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ECHOES FROM THE PAST: TRACING THE PRODUCTION TECHNIQUES AS A METHOD FOR DISTINGUISHING GENUINE COINS FROM COUNTERFEITS

Plates 23–24

The purpose of this article is to propose a suitable way to distinguish metallic archaeological objects in general and coins in particular from forgeries, on the basis of their inherent energetic levels using an approach based on irreversible thermodynamics[1].

A particular feature lending itself to the detection of forgeries produced by fusion techniques as compared to genuine struck coins consists in their different respective total energy supply and its required transference time.

The theoretical aspects of the mechanisms involved in manual coin striking processes, as well as in the production of metallic tools with specific features (for instance swords), are compared to those widely utilized in recent times to cast forgeries. The intrinsic differences between ancient struck coins and counterfeits produced by fusion or press-fusion processes are evidenced by means of XRF EDS- and SEM-based techniques.

In this note some examples are included in order to evidence how specific features are suited to distinguishing a genuine *aureus* of C. Iulius Caesar from a false modern *aureus* of Sextus Pompeius.

The amount of energy needed and transferred to alloys used during the two manufacturing processes described above varies considerably and depends among other factors on the required time of the two different methods. In order to assess the level of energies involved in these processes it is helpful to resort to the two following equations:

equation (1) [impulse equation] relates to striking coins, while

equation (2) [phase transition] relates to fusion or press-fusion processes whereby an alloy undergoes a phase transition from liquid to solid under comparatively small pressure which merely serves to eliminate minimal air bubbles entrapped in the metallic mass while it is in liquid state.

1 See K.G. Denbigh, The Thermodynamics of the Steady State (London, 1951); S.R. De Groot, Thermodynamics of Irreversible Processes (Amsterdam, 1966); C. Botrè, Termodinamica dei Processi Irreversibili (Roma, 1971); I. Prigogine, Introduzione alla Termodinamica dei Processi Irreversibili (Roma, 1971); C. Botrè, F. Botrè, Un'introduzione chimico-fisica allo studio di sistemi complessi. Atti dell'Accademia Pontaniana, vol. LIV (Napoli, 2006), pp. 125–200.

$$\vec{J}_t = \int_{t1}^{t2} \vec{f}_t \, dt = \Delta \vec{M}_{\Delta t} = m\vec{v}_2 - m\vec{v}_1 = m\Delta \vec{v}_{\Delta t} \quad (1) \qquad ; \qquad \Delta J_{\Delta t} = \left[\int_{t1}^{t2} \frac{df}{dA}\right] dt \quad (2)$$

where:

$\vec{J}_t$= mechanical energy flow as a function of time, $d\vec{M}$= instantaneous change of the amount of motion,

$\vec{f}_t$= mechanical force respective to the applied energy flow, m = entity of the beating mass,

$\vec{v}$ = speed of the hammer blow, $\vec{v}_2$ and $\vec{v}_1$ = indicate, respectively, the maximum value of the speed of the hammer and the speed value at its impact with the dies,

$\frac{df}{dA}$ = P = applied pressure on the surface A of the mould, while the metallic mass is still in its molten state during the process and Δt is the interval of time while the pressure is acting.

The energy content of a cast coin is virtually coincident to the one of a corresponding metallic mass independent of embossed or engraved images or inscriptions.

a) Striking

Equation (1) provides a mathematical definition for what happens when the beating mass of a hammer matches the flan positioned between two engraved dies to be transformed in a coin.

The violent strike is responsible for a sharp and sudden increase of high energy density inside the small mass of the coin, stored as an additional hardening of the metal. This modification is consistent with a new organization of the metallic structure, part of which protrudes out of the plane of the coin into the cavities of the engraved letters and images in the dies. The energy increase corresponds to a consequent sharp decrease of entropy within the coin. This is followed by a loss of energy and an increase of entropy in the environment, features that are consistent with the hardening of the metallic structure.

