THE COMPOSITIONAL ANALYSIS OF COPPER AND BRONZE GREEK COINS FOUND AT HISTRIA (*ACROPOLIS CENTRE-SOUTH SECTOR*) USING A PORTABLE X-RAY FLUORESCENCE SPECTROMETER

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Keywords*: Histria, Acropolis Centre-South Sector, Greek coins, XRF analysis*
Abstract*: A number of 42 Greek coins (most of them issued and/or circulated at Histria during the autonomous period of the city and several issued by Histria during Roman times) were found during the 2013-2016 archaeological campaigns conducted in the Acropolis Centre-South Sector. The coins, made of copper and copper-based alloys, were subject to a non-invasive compositional analysis using a portable X-Ray Fluorescence (XRF) spectrometer, in order to determine trends and technological choices in the coinage production. The composition of these items was compared to that characterising a batch of coins found at Histria during older excavations.*

Cuvinte-cheie*: Histria, Sector Acropolă Centru-Sud, monede greceşti, analiză XRF*
Rezumat*: Un număr de 42 de monede greceşti (cele mai multe emise şi/sau în circulaţie la Histria de-a lungul perioadei autonome, precum şi câteva emise de Histria de-a lungul perioadei romane) au fost descoperite în cursul campaniilor arheologice 2013-2016 din Sectorul Acropolă Centru-Sud de la Histria. Monedele, realizate din cupru şi aliaje ale cuprului, au constituit subiectul unei analize compoziţionale non-destructive utilizând un spectrometru cu fluorescenţă de raze X (XRF) portabil, cu scopul de a determina trenduri şi alegeri tehnologice în producerea monedelor. Compoziţia acestor piese a fost comparată cu cea a unui lot de monede provenind din săpături mai vechi efectuate la Histria.*

The excavations on the *Acropolis Centre-South* (*ACS*) Sector at Histria/Istros (Istria commune, Constanţa County) began in 2013, based on a four-year archaeological research program financed by the University of Bucharest. The sector covers a surface of approximately 50 × 40 m (2000 m^2) just south of the centre of the acropolis of Histria and of *street c*. The research brought to light the last Late Roman dwelling level (6th c. AD), covered by massive layers of debris. There were identified a large structure, with two phases, conventionally named Roman building no.1 (CR01), as well as other walls belonging to previous and contemporary structures. The building CR01 was flanked east and west by two streets, which formed crossroads with *street c*[1].

The research occasioned the recovery of a rich and varied archaeological material, of which coinage represents an important and interesting category. During the first two archaeological campaigns 22 coins were found (seven in 2013 and 15 in 2014, including a *passim* coin from outside the sector), and already published[2]. The following two archaeological campaigns (2015–2016) brought to light a larger number of representatives of this category. During the 2015 campaign 73 coins and coin-shaped items were recovered, their preliminary identification resulting in a final number of 68 coins (including one *passim* from outside the sector) and five coin-shaped items (possibly but not certainly coins). During the 2016 campaign 54 coins and coin-shaped items were also recovered and went through preliminary identification.

In an attempt to learn more about the Greek and Roman coinage made of copper and copper-based alloys, the team decided to conduct a compositional non-destructive analysis on the coins found during the 2013–2016 campaigns, using a portable X-Ray fluorescence spectrometer Innov-X Systems Alpha Series, with W anticathode tube, SiPIN diode, Peltier cooling effect, and work parameters 40 kV tension, 35 μA intensity, acquisition time 2 min. The analysis was conducted on this batch both before and after their patina was removed[3]. The results from the second set of analyses (on cleaned coins) were taken into consideration for publication.

[1] For more details see Bottez *et alii* 2015.
[2] Vîlcu, Ţârlea 2016.
[3] The coins were cleaned and restored by Mrs. Georgiana Mureşan (Institute of Archaeology "Vasile Pârvan" Bucharest), to whom we express our thanks for her contribution to this research.

THE ANALYSED ITEMS

The analysed coins fall into the following categories:

1. coins issued by Histria/Istros and other West-Pontic Greek cities during the autonomous period: seven wheel type coins; five River god type coins; two Helios type coins; one Helios or River god type coin; six Apollon type coins; two Demeter type coins; 12 Greek autonomous coins which are too deteriorated to offer more information, of which two are countermarked (Table 1);
2. coins issued by other centres of the Greek world and circulating at Histria during the autonomous period: three coins struck in Macedonia for Philip II; one coin struck in Macedonia for Alexander the Great (Table 2);
3. coins issued by Histria during Roman times: one pseudo-autonomous Apollon on *omphalos* type coin; two coins struck by the city for Commodus (Table 3).

From the chronological point of view, these 42 coins cover a large time span, from the 5th–4th c. BC to the 2nd–3rd c. AD and represent a variety of types. The oldest ones are seven coins with the wheel on the obverse and the legend IΣT on the reverse, issued by Histria between 450–350 BC[4] in large numbers[5]. The River god type is represented by five (possibly six) coins, and the Helios type is represented by two (possibly three) coins, being issued by Histria during the 4th–3rd c. BC (one of the coins being too damaged to allow a more precise determination of the monetary type). The four coins struck in Macedonia for Philip II and Alexander the Great belong also to the 4th c. BC. Other six coins were attributed to the Apollon type (two of them countermarked – struck with the bust of Hermes over the representation of Apollon[6]), being issued by Histria during the 3rd–2nd c. BC. The two coins of Demeter type (one of them found *passim* near Poarta Mare/Great Gate), issued by Histria, are also dated to the 3rd–2nd c. BC. To the 2nd c. AD belong two coins issued by Histria for Commodus. Also, one rarer coin of the type Apollon on *omphalos* issued by Histria (from the category of the pseudo-autonomous coins) could possibly be dated to the 2nd c. AD[7]. In the case of 12 coins belonging to the autonomous period of the Greek cities, their poor preservation state did not allow so far to determine more details regarding their type and chronological frame, which can be loosely proposed as 4th–1st c. BC. As it can be noticed, from the point of view of the issuing authority, the group of Greek coins is clearly dominated by Histria, with at least 26 items from the total, followed by the four items issued in Macedonia.

The composition of the coins found on the *ACS Sector* was compared to the composition analysed using the same XRF device of 28 coins found at Histria during older excavations on various sectors (eight wheel type coins; three River god type coins; two pseudo-autonomous Apollon on *omphalos* type coins; 15 coins issued by Histria, Tomis and Callatis during Roman times), belonging to the numismatic collection of the "Vasile Pârvan" Institute of Archaeology.

THE RESULTS OF THE XRF ANALYSIS

The results of the analysis indicate the use of either copper or copper-based alloys for casting or minting these coins, but in both cases their composition is consistent with the exploitation of polymetallic ores for extracting the copper, which is accompanied by several trace elements in various combinations: **Ni** 0.001–0.12%; **Zn** 0–1.02% (with one notable exception – the pseudo-autonomous coin of Apollon on *omphalos* type contains 13.15% Zn); **Sb** 0–0.77%; **Au** 0–0.14%; **As** 0–0.31%; **Bi**, when determined, as very faint traces (0.001%); **Ag**, frequently present, but usually only as very faint traces (0.001%). The presence of **tin** could be noticed in all the cases, but within a wide range of values, between 0.001–16.74% Sn. The same is the situation of **lead**, which is present either as trace element in some cases, or with high values indicating intentional alloying for a notable number of items (Tables 1–3).

Although it is probable that at least in some cases the present values of **tin** are quite different from the original ones, due to the surface enrichment effect (even after patina has been removed through cleaning from the surface of the bronze objects), the degree of variation in the Sn percentage, even for such a small batch, is clear enough to indicate that further investigations, on larger numbers of coins of the same types, might be rewarding.

Several observations can be made by correlating the amount of tin to the coin type (Fig. 1). The **wheel type** coins prove to be so far an interesting group. While all seven items have tin in their composition, for one of them (Table 1, No. 33) this element amounts to only 0.5%, four of them (Table 1, Nos. 30–32, 35) are strongly clustered by their percentage of tin (3.22–5.58%), while the last two items jump to values of 15.62% and 16.62% Sn, respectively (Table 1, Nos. 29 and 34). The probability of this situation not being just coincidence is enhanced by the presence of relatively high percentages of lead in the composition of the

[4] Poenaru Bordea 2001, p. 15. For the Istrian bronze coins, see also Talmaţchi 2011.

