Precise lead isotope ratios measurements on Ebusus coins and on some Campanian imitations.

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***Abstract* – In this work, precise measurements of lead isotope ratio in old coins from Ebusus are presented and the results are compared to data obtained from the analysis of imitation coins from Campania. Thermal ionization source (TIMS) was used for the measurements. Original coins minted by Ebusus are examined in order to have (certain) data to serve as a reference and then to be compared with coins of different origins or uncertain attributions. The lead isotope ratio resulted to be a valid parameter for the recognition and attribution of tested samples.**

I. INTRODUCTION

The study of the isotopic ratios of lead may be used to provide information about the mine, and therefore the geographical provenance, of the metal used to prepare coins or make manufactured products of various types.
As three of the four lead isotopes (^{206}Pb, ^{207}Pb and ^{208}Pb, but not ^{204}Pb) are produced in the natural decay chains of uranium (^{235}U and ^{238}U) and thorium (^{232}Th), and are associated in turn in different quantities with the mineral from which the lead is extracted, naturally variable isotopic compositions are produced which make it allow to compare the isotopic compositions of the minerals with those of the manufactured products [1].
More sensitive indicators that are generally used in the archaeometric context, ^{206}Pb/^{207}Pb and ^{208}Pb/^{206}Pb, can be obtained from the measurement of the three isotopic ratios ^{206}Pb/^{204}Pb, ^{207}Pb/^{204}Pb and ^{208}Pb/^{204}Pb.
In this work, precise measurements of lead isotope ratio in old bronze coins from Ebusus (Groups VIII, XII, XVIII & XIX, see M. Campo's classification [2], fig. 1 nos. 1-4) are presented and the results are compared to data obtained from the analysis of imitation coins from Campania (fig. 1, no. 5 [3]).
Coin finds in Pompeii are characterised by a large amount of specimens from *Ebusus* e *Massalia* and by Campanian coins that imitate the types of those foreign productions.
Using mass spectrometry it was possible to get information useful to understand in a better way the differences between original issue and imitations; furthermore this study highlighted socio-economic reasons: on one hand, the arrival of a great deal of Ebusitan and Massalian coins in the ancient city, on the other, the need to mint imitation coins in *ager vesuvianus*.
Data about the supply of different metals used to obtain alloys were identified and -also thanks to historical reflection- it can be considered important to discover connections between Ebusitan coinage and the people that introduced those foreign specimens and the Campanian imitations.
A Finnigan Mat 262 VMC mass spectrometer with thermal ionization source (TIMS) was used for the measurements. The instrument is equipped with a variable multicollector, it has extensive optical geometry, but corresponding to a system that has conventional geometry, with a 64 cm deflection radius. Particular attention is paid. All the experimental work has been performed at the Gran Sasso National Laboratory (L'Aquila, Italy).
The sample dissolution and preliminary chemical treatment, which are also described in this work, represent a critical phase of the analysis. All operations must be performed in such a way that no errors are introduced through possible contamination by atmospheric lead. Also, in order to optimize the mass spectrometric measurement and remove any interfering element likely present in the matrix, a chromatographic extraction of Pb was performed using an anionic exchange resin. About 1 mg of Pb was extracted [4]. A microquantity of the eluate is loaded on the TIMS source filament for the MS analysis; this process is described in the reference [5].

II. MATERIALS AND METHOD

A. Samples

A total of 66 samples were analyzed of witch 36 samples of authentic Ebusus coins, 30 from Campania area. The samples were provided by Dipartimento di Scienze del Patrimonio Culturale/DiSPaC Università degli Studi di Salerno: some of the coins come from recent excavations conducted in Pompeii (eg from Regio VIII,7,1-15 – Pompeii Archaeological Research: Porta Stabia-PARP: PS, University of Cincinnati, OH-USA), others pieces belong to a Private Collection.

B. Materials: reagents and standard solutions

Ultrapure HNO3 obtained from a sub-boiling system (DuoPUR, Milestone, Bergamo, Italia) and ultrapure 18.2 MΩ water from a Milli-Q (Millipore, USA) system were used for the sample dissolution. $C_2H_8N_2O_4$ (ammonium oxalate, Carlo Erba Farmitalia) analytic grade was used for sample treatment. SRM 981 isotopic standard from the National Standards and Technology (NIST, Gaithersburg, MD, USA) was used for external precision measurement and method validation.

C. Sample treatment

Between 10 and 100 mg of sample were dissolved in 20 mL of milliQ water and 1 mL of ultra-pure HNO_3 and placed in an ultrasonic bath for about 1 hour. Considering the complexity of the matrix, The sample solution was loaded into a chromatographic extraction column packed with Pb-resin (Triskem, Bruz, France) where Pb and also Fe, Cr, Cu, Ni, Zn are retained. A specific method was used for the elution of individual elements, which provided for two successive steps: 5 ml of HNO_3 for the elution of interfering elements such as Fe, Cr, Cu, Ni, Zn and 4 ml of $C_2H_8N_2O_4$ (ammonium oxalate) 0.1 M for elution of Pb. The content of Pb and other elements in the starting solution and eluates was evaluated by ICP-MS (Agilent 7500a) plasma source. The solution obtained from the last step in the column was transferred to a quartz vial and drained into a muffle at 350 ° C for about 2h, in order to eliminate the organic oxalate residues that might have been able to influence isotopic analyzes. After, the residue was dissolved in about 50 µL of 1% nitric acid solution, in order to ensure a concentration of Pb suitable for TIMS analysis (~200 µg g^{-1}).

