Authentication and Evaluation of the Technique of Minting the Romanian Coins of the 20th Century. I

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The present work highlights the results of optical and electronic microscopy analyses performed on fifteen selected outdated 20th century Romanian coins. The obtained results brought significant contributions in establishing specific archaeometric characteristics of corrosion coins products generated within the in-use and demonetization periods, under the action of both natural and anthropogenic factors. The work was mainly aimed in identifying the nature of the alloy and of the raw material used during coins minting, with specific emphasize on their resistance toward the action of various natural and anthropogenic factors. Emphasize is also given to the manufacturing techniques, edition characteristics and the in-use-interval. Performed elemental chemical analysis clearly showed that major elements abundances are highly correlated with coins origin area and their minting period.

Keywords: coins, numismatics, corrosion, edition, in-use-interval, demonetization, OM, SEM-EDAX

Coins and banknotes are the most common currency forms, with lifespan expanding over four to five stages, *i.e.* 1) monetization (by hammering, casting or printing), 2) usage, 3) withdrawal from use (upon changing the currency or when deteriorated) or abandonment (loss, hiding and forgetting, calamities etc.), 4) official thesaurisation (*e.g.,* collections) or underground buried thesaurus (accidentally discovered or through archaeological digging). If in coin form, the trade value is given by the used metal, coins size and weight. The most valuable coins are usually made from precious (gold, silver) and semiprecious metals (bronze, brass, zinc and iron). When zinc and iron alloys are used plating is the final technical touch to increase coins corrosion resistance [1-3].

Within thesaurisation procedure, coins *nominal* (correct attributed value guaranteed by used materials, weight and size, countries criteria for establishing currencies values) and *numismatic* (outdated, limited editions, age and/or historical context of monetization, quality, conservation state, popularity and exchange rate) values are taken into consideration. At deterioration, fluctuations in the exchange values or at new design requirements, coins are rendered out of circulation within the so known demonetization process [4-10].

Physical coins artefacting can be induced by both mechanical (erosion) and chemical (corrosion, dissolution, pelicular tegumentary lipids effects) processes. Different weighted contributions brought by the deterioration (*i.e.,* mechanical action) or degradation (*i.e.,* chemically induced reactions by air, water and soil components interactions) processes are highly influencing the in-use period, before thesaurisation process to occur [1-3].

Accurate estimation of coins age and clear elucidation of coins destruction and deterioration mechanisms often accounts as discriminator criteria for historical purposes and museum value. Coins preservation state and age, or editions characteristics (number related), represent useful tools in establishing the technological and artistic characteristic for a specific monetization period. For the 20th century Romanian coins currency, alloys with a very low resistance (*e.g.,* zinc and aluminum) were mainly in use while for others plating with nickel or copper was preferred and in-force introduced from 1960 on-ward [11, 12].

For old thesaurised coins, nondestructive and noninvasive instrumental analytical techniques are often employed in analysis laboratories to gain suitable scientific knowledge on coins archaeometric characteristics, *i.e.* surface and deep-inside structure related details. Optical microscopy (OM) and scanning electron microscopy (SEM) coupled with energy dispersive X-ray analyzer (EDAX) are non-destructive analytical techniques suitable for the investigation of specific features in numismatic related samples where specimen integrity is of great importance. Reliable information related to samples chemical composition and surface morphology or deep-insider microstructure are often obtained by using such state-of-the-art techniques [1-10, 13, 14].

Reliable information on the coins chemical composition, referring both to major and minor chemical constituents, is providing an appropriate context for clearly to identify either the time-age of the initial monetization process, the in-use time period of various coins and also the time-interval when demonetization or abandonment occurred. Moreover, for a particular coin, appropriate identification and chemical analysis of traces to ultra-traces elements

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can offer valuable information related to the minerals origin and also to the techniques used for alloys recipes. Sometime, chemical analysis can be used as a discriminator for identifying possible contaminations occuring during the hammering or casting processes.

Often, the expertise of researchers with good knowledge in numismatics helps in rigorously establishing the monetization historical period. Structural and physical deteriorations caused by manipulation, pedological events or storage conditions are highly impacting coins circulation time-period, the occurrence of demonetization or abandonment time-interval. Corrosion and erosion intensity of the coating structure are often used in this regard [1, 6, 13].

The present paper aims in clearly discriminating with the help of OM and SEM (EDAX) techniques between raw materials and alloys used within the monetization period of selected Romanian coins from the 20th century. Emphasize will be given to aspects related to potential evidences revealing coins resistance toward the influence of both natural and anthropogenic factors during two selected stages within a coin's existence (*i.e.*, circulation and demonetization induced by abandon).

