

X-Ray Fluorescence Analysis of Late Roman Imperial Coins

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Abstract – Over 700 late roman imperial coins (end of III century A.D. – beginning of V century A.D.) were analyzed using the X-Ray Fluorescence (XRF) technique. The analysis allowed the semi-quantitative determination of the composition of the coin alloy and a study of its variations in time and from mint to mint; it was also possible to get evidences of possibly fraudulent tampering of some coins for improving their aesthetical aspect and thus increasing their commercial value.

Keywords: Numismatics, X-Ray Fluorescence, Roman Imperial Coinage

I. INTRODUCTION

Late roman imperial numismatics has been the subject of very few analytical studies, in spite of the large number of coins that, in recent time, were made available by the opening of the borders with Eastern countries where the most important mints were located in the past.

In spite of their low value as collectible items, these coins represent a vivid image of the IV and V century political and economic situation. The study of these coins is thus extremely interesting, since they reflect the social and political situation of the times, characterized by the frequent changes in the political leadership and the progressive detachment of the Eastern and Western parts of the Roman Empire.

In our study, we analyzed more than 700 late imperial coins. The coins were mainly bronze *nummi* ranging from the end of III century A.D. to the beginning of V century A.D. Most of the coins were coined in the oriental mints of Constantinople, Cyzicus, Nicomedia (Turkey), Antiochia (Syria), Thessalonica (Greece), Siscia (Balcans); a few of them came also from central and northern Europe (Lugdunum (Lyon, France), Arelate (Arles, France), Aquileia (Italy), Augusta Treverorum (Trier, Germany).

From a typological point of view, most of the coins studied belonged to well-defined classes that were minted

under different rulers during several decades, while maintaining their iconography almost unchanged [1].

A few examples of these types are reported in figures 1a-1f.



Fig. 1a. - VRBS ROMA (minted from 327 A.D. to 337 A.D.)



Fig. 1b – GLORIA ROMANORVM (minted from 364 A.D. to 392 A.D.)



Fig. 1c – FEL TEMP REPARATIO (minted from 348 A.D. to 358 A.D.)



Fig. 1d – GENIO POPVLI ROMANI (minted from 294 A.D. to 314 A.D.)

These coins were mostly made in bronze and should have had, at the times, a very low nominal value. Their size was typically around 20 mm in diameters, with weights not exceeding a few grams.

The analysis of the coins was performed using X-Ray Fluorescence (XRF), a technique that allows a fast quantitative analysis of the samples in a completely non-destructive way. In recent years, the X-Ray Fluorescence

technique was used for the analysis of several numismatic collections [2-7].



Fig. 1e – SECVRITAS REIPUBLICAE (minted from 364 A.D. to 378 A.D.)



Fig. 1f – VOT (minted from 320 A.D. to 383 A.D.)

II. EXPERIMENTAL APPROACH

For the measurement of the composition of the over 700 coins that were analyzed in this study, we use the Elio XRF instrument, produced by XGLab s.r.l., Milano (Italy) (figure 2).



Fig. 2 – The Elio XRF instrument.

The instrument is easy to transport, it weighs about 2 kg and can be mounted on a standard photographic tripod. The X-ray tube has an Rh anode and can deliver X-rays up to the energy of 50 keV; the measurements area is about 1 mm². The X-ray spectrometer is a large area (25 mm²) Silicon Drift detector, having a resolution of 130 eV at the Mn K α line.

The quantitative analysis of the XRF spectra was performed using the PyMCA open source software, realized by the Software Group of the European Synchrotron Radiation Facility (ESRF) [8]. The software performs the analysis using the “fundamental parameters” method, that is, a (in principle) standardless approach which derives the elemental composition of the sample from the basic spectroscopic parameters (fluorescence intensities, absorption coefficients, emission energies, and so forth) of the elements under study [9].

The essential requirement for applying the method is the knowledge of the spectrum of the X-ray tube emission and the absolute intensity of the radiation on the sample, which is needed for the normalization of the elements’ concentrations. This latter parameter is difficult to determine experimentally; therefore, the fundamental parameters method relies on the use of at least one standard, with a known composition similar to the unknown samples to be analyzed, for the empirical determination of the X-ray intensity on the sample.

In our case, 6 reference bronze samples were used for calibration in the fundamental parameter method, to improve the trueness of the quantitative results. However, in our case the analysis on the coins was performed without removing the surface patina; this decision, also forced by the need of doing the analysis in a complete nondestructive way, introduced some indetermination on the analytical estimation of the alloy composition, which in consequence of that should be considered only as semi-quantitative. In fact, it is well known that in the presence

of strong surface degradation, due to corrosion and exchange with the environment, the XRF results might not be fully representative of the original composition of the bulk alloy. Several papers [10,11] demonstrated, however, that the analytical results obtained, although not immediately useful for a precise determination of the alloy composition, can be used for the purpose of classification.

