INTERNATIONAL NUMISMATIC COUNCIL

SURVEY OF NUMISMATIC RESEARCH 2014–2020

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General introduction

In the period of this report from 2014-2020, there have been four main trends. The first is research into improving methods and methodology for analysing coins in order to tackle different questions and especially provenance of metals. This latter research has seen the intensified use of combined elemental and isotopic analysis. It is driven by general acceptance that geolocating silver ore sources can only be done reliably by isotopic analysis using mainly MC-ICP-MS (Multicollector-Inductively Coupled Plasma-Mass Spectrometry). However, elemental analysis can help determine if a set of coins could belong to the same metallic stock and in addition it can contribute useful information about the composition of coins and the technology used to make them. Part of the trend is experimentation with a wide range of analytical techniques and applications investigating the potential information to be derived from specific elements and isotopes, and about manufacturing techniques by metallography or hardness test.

The second trend has been the wide application of a suite of analytical methods to individual coinages from their inception through to modern times.

The third trend has been the investigation of coin manufacture and detection of forgeries.

The fourth trend has been more deliberate aggregation of teams of archaeometallurgists, geologists, geochemists, numismatists, archaeologists and historians for solving numismatic, archaeological and historical problems. This has been made possible through major grants especially from the European Research Commission and the work of university-based institutes and state agencies such as France's CNRS (*Centre national de la recherche scientifique).*

Other methods in the analytical repertoire used in this report include: CT (Computed Tomography); EPMA (Electron Probe Microanalysis); EDX (Energy Dispersive X-ray spectroscopy); FNAA (Fast Neutron Activation Analysis); GRT (Gamma Ray Transmission); ICP-AES (Inductively Coupled Plasma Atomic Emission Spectrometry); LA-ICP-MS (Laser Ablation Inductively Coupled Plasma-Mass Spectrometry); μXRF (Micro X-ray Fluorescence); negative muons; neutron imaging; PAA (Proton Activation Analysis); PGAA (Prompt Gamma Activation Analysis); PIXE (Particle Induced X-ray Emission); pXRF (portable XRF); RBS (Rutherford Backscattering Spectrometry); SEM (Scanning Electron Microscopy); SG (Specific Gravity); SR-WD-XRF (Synchrotron Radiation Induced WDXRF); TOF-ND (Time-of-Flight Neutron Diffraction); TOF-SIMS (Time-of-Flight Secondary-Ion Mass Spectrometry); WDXRF (Wavelength-Dispersive XRF).

Commentary

Research into improving methods and methodology

There has been much research into methods, both old and new, and methodology.

XRF remains a dominant technique because it is rapid, non-destructive, transportable, inexpensive and useful when coins are made of almost pure noble metals such as gold and silver without significant addition of copper such as were typically minted by archaic and classical Greek city-states where the patina does not present a formidable barrier. Gore and Davis (58) proposed a mathematical correction for approximating the bulk composition of almost pure Greek silver coins 'seeing through' the patina. Surface silver enrichment may also occur in some coinages with high fineness (Ag >90 %), see Borges *et al.* (29). A new and experimental development of XRF is μXRF. Although hampered by the extended time needed to analyse samples and lack of portability, it is gaining popularity and it has been used to examine surface enrichment in silver coins by Hrnjić *et al.* (76).

Another use of X-ray is X-ray CT that is relevant for identifying completely corroded coins: Bude and Bigelow (33), and for imaging and examining a coin hoard in a pot without having to excavate it: Miles *et al*. (90). Neutron radiation techniques are also non-destructive but more penetrative than XRF. An important series of studies by Salvemini *et al.* (120, 121, 122), Luzin *et al.* (84) and Olsen *et al.* (109) sought to understand manufacturing

techniques in South Italian incuse and other Greek coins dating to the 6th and 5th centuries BC.

Using LA-ICP-MS's depth profile mode, Sarah and Gratuze (131) analysed silver and Blet-Lemarquand *et al.* (21) gold. Depth profiling was also interrogated on silver coins using SEM-EDS and TOF-SIMS by Marjo *et al.* (85) and applying LA-ICP-MS by Hrnjić *et al*. (76). An innovative, non-destructive method for depth investigation of Roman silver coins was by Hampshire *et al.* (67) using negative muons.

Some studies worked on devising strategies for analysing silver coins (for example 10, 39, 119). A difficult problem for analysts is analysing debased silver coins, made of silver-copper alloys. Moreno-Suárez *et al*. (95) combined XRF with density tests and GRT to evaluate the bulk composition of Republican silver coins. Corsi *et al.* (37) used TOF-ND for determining silver and copper contents in Celtic silver coins from northern Italy. Debernardi *et al*. (39) developed a model based on ND results for determining the silver contents of debased alloy coins using SG tests (summarised explanations of this model are given in the appendix to 40).

