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The Gold of Lysimachus. Elemental Analysis of the collection of the Bibliothèque Nationale de France using LA-ICP-MS

Frédérique Duyrat, Maryse Blet-Lemarquand

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METALLURGY IN NUMISMATICS 6

Metallurgy in Numismatics 6

Mines, Metals, and Money Ancient World Studies in Science, Archaeology and History

EDITED BY

KENNETH A. SHEEDY

and GILLAN DAVIS

AUSTRALIAN CENTRE FOR ANCIENT
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To our daughters:
Lucy Clare Sheedy, Rebecca Allen and Tamara Davis

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PREFACE

The papers in this volume in part stem from a conference that was conceived and organised by the Australian Centre for Ancient Numismatic Studies (Macquarie University) and the Epigraphical and Numismatic Museum, Athens. The conference, held at the Iliou Melathron in Athens from 20-22 April, 2015, was entitled 'Mines, Metals and Money in Attica and the Ancient World'. One of its goals was to survey the applications and current state of non-destructive metallurgical analyses in Greek numismatic study. In recent years, progress in these areas has been rapid; and as laboratory instrumentation and techniques have continued to multiply and expand, the topic could not be more timely. The other work that the conference and now this volume addresses is the renewed interest of geologists and archaeologists in further exploiting the evidence on the ground for reconstructing the silver mining and processing industries in Southeastern Attica and Northern Greece. Accompanying these studies are papers from the staff of the Numismatic Museum on the museum's program of testing new acquisitions and on the study of two hoards excavated in Athens.

Altogether, the articles trace precious metal in the Greek world from the extraction of ore in antiquity to museum artifacts of today. Expanding on previous volumes of the Royal Numismatic Society's *Metallurgy in Numismatics* series, the present contributions range from numismatic metallurgy in its traditional laboratory context to metallurgy in the broader, historical sense of ancient metal working in general. In what is probably the most significant achievement, a core of the papers present abundant, fresh evidence for the tremendous scale of long-distance trade in silver from a handful of sources in the Aegean to the great number of Greek city-states around the Mediterranean that began to coin in the late archaic period, including even the cities of Southern Italy and Sicily.

While this volume will be welcomed for its many such findings, its value rests also on the editors' foresight that by inviting these contributions and bringing them together in one place, the studies will become more accessible and prominent than if they had been published separately.

J. H. KROLL

FOREWORD

As Director of the Numismatic Museum at Athens, I am proud of our longstanding numismatic and scientific collaboration with the Australian Centre for Ancient Numismatic Studies (ACANS) at Macquarie University, Sydney. Many Australian researchers, including the two editors of this volume, have spent extensive periods researching at the museum over many years to our mutual benefit. Together we organised the major international conference entitled *Mines, Metal and Money in Attica and the Ancient World* hosted at the museum from 20-22 April, 2015 which formed the genesis of this volume.

The themes of the conference focused on archaic Greek coinage, methods of mining precious metals, and on the historical and institutional framework of the Archaic period in which the conventions for the organisation and control of mining were developed, and through which the commercial distribution of precious metals was carried out. The conference themes also embraced studies of coin production, and technological and research methods for the analysis and conservation of metals that reliably help authenticate ancient coins. In these themes the conference successfully brought together scientists from all over the world.

At the end of the Conference, the temporary exhibition, *When Silver was Born. Archaic Coinage of Athens, Mines, Metals and Coins*, was inaugurated. The exhibition was displayed in the Great Gallery of temporary exhibitions of the Iliou Melathron, the Library of Heinrich Schliemann, on 28 May 2015. It took as its subject the coinage of the Archaic period, an era during which profound changes occurred in politics, the arts, and in society more generally. The exhibition, which was the conclusion of the very fruitful co-operation of our Museum with our colleagues from Australia, exhibited 263 artifacts, most of them for the first time. The objects displayed included acquisitions by Museums and Ephorates of Antiquities, and objects from the Collection of the Alpha Bank. We thank and acknowledge the Alpha Bank for sponsoring the exhibition, and the Australian Research Council of the Australian Government for sponsoring the Conference.

GEORGE KAKAVAS

12. THE GOLD OF LYSIMACHUS. ELEMENTAL ANALYSIS OF THE COLLECTION OF THE BIBLIOTHÈQUE NATIONALE DE FRANCE USING LA-ICP-MS

Frédérique Duyrat and Maryse Blet-Lemarquand

ABSTRACT

The collection of the department of Coins, Medals and Antiques of the Bibliothèque nationale de France contains 56 lifetime and posthumous gold staters and fractions with the types of Lysimachus. They were struck between the beginning of the third and the beginning of the first century BC. Most mints issuing this type of coinage are represented. The coins have all been analysed using the Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS) method to determine the content of major and trace elements. The purpose of this study was two-fold. First, we wanted to see if there were elemental differences between the mints and the periods of production (lifetime and posthumous issues). Second, since there is a clear discrepancy between the trace elements in Eastern and Western gold revealed in the results obtained by the IRAMAT – Centre Ernest-Babelon during the last twenty years, we wanted to evaluate the case of the Lysimachi in the light of this discrepancy. The results show that, on the one hand, the fractions analysed are probably forgeries. On the other hand, if the lifetime and the third and second centuries issues share the same characteristics, the Mithridatic Wars Lysimachi can be distinguished and seem to be closer in composition to some of the Republican gold coins.

INTRODUCTION

Lysimachus, as satrap and then king of Thrace, ruled that area from Alexander's death in 323 BC until his own death at the battle of Corupedium in 281 BC. As a close friend of Cassander, he benefitted from the support of Macedonia throughout his reign. Our knowledge of his coinage remains incomplete; the only attempt of a complete catalogue is by Müller written back in 1858 and the classification it offers is largely superseded. The classification of the lifetime issues is still under discussion, but the posthumous ones have benefitted from two corpora based on die studies (Marinescu 1996 and Callataÿ 1997) helping to secure their identification. Thrace had not received a royal mint during the reign of Alexander; Pella and Amphipolis supplied the region with Philips and Alexanders. This observation led Newell, whose conclusions were published by Thompson (1968), to propose that Lysimachus did not issue any coinage before the foundation of his new capital, Lysimachia, in 309 BC. These were small silver and bronze coins with the types of Philip II and Lysimachus' initials and his personal mark: the forepart of a lion (Thompson 1968, 164–165, 168–169; Price 1991, 130–131 attributes these issues to Amphipolis c. 310–301 BC and suggests that the issues of Alexanders may also refer to Lysimachus). But Arnold-Biucchi has concluded that these coins were minted before 309 BC (Arnold-Biucchi forthcoming). Newell and Thompson dated the first issues in the name of Lysimachus with the types of Alexander to the period after the battle of Ipsus (Price 1991, 197 follows this dating). Lysimachus retained the same denominations: gold staters, silver tetradrachms and drachms. According to Thompson (1968, 165 in agreement with Newell), it is only after Cassander's death in 297 BC, that Lysimachus began a coinage with his own types: a head of Alexander deified with Ammon horn, and Athena seated on a throne. Arnold-Biucchi (forthcoming) has recently challenged this statement, arguing that a date before 301 BC would better conform to the monetary behaviour of the other successors. The issues with the name and types of Lysimachus are predominantly tetradrachms, and are accompanied by gold staters, and drachms at the Anatolian mints. The royal mints of Lysimachus (Thompson 1968, 164–166) opened and closed following his victories and defeats in Asia Minor and in Macedonia (see Lund 1992 on these military campaigns). After his death, certain authorities, among them cities, continued sporadically to produce posthumous coinage with Lysimachus' types for another two centuries (see Franco 1993, 230–236 for a short overview).

