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Contents

Editorial Committee v

Giuseppe Castellano. XRF Analysis of the Volterra Hoard and a Sample of the Earliest Etruscan Coinage 1

Metodi Manov. An Obverse Die Wrongly Ascribed to a Tetradrachm Struck at Kabyle in the Third Century BC 33

Yoav Farhi, Yuval Gadot, Oded Lipschits and Manfred Oeming. A Note on Two Unique Seleucid Bronze Coins from Ramat Raḥel, Israel 45

Daniel Wolf. A Metrological Survey of Ptolemaic Bronze Coins II: Alexandria First and Second Centuries BC 57

Eneko Hiriart and Julia Genechesi. Gold and Silver "Ingots" across Celtic Continental Europe: A Monetary Use? 121

Katheryn Whitcomb. Coinage and the Client Prince: Philip the Tetrarch's Homage to the Roman Emperor 141

Sven Betjes. Hadrian, the Pantheon and the Ideological Resonance of the Third Consulship 161

Ronald Bude and Erin Bigelow. Non-Invasive Detection of a "Cut and Shut" Ancient Coin Forgery Using Micro-Computed Tomography 185

Pushkar Sohoni and Pallavee Gokhale. Strike Two: Afterlife of Bahmani Coinage 189

Samuel G. Kramer. The Livonese of 1756–1760: Centralizing Economic Policy in Estonia and Livonia 211

Bill Dalzell. The Origins and Context of the First Coinage for Liberia 229

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XRF Analysis of the Volterra Hoard and a Sample of the Earliest Etruscan Coinage

Giuseppe Castellano*

In this article I present two case studies that demonstrate the potential utility of X-ray fluorescence (XRF) in distinguishing outliers (and potential forgeries and imitations) among coin assemblages. The first case study is the 500 BC Volterra hoard and the second is a sample of the earliest confirmed Etruscan coinage including examples of the Monsters and Animals and First Metus groups. To my knowledge, this is the first XRF analysis undertaken on the Volterra hoard as well as on Etruscan silver coinage of this period.

The earliest coins unanimously considered to have been struck in Etruria are the fifth-century BC issues of Populonia and Vulci, "of Greek style, but with an Etruscan flavor and predilection for exotic animals and monsters" (Vecchi 2007, 87). The first Populonian issue, which Vecchi evocatively named "The Monsters and Animals Group," dates to between 450 and 400 BC and consists of several silver denominations bearing images of chimeras, lion-serpent hybrids, and boars, distinguished by the smooth, blank reverses typical of Etruscan coinage (Vecchi 2012a, 1:22, 77). It is important to note that almost no Etruscan coins of the fifth century BC bear reverse types, which seem to be a fourth-century development. Only Cypriot coins share this peculiar smooth reverse with Etruscan coins, but

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it seems that there was no direct connection and that the Etruscans and Cypriots adopted uniface coins independently of one another (Arnold-Biucchi 2002, 57).

The First Metus coins bear a gorgon's face—Metus, or Medusa—on the obverse and the typical smooth reverse. The First Metus represents the first large-scale issue of Etruscan coinage, dated to between 450 and 400 BC. While the Etruscan (specifically Populonian) origin of the Monsters and Animals and the First Metus coins is uncontested, scholars have for years debated the attribution of the contents of the Volterra hoard. While in this case XRF did not unequivocally determine the geographical origin of the unattributed coins in the Volterra hoard, our analysis did successfully identify two outliers, one from the hoard itself and one among the sample of early Etruscan coinage. I have tentatively identified these coins as an ancient forgery and an eighteenth-century forgery, respectively.

XRF has, in the last decade, become an indispensable tool for the study of coinage (Sodaei, Khak, and Khazaie 2013; Markou, Charalambous, and Kassianidou 2014; Corsi et al. 2018; Davis et al. 2020; Alfen, Gitler, and Konuk 2020; Westner et al. 2020). It is the least expensive form of metallurgical analysis, is non-destructive, and provides a nearly-instant reading of the elemental composition of an alloy (Lutz and Pernicka 1996, 313; Guerra 1998, 74; Karydas 2007, 419–20; Frahm and Noonan 2013, 1425–26; Markou, Charalambous, and Kassianidou 2014, 34). Some XRF machines are portable or even hand-held, for example pXRF, or portable X-ray fluorescence.