[5] Preda 1973, p. 89–103, Cat. Nos. 1–231, to which numerous more recent finds should be added.

[6] For more details see Dima 2014, p. 15.

[7] For more details regarding the difficulties surrounding the dating of this coin type see the discussion in Vîlcu, Ţârlea 2016, p. 162.

four items with medium values of tin (3.53–6.41% Pb). The use of a naturally lead-rich copper ore in the case of these four coins cannot be completely ruled out as an explanation, more so when one of the River god type coins (Table 1, No. 25) is taken into consideration, with 3.71% Pb and no tin at all in its composition.

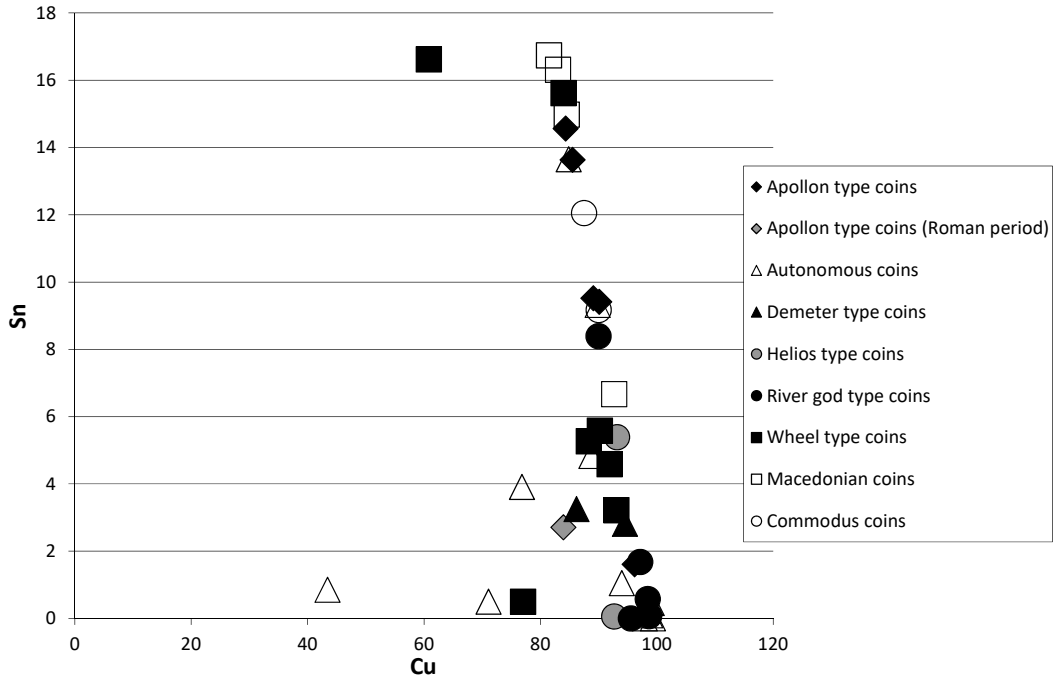

Figure 1. *The Cu-Sn diagram for the Greek coins.*

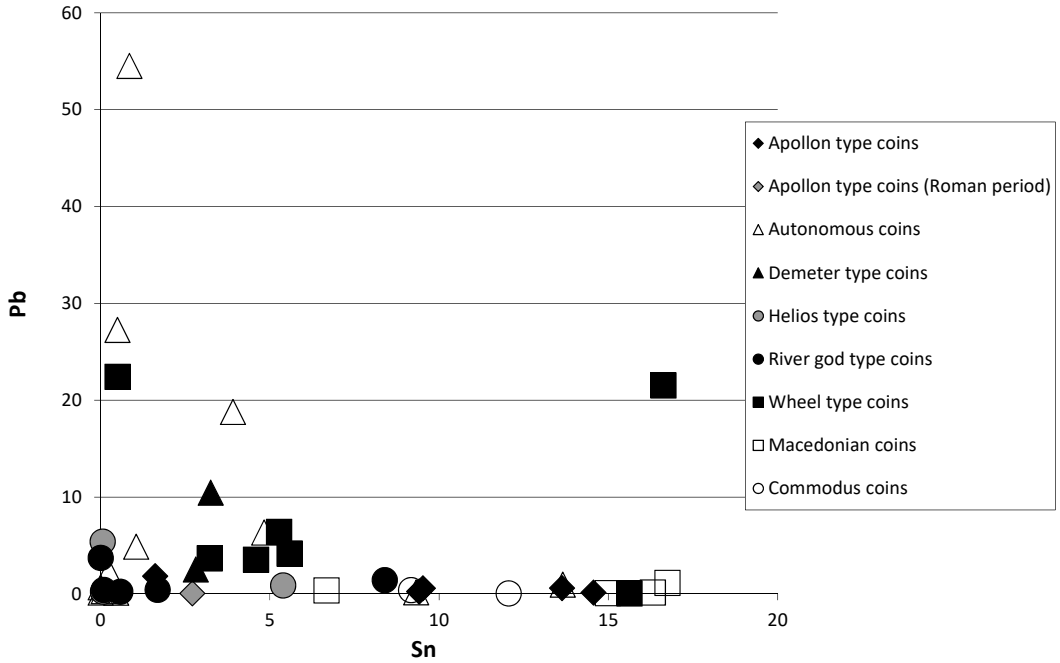

Figure 2. *The Sn-Pb diagram for the Greek coins.*

An alternative explanation, based on the repetitive combination of relatively low percentages of tin with high percentages of lead (Fig. 2), could be the intentional use of a ternary alloy, both tin and lead being added to copper, for reasons which are more difficult to ascertain at this point. A shortage of tin would come to mind as a possible reason, but a technological choice cannot be completely ruled out, as long as adding lead to the alloy would have eased the casting, by lowering the melting temperatures, and would have increased the bulk of the casting[8]. Recent analyses conducted on a large batch of Scythian-type arrowheads, arrowhead-shaped monetary signs and wheel type coins issued by Histria show that lead is frequently present as part of a ternary alloy in the case of arrowheads and arrowhead-shaped monetary signs. Based on the fact that antimony was also found present both in the case of monetary signs and wheel type coins, the authors consider that the latter were partly obtained after melting monetary signs[9]. Although in the case of our wheel type coins antimony (Sb) is conspicuously absent, the presence of lead in their composition could possibly mark a connection between this type of coins and the monetary signs. Very interesting is the situation of the two wheel type coins characterised by the highest amounts of tin: while one of them (No. 29) can be safely described as a binary alloy copper-tin, since lead in its composition has a value of 0.05%, the other one (No. 34) is clearly a ternary alloy, copper-lead-tin, with 16.62% Sn and 21.52% Pb. In the same time, the first item mentioned above (No. 33) could be considered rather as an example of binary alloy, this time a combination copper-lead, since it has only 0.5% Sn, but 22.42% Pb. A comparison with the composition of two wheel type coins from the Ion Donoiu Collection sustains, so far, the observations made here, both being characterised by ternary alloys (copper-tin-lead), with values probably originally slightly different, since the coins from this collection are in general in an oxidised state[10].

The **River god type** coins show a tendency, if this term can be allowed for such a small sample, to be made of copper (three of five items); in one case, already mentioned above, with a higher percentage of lead (either naturally present or intentionally added to create a binary alloy copper-lead). A fourth coin (Table 1, No. 26) can be described as made of tin bronze (8.39% Sn), although the presence of lead in a percentage higher than the average for the Greek coins group (1.42% Pb) cannot rule out the presence of a ternary alloy. The fifth coin belonging to the group (No. 28) has 1.68% Sn in composition, such a low amount making unclear if the alloy is intentional or not.

A rather similar behaviour seems to characterise the **Helios type** coins from the perspective of using low percentages of tin, although the even smaller number of representatives makes any conclusions uncertain. The two items belonging without doubt to this type could both be described as binary alloys, but one is a copper-tin combination (No. 22) and the other a copper-lead combination (No. 21). The third item (No. 23), tentatively attributed at this point to either Helios type or River god type due to its extremely poor state of preservation, can be best described as made of copper (98.62%) with a high amount of trace elements. So far, its composition draws this item nearer to the River god type coins made of copper discussed above.