The royal and then later civic gold coinages with the name and types of Lysimachus were missing from an earlier program of elemental analyses of ancient eastern gold coinages performed at the IRAMAT–Centre Ernest-Babelon (Institut de recherche sur les Archéomatériaux, CNRS–University of Orléans). To fill this gap the Paris collection was analysed in 2010–2011 by Damien Pujol, a Masters student at the University of Orleans (Pujol 2011).¹ The broader purpose of the study was to situate the gold coins struck by Alexander's successors in the Northern Aegean region within the general landscape of gold analyses of ancient coins already available in the IRAMAT–Centre Ernest-Babelon database (Duyrat and Olivier 2010; Suspène *et al.* 2011; Blet-Lemarquand *et al.* 2015 with an updated graph in Fig. 8). The laboratory has been analysing ancient gold for more than twenty years and has developed the LA-ICP-MS method which has proved to be particularly efficient for nearly pure metal (Dussubieux and van Zelst 2004; Gratuze *et al.* 2004; Blet-Lemarquand *et al.* 2009; Blet-Lemarquand *et al.* in this volume).

THE PARIS COLLECTION OF LYSIMACHUS GOLD COINS

The Paris collection of Lysimachus gold coins can be separated into three groups: 48 staters and imitations, 3 fractions and 6 coins classified as forgeries. 34 coins entered the collection before the beginning of the twentieth century. The oldest identified was part of Joseph Pellerin's collection from the eighteenth century (Fonds général 62, Pellerin 1763, pl. II) but it is possible that some of the coins of the Fonds général are older. Most of the twentieth century acquisitions are gifts (Armand-Valton, Beistegui, Smith-Lesouëf) or part of the collection of Henri Seyrig bought by the Bibliothèque nationale in 1973. Thus the collection has many different origins. None of the coins come from an identified hoard.

The general arrangement of the coins adopted here follows the classification by E.T. Newell, summarised by M. Thompson, for lifetime Lysimachi (Thompson 1968 and 1986). Newell's criteria for distinguishing the lifetime mints remain quite obscure since the same monograms, and sometimes the same dies (see Arnold-Biucchi forthcoming), are shared by different mints. The style of Alexander's head on the obverse has been carefully studied by H.A. Cahn (1991) who distinguished two main groups (A and B) in Thompson's catalogues. Here he emphasised the peculiarities in the style of each of the mints. From the complexity of this coinage, we must conclude that the principles of classification used by Newell (1923) for the Alexanders cannot be easily applied to the Lysimachus coinage. This led Thompson to the conclusion that there were probably several central workshops issuing the coins for different mints (Thompson 1968, 166-167). In the absence of a corpus of Lysimachus gold coins, the classification remains under discussion. That explains why nine staters in the Paris collection remain of uncertain origin, if we follow the bibliography currently available (Fonds général 62, Fonds général 68, Fonds général 71, Fonds général 73, Beistegui 28, Luynes 1812, 1973.1.9, 1973.1.13, 1973.1.14, 1973.1.16).

The Paris collection does not reflect the general output of Lysimachus. For the lifetime Lysimachi, Thompson's article (1968) is a type catalogue and gives no information regarding dies, so that it is impossible to make a precise evaluation of the importance of the collection. Thompson gives a long list of control-marks that are not represented in Paris. However, the unpublished manuscript of Newell that her article summarises seems not to have included some of the Paris coins that could be lifetime issues.

For posthumous issues, the reference works used are the PhD thesis and publications of Constantin Marinescu (1996) on the mint of Byzantium and Chalcedon and of François de Callataÿ (1997) on the Mithridatic Wars. They are based on die-studies that permit an evaluation of the representativeness of the Paris collection. This provides some opportunity to

¹We are very grateful to Damien Pujol for authorising us to use his results to write this article. His research also included the Flamininus stater and the seven Antigonic gold coins kept at the BnF.

evaluate the output of posthumous Lysimachi from the third to the first century BC. However, this is a partial overview since the third and second century BC issues and mints other than Byzantium and Chalcedon have never been thoroughly studied (but note Fonds général 79 is attributed to Istros during the second century BC by Callataÿ 1997, 146, n. 12). Nonetheless, they give a general idea of what this incomplete landscape might be. Only one coin in Paris drifts from lifetime to posthumous issues in the Marinescu thesis: the stater, Fonds général 69, that he dates to *c.* 230-220 BC and attributes to Chalcedon instead of Pella *c.* 286/5-282/1 BC (as Thompson 1968). The reasons for this attribution are the closeness of the obverse style with two other obverse dies of his group III and a nearly identical monogram on a tetradrachm of the same group (Marinescu 1996, 222). The Paris coins in the catalogue of these two mints provided by Marinescu (1996) is as follows (Table 1):

Table 1. Representativeness of the Paris collection of gold staters of Lysimachus (Byzantium and Chalcedon) in Marinescu (1996).

	<i>Total</i>	<i>Staters</i>	<i>Paris</i>
Byzantium	1,166	333	7 (2.1%)
Chalcedon	258	40	4 (10%)

Moreover, the chronological spread of the Paris collection is not regular: only one stater of Byzantium of the second century has been analysed although that period is the most productive (Table 1). On the contrary, the Paris collection represents 10% of the corpus of Chalcedon staters in Marinescu's study. The concentration of this relatively limited output between *c.* 260 and the 190s makes the Paris collection a good sample. Callataÿ's 1997 book on the Mithridatic Wars gathers the issues of four mints active between *c.* 150 and 72 BC: Byzantium, Callatis, Istros and Tomis. The share of Paris coins in Callataÿ's study is respectively 20% for Byzantium (note that two staters are missing in the latter study: Fonds général 89 and 1973.1.12, which means three coins in a catalogue of fifteen), 14.3% for Istros, 8.3% for Callatis and 3.5% for Tomis.

Callataÿ (1997, 139, no. D1-R1d) re-examined the coins in the Paris collection, and reclassified two supposed forgeries as genuine (Rothschild 921 and 922). By contrast, he noticed that the stater 1973.1.16, previously considered genuine, has an unusual style and control-marks, which suggest it may be modern.² Finally, we must note that the Paris collection contains three fractions that are completely unknown within the whole literature on the Lysimachus gold coinage (Fonds général 572; Fonds général 95; M 4901–Fonds général 1115 a). This obviously raises the question of their authenticity.

To summarise, the collection of Paris is a small but relatively well-distributed sample of the gold of Lysimachus, with several dubious coins requiring verification of their authenticity. It can be divided into five groups: the lifetime staters, the third and second century posthumous staters (mainly Byzantium and Chalcedon), the Mithridatic Wars staters and the uncertain staters. The three fractions form a sixth and separate group. The analyses performed were intended to improve the classification and our knowledge of these coinages.