Experimental part

In the present work, 15 Romanian manufactured coins (C1-C15), which were in use over the 20th century (fig. 1), were under laboratory scrutiny in order to determine their metals content and corrosion level. Both OM and SEM/EDAX instrumental techniques have been employed to perform both morphological investigations and elemental composition analysis.

Table 1 presents details related to the investigated coins nominal value, year of monetization, edition characteristics (number), in-use period, original alloy used during manufacturing processes. The C1 to C3 coins are often used as references for Romanian currencies minted immediately after 1900 with silver alloy, which is usually highly resistant to anthropogenic and biogenic corrosion agents.

In order to asses the evolution of the conservation status of the two periods (circulated and uncirculated pieces), the coins which were in circulation in our country, with known circulation an periods of use, along with the first three coins in silver with high numismatic value and resistance to anthropic and environmental factors used as comparison system.

Fig.1. Selected coins under laboratory scrutiny in both upward (a) and downward (b) side

Table 1
FEATURES OF THE STUDIED COINS

Coin	Nominal value	Year of release	Edition	Circulation period	Base alloy, characteristics
C1	1 Leu	1906	2.500.000	1906	Ag 5 g/23 mm
C2	2 Lei	1914	2.452.000	1914-1921	Ag 10 g/27 mm
C3	500 Lei	1944	9.731.000	1944-1947	Ag 12 g/32 mm
C4	10000 Lei	1947	11.850.000	1947-1947	Cu-Zn-Ni 7.5 g/27 mm
C5**	15 Bani	1960	126.900.000	1967-1996	Ni/Steel* 2.87 g/19.5 mm
C6	15 Bani	1966	41.165.000	1967-1996	Ni/Steel* 2.87 g/19.5 mm
C7	25 Bani	1960	87.600.000	1960-1996	Ni/Steel 3.38 g/22 mm
C8**	25 Bani	1966	18.955.000	1967-1996	Ni/Steel* 3.38 g/22 mm
C9	1 Leu	1963	71.910.000	1963-1996	Ni/Steel* 5.06 g/24 mm

C10**	1 leu	1966	75.437.000	1967-1996	Ni/Steel* 5.06 g/24 mm
C11	3 Lei	1963	18.436.000	1963-1996	Ni/Steel* 5.86 g/27 mm
C12**	3 Lei	1966	8.477.000	1967-1996	Ni/Steel* 5.86 g/27 mm
C13	20 Lei	1992	48.000.000	1992-2003	Cu-Zn/Steel* 5.0 g/26 mm
C14	5 Lei	1993	70.000.000	1993-2003	Ni/Steel* 3.35 g/21 mm
C15	50 Lei	1994	30.000.000	1994-2003	Cu-Zn/Steel* 5.9 g/26 mm

**iron coins plated with nickel; **uncirculated coins (coins not in-use)*

A ZEISS optical microscope (with video-camera and computer software control) was employed for laboratory investigations in order to distinguish between potential similarities or differences in coins appearance, color or chemical composition homogeneity as a result of corrosion contribution. Samples were analyzed by reflection in dark field at 200X magnification.

Details on coins morphology and elemental composition were determined by using a scanning electron microscopy (SEM) unit coupled with energy dispersive X-ray analyzer (EDAX) (FEI QUANTA-250) available at CERNESIM center of the Alexandru Ioan Cuza University of Iasi.

For SEM-EDAX investigations measurements have been performed in vacuum (10^{-4}-10^{-2} Pa) without any mechanical processing or coating. After direct visual introspection, the coins were cleaned with nondestructive solution of methanol:ethanol in a 1:1 ratio and subsequently immersed twice, for a 15 min period, in a thermostatic (at 35°C) ultrasonic bath in order to remove potentially present organic and inorganic impurities. These cleaning procedures had been carried out in LAICA laboratory at the Department of Analytical Chemistry of the Alexandru Ioan Cuza University of Iasi.

SEM images were recorded by an Everhart-Thornley detector (ETD) with the instrument being operated at 10-15 keV and a work distance between 10 - 13 mm depending on probes features. Qualitative and quantitative EDAX analysis were made by selecting three focusing area on every coin. For each area two X ray spectra, with 10 - 30 seconds collection time, have been recorded. Elements with atomic number lower than 11 could not be detected because of the techniques limitations and eventual due to carbon atoms present in the investigated matrix [15].

Results and discussions

Figure 2 highlight representative selected surface areas (obtained by OM investigation) revealing clear differences between the investigated samples as a result either of the patina aging, corrosion type or of the characteristics of the raw material used during manufacturing. Non-uniform spatial distribution of corrosion units such as those in samples associated with C4, C13 and C15 codes with reddish (Cu_2O associated), greenish (CuCO(OH) or malachite related), bluish ($Cu_3(CO)_2(OH)$) or azurite related, etc) spots, and Ni and Fe oxides in the C6, C7, C9, C11 and C14 samples were mainly observed.