From the six **Apollon type** coins issued during the autonomous period (Table 1, Nos. 1–6), four form a consistent group, having in common a composition based on bronze with a high percentage of tin (9.41–14.56% Sn), the two coins with the bust of Hermes superimposed on the image of Apollo being the richest in tin. At the other end of the spectrum are situated the remaining two coins: one of them can be included in the category of coins made of copper (No. 3), while the other (No. 4) has a composition situated at the limit between copper with a high amount of trace elements and a very weak ternary alloy copper-lead-tin. It should be mentioned that these last two items are late small nominal Apollon type coins, situation which could be either just coincidence or an indicator (if sustained by a larger number of similar results) of possible changes in time in the monetary activity of the city regarding at least this type of coins. Other coins of the Apollon type, belonging to the Ion Donoiu Collection, seem to point in an opposite direction: two of the three coins dated by Steluţa Marin[11] to the 3rd c. BC are made of alloys with high amounts of copper (95.7% and 98% Cu, respectively), while six coins dated by the same author to the 1st c. BC present between 67.5% and 84% Cu[12]. Even allowing for their oxidised condition, which normally comes with the enrichment of the surface in tin, these values could indicate that rather being a question of chronology we deal with a variation connected to the subtype, variant or nominal of these coins.

The two **Demeter type** coins are similar in that they are made of ternary alloys but vary in details. One of the coins (No. 19) is characterised by a combination copper-tin-lead with very close values for tin and lead (2.81% Sn and 2.51% Pb), and the other (No. 20) by a combination copper-lead-tin where lead not only clearly outruns tin, but also is present in a high amount (10.45% Pb and 3.25% Sn). The metal composition is not the only sign of eccentricity of this last item, which displays a less usual reverse with the eagle placed to the left on the dolphin but with its head turned to the right and interrupting the legend. A comparison with Demeter type coins from the Ion Donoiu Collection indicates that there are chances to be a compositional evolution between earlier and later

[8] Scott 2002, p. 3.
[9] Vasilescu *et alii* 2017, p. 3–4, 7.
[10] Marin 2013–2014, p. 31, Table 1 (Nos. 4–5).
[11] Marin 2013–2014, p. 31, Nos. 23–25.
[12] Marin 2013–2014, p. 31–32, Table 1 (Nos. 26–30).

coins of this type, towards higher values of the alloying materials (tin and lead). The Demeter type coins dated by Steluţa Marin to the 3rd c. BC tend to be made of an alloy with a high amount of copper (95.6–97% Cu), while those dated by the same author to the 1st c. BC have values of copper between 72.7% and 83%[13].

The four coins issued in Macedonia (Table 2, Nos. 36–39) for **Philip II** and **Alexander the Great** form a rather homogeneous group, all being made of quality tin bronze. In fact, the highest values of tin of the entire analysed batch belong to this group, two of the coins displaying values over 16% Sn. Only one of the coins issued for Philip II (No. 37) contains a smaller amount of tin (6.67%), but otherwise blends well with the rest of the group. The general aspect of their composition, with no visible addition of lead and high amounts of tin, brings them nearer to a part of the Apollon type coins (Nos. 1–2, 5–6) and one of the wheel type coins (No. 29).

The coins from the analysed group issued by Histria during Roman times consist of two items issued for Commodus and one item of the so-called pseudo-autonomous Apollon on *omphalos* type (Table 3, Nos. 40–42). The coins issued for **Commodus** are made of quality tin bronze, with quite similar values for the addition of tin (9.17% and 12.05%).

The coin issued by Histria and belonging to the **Apollon on *omphalos* type** coin proved to be made of **brass**. To be more precise, this item can be described as made of a ternary alloy (83.93% Cu; 13.15% Zn; 2.71% Sn). The only other item made of brass which belongs so far to the numismatic finds from the *ACS Sector* is a coin issued by Tomis for Gordian III, although the coin from Tomis is characterised by a binary alloy (79.1% Cu; 19.99% Zn), all the other elements being in such low percentages as to raise serious doubts regarding any intentional addition in their case. Brass as such is an alloy frequently used during Roman times for the production of various objects. The golden appearance given to the alloy by the presence of zinc made it especially suitable to be used for ornaments, possibly as a substitute for the more noble and expensive metal. Still, the presence of zinc in such high amounts in the composition of these two coins is intriguing at least from two perspectives. First, it creates a compositional "gap" between the Apollon on *omphalos* type coin, which was tentatively attributed to the 2nd c. AD, and the other two coins from our batch issued by Histria during the same century, both for Commodus, which are made of tin bronze. Secondly, it establishes a link, even if superficial, between Histria and Tomis, and between a coin with problematic chronological framing and a coin with indubitable dating. Of course, there is no rule to say that different types of coins issued by the same city during a certain period of time must be made of the same alloy. Even coins of the same type can present important compositional variations, as the wheel type coins discussed above clearly show. As such, the use of zinc for the coin issued by Histria and the coin issued by Tomis could prove to be their only common trait, with no deeper implications. Yet this situation certainly needs further investigations and more analyses on coins issued by Histria (both pseudo-autonomous and for the Roman emperors) and other Greek cities from this area should be conducted in order to determine if any trends shape themselves.

FURTHER INVESTIGATIONS

One of the main drawbacks in the case of compositional analyses on reduced numbers of similar items is the uncertainty regarding their degree of statistical relevance for the entire category they represent. Taking this into account, the team decided to conduct an XRF analysis using the same device on a series of coins brought to light during older excavations in Histria and belonging to the Numismatic collection of the "Vasile Pârvan" Institute of Archaeology in Bucharest, and to compare the results with those already obtained on the coins excavated in the *ACS Sector*.

The coins which have been analysed so far constitute also a rather small batch, and this enterprise should be regarded as being rather an experiment which hopefully will offer a result encouraging enough for the team to continue on the same line – trying to determine the place of the numismatic finds from the *ACS Sector* in the larger context of the city of Histria also from the perspective of their metal composition.

Based on what was available during this stage of our research, the following coins from older excavations were analysed: eight wheel type coins[14]; three River god type coins[15]; two pseudo-autonomous Apollon on *omphalos* type coins[16]; 15 coins issued by Histria, Tomis and Callatis for various emperors[17]. All these coins went through cleaning and conservation processes after their recovery, so the XRF analysis was made on items with a comparable state of preservation with the items discussed above.

1. Wheel type coins

The metal composition for all the wheel type coins analysed by our team is presented below (Table 4), where the seven items found so far on the *ACS Sector* are

[13] Marin 2013–2014, p. 31–32, Table 1 (Nos. 8–22).
[14] Inv. Nos. 292/252–255; 320/282; 337/2; 357/3; 1272/2.
[15] Inv. Nos. 338/4; 338/8; 1272/3.
[16] Inv. Nos. 405/2; 445/6.
[17] Inv. Nos. T94/15; 391/7; 786/2; 910/2; 1289/4; 1408/14; 1408/18; 1674/134; 1674/151; 1674/153; 1674/159; 1700/183; 1700/186; 1700/190; 1774/143.

compared with eight coins of the same time found during older excavations. It can be easily noticed that the values of the trace elements in the case of the items used for comparison match well those already discussed for the coins found on the *ACS Sector*. The main difference that could be noticed regards the values for zinc, conspicuously absent in the metal composition of the *ACS Sector* coins, and clearly present in the case of the coins coming from older excavations. This situation needs further enquiries, but an explanation regarding the presence of zinc as a result of using zinc-based solutions during the restoration and conservation processes cannot be at this moment completely overruled.

The presence of tin is noticed in all the cases, with quite a large range of values (Fig. 3). Despite this fact, a diagram copper-tin allows to notice the formation of a main cluster (12 items) which leaves few items in eccentric positions. Although it is possible that the analysis of a larger number of items will bring the emergence of new clusters, so far, the results for our small batch indicate a preference for using tin in the alloy of this category of coins between certain percentages: 12 of 15 coins (80%) contain tin between 3–10%; 10 of 15 coins (66.6%) contain tin between 4–8%. In the same time, it is interesting to notice that although the results tend to cluster they overlap only partially. Also, all the eccentric items come so far from the *ACS Sector*, the metal composition of the coins from older excavations being far more homogenous from this perspective.