GOLD FINENESS, MINOR AND TRACE ELEMENTS CONCENTRATIONS OF LYSIMACHUS' GOLD COINS

LA-ICP-MS analyses were performed on all the Lysimachus gold coins to determine the contents of the major, minor and trace elements. This method requires several micro samplings using a laser. The hole created on the surface of the coin is so small that it is

² We are grateful to F. de Callataÿ who kindly gave us his opinion of this doubtful coin. However, the metal of this coin is consistent with the characteristics of the Hellenistic Eastern gold. If it is a modern fake, it may have been produced with ancient gold.

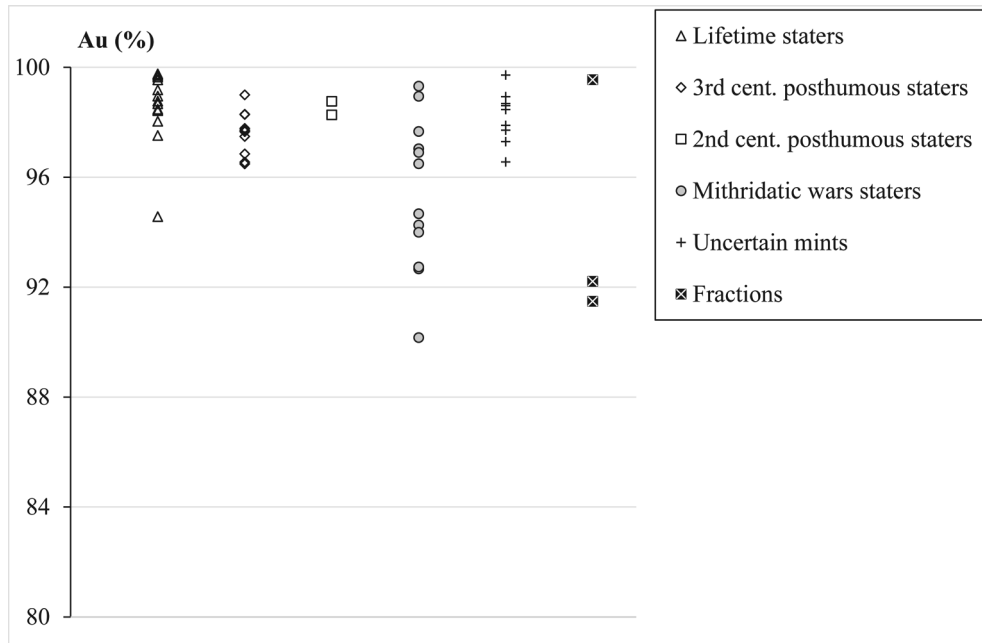


Figure 1. Gold fineness of the Paris Lysimachi

virtually invisible to the naked eye (see Blet-Lemarquand *et al.* 2009 and in this volume). The elemental contents that are discussed in the next pages can be found in Table 2. They shed light on the monetary choices of the issuer, on the manufacture of the gold alloy and on the provenance of the minted gold.

In Figure 1, the lifetime Lysimachi have the highest gold contents, ranging from 97.5% to 99.7% and with an average of 98.7%. There appears to be a slight decrease in the gold content for the third century posthumous Lysimachi which contain an average of 97.8% gold. The second century BC coins are too few to suggest a meaningful trend. Most of all, there is a clear drop in the gold content for the Mithridatic Wars Lysimachi staters, for their average fineness decreases to 95.3% and they show a higher dispersion than the previous series (as noted by Vilcu *et al.* 2011, 507 from XRF analyses carried out on around 50 lifetime and early posthumous Lysimachus type staters). The standard deviation of this group reaches almost 3%; in contrast, this parameter is less than 1.5% for the other groups. The corpus of these coins is not sufficient to try to interpret separately the monetary policy of each of the four mints of Byzantium, Istros, Tomis and Callatis. Nevertheless the data show that the mints of Byzantium and Callatis did not strike gold at a fixed fineness, and further analyses of coins from Istros or Tomis are likely to lead to similar conclusions.

The three fractions give a contrasting picture: one of them contains 99.6% gold, whereas the other two present an anomalously low gold content of 92%.

The gold contents of lifetime, third and second century BC Lysimachi are consistent with the fineness measured for late fourth century BC gold coins and other series of Hellenistic gold coins, which are usually over 96% (Duyrat and Olivier 2010, 75). The Mithridatic Wars Lysimachi are, by contrast, clearly separated from the bulk of these classical and Hellenistic royal issues.

As usual in Roman or Greek gold coins, silver is the main minor element of all the analysed coins, fractions included. The silver contents range from 0.07% to almost 9%. The silver amounts in ancient gold either come from gold ore which has not been completely purified or testify that gold was deliberately alloyed with silver. The copper and lead concentrations can help to interpret these silver contents because gold ores are generally poor in

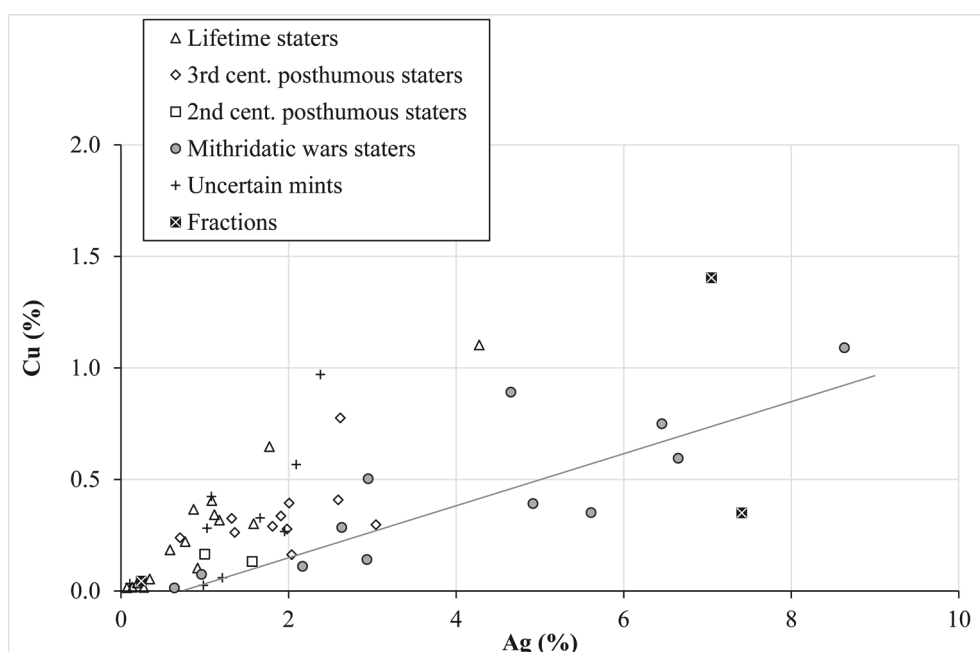


Figure 2. Silver and copper in gold

both these elements. The copper contents are between 0.01% and 1.4% (Fig. 2 and Table 2). There appears to be a linear correlation between the copper and silver contents for almost all the Mithridatic Wars Lysimachi and this is marked by the grey straight line on the graph (Fig. 2). As copper is an impurity of silver, the correlation between the two metals might suggest that some silver was added to purified gold when preparing the bullion. The silver used in the Black Sea mints in the context of the Mithridatic Wars would have contained ten times more silver than copper. On the contrary, no clear trend can be noticed between the copper and silver contents measured for the lifetime or the other posthumous staters. The small silver and copper amounts contained in these latter coins can be understood as remaining from purification of the gold.