Many studies examined the potential advantages and limits of using stable isotopes (Ag, Sn, Fe) for provenancing ancient metals. A significant development is the use of silver isotopes by Albarède *et al.* (3) since it analyses the metal from which silver coins were made, rather than the residual lead which did not always come from the same ore source, see Albarède *et al.* (2). The method is described in Milot *et al.* (92). Berger *et al.* investigated tin isotopes (8, 9) and Milot *et al.* iron isotopes (91).

Other studies looked at individual elements for tackling different problems. There were archaeometallurgical experiments and/or simulation for determining how certain elements behave during pyrotechnical treatments and interpreting contents. These included L'Héritier *et al.*'s (83) study of bismuth in silver, and Blet-Lemarquand *et al.*'s (23, 24) study into platinum and palladium and other trace elements in gold. Wood *et al.* (155) discussed using iridium as a specific marker for provenancing silver objects, including coins, in an article contested by Pernicka (116) to which Wood *et al.* replied (156). Hinds *et al.* (72) sought to determine platinum in Roman gold coins using WDXRF and this research was complemented by Van Loon *et al.* (147) who applied SR-WD-XRF for determining platinum distributions. Uhlir *et al.* (146) examined mercury in some Sasanian coins.

An overview about provenance studies of silver and gold coins was conducted by Blet-Lemarquand *et al.* (22) as well as one on the characteristics of analytical methods for coined metals (19).

Metal analysis (references classified by period)

Greek coins received considerable attention. Different studies relate to the analysis of early electrum coins: by XRF in Gitler *et al.* (57), Hilbert (70, 71), and by LA-ICP-MS in Blet-Lemarquand and Duyrat (17). Davis *et al*. (38) used key diagnostic elements in a large-scale XRF study of archaic Athenian coins to reveal compositional patterns. Markou *et al.* (86) presented pXRF results of gold coins struck by the kings of Cyprus. Agathocles' coins issued in electrum were analysed using LA-ICP-MS by Hochard and Artru (73). Nieto-Pelletier *et al.* (101, 102) investigated staters of Philip II of Macedon. Gold Lysimachi were analysed by LA-ICP-MS by Duyrat and Blet-Lemarquand (44) and by XRF by Vîlcu and Pîrvulescu (148). Smekalova (139) commented on XRF results obtained for coins minted by Greek states on the Black Sea shores. Sheedy *et al.* (135) provided elemental analysis of Siphnian coins. Birch *et al.* (10, 12) used EPMA and LA-ICP-MS for silver coins from Magna Graecia. Flament (50) gave an overview of available chemical data of Athenian owls. Faucher (46) examined the first Egyptian gold coins of Nectanebo II and in Faucher (48), Athenian owls and their imitations. Ptolemaic silver and bronze coins were analysed by Faucher and Olivier (49), Olivier (105, 106) and Olivier and Keen (108). Olivier *et al.* (107) studied the question of the provenance of Alexander's minted silver. Blet-Lemarquand *et al.* (18) looked at Hellenistic silver coins from *koina* and cities. General trends in the composition of Greek bronze coins were given in Blet-Lemarquand (16). Wojan (154) pinpointed a series of Greek 'bronze' coins made of pure copper. Sheedy *et al*. (136) analysed by XRF and ICP-AES a few specimens of a series of 4th century bronze coins to discuss ancient written sources.

Carthaginian gold coins were analysed by Artru (5) using LA-ICP-MS to tackle the question of their gold provenance. García-Bellido *et al*. (52) carried out elemental and lead isotope analyses of coins found in a Second Punic War battlefield site.

Judaean bronze prutahs were investigated by Bower *et al.* (31) using XRF and XRD to study their manufacture, and in Bower *et al.* (32), their tin isotopes.

Celtic coins received considerable analytical attention. Nieto-Pelletier (98) emphasized the importance of

archaeometric data for Celtic gold numismatics. Nieto-Pelletier and Olivier (101) developed different approaches for studying Celtic Gaul imitations of Philip II of Macedonia staters - see also the publication of one specimen of these imitations by Geneviève and Nieto-Pelletier (53). Sillon (137, 138) updated understanding of gold Celtic coinages of northern Gaul with a large, interdisciplinary study combining numismatic and archaeometric approaches by LA-ICP-MS of almost 600 coins. Nieto-Pelletier *et al.* (100) brought together composition results of 'globules à la croix' and published new results. Bossavit (30) studied the coin composition and production policies of silver Celtic coinages of Central Eastern Gaul. Šmit *et al.* (145) analysed Celtic coins from Slovenia combining PIXE and PGAA. Different Celtic coinages from Armorica were characterised using various methods: billon by FNAA in Gruel and Nieto-Pelletier (60) and gold and billon by PAA or PIXE in Guerra and Abollivier (61). Nieto-Pelletier *et al.* (103, 104) looked at whether Celtic bronze coins were fiduciary using FNAA of potin and struck coins. Nieto-Pelletier (97) initiated research on Celtic orichalcum coinages with FNA.