Table 1. Average value of lead isotopic ratios measured in coin samples minted by Ebusus, whose origin is considered reliable. The outliers column shows the number of coins whose values have not been taken into account because they are considered abnormal and deserving to be discussed separately.

Groups	Period	Coins	$^{206}Pb/^{207}Pb$	$^{208}Pb/^{206}Pb$
Group VIII Group XII Group XVIII Group XIX	c. 300-225 BC c. 225-218 a.C. c. 218-100 BC I sec. a.C.	27	1,1951 ± 0,0006	2,0788 ± 0,0024
Campanian imitations (Bes/Bes)	130/120-80/70 BC	22	1,1951 ± 0,0005	2,0780 ± 0,0021

III. RESULT AND DISCUSSION

The first set of samples examined are original coins minted by Ebusus. The measurement of lead isotope ratios in these coins has taken on a fundamental character in order to have (certain) data to serve as a reference, and then to be compared with coins of different origins or uncertain attributions. 36 samples were analyzed, divided into 4 groups, whose mean values of isotope ratios are reported in table 1.

Table 2. Average values of the lead isotopic ratios constituting respectively the cluster attributed to the Ebusus (indicated period) and the cluster containing a group of 22 coins of 30 identified as Campanian imitations.

Group	Period	Coin	Outliers	$^{206}Pb/^{207}Pb$	$^{208}Pb/^{206}Pb$
Group VIII (Bes/Bes)	c. 300-225 BC	6	0	1,1951 ± 0,0005	2,0778 ± 0,0030
Group XII (Bes-Bull butting)	c. 225-218 BC	8	1	1,1948 ± 0,0004	2,0792 ± 0,0028
Group XVIII (Bes/Bes)	c. 218-100 BC	17	5	1,1952 ± 0,0007	2,0793 ± 0,0021
Gruppo XIX Bes- Legend	I cent. BC	5	3	1,1955 ± 0,0003	2,0784 ± 0,0031

The second campaign of measurements was carried out on a set of 30 coins whose conveyance can be traced back to Campania area (the mint was ubicated in the ager vesusvianus). The first comparison was made with the cluster constructed with the isotopic ratios measured in coins minted certainly in Ebusus. It is noted that 22 of the

Fig. 1. 1-4: AE coins from Ebusus (Groups VIII, XII, XVIII & XIX); 5: AE Campanian imitation (with 'rudimentary' Bes).

30 coins show an isotopic composition that is definitely compatible with that determined for Ebusus coins, while 8 are not compatible. Table 2 shows the average value calculated for the 22 compatible samples and, in terms of comparison, the average value of the Ebusus cluster.

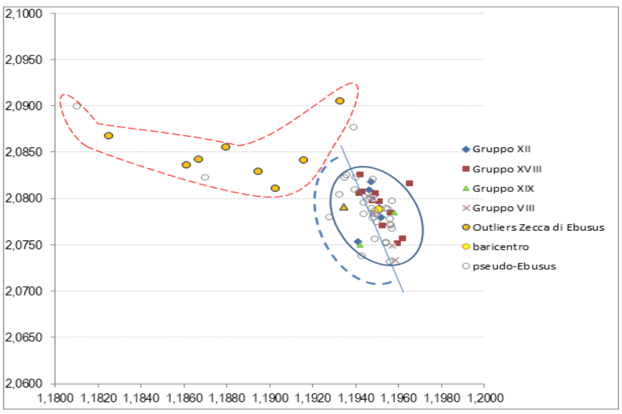

Fig. 2. Cluster containing lead isotope ratios measured on 27 coin samples coined from Ebusus, divided into 4 Groups and isotope ratios of 22 Campanian imitation coins. Outside, with orange and white circle symbols, coins with isotope ratios that are not compatible with the previously built cluster are represented. The dotted outline indicates a potential cluster enlargement that would include another 5 samples

IV. CONCLUSION

The preliminary results, obtained through these recent analysis, are crucial not only to underline particular aspects concerning the coin production of the Balearic island between 300 and the 1st century BC, but also to better understand the phenomenon of the Campanian imitations which are generally dated around 130/120-80/70 BC.

Thanks to he analysis of a large amount of specimens it has been possible to discover the origin of the lead used in the Ebusitan mint. It seems to come from the mining area of Cartagena (Carthago Nova), thus confirming the importance of the little island in the Western Mediterranean between the 3rd and the 2nd century BC. Ebusus was fully integrated into economic commercial network of Carthage as a place of 'consumption' of goods (not just metals) and as an important port of call for the redistribution; both these roles were also central in the 2nd century BC, after the defeat of Carthage, when the Roman supremacy enshrined the control over the Punic mining areas.

The fact that the imitation coins testified in Campania were minted with the same lead used by the mint of Ebusus, without the recycled metal that was typical of a coinage 'of necessity', has to be considered a fundamental clue to understand the real origin of the people involved in the striking process. It is still a suggestion, but it could be possible that the main players of this dynamic ware both private and/or public mercatores and/or negotiatores from Iberian or Italian soil and are probably the same people from Ebusus; they seemingly lived in Pompeii or in another place of ager vesuvianusand for that the same group handled the trade in metal. In this sense, it is necessary to be aware that a large amount of Ebusitan coins and local imitations can be found only in the ager vesuvianus around Pompeii and in Minturnae, a crucial place for the trade routes between Central South Italy and South Spain, and so Ebusus included.

Finally, the analysis on the isotopes of lead seem not to exclude a clear connection between who brought coins from Ebusus to Campania and those who produced the imitation coins in Italian soil, thus highlighting how they both took part in vibrant trades with Iberian Peninsula immediately after the Second Punic War.

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