The highest lead contents (mainly up to 250 ppm but even as high as 600 ppm) were measured in the coins containing 2% or less silver, that is to say most of the lifetime and third and second century posthumous staters (Table 2). These lead amounts surely did not enter gold as an impurity of silver. One wonders if they could be pollution from the purification process of gold.³

Platinum and palladium are gold impurities which follow gold when it is melted down and purified by cupellation or cementation (Blet-Lemarquand *et al.* 2014). The platinum to gold and palladium to gold ratios are relevant and reliable to tackle the question of the characterisation of gold. These parameters are plotted on a graph to determine if the Lysimachi coins present a similar chemical fingerprint in platinum and palladium, or if they were manufactured from different gold bullions, and also to discuss the authenticity of the three fractions (Fig. 3). Most of the lifetime Lysimachi and the third and second century posthumous coins can be grouped into a rectangle characterised with a platinum/palladium ratio around 23. The corresponding contents generally span from 240 to 450 ppm for platinum and from 10 to 24 ppm for palladium. The Lysimachi issued during the Mithridatic Wars can be

³ A cementation process of gold is described by Diodorus Siculus who quotes, in the first century BC, Agatharchides of Cnidus (*fl.* second century BC). This recipe reports a problematic use of lead and tin to purify Egyptian ground gold ore (Craddock 2000, 34 see also Halleux 1985, 50).

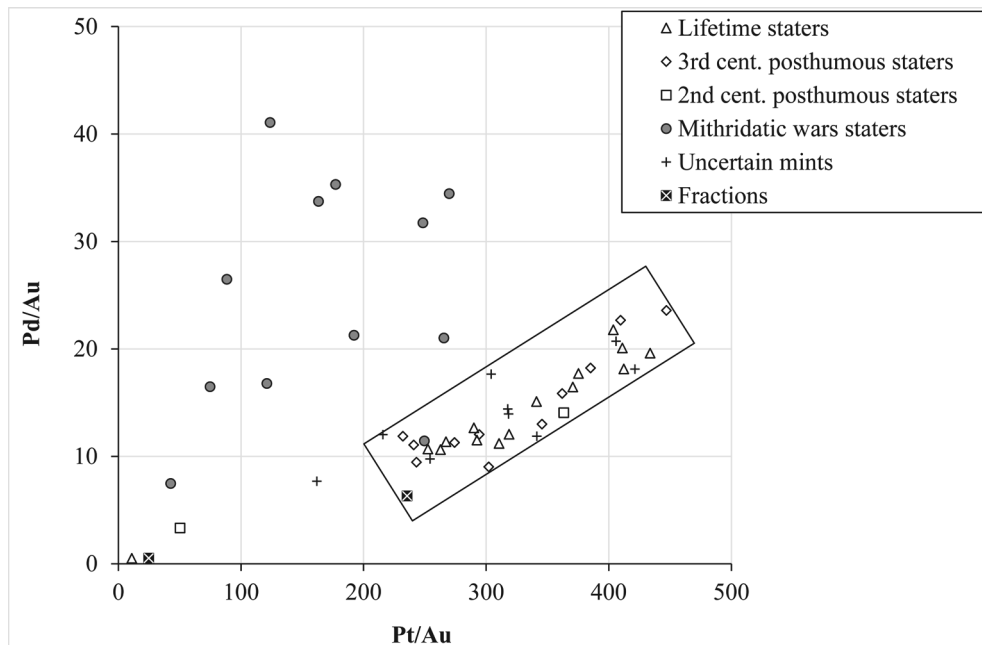


Figure 3. Platinum and palladium normalized to gold. A fraction isn't plotted on the chart because its Pt/Au and Pd/Au ratios are out of the scale (FG 95; Pt/Au 698 and Pd/Au 546)

clearly distinguished because they contain more palladium and less platinum than the previous coins and are spread on the graph (the platinum/palladium ratios are ranging between 3 and 13). The gold from which they are made is different from the gold used for the lifetime or posthumous Lysimachi.

One of the fractions, Fonds général 95, lies outside the boundaries of Figure 3. It contains 99.6% gold and has very high platinum and palladium levels (Pt 695 ppm and Pd 544 ppm), which are unusual for ancient gold as far as we know. These ratios can be compared with the contents of certain eighteenth century gold coins for instance (cf. Morrison and Barrandon 1999); nevertheless, these modern coins were struck with a lower gold ratio of about 90% gold. The two other fractions cannot be separated from genuine coins on the basis of their platinum to gold and palladium to gold ratios. However, one of them (M 4901–Fonds général 1115 a) has a gold ring soldered on it showing that it was part of a jewellery piece. As the ring has exactly the same composition as the coin, it can be deduced that the coin was actually conceived to be jewellery.

LYSIMACHUS GOLD IN THE CONTEXT OF CLASSICAL AND HELLENISTIC ROYAL GOLD COINAGE

The laboratory of Orléans has been working on Hellenistic gold for 20 years, mostly on the collections of the Bibliothèque nationale de France. The aim of these studies is to complete regional or chronological studies by combining the research of a physicist and an historian and by constantly using the same method for elemental analysis. At present (2017) the results of the analyses of about 300 Greek and Roman gold coins can be compared. They have been performed with the same machines and method or with methods that prove to be comparable for seeking the same information. They allow us to situate the gold Lysimachi in a global metal context.

The coins with types of Philip II and Alexander the Great, issued after 323 BC commonly show marked levels of platinum and palladium, whereas the Macedonian coins struck before

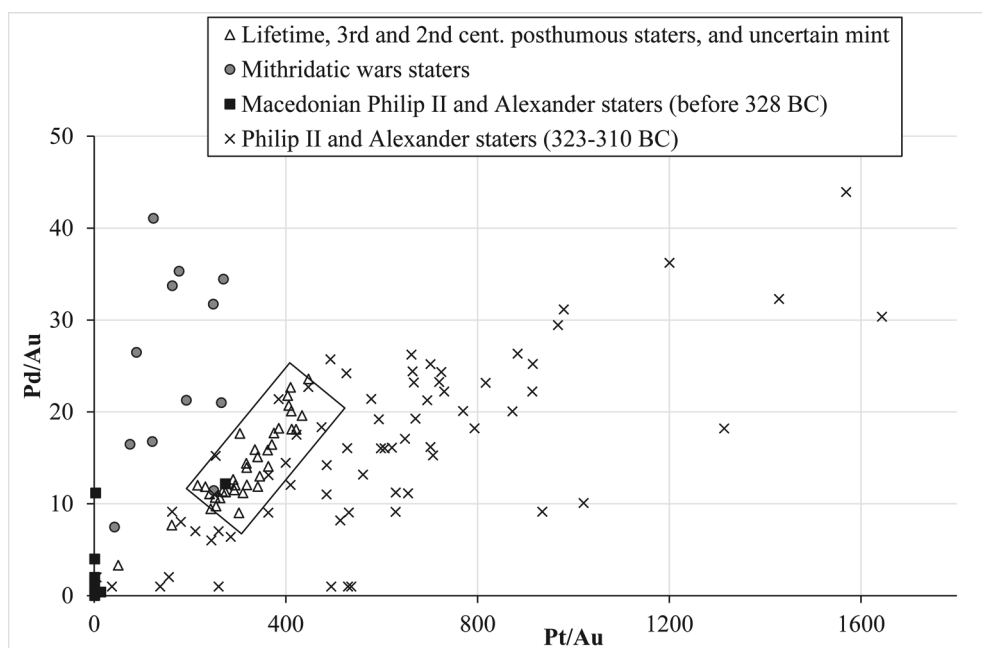


Figure 4. Platinum and palladium normalized to gold. Comparison between the gold Lysimachi (this study) and the gold coinages of Philip II and Alexander the Great (from Gondonneau 2001)