Micromorphological SEM details, clearly presented in figure 3, reveal on the C4, C6, C7, C9, C11, C13, C14 and C15 sample coins, the existence of various spots associated either with mechanically induced defects or with timely dependent corrosion processes. Cracks and irregular shaped holes are more specific for ally brass or copper-plated coins. Microparticles of different morphology generated either by contamination or corrosion processes [1-7, 13] can be clearly seen inside the coins surface holes. Smooth surface areas are revealed in some investigated samples: C5, C8, C10 and C12.

Suitable information on the elemental chemical composition of the interest coins surface was generated with the help of the Energy dispersive X-ray analyzer (EDAX) by scanning 3 selected areas (fig. 3).

Quantitative assignment within the elemental analysis was performed in the standard less operational mode, referring to background analysis, background noise subtraction and matrix compensation procedure. Net intensity of identified peaks is calculated with the final estimation of the weight percent (wt %).

For the identified and quantified elements mean values of the EDAX determined concentrations are represented in Table 2. In the C1 to C3 coin samples silver was the most abundant identified element, while copper and zinc alloys were used for the production of the C4, C13 and C15 coins. EDAX analyses revealed that iron and nickel were major constituents of C5, C6, C7, C8, C9, C10 and C12 coin samples. Minor identified elements, such as C, and O,

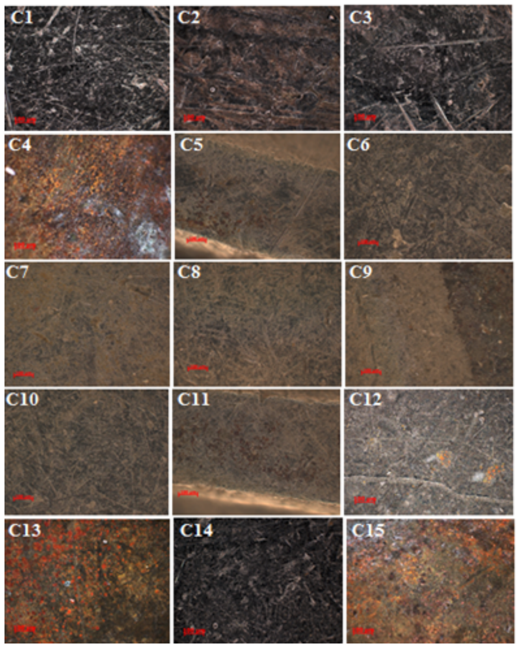

Fig. 2. Analyzed coins details generated from optical microscopy analysis:C1- 1 Leu/1906; C2 - 2 Lei/1914; C3 - 500 Lei/1944; C4 - 10000 Lei/1947; C5 – 15 Bani/ 1960; C6 - 15 Bani/1966; C7 – 25 Bani/1960; C8 – 25 Bani/1966; C9 – 1 Leu/1963; C10 – 1 Leu/ 1966; C11 – 3 Lei/1963; C12 – 3 Lei/1966; C13 – 20 Lei/1992; C14 – 5 Lei/1993; C15 – 50 Lei/1994

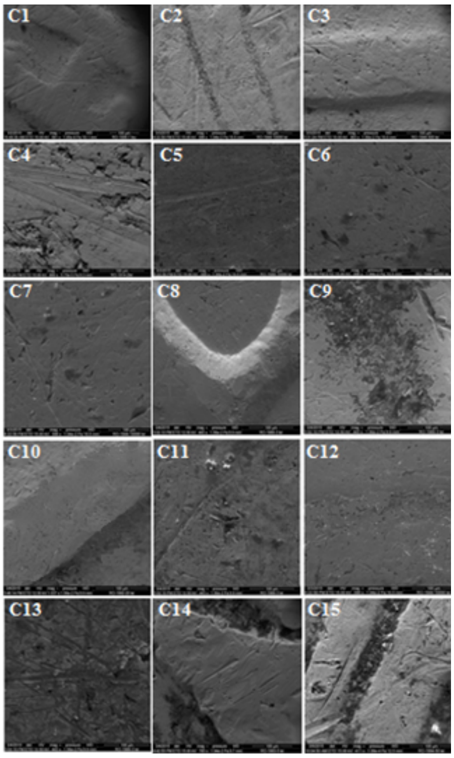

Fig. 3. Micrographic SEM details for the investigated samples

suggest either the influence of contamination or the existence of some oxides or hydroxyl groups on coins surface, mainly induced by the in-use time-period [13, 14].