Entropic/energetic interchanges as described above are defined by a loss of energy which is characteristic for all processes that take place instantaneously and in conditions far from equilibrium.

However it must be taken into account that the hammer blows were applied in a direction only approximately, but not exactly, perpendicular to the plane of the coin. This individual factor and the lack of a reproducible intensity of the applied strength exclude the possibility of two perfectly identical coins if struck manually. This rule is in perfect agreement with the irreversible thermodynamic approach and makes for a convenient method to detect forgeries.

b) Fusion

Ancient forgeries are frequently produced by a simple fusion process, based on a liquid to solid phase transition at room temperature during the time needed for the cooling of the liquid metallic mass. The spontaneous phase transition from a liquid to a solid state does not require any further energetic supply to solidify the metal in the moulds but it goes together with a dissipation of thermal energy (as heat) to the environment.

The liquid mass poured into the mould fills the void and assumes, after cooling, the definitive aspect of the coin which had been used to produce the mould. Frequently, however, there are minute cavities left in the resulting cast which are easily detected as unfilled small holes with the help of a magnifying glass.

Manufacture of forged coins by fusion therefore is a spontaneous process of filling a liquid metallic mass into a mould not requiring any contribution of mechanical energy.

c) Press-fusion

As opposed to the fusion process which requires no additional energy supply (after melting the alloy) press-fusion requires additional energy as pressure is applied to the metal alloy cooling in the moulds. The press-fusion technique allows a major draw-back of the simple fusion process to be overcome by improving the filling out of small cavities in the mould.

The amount of additional energy applied as pressure during the press-fusion process is negligible when compared to the entirety of energy set free in the form of heat during the spontaneous cooling process of the liquid cast or to the amount of energy set free by sledgehammer action in coining.

Press-fusion therefore is an improvement over the simple fusion yielding fewer flaws by more reliably filling out micro-cavities. This technique also minimizes some typical structural defects although the fill-out on the coins' edges is not always successful. The lack of a perfect fill-out is, however, easily detected by simple electron microscope inspection.

In the following section some differences between a press-fused forgery and a genuine struck coin will be emphasized in detail. Size and shape of images on coins manufactured by fusion or press-fusion show distinct structural differences when compared to corresponding struck coins.

In conclusion the basis of the forgery produced by press-fusion can be expressed in terms of a melting process of the metal associated with a relatively low difference of pressure between the mould and the molten metallic mass, in turn associated with a slow, or stepwise, energy transfer as defined by equation (2). Based on the above considerations it becomes evident that all casting methods for coins, be they genuine or forged, are irreversible processes.

d) Experimental comparison of a genuine aureus of Iulius Caesar and a false aureus of Sextus Pompeius (Plates 23–24)

In order to detect significant structural features suited to clearly setting apart genuine and counterfeit coins non-destructive and non-invasive methods were applied.

Instruments used:

1) scanning electron microscope (SEM)LEO1450VP equipped for micro-analyses
2) energy dispersion spectroscope (EDS) INCA300 (EDS) and
3) X-ray fluorescence (XRF) spectroscope Philips model PW 1404 for extensive analytical determination work.

Investigations carried out with the help of the above instrumentation are entirely non-destructive / non-invasive and any test may be repeated again without affecting specific features of the metallic structures in question.

In order to emphasize the sharp specific differences in the structures of the surfaces between a genuine struck coin and a counterfeit cast coin we compared an *aureus* of Iulius Caesar struck in Gaul or Illyricum in 50 or 48 BC *(pl. 23)*[2], and a modern forgery of an *aureus* of Sextus Pompeius, produced by press-fusion *(pl. 24)*.

Abstract

The specific differences between struck coins, cast coins and coins produced by press-fusion lend themselves to distinguishing modern counterfeits from ancient coins. The article discusses these processes from a scientific point of view and emphasizes the results of non-destructive analyses of a genuine *aureus* of C. Iulius Caesar as opposed to a modern counterfeit *aureus* of Sextus Pompeius.

