	10 nummia	0.15	0.15	93.54	4.57	trace	ND	1.48	
407/2013	Justin II	Constantinople / E	570/571	follis	trace	0.49	99.33	0		ND	0.17	trace
482/2014	Justin II	Constantinople / B	570/571	follis	0.03	0.27	99.25	0		ND	0.45	
550/2015	Justin II	Kyzikos	574/575	1/2 follis	trace	0.05	93.98	3.44		ND	2.53	
357/2013	Justin II	Nicomedia / A	570/571	follis	trace	0.04	99.61	0	0.12	0.18	trace	0.05
861/2015	Justin II	Nicomedia / A	577/578	follis	0.02	0.35	99.41	0	trace	0.14	0.08	
389/2013	Justin II	Thessalonica	569/570 577/578	1/2 follis	0.05	0.24	99.13	0	0.16	ND	0.43	
249/2015	Justin II	Thessalonica	569/570	1/2 follis	trace	trace	98.31	0	0.42	ND	0.79	
168/2015	Justin II	Thessalonica	568/569	1/2 follis	trace	0.04	99.34	0	0.14	ND	0.48	
379/2014	Tiberius II Constantine	Nicomedia / B	578	follis	trace	0.23	99.25	0	0.13	0.06	0.2	0.13
336/2015	Mauricius		582-602	1/2 follis	trace	0.18	99.57	0	ND	ND	0.25	
352/2014	Phocas	Constantinople / B	603-610	20 nummia	trace	0.23	98.97	0.08		0.08	0.45	0.18

Table 1. The composition of the Early Byzantine coins found on the ACS Sector during the 2013-2015 archaeological campaigns

The smaller denominations are represented by the 10 nummia coin from Nicomedia, made of bronze (tin added to copper with impurities) and the 20 nummia coin from Constantinople, made of copper (98.97%), with impurities (minor or trace elements Fe, Ni, Sn, Au, Pb, As).

The composition of the 10 nummia coin from Nicomedia comes as a novelty, as for this mint only the issuing of pentanummia of bronze was known until now.

It seems that it is a very weak connection between composition and monetary value in the case of the higher denominations: the composition of folles and half-folles follows in general the same pattern. There is no sign that special efforts were made in order to emphasise any kind of differentiation between the two denominations based on quality of metal and/or colour. It can be hypothesised that most of the eastern mints had the same technological approach towards folles and half-folles, minting them from the same type of metal.

It seems to be a stronger connection between composition and monetary value when the higher denominations (folles and half-folles) are placed against smaller denominations, but the number of items is too small to draw clear conclusions, and also here the chronological factor, as well as the mint, could play a role. This characteristic of the 6th c. AD minting, with smaller denominations being made of tin bronze in some instances, will be again addressed below.

Composition versus issuing authority

Justinian I. The follis issued by Antioch (officine Γ), in 554/555, has 98.24% Cu, with several minor elements (Fe, Zn, Ni, and Pb). The coin of 10 nummia issued by Nicomedia, in 561/562, is made of relatively low tin bronze, with 93.54% Cu, 4.57% Sn, and minor elements (Fe, Zn, Ni, Pb), and a weak trace of Sb.

Out of all the analysed Early Byzantine coins, these two are the only ones showing a clear presence of zinc, although only in proportion of 0.1%. In combination with the presence of iron, this could indicate either that the technological process in their case did not include a purification of the copper by controlled oxidation of the molten metal, or resorting to recycling²⁰.

The composition of the two coins shares the majority of the minor/trace elements, with the exception of antimony, which is present as a trace in the 10 nummia coin, as mentioned above. At this point of the discussion, it is tempting to propose the hypothesis of a shared source of copper ore between the mints of Antioch and Nicomedia, and similar technological solutions (but see discussion below).

²⁰ Padfield 1972, 229.

Justin II. The composition of the four folles issued during the reign of this emperor (two by Constantinople, and two by Nicomedia) is very homogeneous, with values of copper between 99.25% and 99.61%. The difference, in comparison with the follis of Justinian I, is created mainly by the higher amount of lead as a minor element in the case of the latter. The same homogeneity characterises the composition of three of the four half-folles, issued by Thessalonica, with values of copper between 98.31% and 99.33%. From this perspective, there is no clear separation between the two denominations; they were both minted of copper with various impurities. The clear outlier is the half-follis minted by Kyzikos in 574/575, which is made of bronze, by adding tin to copper with impurities. At this point of the discussion, it is not clear if this deviation has to do rather with the moment of the issuing (the moment in the reign of Justin II), or a specificity/technological tradition of the mint from Kyzikos. This aspect will be tackled again below.