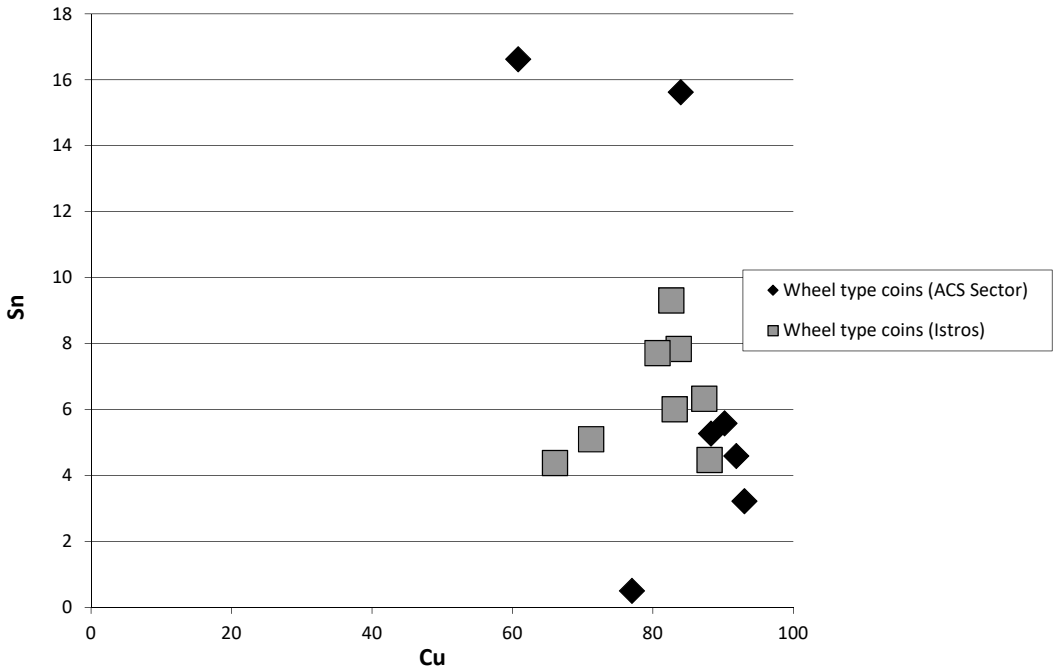

Figure 3. *The Cu-Sn diagram for the wheel type coins presenting in comparison the items found on the ACS Sector and the items found during older excavations at Histria/Istros.*

The presence of lead with values which clearly indicate intentional alloying made necessary a diagram tin-lead, in order to determine how these two alloying materials behave towards one another (Fig. 4). The resulting image confirms and refines the previous diagram. First of all, the cluster noticed in the copper-tin diagram is confirmed in main: 10 items preserve their closeness, while two items which were already a little bit separated in the previous cluster are drawn further away by their higher amount of lead. The result is that 10 of 15 coins (66.6%) have values of tin between 4–10% and lead between 4–12%, the most consistent grouping with 4–6% Sn and 4–8% Pb. Again, the possible existence of a preference or even recipe for the production of this type of coins comes to mind and should be verified with the help of future analyses on larger samples.

The results obtained so far indicate that at least in the case of this small batch of wheel type coins some trends or even norms evidence themselves. The first clear fact is that these coins are all made of alloyed copper, and the second that for the majority of the items a ternary alloy (copper-tin-lead or copper-lead-tin) represents the norm, 13 of the total of 15 coins being in this situation. It is less clear at this point if this is the result of an intentional combination at the moment when the metal charge was prepared or, how it was suggested in the literature, the more or less unintentional effect of re-using metal objects

withdrawn from circulation, such as pre-monetary signs[18]. The cluster emerging in the diagrams would suggest that, no matter the method involved, it is not impossible for a certain degree of control to have existed. The small number of analysed items does not allow for more certainty at this point, as long as the possibility of at least some of the items to have come from the same charge of metal cannot be completely ruled out.

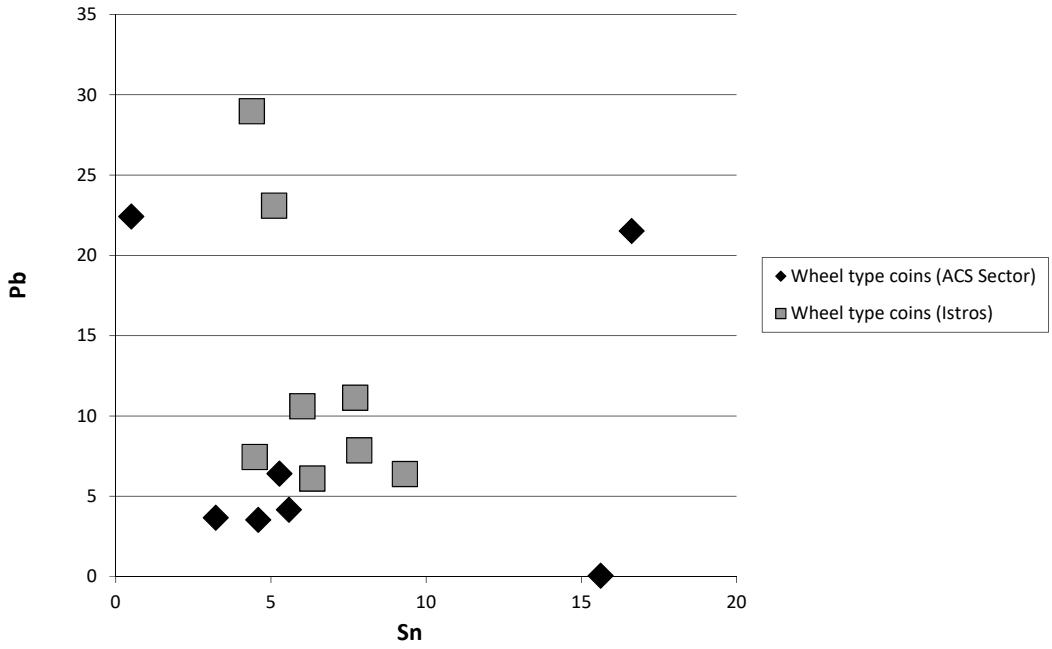

Figure 4. *The Sn-Pb diagram for the wheel type coins presenting in comparison the items found on the ACS Sector and the items found during older excavations at Histria/Istros.*

2. River god type coins

The metal composition of the group of coins of this type found on the *ACS Sector* was compared with the composition of three River god type coins from older excavations (Table 5). As in the case of the wheel type coins, the results for the coins used as comparison match well those characterising the items found on the *ACS Sector*.

The diagram copper-tin shows, with one notable exception (No. 26), that these coins have the tendency to form a loose cluster (Fig. 5), based on their shared characteristic of being made of copper with very low amounts of tin. Leaving aside the above-mentioned exception, all these coins have more than 95% Cu in combination with less than 2% Sn. In fact, six of the total of seven coins present values for tin lower than 1%.

A verification of the relation between tin and lead in the composition of these coins shows that five of the eight coins have less than 2% Sn and 0.5% Pb, forming a small cluster, and seven out of eight coins have less than 2% Sn and 4% Pb (Fig. 6). Given the small values for both tin and lead in the majority of cases, it is almost impossible to say at the present if this situation is intentional or not, and if the metal could be described as intentional alloy or not.

As a result of these observations, the safest thing that can be said so far for the analysed group of River god type coins is that in main they seem to have a very different behaviour than the analysed group of wheel type coins, being in general made either of copper with a high amount of trace elements or of very weak binary or ternary alloys. Another aspect to be taken in consideration is the absence of antimony in the case of the wheel type coins and its presence in the case of seven of the eight River type coins, situation which could hint towards the use of a different source of copper. It is interesting to notice that the only composition where antimony is not present belongs to the coin which has an eccentric position due to the use of tin as alloying material.

[18] Vasilescu *et alii* 2017, p. 3–4, 7.

