



Combined use of the non-destructive XRF and low energy micro-XRF techniques for the analysis of silvered nummi belonging to the Treasure of Misurata (Libya)

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Roman coinage underwent a severe debasement of silver during the time and the production of plated coins became a common practice for giving the impression of a high fineness of the alloy. In 294 AD, Diocletian introduced the nummus, manufactured with the same standard in all the mints by using an internal Cu-Sn-Pb-Ag core and presenting a thin silvered patina (about 2 micron) on its surface. The silver plating of the nummi have been investigated in the past and different methods have been suggested for its manufacturing (e.g. segregation during casting, chemical treatments, mercury-silvering). However, previous analyses were focused on few samples and, consequently, this technological issue remained unresolved. In the present work, the BSC-XRF (Beam Stability Controlled -XRF) and a LE-micro-XRF portable spectrometers developed at the LANDIS laboratory of IBAM-CNR and LNS-INFN in Catania (Italy), have been applied for the in-situ analysis of the silvered nummi belonging to the Misurata Treasure (Museum of Leptis Magna, El-Khomes, Libya). The treasure is composed of 108 thousand coins manufactured in 19 Imperial mints operating in the period 294-333 AD. In order to establish if, and at what extent, the mercury-silvering was used to produce the thin Ag-patina of the nummi, the non-destructive investigation was extended to 1050 well preserved coins. Measurements allowed to explore the presence of Hg and the Hg-Ag correlation at the coin surface. The portable BSC-XRF and the LE-micro [U+F02D] XRF techniques are suited to approach this study. A new version of the BSC-XRF spectrometer, consisting of a compact high-intensity x-ray tube (50 kV; 4 mA) coupled to a 80 mm² SDD detector (138 eV @ 5.9 keV), was developed for the fast determination of mercury traces in a large number of coins (measurement time is 150 seconds; MDL for Hg is 100 ppm). The investigation allowed to identify the Imperial mints and the periods where the mercury-silvering were probably used. However the BSC-XRF analysis is not limited to the surface and the Ag-Hg correlation cannot be evidenced in the patina layer. The integration of the results with the LE-micro-XRF measurements allowed to overcome this limit. Our LE-micro-XRF technique operates in a low energy domain; the system consists of a fine focus x-ray tube (8 kV; 1.5 mA) equipped with a 200 [U+F06D] m straight-shaped capillary, coupled to a 50 mm² SDD detector (133 eV @ 5.9 keV). The system, applied to selected samples, excited efficiently the Hg-M and Ag-L lines, limiting the analytical depth to about 2 micron. Moreover the high lateral resolution allowed to perform the surface scansion of the coins, evidencing the searched correlation between Hg and Ag at the surface of the nummi. Results allowed to demonstrate that mercury-silvering was used in the late period (mainly after 318 AD) and only in some specific mints.