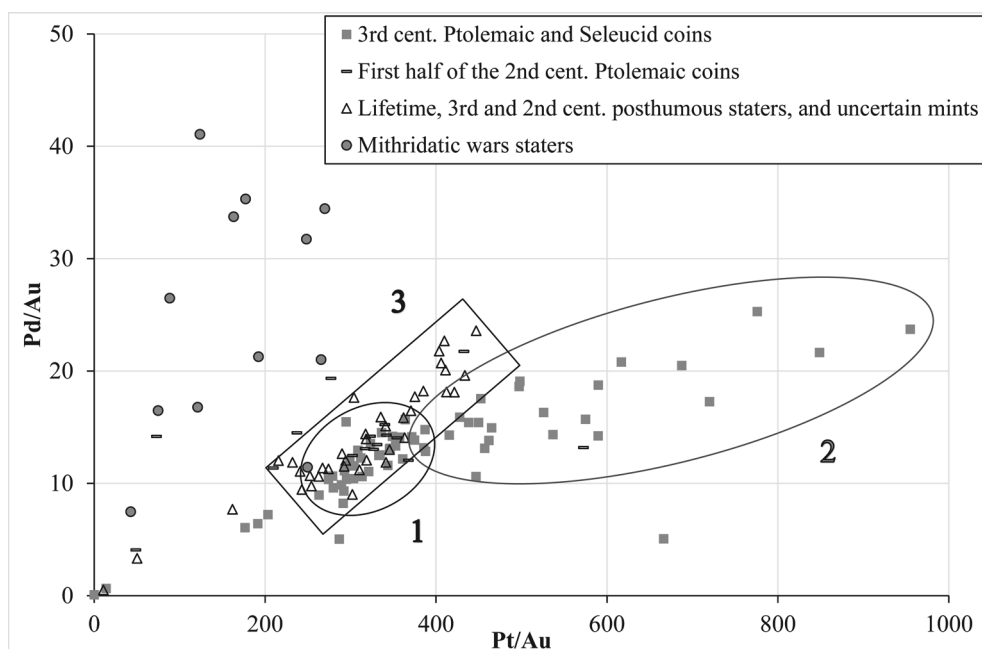


Figure 5. Comparison between the gold Lysimachi and the gold coinage of the Ptolemies and the Seleucids (from Duyrat and Olivier 2010; Olivier and Lorber 2013)

328 BC have low levels in both platinum and palladium (Gondonneau and Guerra 2000). None of the Lysimachi has this peculiar Macedonian chemical ‘fingerprint’ (Fig. 4).

Previous works made it possible to discriminate between the coins minted in the Eastern part of the Seleucid kingdom (Fig. 5, ellipse 2), and most of the coins from Alexandria and from the western Seleucid mints (ellipse 1) (Duyrat and Olivier 2010; Olivier and Lorber 2013). The rectangle 3 in Figure 5 draws the limits of the lifetime to second century BC gold Lysimachi. It is remarkable that it includes the ellipse 1, gathering the Western Seleucid

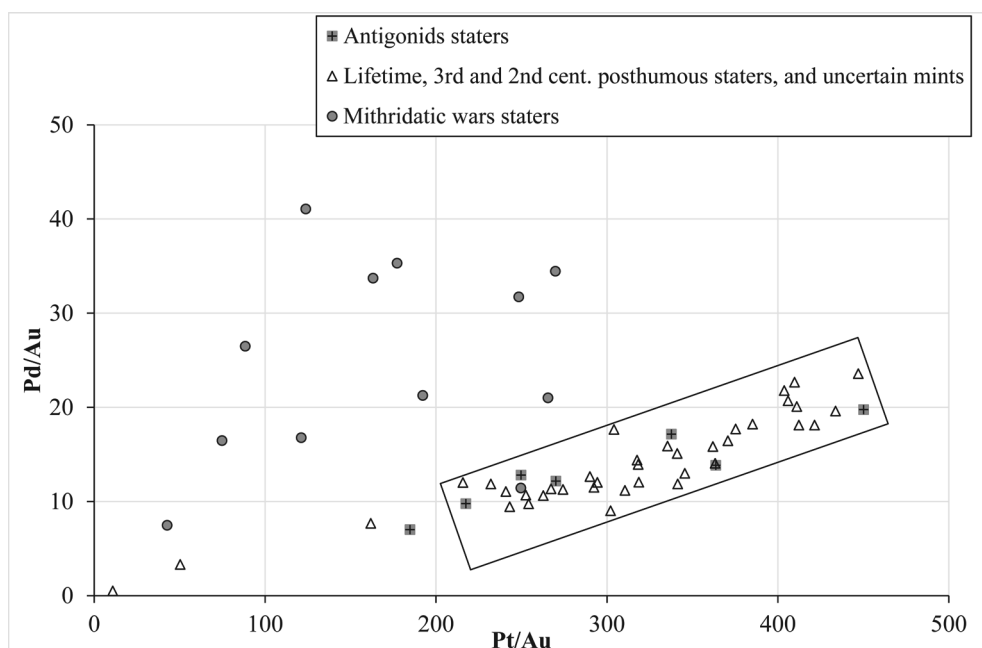


Figure 6. Comparison between the gold Lysimachi and the gold coinage of the Antigonids

mints and Alexandria, but does not overlap the group of the Eastern Seleucid mints (ellipse 2). The lifetime and the third and second century posthumous Lysimachi are generally consistent with coins minted in the Western mints of the Seleucids and especially by the Ptolemies during the third century BC. In contrast, the Mithridatic Wars coins were manufactured from a gold bullion that appears to be completely different from the other royal Hellenistic coins. Another provenance must be hypothesised the characteristics of which are not easily recognised.

Seven rare Antigonid gold coins (Fig. 6) from the Hellenistic kings of Macedonia have been analysed (Pujol 2011). These coins (four from Demetrius Poliorcetes (294–288), one of Antigonus Gonatas (277–239), one of Philip V (221–179) and one of Philip VI Androniscus (149–148) all date to the third century BC and the first half of the second century BC. They have a platinum-palladium ‘fingerprint’ that perfectly matches the gold of the Lysimachi issued before the Mithridatic Wars. The strong links between Cassander and Lysimachus have already been emphasised but the relationships between Macedonia and Thrace, especially from a monetary point of view, were constant. It seems that the gold supply was common to the whole area.