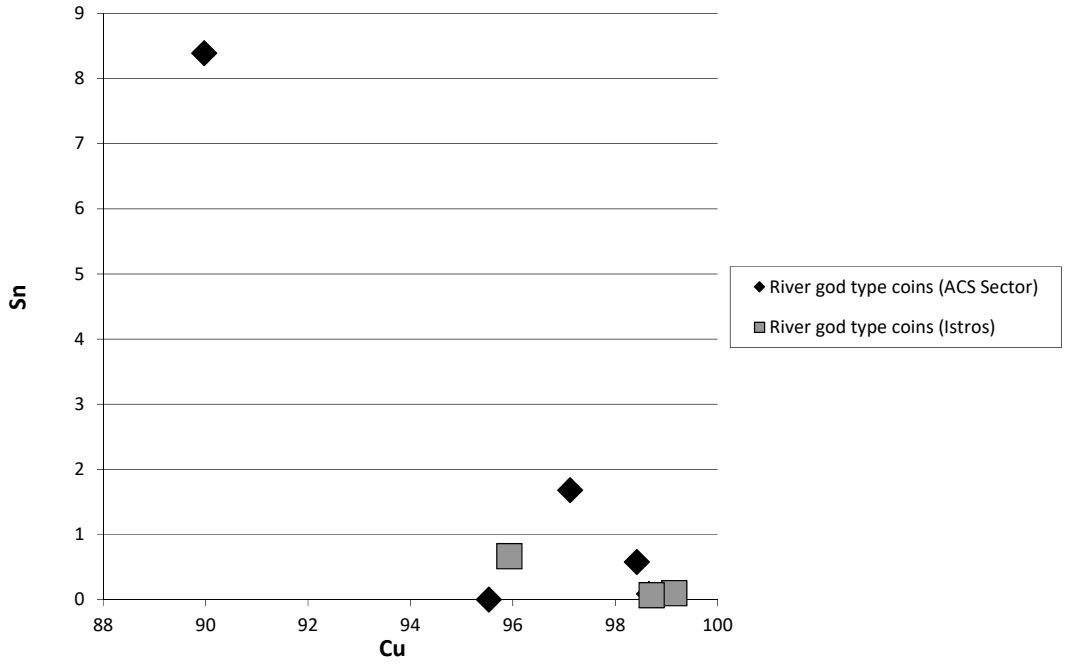

Figure 5. *The Cu-Sn diagram for the River god type coins presenting in comparison the items found on the ACS Sector and the items found during older excavations at Histria/Istros.*

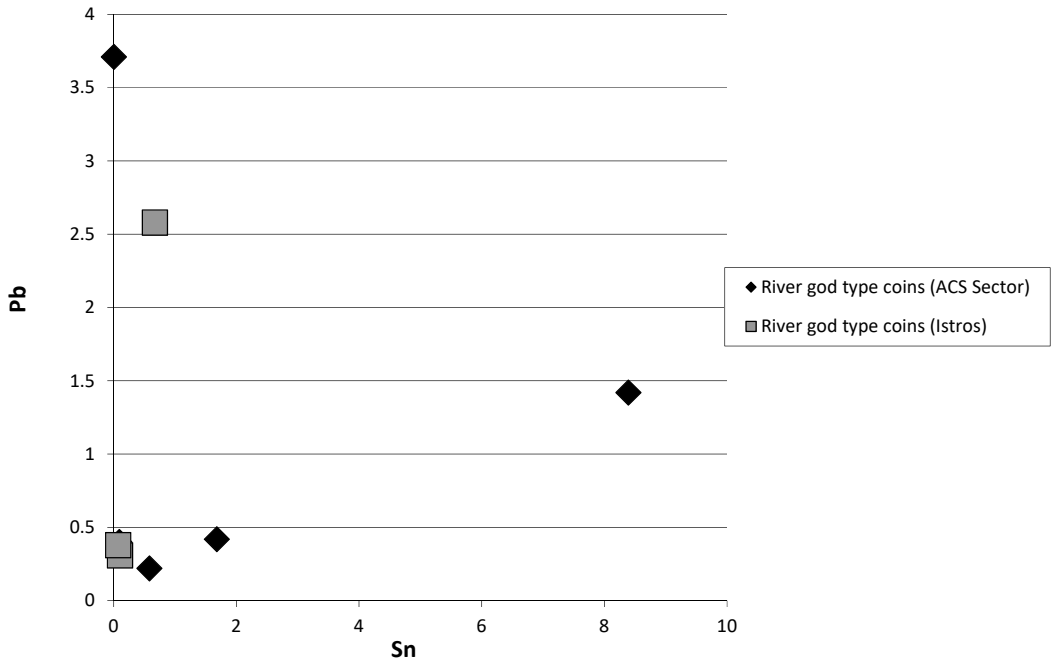

Figure 6. *The Sn-Pb diagram for the River god type coins presenting in comparison the items found on the ACS Sector and the items found during older excavations at Histria/Istros.*

3. The pseudo-autonomous Apollon on *omphalos* type coins

It was already mentioned that a coin of a rare type, issued by Histria with the representation of Apollon on *omphalos* during Roman times, offered a surprise from the compositional point of view as it turned out to be made of brass. The only two other coins issued for Commodus by Histria during that period of time which were found on the *ACS Sector* are made of tin bronze, so this coin tends to stand out. The closest parallel found in the beginning was in a coin, also found on the *ACS Sector*, issued for Gordian III by Tomis. This situation raised some questions and the team decided to compare these items with a number of older finds, including two other pseudo-autonomous Apollon on *omphalos* type coins and several other coins issued for the Roman emperors by Histria, Tomis and Callatis, in an attempt to determine possible trends.

The results of the XRF analysis are presented in the following table (Table 6).

The 21 analysed coins are: three coins of pseudo-autonomous Apollon on *omphalos* type issued by Histria; five coins issued for Commodus by Histria; three coins issued for Gordian III, one each by Histria, Tomis and Callatis; three coins issued for Gordian and Tranquillina, two by Histria and one by Tomis; two coins issued for Severus Alexander, one by Callatis and one by Histria; one for Elagabal, one for Iulia Mamaea, one for Caracalla, issued by Histria; one for Philip Jr. and one for Philip the Arab issued by Tomis[19].

Although the situation is far from balanced from the point of view of either the degree of representation of the emitting authority (16 coins were issued by Histria, three by Tomis, and two by Callatis) or the number of coins for each type, the results of the XRF analysis are quite interesting, as a diagram zinc-tin shows (Fig. 7).

In general lines, the batch of coins analysed so far has the tendency to split into three groups:

1. coins made of copper: Gordian III (Histria) – 1; Caracalla (Histria) – 1;
2. coins made of alloys based on tin (tin bronze or copper-tin-lead/copper-lead-tin alloy): Iulia Mamaea (Histria) – 1; Gordian and Tranquillina (Histria) – 2; Severus Alexander (Histria) – 1; Commodus (Histria) – 5; Elagabal (Histria) – 1;
3. coins made of brass (as binary alloy or ternary alloy with tin): Apollon on *omphalos* (Histria) – 3; Gordian III (Tomis) – 1; Gordian III (Callatis) – 1; Gordian and Tranquillina (Tomis) – 1; Severus Alexander (Callatis) – 1; Philip Jr. (Tomis) – 1; Philip the Arab (Tomis) – 1.