The obtained results and critical introspection of historical database available information allowed us claiming the following idea:

i)At the beginning of the 20[th] century, under Carol the first, silver and copper alloys were mainly used to generate in Brussels valuable Romanian currency [11, 12].

ii)Second World War (1944) associated economic crisis diminished the importance of precious metal use in coins production process and enhanced that mainly based on the use of lower value metals (*e.g.*, zinc, copper) and even alloys or nickel plated steel. However, within this period, gold and silver commemorative coins or coins of very high nominal value were also minted [11, 12].

iii)Nickel-plated steel coins, however, seem to predominate the post Second World War period [11, 12].

Under the conditions of the present study, silver is assigned as a tracer of specific monetization process in the initial stage of the 20[th] century, while the mid-period is traced by copper and zinc metal coins. In the communist period, for low nominal coins nickel plated steel can be assigned as suitable tracer for coins historical purposes. However, for coins of higher nominal values from the communist period, alloys increasing coins resistance properties were preferred.

Within the study performed in the present work, especially the first three investigated coins attracted particular attention not only due the characteristics from the chemical (silver made) point of view but also due to a specific number of particularities. The 1 leu currency coin minted in 1906, has been proven to be produced in Brussels with engraved details of Alfons Michaux. The origin is confirmed by the coins size (23 mm), weight (5 g), its jagged edge and other specific marks on it (such as CAROL I REGE AL ROMANIEI effigy to the left, the 1866-1906 period engraved in between two stars, the initials of the graver, Alfons Michaux; on the downward part CAROL I DOMNUL ROMANIEI effigy to the left, 1 LEU nominal value in between two stars and again the initials of the graver, Alfons Michaux). The 2 lei coin, minted in 1914 in Brussels also, has as unique characteristics a diameter of 27 mm and a mass of 10 g, in the right corner its edges are engraved on the upward side with the inscription Ernst Paulini TASSET, and on the downward side with Costache BASSARAB. Similar coin minted in Hamburg has as distinct characteristics a grated edge but in rounded corner. The 500 lei coin produced in Bucharest is of 32 mm large in diameter and of 12 g in weighted mass. All other coins were produced in Bucharest [11, 12].

Table 2

SEM/EDAX GENERATED ELEMENTAL COMPOSITION OF THE INTEREST COINS

Coin	Nominal value	Ag	Cu	Ni	Zn	Fe	O	C
		wt%						
C1	1 Leu	83.5	15.2	-	-	-	1.3	-
C2	2 Lei	83.5	15.3	-	-	-	1.2	-
C3	500 Lei	70.0	27.9	-	-	-	2.1	-
C4	10000 Lei	-	61.6	-	35.4	-	3.0	-
C5	15 Bani	-	-	93.3	-	4.6	-	2.1
C6	15 Bani	-	-	93.9	-	4.2	0.6	1.3
C7	25 Bani	-	-	92.9	-	4.6	0.7	1.8
C8	25 Bani	-	-	93.4	-	4.5	-	2.1
C9	1 Leu	-	-	93.8	-	4.1	0.8	1.3
C10	1 Leu	-	-	93.6	-	4.5	-	1.9
C11	3 Lei	-	-	92.8	-	4.5	1.2	1.5
C12	3 Lei	-	-	93.5	-	4.6	-	1.9
C13	20 Lei	-	58.0	-	37.2	-	4.8	-
C14	5 Lei	-	-	93.8	-	4.3	0.8	1.1
C15	50 Lei	-	42.9	-	26.3	-	25.2	5.6

Conclusions

The results obtained by corroborating the OM and SEM-EDAX analyzes allowed us concluding that the 1906, 1914 and 1944 coins are made of silver, those from 1947 are made of brass, those from 1992 and 1994 are brass-plated steel, while those from the 1960s, 1963, 1966 and 1993 are Ni-plated steel coins. All coins were confirmed as genuine (and not counterfeit) specimen.

The C1, C2, C3, C4, C6, C7, C9, C11, C13, C14 and C15 coins were in-use specimen at specific times but after demonetization they entered into private collections. The C5, C8, C10 and C12 coins are integral part of rare coins collections. Significant differences exist between these 2 groups mainly concerning the patina aging and the conservation state. While the first group presents corrosion spots or contamination products, the second one seems to be very smooth, in almost untouched state.

Data related to the elemental chemical composition of the investigated coins surface gives a clear indication on their resistance status toward the action of environmental and anthropogenic factors between the in-use and demonetization periods. Assignments on progress in the minting technology and the materials used according to the economic condition of the country are highlighted.

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