CONCLUSION

The analyses of gold Lysimachi in the collection of the Bibliothèque nationale de France allow us to characterise the three different groups according to their elemental composition. Our first conclusion is that the lifetime, third and second century posthumous Lysimachi share the same general characteristics. They have a high ratio of gold of over 96%. Their levels of platinum and palladium attach them to the group of ‘Eastern gold’, in contrast to the ‘Western gold’ used to strike Philips and Alexanders before 328 BC (Fig. 4). More precisely, these Lysimachi share the same characteristics with coins from the Western Seleucid mints and Alexandria group. The closeness to the few Antigonid gold coins analysed is not a surprise. The interesting point is that the very low levels of platinum and palladium discovered in the issues of Philip II and Alexander the Great in Macedonia before 328 BC are no

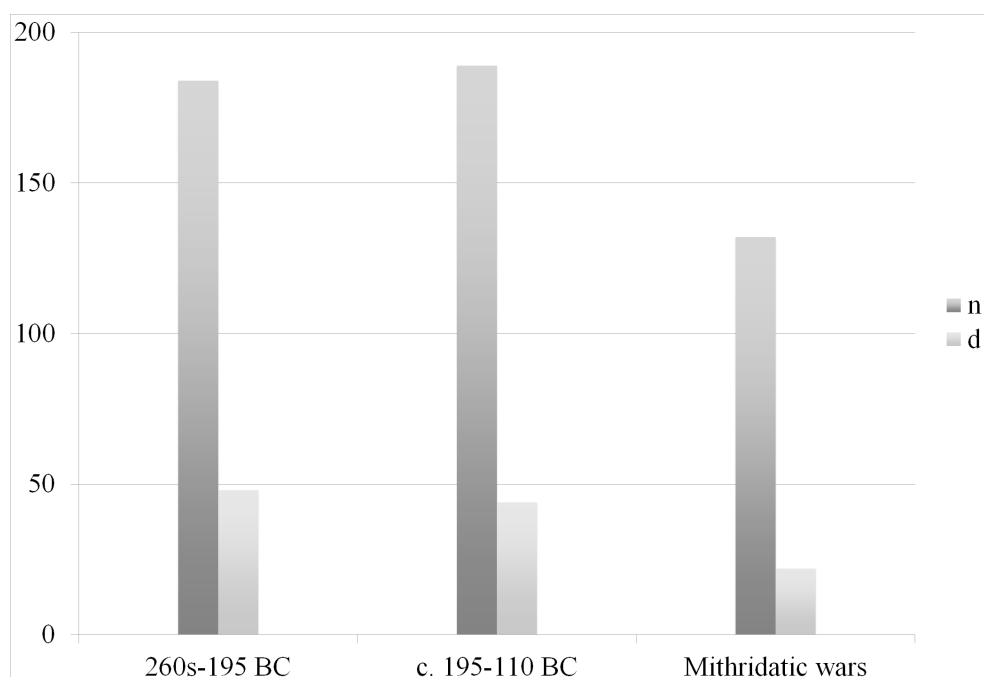


Figure 7. Global output of gold Lysimachi according to Marinescu's (1996) and Callataÿ's (1997) die-studies (n: number of coins and d: number of obverse dies)

longer a characteristic of Macedonian and Thracian coinage after 323 (Gondonneau and Guerra 2000). They are closer to the characteristics of coinages probably minted with the metal seized by Alexander in the Persian treasuries and then re-struck by his successors.

Thanks to Marinescu's PhD (1996), we have a detailed die-study of the issues of Chalcedon and Byzantium. Marinescu determined that Byzantium increased its gold production during the second century BC, when the relatively limited issues of Chalcedon were interrupted (Fig. 7). The importance of this observation for our study is that we can see the continuity of production and use of staters with the types of Lysimachus down to the beginning of the Mithridatic Wars. This explains why the cities of the northern shore of the Pontus Euxine began minting Lysimachi due to the pressures of war (Callataÿ 1997, 150). But it also underlines changes in the source of the metal. While Byzantium used gold with the 'Eastern' characteristics described above, the Lysimachi from the period of the Mithridatic Wars are different in composition. Their gold content is lower on average (from 90.2 to 99.3%). Moreover, their lead, copper, platinum and palladium levels put them in a completely different category. It is unfortunate that the collection of Paris has so few staters of Byzantium of the second century BC. However, the one specimen analysed does not show any change from the third century issues. It is interesting to add the gold Lysimachi to the general graph of ancient gold presented at the beginning of this article (Fig. 8). This clearly shows that the lifetime of second century Lysimachi are part of the more general 'Eastern' group of gold coins with relatively high levels of platinum and palladium. In contrast, the Mithridatic Wars Lysimachi are spread across the gap that separates the Classical and Hellenistic coinages from the beginning of the first century AD Roman coinage (black triangles). It is not possible to draw detailed conclusions from this observation. But it is clear that from the end of the second century and during the first century BC, major changes occurred in the supply of gold in the Mediterranean (Suspène *et al.* 201, Suspène *et al.* 2018).

Finally, the existence of three fractions in the Paris collection can now be explained: these coins are forgeries of different kinds. Two have a low gold content and one has abnormally

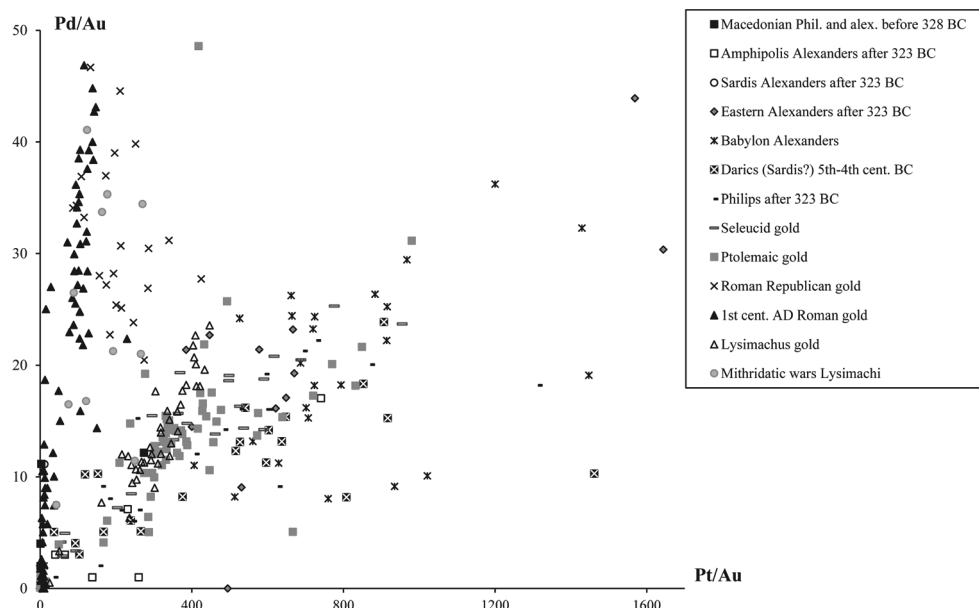


Figure 8. The Lysimachi in the LA-ICP-MS analyses landscape of ancient gold coins (4th century BC to the beginning of the 1st century AD) (from Duyrat and Olivier 2010; Suspène *et al.* 2011)

high contents of platinum and palladium. The remaining example was mounted as jewellery and has the same composition as the ring.

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Since the 2015 conference where this article was presented, the IRAMAT-Centre Ernest-Babelon performed several hundreds of new analyses thanks to a reasearch program funded by the Région Centre: Aureus. The conclusions of this new research are to be published in the final conference proceedings: Arnaud Suspène, Frédérique Duyrat, Sylvia Nieto-Pelletier, Maryse Blet-Lemarquand (eds.), Aureus. Le pouvoir de l'or - The Power of Gold. Actes du colloque d'Orléans, 13-14 novembre 2018, Bordeaux.