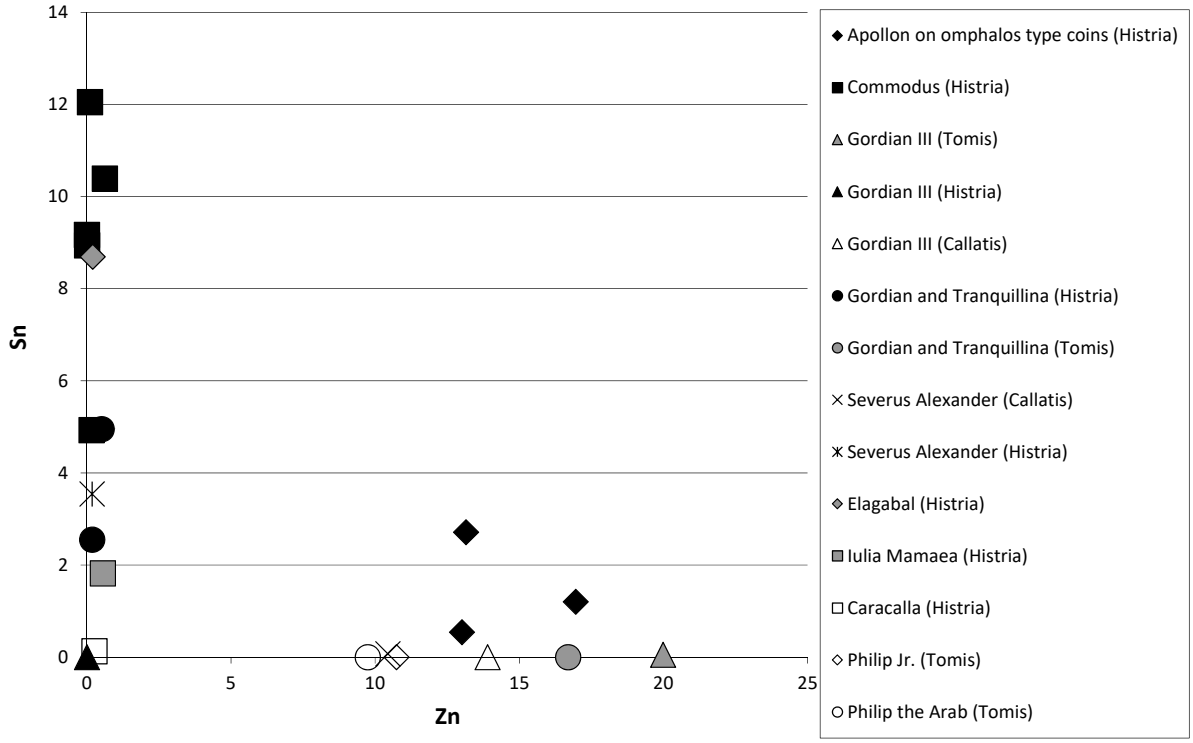

Figure 7. *The diagram Zn-Sn for coins issued by Histria, Tomis and Callatis during the Roman period (for each type the issuing centre being indicated between parentheses).*

[19] For the coins issued by Istros, Tomis and Callatis in the first half of the 3rd century AD, see Dima 2005 and Dima 2011.

From the point of view of the emitting authority, **Histria** shows a clear preference to use binary alloys copper-tin and especially ternary alloys copper-tin-lead or copper-lead-tin. Also, in two cases the percentage of copper in composition is so high as to be possible to talk about coins made of copper. In this perspective, it would be tempting to consider this situation as representing either the preservation or the renewal of an older tradition in the casting and minting of coinage, if we compare the compositional choices for these items with those made for the coinage of the autonomous period of the city. The only real novelty seems to be the presence of zinc as alloying material for the coins of Apollon on *omphalos* type, which are all three made of brass. In the same time, all the analysed coins issued by **Tomis** and **Callatis** have zinc in their composition, being also made of brass. As such, the emerging image is that there is a sort of divergence between the technological choices of Histria and the two other Greek cities, which in their turn seem to be closer to each other in this respect. It is surely risky to draw such a conclusion based only on the comparison between such small numbers of coins, but the fact that coins issued for the same ruler(s), as is the case with Gordian III, Gordian and Tranquillina or Severus Alexander, are made of brass in Tomis or Callatis and of copper/bronze in Histria lends some weight to this supposition. Even in the only case indicating, so far, the use of zinc for coins in Histria, the composition of the three coins of Apollon on *omphalos* type varies when compared to that of the coins made of brass from Tomis and Callatis. While the last-mentioned represent a binary alloy copper-zinc, the Apollon on *omphalos* type coins are made of a ternary alloy, copper-zinc-tin, either intentionally or by adding zinc to tin bronze (Fig. 7). In the same time, in general lines and allowing for local choices and possibilities, all these West-Pontic Greek cities do nothing more than to align themselves to the metallurgical trends of the Roman world, where the use of brass both for minting coinage and for other categories of objects is already frequent during this chronological framework.

CONCLUSIONS

Comparing the behaviour of the coins taken into discussion, certain patterns tend to be established more or less clearly. In the case of the earliest coinage issued by Histria, the wheel type coins, binary (copper-tin or copper-lead) and especially ternary (copper-tin-lead or copper-lead-tin) alloys seem to be greatly in favour. On the contrary, the River god type coins tend to be made either of copper or very weak copper-based alloys. Tin bronze is rather the norm for the Apollon type coins of the autonomous period, while for the Demeter type coins a ternary alloy with tin and lead seems to be preferred. The coins issued by Histria for the Roman emperors tend to follow what could be described as already existing traditions from the compositional point of view, the only clear exception so far being the pseudo-autonomous Apollon on *omphalos* type coins, made of brass.

It is to be hoped that future analyses will help completing and clarifying the image offered by the copper and copper-based coinage issued by Histria, from the compositional and technological perspective.

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No.	Type	Mint	Ti	Fe	Co	Ni	Cu	Zn	Ag	Sn	Sb	Au	Pb	Bi	As
1.	Apollon	Histria	0	0.05	0.08	0.08	90.09	0	0.001	9.41	0	0.06	0.23	0	0
2.	Apollon (?)	Histria	0	0.45	0	0.04	89.08	0.19	0.001	9.52	0.14	0	0.58	0	0
3.	Apollon	Histria	0	0.03	0	0.001	98.91	0.12	0	0.11	0.46	0.05	0.22	0	0.11
4.	Apollon	Histria	0	0.06	0	0.03	96.16	0	0	1.61	0	0	1.82	0	0
5.	Apollon/countermarked Hermes	Histria	0	0.001	0	0.001	84.31	0.11	0.001	14.56	0.76	0.14	0.13	0	0
6.	Apollon/countermarked Hermes	Histria	0	0.13	0.07	0.001	85.52	0	0.001	13.63	0.001	0.06	0.59	0	0
7.	Uncertain	Histria	0.06	0.12	0.17	0.001	89.82	0	0.001	9.32	0.29	0.06	0.16	0	0
8.	Uncertain	Greek autonomous coin (4^{th}–1^{st} c. BC)	0	0.23	0.02	0.04	97.93	0.91	0.001	0.001	0.21	0	0.67	0	0
9.	Uncertain	Greek autonomous coin (4^{th}–1^{st} c. BC)	0.09	0.33	0.03	0.001	84.84	0	0.001	13.65	0	0.11	0.94	0	0
10.	Uncertain	Histria	0	0.001	0	0.03	99.11	0	0.001	0.46	0.22	0.06	0.11	0	0
11.	Uncertain	Histria	0	0.001	0	0.001	98.86	0	0.001	0.09	0.67	0.13	0.26	0	0
12.	Uncertain	Greek autonomous coin (4^{th}–1^{st} c. BC)	0	0.03	0	0.001	97.47	0	0	0.24	0	0	2.25	0	0
13.	Uncertain	Greek autonomous coin (4^{th}–1^{st} c. BC)	0	0.15	0	0.03	43.42	1.02	0	0.85	0	0	54.51	0	0
14.	Uncertain	Greek autonomous coin (4^{th}–1^{st} c. BC)	0	0.12	0	0.001	93.96	0	0	1.05	0	0	4.87	0	0
15.	Uncertain	Greek autonomous coin (4^{th}–1^{st} c. BC)	0	1.04	0	0.12	71.09	0	0	0.5	0	0	27.25	0	0
16.	Uncertain	Greek autonomous coin (4^{th}–1^{st} c. BC)	0	0.5	0	0.001	76.82	0	0	3.91	0	0	18.77	0	0
17.	Uncertain	Greek autonomous coin (4^{th}–1^{st} c. BC)	0	0.1	0	0.001	88.74	0	0	4.83	0	0	6.32	0	0
18.	Uncertain	Greek autonomous coin (4^{th}–1^{st} c. BC)	0	0.09	0	0.001	99.33	0	0	0	0.34	0.05	0.13	0	0.06
19.	Demeter	Histria	0	0.001	0	0.001	94.5	0	0.001	2.81	0.18	0	2. 51	0	0
20.	Demeter	Histria	0	0.1	0	0.001	86.19	0	0	3.25	0	0	10.45	0	0
21.	Helios	Histria	0	0.34	0	0.001	92.64	0.23	0	0.06	0.77	0.1	5.4	0.15	0.31
22.	Helios	Histria	0	0.08	0	0.001	93.15	0.1	0	5.39	0.23	0.06	0.87	0	0.12
23.	Helios or River god	Histria	0	0.05	0	0.001	98.62	0	0	0.07	0.68	0.14	0.23	0.06	0.15
24.	River god	Histria	0	0.001	0	0.001	98.42	0	0.001	0.58	0.54	0.09	0.22	0.001	0.14
25.	River god	Histria	0	0.19	0	0.001	95.53	0.24	0.001	0.001	0.32	0	3.71	0	0
26.	River god	Histria	0	0.18	0	0.04	89.97	0	0.001	8.39	0	0	1.42	0	
27.	River god	Histria	0	0.001	0	0.03	98.66	0	0.001	0.09	0.75	0.08	0.4	0	0
28.	River god	Histria	0	0.12	0	0.03	97.12	0.1	0	1.68	0.32	0.1	0.42	0	0.13
29.	Wheel	Histria	0	0.24	0	0.001	83.96	0.001	0	15.62	0	0.06	0.05	0.001	0.07
30.	Wheel	Histria	0	0.001	0	0.001	91.87	0	0.001	4.59	0	0	3.53	0.001	0.001
31.	Wheel	Histria	0	0.001	0	0.001	93.04	0	0.001	3.22	0	0	3.66	0.001	0.001
32.	Wheel	Histria	0	0.04	0	0.03	90.19	0	0.001	5.58	0	0	4.16	0	0
33.	Wheel	Histria	0	0.07	0	0.001	77.01	0	0	0.5	0	0	22.42	0	0
34.	Wheel	Histria	0	0.9	0	0.001	60.82	0	0	16.62	0	0.12	21.52	0	0
35.	Wheel	Histria	0	0.04	0	0.001	88.27	0	0	5.27	0	0	6.41	0	0