Zusammenfassung

Die spezifischen Unterschiede zwischen geprägten, gegossenen und mittels Druckguss hergestellten Münzen können zur Entlarvung moderner Fälschungen verwendet werden. In diesem Aufsatz werden zunächst die physikalischen Vorgänge erklärt, die den unterschiedlichen Herstellungsverfahren zugrunde liegen. Danach werden an Hand von zerstörungsfreien Metallanalysen die

[2] C. Botrè, E. Fabrizi, G. Scibona, P. Serafin Petrillo, Applicazione della spettrografia con fluorescenza a raggi X nello studio di antiche monete romane: implicazioni di carattere storico ed economico. BdN 13, 1989, pp. 129–143; C. Botrè, Alcune considerazioni sulla prima coniazione aurea di Cesare, RIN 108, 2007, p. 121–134 (Gaul, 50 BC). B. Woytek, Arma et nummi. Forschungen zur römischen Finanzgeschichte und Münzprägung der Jahre 49 bis 42 v. Chr. (Vienna, 2003), pp. 142–150 dates the LII-issue to BC 48 and localises its production in Illyricum.

charakteristischen Unterschiede zwischen einem echten Aureus des C. Julius Caesar und der modernen Fälschung eines Aureus des Sextus Pompeius aufgezeigt.

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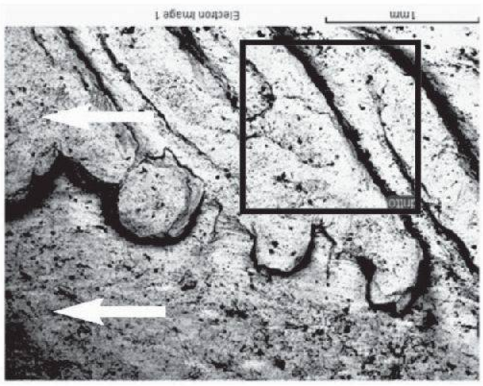
Key to plates 23–24

Pl. 23	1	C. Iulius Caesar. *Aureus,* Gaul (or Illyricum) 50/48 BC. RRC 452/1. 8.661 g.
	2	SEM image of the obverse (detail of the hair).
	3	SEM image of the reverse (helmet on top of trophy).
	4	Obverse; analytical data recorded in the square in *pl. 1, 2.*
	5	Reverse; analytical data recorded in the square in *pl. 1, 3.*
Pl. 24	6	Modern counterfeit *aureus* of Sextus Pompeius (cf. RRC 511/1)[3]. 7.850 g.
	7	SEM image of the obverse (edge of the neck).
	8	SEM image of the reverse. Note the sharp perpendicular edges of the relief.
	9	Analytical data recorded on the obverse and reverse of the coin. The spectra of both sides are identical: Au 98.0%, Ag 1.0%, Cu 1.0%.
	10	Edge of the coin, with small cavities typical of a press-fusion process.

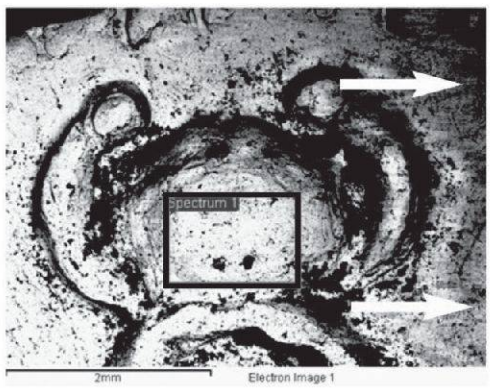
[3] D. Ferro, C. Botrè, Sull'identificazione di aurei romani (Autentici e falsi). RIN 109, 2008, pp. 133–156.