The device emits X-rays at a known energy level, which excites the atoms within the tested object and causes them to emit X-rays at energy levels determined by the elemental makeup of the material. These X-rays are read by the device, and the elemental makeup is almost immediately represented graphically on a computer attached to the XRF unit. It is worth noting that XRF provides an essentially relative measure of elemental composition, rather than an absolute one.

A potential limitation of XRF is that readings are restricted to the surface of the object (to a depth of about 100 microns). This can be a problem with corrosion-prone bronze or copper alloy coinage, where the surface of the coin can be elementally quite different from the core, but is less of a concern with coins of more corrosion-resistant precious metals like silver or gold (Denker et al. 2005; Baldassari et al. 2014; Markou, Charalambous, and Kassianidou 2014, 34–35). Nevertheless, surface enrichment is still a potential problem with gold and silver, particularly if the coin is debased or *fourré* (having a core of base metal with an outer layer of precious metal) (Beck et al. 2004). Surface enrichment

is a phenomenon that occurs over time, especially if a coin or metal object is buried, in which less-stable elements leach out of the alloy, leaving the more stable noble metals behind. This results in a higher concentration of precious metal on the surface of the coin. The coin's surface can also undergo oxidation and can be contaminated by elements from the soil as well as by nearby objects, particularly if it comes from a hoard. XRF is, however, generally recommended as the first step in a metallurgical analysis, as it is relatively inexpensive, portable (in the case pXRF), and nondestructive, and its results can inform scholars and scientists as to what type of further analysis might help them answer their research questions (Guerra 2008; Caponetti et al. 2017; Davis et al. 2020). The XRF machine used for these analyses was built by Professor Stefano Ridolfi of Labor Artis CR Diagnostica, SRL specifically for the purposes of cultural heritage applications.[1]

CASE-STUDY I: THE VOLTERRA HOARD

The earliest coin hoard from Etruria, the Volterra hoard was discovered in 1868 in a bucchero vase near the walls of Volterra (*IGCH* 1875; Cristofani Martelli 1976, 87; Catalli 1990, 33; Vecchi 2012a, 1:22). It was deposited around 500 BC. The hoard originally contained 65 silver coins, almost all in small denominations.[2] While some of the coins have long been identified as Phokaian, similar to coins in the Auriol Hoard (*IGCH* 2352), another group—bearing Gorgoneia and Hippalektryones or Pegasi—have been attributed variously to Lampsacus,

1. The X-ray machine is completely home-made, and operates at a maximum power of 30 kV (kilovolts), with a maximum current of 0.01 mA (milliamperes). The X-ray detector itself is an XR-100 SDD (Silicon Drift Detector) unit manufactured by Amptek. The detector has an active area of 25 mm^2, a 500 μm-thick crystal, and a resolution of 125 eV FWHM at 5.9 keV. We tested two points on each coin, one on the obverse and one on the reverse. This relatively small sample size was necessary on account of time limitations, but with coins as small as most of those from the Volterra hoard two samples is certainly acceptable. There were no coins in which the two sides were significantly different so the table of results displays the average of both sides of the coin. The XRF machine is fitted with a small camera, which allowed us to photograph the exact location of the test, and which also allowed us to avoid any areas of the coin that were visibly encrusted or corroded. Professor Ridolfi undertook all of the actual readings. At the beginning and end of each testing session, as well as periodically during the session, Prof. Ridolfi would take readings of samples of metal of known composition and alloy that were produced for him by a jeweler as controls to ensure that the machine was properly calibrated. Prof. Ridolfi assembled the numerical data and the results using the Amptek visualization software (DPPMCA Display & Acquisition Software for Windows).

2. Two gold coins originally attributed to the hoard and identified as Etruscan are now thought to have come from the much later Cecina Hoard, possibly deposited in 300 BC, near modern Livorno (*IGCH* 1954).

Figure 1. Phokaian coin from the Volterra hoard, circa 500 BC (inv. 83099–11). Photo reproduced by permission of the Museo Archeologico Nazionale di Firenze (Direzione regionale Musei della Toscana).

Figure 2. "Colonial" Phokaian coin from the Volterra hoard, circa 500 BC (inv. 83099–2) (Massalian or Emporitan). Photo reproduced by permission of the Museo Archeologico Nazionale di Firenze (Direzione regionale Musei della Toscana).