Roman coins continued to attract interest. Westner *et al*. (153) combined LIA and elemental analysis of bronze coins issued in Italy and Sicily from the 5th to 2nd centuries BC to trace the development of these coinages. Several studies dealt with silver supply during the Republican period: Albarède *et al.* (3) using silver isotopes and LIA, Westner *et al*. (152) combining LIA and trace elements analysis and Parisot-Sillon and Sarah (112) using chemical analysis of a large set of coins. Parisot-Sillon (111) discussed the minting of the *victoriatus* (silver currency from the 2nd century BC) focussing on composition. Work was also done on this topic by Debernardi and Manenti (40). Suspène and Blet-Lemarquand (142) published the analysis of a gold coin in the name of Flamininus. The gold coins struck by Brutus and Cassius interested Suspène *et al.* (143), as well as Octavian/Augustus' gold coins, Suspène (140) and Blet-Lemarquand *et al.* (25), while Bocciarelli *et al.* (26) delved into Roman gold coins from AD 68-69 and Suspène *et al*. (144) examined the fineness of gold coinage from the Republic and early Empire. Butcher and Ponting (36) studied the reform of Trajan as an extension of their previous large-scale work on silver Roman coinage in Butcher and Ponting (35). Woytek and Blet-Lemarquand (157) provided a thorough study of a peculiar type of silver denarius formerly attributed to Augustus which they linked to the reign of Hadrian based on metallurgical, numismatic and archaeological arguments. Orejas Saco del Valle *et al*. (110) provided LIA and XRF analysis of Roman coins from an archaeological site. Estiot (45) published a detailed study of the special issues of the Rome mint under the Emperor Probus that includes analysis of gold coins and bronze medallions. Elemental analysis of gold coins minted by Aurelian and his successors can be found in Gricourt *et al.* (59). Guihard *et al*. (62, 63) carried out XRF analysis on abraded areas of a hoard of *nummi*. Di Fazio *et al.* (43) studied the microstructure and composition of cross-sections of orichalcum coins minted after Augustus' reform. Birch *et al.* (11) examined copper and copper alloy coins from the Late Roman to Byzantine periods found in archaeological contexts. Montero Ruiz and Orejas Saco del Valle (94) investigated the copper supply in the Roman Empire and Late Antiquity.

Roman provincial coinage was addressed. Asses of Nimes/ Nemausus under Augustus were looked at by Pellé and Blet-Lemarquand (115), and medals showing types of this colony by Villemur *et al.* (151) and Villemur and Blet-Lemarquand (149, 150). Geneviève *et al.* (54) studied cast coins imitating the bronze coins from Nimes. Amandry and Burnett (4) compared different methods used for silver coins and presented FNA results of copper alloy medallic coins in the name of Antinous and of silver coins in volume III of *Roman Provincial Coinage*. FNA analysis was also carried out by Hochard *et al.* (75) on provincial bronze coins coming mainly from Lydia to diachronically outline general compositional trends, and to discuss the organisation of minting, Hochard *et al.* (74). Lempereur and Blet-Lemarquand studied *denarii* minted in Alexandria at the end of the 2nd century (82).

Later periods were also tackled. Merovingian gold coins were analysed by Blet-Lemarquand (15) and Merovingian silver coins by Blanchet (13), Blanchet *et al*. (14), Foucray *et al*. (51), Schiesser and Sarah (133). Sarah *et al*. (130) provided a full study of a Carolingian hoard that combines many approaches including archaeometry with elemental and lead isotope analyses of the coins. Elemental analyses were of particular interest in a discussion of the monetary politics of the Carolingian Empire (Sarah (126)). The fineness of the rare gold Carolingian coins was commented on in Sarah (124). LA-ICP-MS analysis of 10th century coins allowed Moesgaard and Sarah (93) to pinpoint when debasement occurred. Peigney and Sarah (113, 114) clarified the classification of a French feudal coinage with the help of elemental analysis. Work on medieval excavation finds was the starting point of larger studies conducted by Sarah (123, 125) and by Sarah and Jesset (132). Matzke (87) analysed medieval coinages struck in