Table 2. LA-ICP-MS results in percentage or ppm

The pictures of all these coins are available online.¹ They all bear the types of Lysimachus and his name:

Obverse: Laureate head of Alexander with horn of Ammon r.

Reverse: Athena seated l. on a throne, Nike in her outstretched r., resting l. elbow on a shield, a spear behind her.

Only the coin Fonds général 62 has Alexander types and Lysimachus' royal title.

<i>Acquisition number and link to image</i>	<i>Mint</i>	<i>Date</i>	<i>Bibliographical ref.</i>	<i>Au%</i>	<i>Ag%</i>	<i>Cu%</i>	<i>Pb</i>	<i>Pd</i>	<i>Pt</i>
<i>Lifetime staters</i> Armand-Valton 284 http://gallica.bnf.fr/ark:/12148/btv1b8480744v	Lysimachia	297/6 – 282/1	Thompson 1968, 8 var (nothing in exergue)	98.7	0.87	0.37	21	17	370
FG 67 http://gallica.bnf.fr/ark:/12148/btv1b8576561h	Lysimachia	297/6 – 282/1	Thompson 1968, 8 var (nothing in exergue)	98.7	0.87	0.37	21	17	370
Beistegui 26 http://gallica.bnf.fr/ark:/12148/btv1b85765670	Pella or Byzantium	286/5 – 282 or c. 270	Thompson 1968, 241 (Pella); Marinescu 2014 (Byzantium)	99.0	0.77	0.22	205	11	264
Beistegui 27 http://gallica.bnf.fr/ark:/12148/btv1b8576568d	Pella	286/5 – 282	Thompson 1968, 241	99.2	0.58	0.18	48	12	316
FG 78 http://gallica.bnf.fr/ark:/12148/btv1b8576566k	Pella	286/5 – 282	Thompson 1968, 253 (tetradrachm)	99.5	0.34	0.054	23	15	340
FG 64 http://gallica.bnf.fr/ark:/12148/btv1b8576559f	Pella	286/5 – 282/1	Thompson 1968, 247 (tetradrachm)	98.5	1.1	0.34	58	10	259

Table 2. Continued.

<i>Acquisition number and link to image</i>	<i>Mint</i>	<i>Date</i>	<i>Bibliographical ref.</i>	<i>Au%</i>	<i>Ag%</i>	<i>Cu%</i>	<i>Pb</i>	<i>Pd</i>	<i>Pt</i>
FG 66 http://gallica.bnf.fr/ark:/12148/btv1b85765603	Pella?	286/5 – 282/1	Thompson 1968, 241, 252-5 var. tetradrachm	98.4	1.1	0.41	98	18	406
Beistegui 28 http://gallica.bnf.fr/ark:/12148/btv1b8576569t	Pella	?	Thompson 1968, 244 var. (tetradrachm with other monogram), Thompson Armenak 931 var.	98.0	1.6	0.30	12	16	363
Luynes 1808 https://gallica.bnf.fr/ark:/12148/btv1b11316927g	Pella	286/5 – 282/1	Thompson 1968, 247 (tetradrachm)	98.4	1.2	0.32	18	19	427
FG 69 http://gallica.bnf.fr/ark:/12148/btv1b8576563b	Pella or Chalcedon	286/5-282/1 or c. 230-225	Thompson 1968, 240 (Pella) / Marinescu 1996, 73.1 (Chalcedon) = Marinescu Forthcoming C120	98.8	0.91	0.10	9	11	307
FG 63 http://gallica.bnf.fr/ark:/12148/btv1b85765581	Alexandria Troas	297/6 – 282	Thompson 1968, 146 or 157?	99.7	0.27	0.016	30	0.5	11
FG 74 http://gallica.bnf.fr/ark:/12148/btv1b85765655	Lampsacus	297/6 – 282/1	Thompson 1968, 57 (tetradrachm)	94.6	4.3	1.1	61	11	277
Luynes 1809 https://gallica.bnf.fr/ark:/12148/btv1b11316928x	Amphipolis?	288/7 – 282/1	Thompson 1968, 190 var. (tetradrachm)	99.7	0.14	0.017	54	22	403

Table 2. Continued.

<i>Acquisition number and link to image</i>	<i>Mint</i>	<i>Date</i>	<i>Bibliographical ref.</i>	<i>At%</i>	<i>Ag%</i>	<i>Cu%</i>	<i>Pb</i>	<i>Pd</i>	<i>Pt</i>
HS 1973.1.11 http://gallica.bnf.fr/ark:/12148/btv1b8576593g	Ephesus	c. 294 – 287	Thompson 1968, 166 var. (tetradrachm)	99.6	0.19	0.036	125	20	410
HS 1973.1.10 http://gallica.bnf.fr/ark:/12148/btv1b85765922	Ephesus	c. 294 – 287	Thompson 1968, 164	99.8	0.070	0.015	608	13	289
3rd century posthumous staters									
FG 76 http://gallica.bnf.fr/ark:/12148/btv1b8576586b	Byzantium	c. 260 – 245	Marinescu 1996, 63.1 Issue 25 = Marinescu forthcoming B104	99.6	0.29	0.062	25	16	334
Smith Lesouëf 22 – Y 289 J2.22 http://gallica.bnf.fr/ark:/12148/btv1b8479032r	Byzantium	c. 260 – 245	Marinescu 1996, 84.3 Issue 35 = Marinescu forthcoming B136	96.5	2.6	0.78	104	9	235
1968.1183 http://gallica.bnf.fr/ark:/12148/btv1b85765796	Byzantium	c. 245 – beginning of the 220s	Marinescu 1996, 122.2 Issue 47 = Marinescu forthcoming B182	96.6	3.0	0.30	9	13	334
FG 85 http://gallica.bnf.fr/ark:/12148/btv1b8576577c	Byzantium	c. 245 – beginning of the 220s	Marinescu 1996, 145.1 Issue 62 = Marinescu forthcoming B200	98.3	1.3	0.33	103	11	270
FG 86 http://gallica.bnf.fr/ark:/12148/btv1b8576580v	Byzantium	c. 245 – beginning of the 220s	Marinescu 1996, 148.1 Issue 65 = Marinescu forthcoming B213	98.3	1.4	0.26	45	23	439

Table 2. Continued.