Etruria, and southern Gaul (for the Auriol hoard, see Furtwängler 1978). XRF analysis was undertaken with the hope of answering some of the questions surrounding the unattributed coinage in the hoard, for example whether any of the coins are of Etruscan manufacture. It was thus decided to test these coins against a control group consisting of the earliest confirmed Etruscan coinage of the fifth century: the Populonian Monsters and Animals and the First Metus issues.

In addition to the coins, the Volterra hoard contained about a kilogram of silver bars and a small silver lion (Catalli 1990, 33). Unfortunately, the ingots were melted down, destroying a potential source of evidence for silver weight standards, the source of the metal, and metallurgical practice (Gammurini 1872, 208; Cristofani Martelli 1976, 87). The discovery of coins in the company of such silver objects supports the hypothesis that in this early period the Etruscans conceived of coins essentially as small ingots, using them by weight in the manner of *hacksilber* (Catalli 1990, 35). This would be in keeping with the native Italic tradition of metal exchange by weight (Cristofani 1986, 141).

M. Cristofani Martelli divides the 52 known coins from the Volterra hoard into two metrological groups. The first group is further divided into two subgroups. The first subgroup is represented by a single coin with a swimming seal on the obverse and an incuse square on the reverse, weighing 1.30 grams (inv. 83099–11) (Fig. 1). The second subgroup is made up of twelve smaller coins ranging from 0.54 grams to 0.69 grams, with a mean of 0.63 grams. These smaller coins bear diverse types including a female head, a helmet, the head of a seal, a goat's head, a ram's head (inv. 83099–2) (Fig. 2), and an eagle's head. Cristofani Martelli notes the stylistic and metrological conformity with coins known from contexts in the Phokaian sphere of influence, citing comparanda from Etruria itself, Auriol, Marseilles (Massalia), Saint Rémy in southern France, and Ampurias (Emporion) in Catalonia (Cristofani Martelli 1976, 98–99).

Figure 3. Hippalektryon from the Volterra hoard, circa 500 BC (inv. 111020). Photo reproduced by permission of the Museo Archeologico Nazionale di Firenze (Direzione regionale Musei della Toscana).

Figure 4. Gorgoneion from the Volterra hoard, circa 500 BC (inv. 83099–14). Photo reproduced by permission of the Museo Archeologico Nazionale di Firenze (Direzione regionale Musei della Toscana).

The second metrological group also consists of two subgroups, each of which includes a single type. The first is represented by 24 coins bearing a Pegasus or more likely a Hippalektryon on the obverse and an incuse square on the reverse (inv. 111020) (Fig. 3). These range between 0.85 and 1.33 grams in weight with a mean weight of 1.06 grams (Cristofani Martelli 1976, 97). The other type is a smaller coin bearing a Gorgoneion on the obverse and an incuse square reverse (inv. 83099–14) (Fig. 4). This subgroup is represented by 15 specimens weighing between 0.40 and 0.65 grams, with a mean of 0.53 grams (Cristofani Martelli 1976, 97). Neither of these coin types is unique to this hoard. Examples of the Hippalektryon type have been found in France, including two examples reportedly discovered near Marseilles (Catalli 1990, 34). Examples of both Gorgoneia and Hippalektryones have recently been seen on the French numismatic market, with provenances claiming that they were discovered in France.[3] This tends to confirm the contextualized evidence suggesting a concentration of this type in southern France in the neighborhood of Marseilles.

Cristofani Martelli's diverse first group is generally accepted as being of Phokaian origin, but there has been a vigorous debate regarding the attribution of the Hippalektryones and Gorgoneia. Though in the past the Hippalektryon/Pegasus type was identified as a Lampsacene issue, Cristofani Martelli rejects this on typological and stylistic grounds. Describing the style as "imitative," she suggests that they might be Etruscan—specifically Populonian—on the basis of iconographical and historical evidence (Cristofani Martelli 1976, 99, 104). I am inclined to agree that the extreme crudeness of the engraving among the

3. See for example CGB Numismatique Paris v28 0493 (Gorgon); CGB Numismatique Paris, Dicomon.OBE-1, 28 F (Hippalektryon). Unfortunately, the lack of formal provenance and archaeological context of for these coins hinders our ability to use them as solid evidence—sadly quite typical of material from the numismatic market.