The remaining three issuing authorities are represented in this batch by only one coin each, and in consequence their discussion is not statistically relevant for now.

Tiberius II Constantine. The follis follows the trend established by the previous emperors, being made of copper with a small amount of impurities (99.25% Cu). The represented minor and trace elements are Fe, Ni, Sb, Au, Pb, and As.

Mauricius. Also this half-follis respects the technological trend, being made of copper (99.57%), with a few minor or trace elements (Fe, Ni, Pb).

Phocas. The 20 nummia coin is the only one of the analysed batch with this denomination. It seems that it rather follows the trend of the higher denominations of the previous period, being made of copper (98.97%), with a wide range of minor/trace elements (Fe, Ni, Sn, Au, Pb, As).

There seems to be a certain correlation between the issuing authority and the composition of the coins, reflecting most probably both technological solutions and use of a variety of copper ores (with the question of recycling always in the back of the mind).

Composition versus mint

The last possible correlation to be tackled is that between composition and the mints issuing the respective coins. A certain variation among the mints is to be expected, taking into consideration the variables at play. The local technological traditions, the geographical aspect and degree of local/regional/supra-regional contacts influencing the access to specific copper ores or sources of recycled metal, the chronological aspect (various events), and the relation with the central authority could have influenced the activity of a specific mint.

Antioch. One coin of the Early Byzantine batch was identified as minted in Antioch, the follis issued during the reign of Justinian I. The result of the analysis indicated the use of copper with impurities (Fe, Zn, Ni, and Pb). Except for the

absence of antimony, the combination of minor/trace elements is very similar to that of the other coin dated to the reign of Justinian I and minted in Nicomedia, even in the relatively high amount of lead. This similarity was already mentioned above, during the discussion regarding composition versus issuing authority.

Constantinople. This mint is better represented, with two folles issued during the reign of Justin II and the 20 nummia coin issued during the reign of Phocas. The two folles show a very similar composition, with minor/trace elements Fe, Ni, Pb, and in one of the cases the very weak presence of As. The use of the same source can be taken into consideration, especially as they were minted in the same year.

The composition of the later coin, although also copper, is characterised by a much larger number of minor/trace elements: Fe, Ni, Sn, Au, Pb, As. Two explanations can be advanced for this situation, especially taking into consideration the presence of tin as a minor element. It reflects either a change in the copper ore sources (the tin has such a small value that there are good chances to occur naturally in the copper ore) or the recycling of metal, mixing copper and bronze from various sources. Still, the extremely reduced number of analyses makes prudence necessary.

Kyzikos. The only coin from the batch issued by this mint came as one of the greatest surprises. Given the fact that the coin is a half-follis, following the general trend would have meant a composition based on copper with various impurities. Instead, the analysis indicated clearly tin bronze. Again, two hypotheses can be taken into consideration. One explanation could be that the activity of this mint in general deviated from the trend of issuing higher denomination using copper (in other words, a local technological tradition). Another explanation is that this was a fluke, a special case maybe triggered by the difficult military and economical period (574/575), necessitating the use of recycled metal to support the war effort.

Nicomedia. Four of the analysed coins were issued by this mint, a 10 nummia coin from the reign of Justinian I, two folles from the time of Justin II, and one follis from the reign of Tiberius II Constantine. The compositional characteristics of the three folles are remarkably similar, despite the difference in the issuing authority. The minor elements are Fe, Ni, Sb, Au, and also traces of As are present in two cases.

The 10 nummia coin varies both in terms of major elements and slightly in terms of minor/trace elements. It is made of a relatively low tin bronze, with a series of minor/trace elements in common with the other coins from Nicomedia (Fe, Ni, Sb, Pb), but it has also 0.1% zinc, the lead has a higher value than in the other cases, and gold is absent.

Thessalonica. The three coins from this mint were all issued during the reign of Justin II, and are all half-folles. Their composition matches very well, the same impurities being present in all three cases: Fe, Ni, Sb, Pb.