<i>Acquisition number and link to image</i>	<i>Mint</i>	<i>Date</i>	<i>Bibliographical ref.</i>	<i>Au%</i>	<i>Ag%</i>	<i>Cu%</i>	<i>Pb</i>	<i>Pd</i>	<i>Pt</i>
FG 90 http://gallica.bnf.fr/ark:/12148/btv1b8576578s	Byzantium	c. 245 – beginning of the 220s	Marinescu 1996, 102.1 Issue 41 = Marinescu forthcoming B157	99.0	0.71	0.24	69	11	238
Luynes 1810 https://gallica.bnf.fr/ark:/12148/btv1b11316929c	Byzantium	c. 210 – 195	Marinescu 1996, 213.1 Issue 90 = Marinescu forthcoming B293	97.7	1.9	0.34	53	22	400
R 2977 http://gallica.bnf.fr/ark:/12148/btv1b8576576z	Chalcedon	c. 260 – 230	Marinescu 1996, 47.1 Issue 20 = Marinescu forthcoming C85	96.9	2.6	0.41	197	12	285
FG 75 http://gallica.bnf.fr/ark:/12148/btv1b8576585x	Chalcedon	230s – c. 225	Marinescu 1996, 78.1 Issue 35 = Marinescu forthcoming C127	97.5	2.0	0.39	162	15	353
FG 91 http://gallica.bnf.fr/ark:/12148/btv1b8576587r	Chalcedon	230s – c. 225	Marinescu 1996, group III, 79, 81, 84, 85, 97, 92 var: other monogram = Marinescu forthcoming C203	97.7	2.0	0.28	52	18	376
HS 1973.1.15 http://gallica.bnf.fr/ark:/12148/btv1b85765885	Chalcedon	c. 225 – 190	Marinescu forthcoming C203	97.8	1.8	0.29	239	12	227
FG 77 http://gallica.bnf.fr/ark:/12148/btv1b8576596q	Odessos	c. 255-240 ? or 230 ?	Marinescu 1996, p. 420	97.7	2.0	0.16	48	9	295

Table 2. Continued.

<i>Acquisition number and link to image</i>	<i>Mint</i>	<i>Date</i>	<i>Bibliographical ref.</i>	<i>At%</i>	<i>Ag%</i>	<i>Cu%</i>	<i>Pb</i>	<i>Pd</i>	<i>Pt</i>
2nd century posthumous staters									
FG 79 http://gallica.bnf.fr/ark:/12148/btv1b8576594w	Istros	2nd century	Callatay 1997, p. 146, n. 12	98.8	1.00	0.17	44	14	359
FG 87 http://gallica.bnf.fr/ark:/12148/btv1b85765818	Byzantium	c. 195 – 110	Marinescu 1996, 509.1 Issue 150 = Marinescu forthcoming	98.3	1.6	0.13	70	3	49
Mithridatic wars									
HS 1973.1.12 http://gallica.bnf.fr/ark:/12148/btv1b8576582p	Byzantium	105-96	Callatay 1997, D2 R1	94.3	4.7	0.89	83	11	235
FG 88 http://gallica.bnf.fr/ark:/12148/btv1b85765833	Byzantium	105-96	Callatay 1997, D7 R1a	97.7	2.2	0.11	169	7	42
FG 89 http://gallica.bnf.fr/ark:/12148/btv1b8576584h	Byzantium	105-96	Callatay 1997, D2 R1	90.2	8.6	1.1	70	31	243
FG 80 http://gallica.bnf.fr/ark:/12148/btv1b8576589k	Callatis	110-90	Callatay 1997, D4 R2a	92.7	6.7	0.60	163	20	178
FG 81 http://gallica.bnf.fr/ark:/12148/btv1b85765907	Callatis	110-90	Callatay 1997, D6 R1a	99.3	0.64	0.014	0.3	35	176

Table 2. Continued.

<i>Acquisition number and link to image</i>	<i>Mint</i>	<i>Date</i>	<i>Bibliographical ref.</i>	<i>Au%</i>	<i>Ag%</i>	<i>Cu%</i>	<i>Pb</i>	<i>Pd</i>	<i>Pt</i>
2015.24 https://gallica.bnf.fr/ark:/12148/btv1b113536782	Callatis	110-90	Müller 1858, 260; Callatay 1997, D3 R-	96.5	2.9	0.50	77	31	240
Rothschild 921 http://gallica.bnf.fr/ark:/12148/btv1b10316657b	Callatis	110-90	Callatay 1997, D6 R1a	94.7	4.9	0.39	60	16	71
Luynes 1811 https://gallica.bnf.fr/ark:/12148/btv1b11316930r	Callatis	110-90	Callatay 1997, D6 R2b	98.9	0.96	0.075	7	26	87
FG 82 http://gallica.bnf.fr/ark:/12148/btv1b85765959	Istros	150-72?	Callatay 1997, D1 R1c	97.0	2.6	0.28	13	33	158
Rothschild 922 http://gallica.bnf.fr/ark:/12148/btv1b10316656w	Istros	150-72?	Callatay 1997, D1 R1d	96.9	2.9	0.14	9	40	120
FG 83 http://gallica.bnf.fr/ark:/12148/btv1b85765974	Tomis	Beginning of the 1st century BC	Callatay 1997, D4 R1a	92.7	6.5	0.75	49	19	246
FG 84 http://gallica.bnf.fr/ark:/12148/btv1b8576598j	Tomis BC	Beginning of the 1st century	Callatay 1997, D2 R1a	94.0	5.6	0.35	34	16	114

Table 2. *Continued.*
Bibliographical ref.

<i>Acquisition number and link to image</i>	<i>Mint</i>	<i>Date</i>	<i>Bibliographical ref.</i>	<i>At%</i>	<i>Ag%</i>	<i>Cu%</i>	<i>Pb</i>	<i>Pd</i>	<i>Pt</i>
<i>Uncertain mints</i> HS 1973.1.13 http://gallica.bnf.fr/ ark:/12148/ btv1b85765744	?	?	Müller 1858, 341 (Aphytis)	98.6	1.0	0.28	82	18	416
HS 1973.1.14 http://gallica.bnf.fr/ ark:/12148/ btv1b8576575j	?	?	Close to Thompson 1968, 113 and 115 (Magnesia) but with different obverse style	98.9	0.98	0.025	14	12	213
HS 1973.1.16 http://gallica.bnf.fr/ ark:/12148/ btv1b8576570g	?	?	Fake?	97.7	2.0	0.27	21	14	311
FG 71 http://gallica.bnf.fr/ ark:/12148/ btv1b103037168	?	?	No control-mark	96.6	2.4	0.97	90	17	294
FG 62 http://gallica.bnf.fr/ ark:/12148/ btv1b8576557m	?	?	Müller 1858, 29	98.5	1.1	0.42	33	8	159
FG 68 http://gallica.bnf.fr/ ark:/12148/ btv1b8576562x	?	?	Marinescu 1996, 79 (without the bull)	99.7	0.11	0.033	73	14	317
FG 73 http://gallica.bnf.fr/ ark:/12148/ btv1b8576564r	?	?	Müller 1858, 464	97.3	2.1	0.57	247	12	332

Table 2. Continued.

<i>Acquisition number and link to image</i>	<i>Mint</i>	<i>Date</i>	<i>Bibliographical ref.</i>	<i>Au%</i>	<i>Ag%</i>	<i>Cu%</i>	<i>Pb</i>	<i>Pd</i>	<i>Pt</i>
Luynes 1812 https://gallica.bnf.fr/ark:/12148/btv1b113169316	Rhodes?	?	Müller 1858, 451 (Rhodes)	98.7	1.2	0.059	27	20	401
HS 1973.1.9 http://gallica.bnf.fr/ark:/12148/btv1b8576591n	Kios?	?	Thompson 1968, 179 – 185, (tetradrachm), with ear of corn	97.9	1.7	0.33	168	10	249
Fractions									
FG 572	?			92.2	7.4	0.35	4	0.5	23
FG 95 http://gallica.bnf.fr/ark:/12148/btv1b8576573q	?			99.6	0.24	0.044	0.6	544	695
M 4901 – FG 1115 a http://gallica.bnf.fr/ark:/12148/btv1b85765729	?			91.5	7.0	1.4	44	6	215