coins of the Volterra hoard precludes an attribution to the mint of Lampsacus, whose product was far superior in technical execution at the time and which bore not the Hippalektryon but only the forepart of Pegasus (Kraay 1976, 29–30, pls. III–IV, nos. 73–74). A. E. Furtwängler tentatively supports an Etruscan identification, arguing on both stylistic and metrological grounds against the notion reflected in *IGCH* 1875 that the Hippalektryones/Pegasi and Gorgoneia ought to be associated with the Auriol-type coins of southern France, like others in the hoard (Furtwängler 1978, 41–44; 1993, 431–38). C. Arnold-Biucchi follows Furtwängler and Cristofani Martelli, and agrees that the Gorgoneia and Hippalektryones might represent the earliest Etruscan coinage (Arnold-Biucchi 2002, 54). The National Archaeological Museum in Florence positively attributes the coinage to Populonia, following Catalli.[4]

That said, Rutter's estimation of the positive attribution to Populonia as "hypothetical" is absolutely correct (Rutter 2001, 29). Though it is possible that these coins are Etruscan, there is no direct evidence that they were minted in Etruria, much less at Populonia. It must be said that if the Hippalektryones and Gorgoneia are Etruscan coins, they would be the only ones known from the period to bear incuse punches on the reverse: all of the earliest confirmed Etruscan coins have distinctive smooth reverses, as evinced by the Monsters and Animals and First Metus coinage.

The tentative Etruscan attribution of the Volterra hoard has been challenged recently, and some modern scholars suggest a foreign, perhaps Gallic, origin for most of the coins in the hoard. In Rutter's view, "it remains very doubtful whether any of [the coins in the Volterra hoard] are in fact Etruscan" (Rutter 2001, 29). He cites the recent discovery at Gignac, in the southern French region of Occitanie, of a piece identical to one of the Hippalektryones in the hoard. As mentioned above, coins identical in style to these have emerged on the French numismatic market along with claims that they were found in the area around Marseilles. If true, this supports the argument that they were struck nearby, within the Phokaian sphere of influence. Although we must take such evidence *cum grano salis* given the unfortunate lack of context and provenance, the notes provided with some of the Gorgoneia and Hippalektryones on the market indicate that they were discovered on the Provençal coast of France, between the Étang de Berre—the great coastal lagoon about 25 kilometers northwest of Marseilles—and the sea.[5] The fact that the Volterra hoard provides the only evidence

4. *SNG Florence*.

5. CGB Numismatique Paris, LT.1/87 BN.93, groupe M1, pl. 16–17; Monnaies 8 (2000) (Gorgon) (previously VSO); C. Burgan 30 (1992), no. 180; Monnaies II (1997), no. 35; CGB Numismatique Paris Monnaies 8 (2000) (Hippalektryon).

Figure 7. Heavily-leaded Hippalektryon from Volterra hoard, interpreted by the author as an ancient imitation, circa 500 BC (inv. 83099–31).
Photo reproduced by permission of the Museo Archeologico Nazionale di Firenze (Direzione regionale Musei della Toscana).

of these coins in Italy and that individual specimens of the Gorgon and Hippalektryon types have been found around southern France suggests that the coins are indeed of Gallic origin.

The XRF compositional analysis shows a high level of silver purity among almost all the coins in the hoard, though we must always keep in mind the possibility of surface enrichment. Copper content ranges between 0.6 and 1.8%, which is roughly consistent with the approximately 1% naturally-occurring copper content typical of ancient silver when smelted directly from ore. Any more than this and the likelihood increases that copper has been introduced on purpose or that the metal used has been recycled and contains more copper than would naturally occur in the ore (Tykot 2020). Of 52 coins, 51 have a silver content of between 97% and 98.9% with an average of purity of 98.4% (Figs. 5–6, below). This level of fineness is comparable to that of the silver coins from the Phokaian colony of Emporion in Spain (Pitarch and Queralt 2010; Westner et al. 2020) and is indeed typical of Greek coinage (Westner et al. 2020, 582). Every coin in the Volterra hoard has a silver content of at least 97% with the exception of one: a heavily-leaded Hippalektryon that is also the only one among the hoard without an incuse square on the reverse (inv. 83099-31) (Fig. 7). To my knowledge, no one has ever noted this lack of an incuse square in publication. It weighs 0.85 grams—the lowest by 1/10 of a gram of all the Hippalektryones—and it is only 83.5% silver, with a significant 14% lead content (Fig. 8, below). This high lead content is very suspect considering the high purity of the other Gorgoneia and Hippalektryones, so it is unlikely that this leaded piece is a genuine coin from the minting city.