At this point of the discussion, it seems that the strongest correspondence can be identified between composition and mint, translating into both the almost certain use of different copper ore(s) by each mint and possibly different technological traditions.

Thus, several observations could be made, under the reserve of validating, correcting and/or refining the results in the future, as more analyses will be conducted:

- all the mints represented in the batch, with the exception of Kyzikos, respect the trend identified in the dedicated literature in the case of higher denominations (folles and half-folles), of issuing copper coins
- despite using different copper ores, the common point is the high purity of copper (the minor/trace elements cover usually approximately 0.5%-1.5% of the composition)
- all the sources are represented by poly-metallic ores
- recycling cannot be excluded (probable in the case of the 20 nummia coin from Phocas)
- more coins issued by Kyzikos should be analysed in the future, in order to determine if the compositional deviation represents the rule or an exception
- it was determined in the case of the mint from Nicomedia that not only the pentanummia were issued of tin bronze (as already known)²¹, but also the 10 nummia coins; more analyses on 10 nummia coins issued by this mint are necessary for confirming this situation as an established pattern
- based on the compositional characteristics, the coin from the reign of Mauricius could have been issued by either the mint of **Antioch**, or the mint of **Constantinople**. The comparison of the values of the minor/trace elements makes the second option more probable at this moment.

Some compositional characteristics could be emphasised for the moment as reflecting the activity of a specific mint, but with all due prudence, taking into consideration the limitations of the method and the small size of the analysed sample (to be further checked in the future).

Nicomedia uses at least from the time of Justin II a copper ore with a distinctive signature, characterised by a high number of minor/trace elements, but summing a very small percentage in the metal (over 99% Cu). The distinctiveness is given by the presence of antimony (sometimes only as traces in the spectra) and gold, aside Fe, Ni, and Pb (with or without traces of As). It is less probable that the metal used for the 10 nummia coin issued by Justinian comes from the same source. Chances are that either the source of copper changed between the reigns of Justinian I and Justin II, or this

²¹ Padfield 1972.

coin was made of recycled metal (reserved for small denominations), used in parallel with the local copper source (for higher denominations). The presence of zinc and iron, together with tin, would rather sustain the hypothesis of using recycled bronze²².

Thessalonica uses during the reign of Justin II a different source than Nicomedia, very similar from the point of view of present minor/trace elements (Fe, Ni, Pb, and Sb). The main difference seems to be the absence of gold as a minor/trace element.

Constantinople uses a source with a reduced number of minor/trace elements (Fe, Ni, Pb) in the time of Justin II, and possibly relies also on recycling in the time of Phocas, or uses an alternative source.

Antioch uses a source very similar to the Constantinopolitan one, from the point of view of presence/absence of the minor/trace elements. The only marked difference is in the higher value of lead. The observation being based on only one coin, it is impossible to determine if this difference is connected to the difference in copper ores or reflecting the technological process.

Kyzikos, in the case of which the use of tin bronze for pentanummia was postulated a long time ago²³, seems to have deviated from the pattern even more than presumed, with a half-follis made of tin bronze. The copper used has very few impurities. The only detectable minor elements are Ni and Pb; silver and iron appear as traces in the spectra. The value of Pb is very high. The fact that in general the bronzes have more lead than the coppers was emphasised previously²⁴. It is unclear if this means that lead comes together with tin, or represents the effect of a technological approach to the treatment of copper. The absence of iron and zinc seems to indicate that (no matter if recycled metal was used or tin was freshly added to copper) initially copper was purified from these two minor elements by controlled oxidation of the molten metal²⁵.

CONCLUDING REMARKS

Although conducted on a very small number of coins, the XRF analysis clearly shows the great potential of determining the composition of ancient coins made of copper or copper alloys. As more and more Early Byzantine coins from the Acropolis Centre-South Sector in Istros will be analysed in the following years, it is to be hoped that

²² Padfield 1972, 229.

²³ Padfield 1972 (numismatic commentary by Grierson: "the use of bronze for pentanummia was limited, on the evidence so far available, to the mints of Constantinople and Nicomedia, but one would expect it for Cyzicus also").

²⁴ Padfield 1972, 229.

²⁵ Padfield 1972, 229.

clearer trends in their composition would be established. These results could prove of use in completing the existing image of the monetary issuing and circulation of the 6th and 7th c. AD.

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