Table 1. *The metal composition of the Greek coins from the ACS Sector issued by Histria during the autonomous period of the Greek cities.*

No.	Type	Mint	Ti	Fe	Co	Ni	Cu	Zn	Ag	Sn	Sb	Au	Pb	Bi	As
36.	Alexander the Great	Macedonia	0	0.32	0	0.001	81.46	0.12	0	16.74	0	0.08	1.14	0	0.14
37.	Philip II	Macedonia	0	0.04	0	0.03	92.64	0.12	0.001	6.67	0.16	0	0.35	0	0
38.	Philip II	Macedonia	0.11	0.18	0	0.001	83.01	0.11	0.001	16.31	0	0.06	0.14	0.001	0.08
39.	Philip II	Macedonia	0	0.18	0.08	0.03	84.5	0.1	0.001	14.98	0	0.07	0.07	0	0

***Table 2**. The metal composition of the Macedonian coins from the ACS Sector.*

No.	Type	Mint	Ti	Fe	Co	Ni	Cu	Zn	Ag	Sn	Sb	Au	Pb	Bi	As
40.	Apollon on omphalos	Histria	0	0.06	0	0.06	83.93	13.15	0.05	2.71	0	0.001	0.04	0.001	0.01
41.	Commodus	Histria	0.08	0.11	0.03	0.04	89.98	0	0.001	9.17	0.22	0	0.39	0	0
42.	Commodus	Histria	0	0.12	0	0.09	87.47	0.1	0	12.05	0	0.07	0.05	0	0.06

***Table 3.** The metal composition of the Greek coins from the ACS Sector issued by Histria during the Roman times.*

No.	Type	Mint	Ti	Fe	Co	Ni	Cu	Zn	Ag	Sn	Sb	Au	Pb	Bi	As
29.	Wheel	Histria	0	0.24	0	0.001	83.96	0.001	0	15.62	0	0.06	0.05	0.001	0.07
30.	Wheel	Histria	0	0.001	0	0.001	91.87	0	0.001	4.59	0	0	3.53	0.001	0.001
31.	Wheel	Histria	0	0.001	0	0.001	93.04	0	0.001	3.22	0	0	3.66	0.001	0.001
32.	Wheel	Histria	0	0.04	0	0.03	90.19	0	0.001	5.58	0	0	4.16	0	0
33.	Wheel	Histria	0	0.07	0	0.001	77.01	0	0	0.5	0	0	22.42	0	0
34.	Wheel	Histria	0	0.9	0	0.001	60.82	0	0	16.62	0	0.12	21.52	0	0
35.	Wheel	Histria	0	0.04	0	0.001	88.27	0	0	5.27	0	0	6.41	0	0
292/252	Wheel	Histria	0	0.04	0	0.001	83.08	0.28	0.001	6.01	0	0	10.61	0	0.001
292/253	Wheel	Histria	0	0.09	0	0.03	82.61	1.55	0.001	9.31	0	0	6.39	0	0.001
292/254	Wheel	Histria	0	0.001	0	0.001	87.31	0.24	0.001	6.33	0	0	6.11	0	0.001
292/255	Wheel	Histria	0	0.18	0	0.001	83.67	0.37	0.001	7.84	0	0.08	7.86	0	0.001
320/282	Wheel	Histria	0	0.03	0	0.001	88.05	0	0.001	4.47	0	0	7.45	0	0.001
337/2	Wheel	Histria	0	0.001	0	0.001	71.19	0.60	0.001	5.10	0	0	23.1	0	0
357/3	Wheel	Histria	0	0.001	0	0.04	80.63	0.48	0.001	7.71	0	0	11.14	0	0
1272/2	Wheel	Histria	0	0.001	0	0.001	66.04	0.60	0.001	4.38	0	0	28.98	0	0

***Table 4.** The metal composition of the wheel type coins found on the ACS Sector and from older excavations at Histria/Istros.*

No.	Type	Mint	Ti	Fe	Co	Ni	Cu	Zn	Ag	Sn	Sb	Au	Pb	Bi	As
24.	River god	Histria	0	0.001	0	0.001	98.42	0	0.001	0.58	0.54	0.09	0.22	0.001	0.14
25.	River god	Histria	0	0.19	0	0.001	95.53	0.24	0.001	0.001	0.32	0	3.71	0	0
26.	River god	Histria	0	0.18	0	0.04	89.97	0	0.001	8.39	0	0	1.42 0	0	
27.	River god	Histria	0	0.001	0	0.03	98.66	0	0.001	0.09	0.75	0.08	0.4	0	0
28.	River god	Histria	0	0.12	0	0.03	97.12	0.1	0	1.68	0.32	0.1	0.42	0	0.13
338/ 8	River god	Histria	0	0.06	0	0.001	99.15	0.001	0.001	0.10	0.32	0	0.31	0	0.06
338/ 4	River god	Histria	0	0.001	0	0.001	98.71	0.10	0.001	0.07	0.53	0.1	0.38	0	0.12
1272/ 3	River god	Histria	0	0.001	0	0.001	95.93	0.16	0.001	0.67	0.57	0.09	2.58	0	0.001

***Table 5.** The metal composition of the River god type coins found on the ACS Sector and from older excavations at Histria/Istros.*