III. RESULTS

Our research was mainly oriented to the study of the variation in composition of the coins in time (over one century) and between the different mints. For simplifying the discussion, the data will be presented here in aggregated form. In some cases, the corrosion layer was too thick for allowing a meaningful (although semi-quantitative) analysis of the coin; the corresponding coins, apparently associated to an anomalous low concentration of copper, were thus discarded and not considered for the statistical analysis.

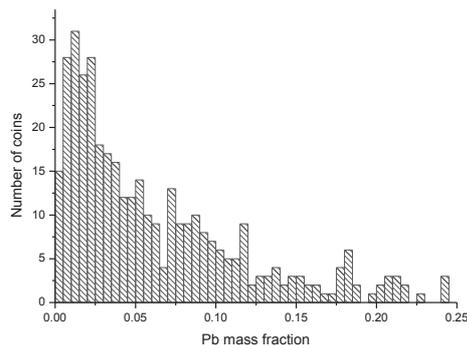


Fig. 3a – Statistical distribution of the lead mass fraction in the coins analyzed.

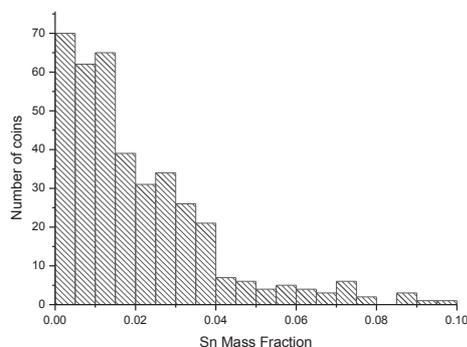


Fig. 3b – Statistical distribution of the tin mass fraction in the coins analyzed.

On the average, although the composition of the analyzed coins shows large variations, the alloy used for the *nummi* was essentially copper with lead (average mass concentration around 6%); the concentration of tin, on the other hand was typically lower than 2-3 % in weight.

An interesting by-product of this research was the evidence of tampering of some coins, probably determined by the intention of improving their aesthetic aspect and, consequently, increasing their commercial value. Figure 4 shows the XRF spectrum of a coin (shown in figure 5), evidencing an anomalous concentration of selenium (selenium dioxide is used for cold burnishing of metals).

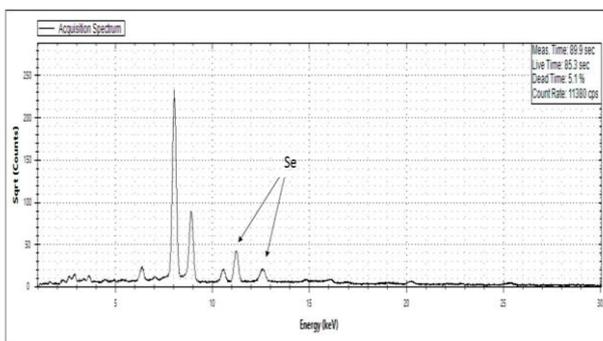


Fig.4- XRF spectrum of the coin in figure 5, showing an anomalous surface concentration of selenium.



Fig.5- The coin corresponding to the spectrum shown in figure. Maximinus II AE Follis. 310-311 AD. IMP C GAL VAL MAXIMINVS P F AVG, laureate head right / GENIO AVGVSTI CMH, Genius standing left, modius on head, with chlamys, patera from which liquor flows, & cornucopiae, SMNA in ex (Nicomedia).

In figure 6 another XRF spectrum is shown, evidencing substantial traces of chromium (> 1% in weight). Chromium can be deposited on the coin surface during the process of electrolytic cleaning. Electrolysis is usually applied for removal of the original, inhomogeneous patina, in preparation of the application of a fake, more aesthetically appealing modern patina.

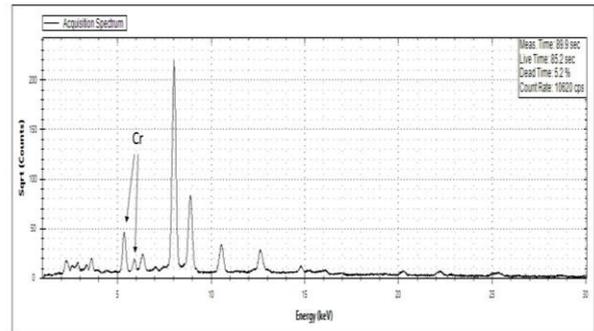


Fig. 6 - XRF spectrum of a coin, evidencing the presence of chromium at anomalous concentration

IV. CONCLUSION

The study reported represented one of the largest study on late Roman Imperial Coins composition ever realized. More than 700 bronze coins were analysed, spanning a period of about one century (from the end of III century A.D. to the beginning of V century A.D.), mostly from oriental mints. In spite of the changes in coin composition in time and in different mints, the alloy of the coins considered was mostly copper with lead (6% on the average) and small amounts of tin (< 3%). As an interesting by-product of this study, we were able to identify several coins showing evidence of manipulations and treatments, probably aimed to the fraudulent increase of the economic value of the coin through the removal of the original patina and the application of a fake modern one.

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