mining areas in South-western Germany. Sarah (128) investigated the question of the use of brass to debase medieval silver coinages while Sarah (127) dealt with the provenance of early medieval silver comparing lead isotope and elemental analysis of traces; see also Sarah and Geneviève (129) for another supply study. Jonson *et al.* (79) examined Byzantine and Islamic mints in North Africa with the help of SG measurements and LA-ICP-MS analysis. In the framework of his study dealing with silver of the Viking Age, Merkel (88, 89) studied Islamic coins combining elemental and lead isotope analyses. Bulk analysis by FNAA of Arab-Sasanian 'copper' coins was conducted by Blet-Lemarquand and Gyselen (20); and Ham-Meert *et al.* (65, 66) used μXRF and lead isotope analyses for Sasanian lead coins.

Modern coins received some attention. Beck *et al.* (7) studied a hoard of 15th to 17th century coins applying PIXE and RBS and dated linen fibers attached to the coins by radiocarbon dating. Gold coins from a small 16th century hoard were looked at by Bompaire *et al.* (28) using LA-ICP-MS. This method was also performed for analysis of hoards of Spanish gold and silver coins discovered in France in Jambu (78), while XRF was used for Spanish gold coins from South American mints by Gutiérrez Neira *et al.* (64). Gentelli (55) performed a provenance study of 17th-19th century Spanish silver coins using LA-ICP-MS.

Coin manufacture (official/irregular coins and modern forgeries)

Faucher (47) summarised the technical processes in manufacturing Ptolemaic coins. Delestrée and Pilon (41) studied the unique bronze mould discovered for Celtic potin coins and published the analysis of a monetary punch (42). Nieto-Pelletier *et al.* (99) analysed metallic residue in Iron Age 'coin' moulds. Ingo *et al.* (77) investigated plated Roman Republican coins to decipher the silvering methods. George (56) carried out experiments to recreate Roman debased alloy coins. Abramson *et al.* (1) examined 3rd century AD billon staters by XRF, NT and ND. Herringer *et al*. (69) highlighted alloy segregation in sesterces using neutron imaging. Pilon (117, 118) published analyses of metallurgical materials in his large study dedicated to mints of imitative coins in 3rd century AD Gaul. Nicot and Pilon (96) analysed clay coin moulds excavated in Lyons by XRF and provide FNAA of an imitation denarius. Roman iron coins coated with copper alloy (*subferrate*) were studied in different articles: Haubner *et al*. (68); Klein and von Kaenel (80, 81). Bompaire and Blet-Lemarquand (27) analysed a hoard of fake silver coins from the 12th century manufactured through tinning of copper alloy flans. Beck *et al*. (6) studied the silvering processes implemented for 16th century coins and replicated them. A modern forged die was published by Suspène and Blet-Lemarquand (141). Gold tracks analysed by SEM-EDX suggested that it has been used to strike coins, and Woytek and Williams succeeded in matching the die with coins struck from it (158).

Team projects and major publications

Important team projects relevant to numismatics have received an ERC Advanced Grant. These include: 'Token Communities in the Ancient Mediterranean', University of Warwick (Grant agreement ID: 678042); 'Silver Isotopes and the Rise of Money', ENS Lyon (Grant ID 741454); 'Silver and the Origins of the Viking Age', University of Oxford (Grant ID 802349); 'Rome and the Coinages of the Mediterranean 200 BCE - 64 CE', University of Warwick (Grant ID 835180).

Many projects have been funded by State agencies, local institutions or private foundations: ACANS - early Attic silver; incuse coinage of South Italy (jointly with ANSTO); A Spring of Silver, a treasury in the earth: coinage and wealth in archaic Athens – *Wappenmünzen* and Archaic Owls; ATMOCE - Celtic bronze coins; Aureus - antique gold; CELTIC GOLD - Celtic gold coins hoarded with gold objects; FANUM - XRF for archaeology and numismatics; GlobaLID - database for lead isotope data; IMAGMA - Roman and barbarian coins; KOINON - Arcadian, Achaian and Aetolian coinages; OLBIA - Münzen aus einer griechischen Kolonie.

There have been a number of significant numismatic publications. Here we list three: Butcher edited a book on debasement phenomena that comprises several contributions interpreting scientific data (34); Butcher and Ponting (35) published a major work on Roman silver coinage from Nero to Trajan; Volume 6 of the *Metallurgy in Numismatics* series edited by Sheedy and Davis (134) includes eleven chapters on scientific analysis of coins.

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