No.	Type	Mint	Ti	Fe	Co	Ni	Cu	Zn	Ag	Sn	Sb	Au	Pb	Bi	As
40.	Apollon on omphalos	Histria	0	0.06	0	0.06	83.93	13.15	0.05	2.71	0	0.001	0.04	0.001	0.01
405/ 2	Apollon on omphalos	Histria	0	0.10	0	0.06	81.42	16.96	0.001	1.20	0	0	0.26	0	0
445/ 6	Apollon on omphalos	Histria	0	0.05	0	0.04	86.20	13.01	0.001	0.54	0	0	0.15	0	0
41.	Commodus	Histria	0.08	0.11	0.03	0.04	89.98	0	0.001	9.17	0.22	0	0.39	0	0
42.	Commodus	Histria	0	0.12	0	0.09	87.47	0.1	0	12.05	0	0.07	0.05	0	0.06
1674/ 151	Commodus	Histria	0.1	0.17	0	0.001	87.00	0.62	0.001	10.39	0	0	1.71	0	0
T94/ 15	Commodus	Histria	0	0.08	0	0.11	90.62	0.001	0.001	8.94	0	0.07	0.06	0.06	0.06
1674/ 134	Commodus	Histria	0	0.35	0	0.04	92.83	0.16	0.001	4.93	0	0	1.69	0	0
	Gordian III	Tomis	0	0.16	0.07	0.46	79.1	19.99	0.07	0.05	0	0	0.11	0	0
786/2	Gordian III	Histria	0	0.03	0	0.66	99.18	0.001	0.001	0	0	0.06	0.03	0	0.04
910/2	Gordian III	Callatis	0	0.11	0	0.44	84.93	13.9	0.001	0	0	0.11	0.25	0.07	0.16
1700/ 186	Gordian and Tranquillina	Histria	0	0.11	0	0.04	93.15	0.51	0.001	4.95	0	0	1.24	0	0
1289/ 4	Gordian and Tranquillina	Histria	0	0.23	0	0.83	90.05	0.18	0.001	2.55	0	0	6.14	0	0
391/7	Gordian and Tranquillina	Tomis	0	0.06	0	0.34	82.01	16.69	0.001	0	0	0	0.53	0	0.26
1674/153	Severus Alexander	Callatis	0	0.13	0	0.32	88.87	10.44	0.001	0.07	0	0	0.09	0	0.08
1700/183	Severus Alexander	Histria	0	0.58	0	0.05	92.67	0.18	0.001	3.54	0	0	2.97	0	0.001
1774/143	Elagabal	Histria	0	0.07	0	0.001	71.04	0.20	0.001	8.69	0	0	20.01	0	0
1408/18	Iulia Mamaea	Histria	0	0.42	0	0.04	93.43	0.55	0.001	1.82	0	0	3.74	0	0
1408/14	Caracalla	Histria	0	0.03	0	0.07	98.62	0.26	0.001	0.13	0.16	0.24	0.20	0.1	0.19
1674/159	Philip Jr.	Tomis	0	0.18	0	0.39	88.00	10.74	0.001	0	0	0.14	0.33	0	0.22
1700/190	Philip the Arab	Tomis	0	0.07	0	0.30	89.34	9.74	0.001	0	0	0.13	0.17	0.11	0.16

Table 6. *The metal composition of coins issued by Histria, Tomis and Callatis during the Roman period (found on the ACS Sector and from older excavations at Histria/Istros).*

ABRÉVIATIONS / ABBREVIATIONS / ABREVIERI

AA – Archäologischer Anzeiger. Deutsches Archäologisches Institut, Darmstadt, München, Tübingen–Berlin
ACMI – Anuarul Comisiunii Monumentelor Istorice, Bucureşti
ActaMN – Acta Musei Napocensis, Cluj
ActaMP – Acta Musei Porolissensis, Zalău
ActaTS – Acta Terrae Septemcastrensis, Universitatea Lucian Blaga, Sibiu
Acta Siculica – Acta Siculica. Anuarul Muzeului Naţional Secuiesc, Sfântu Gheorghe
l'Anthropologie (Paris) – l'Anthropologie, Paris
Antiquity – Antiquity. A Quarterly Review of Archaeology, University of York
Anuarul MJIAP – Anuarul Muzeului Județean de Istorie și Arheologie Prahova, Ploiești
ARA – Annuaire Roumain d'Anthropologie
Archaeometry – Archaeometry, Research Laboratory for Archaeology and the History of Art, Oxford University
ArchBulg – Archaeologia Bulgarica, Sofia
Area – Area, Royal Geographical Society, London
ArheologijaKiiv – Arheologija. Nacional'na akademija nauk Ukraini. Institut archeologii, Kiiv
ArheologijaSSSR – Arheologija SSSR. Svod Archeologičeskih Istočnikov, Moskva
ArhMold – Arheologia Moldovei, Iaşi
BA – Biblioteca de Arheologie, Bucureşti
BARIntSer – British Archaeological Reports. International Series, Oxford
BiblThrac – Bibliotheca Thracologica, Bucureşti
BMC – *Coins of the Roman Empire in the British Museum*, London. I, *Augustus to Vitellius*, 1923; II, *Vespasian to Domitian*, 1930; III, *Nerva to Hadrian*, 1936; IV, *Antoninus Pius to Commodus*, 1968; V, *Pertinax to Elagabalus*, 1950 (H. Mattingly); VI, *Severus Alexander to Balbinus and Pupienus*, 1962 (R.A.G. Carson)
BMJT – Buletinul Muzeului Judeţean Teleorman, Alexandria
BMJTAG – Buletinul Muzeului Județean „Teohari Antonescu", Giurgiu
BSNR – Buletinul Societăţii Numismatice Române, București
Bull. et Mém. de la Soc. d'Anthrop. de Paris – Bulletins et Mémoires de la Société d'Anthropologie de Paris
CA – Cercetări Arheologice, Bucureşti
Caiete ARA - Caietele ARA, Revistă de Arhitectură, Restaurare şi Arheologie, Asociaţia ARA, Bucureşti
CCA – Cronica Cercetărilor Arheologice din România, Bucureşti
CercNum – Cercetări Numismatice, București
Dacia / Dacia NS – Dacia / Dacia Nouvelle Série. Revue d'archéologie et d'histoire ancienne. Académie Roumaine. Institut d'archéologie « Vasile Pârvan », Bucarest
DOW, I – Dumbarton Oaks Catalogues. A. Bellinger, Ph. Grierson (eds.), *Catalogue of the Byzantine coins in the Dumbarton Oaks Collection and in the Whittemore Collection*, I, *Anastasius to Maurice (491-602)*, Washington, 1966 (A. Bellinger)
EAIVR – C. Preda (ed.), *Enciclopedia Arheologiei și Istoriei Vechi a României*, vol. I-III (1994, 1996, 2000), București
EphemNap - Ephemeris Napocensis. Academia Română, Institutul de Arheologie şi Istoria Artei, Cluj-Napoca
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Fl – File de Istorie, Bistriţa
FolArch – Folia Archaeologica, Budapest
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IJO – International Journal of Osteoarchaeology
IstMitt – Istanbuler Mitteilungen, Istanbul
Istros – Istros, Muzeul Brăilei, Brăila
JAS – Journal of Archaeological Science, London
JEA – Journal of European Archaeology
JFA – Journal of Field Archaeology

KSIA (Kiiv) – Kratkije Soobščenija Instituta Arheologij Akademij Nauk SSSR, Kiiv
KSIA (Moskva) – Kratkije Soobščenija Instituta Arheologij Akademij Nauk SSSR, Moskva
Ktèma – Civilisations de l'Orient, de la Grèce et de Rome antiques, Strasbourg
MCA – Materiale şi Cercetări Arheologice, Bucureşti
MemAnt – Memoria Antiquitatis, Piatra Neamţ
MIAR – Materialy i issledovanija po arheologii Rossii
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MuzNaţ – Muzeul Naţional, Bucureşti
NZ – Numismatische Zeitschrift, Viena
Peuce – Peuce, Studii şi cercetări de istorie şi arheologie, Institutul de Cercetări Eco-Muzeale, Tulcea
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Pontica – Pontica. Studii şi materiale de istorie, arheologie şi muzeografie, Muzeul de Istorie Naţională şi Arheologie Constanţa
PZ – Prähistorische Zeitschrift, Berlin-Mainz
RA – Revue Archéologique, Paris
Radiocarbon – An International Journal of Cosmogenic Isotope Research, Cambridge
REA – Revue des Études Anciennes, Bordeaux
RevBistr – Revista Bistriței. Complexul Muzeal Bistriţa-Năsăud, Bistriţa
RevMuz – Revista Muzeelor, Bucureşti
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SAA – Studia Antiqua et Archaeologica, Iaşi
SCA – Studii și Cercetări de Antropologie, București
SCIV(A) – Studii şi Cercetări de Istorie Veche (şi Arheologie), Bucureşti
SCN – Studii şi Cercetări de Numismatică, Bucureşti
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SovArh – Sovetskaja Arheologija, Moskva
SP – Studii de Preistorie, Bucureşti
Stratum(Plus) – Stratum (Plus), Şcoala Superioară de Antropologie, Chişinău, Sankt Petersburg, Bucureşti
StudCom Satu Mare – Studii şi comunicări Satu Mare
StudCom Sibiu – Studii şi Comunicări, Sibiu
Th-D – Thraco-Dacica, București
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