CAE SAR

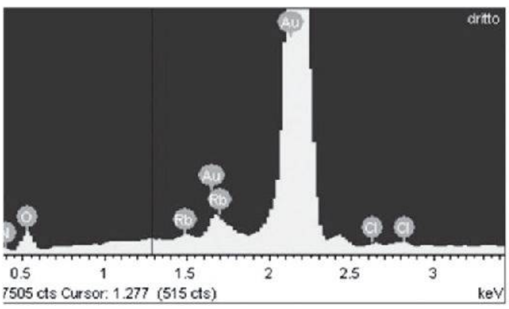
1


1mm

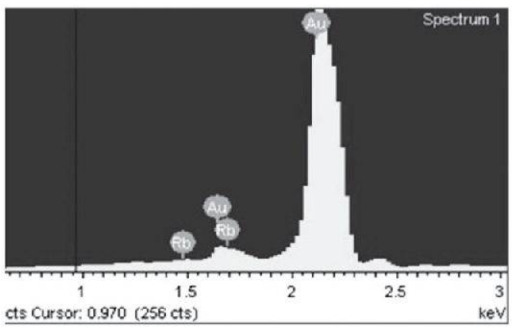
2


Spectrum 1
2mm
Electron Image 1

3

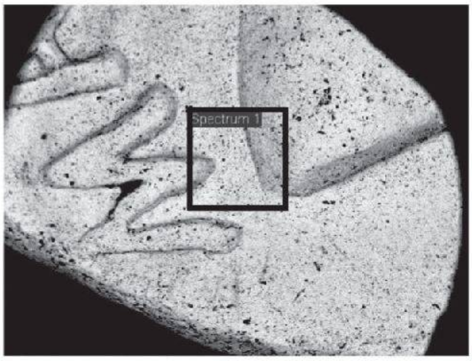

dritto
Au
O
Rb
Cl
7505 cts Cursor: 1.277 (515 cts)
keV

4

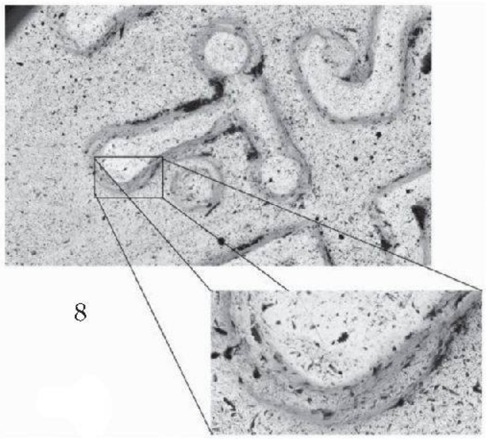

Spectrum 1
Au
Rb
cts Cursor: 0.970 (256 cts)
keV

5

6


Spectrum 1

7



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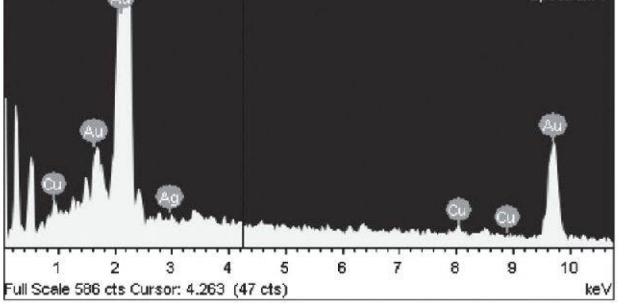
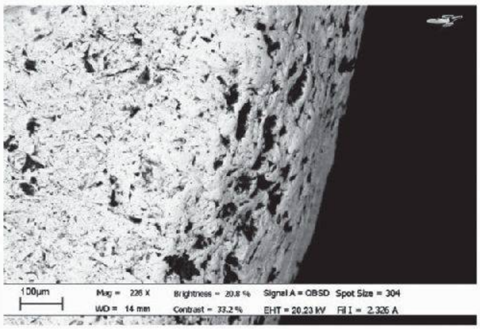

Spectrum 1
Au
Au
Cu
Ag
Cu
Cu
Au
1 2 3 4 5 6 7 8 9 10
Full Scale 586 cts Cursor: 4.263 (47 cts)
keV

9



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