Considering that this coin is less pure silver than all the other Hippalektryones by almost 15%, that it is adulterated with lead, and that it bears no incuse square, it may be tentatively identified as an ancient forgery. It is small and underweight, but the addition of lead makes the coin heavy for its size and therefore more likely to fool an unsuspecting person. The earliest known Etruscan coins, dated to within decades of the deposition of the Volterra hoard, all lack reverse types. Greek and Gallic coins, on the other hand, never lack reverse types (with the exception of the unrelated Cypriot examples discussed earlier). This

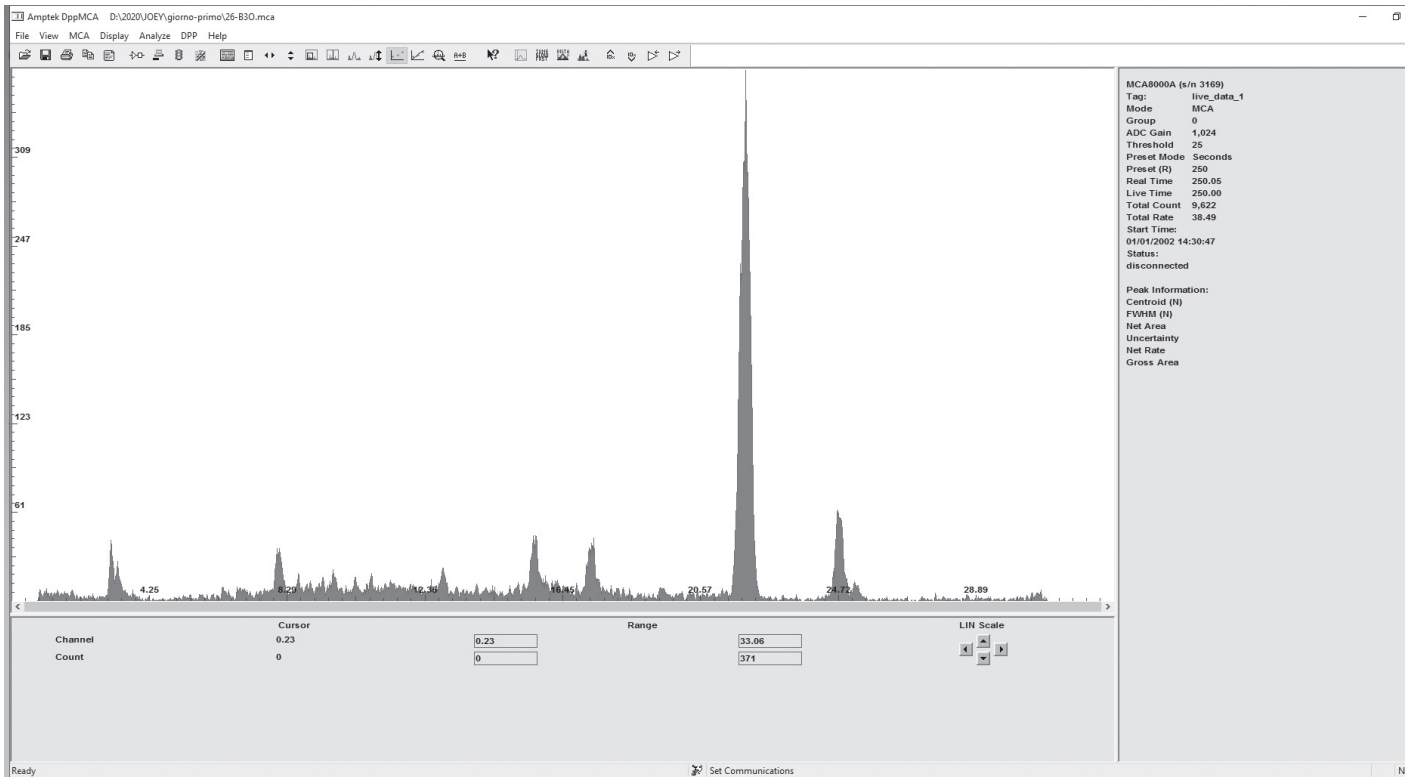

Figure 5a. Graphic representation of the metallic composition of Hippalektryon inv. 111020 (obverse).

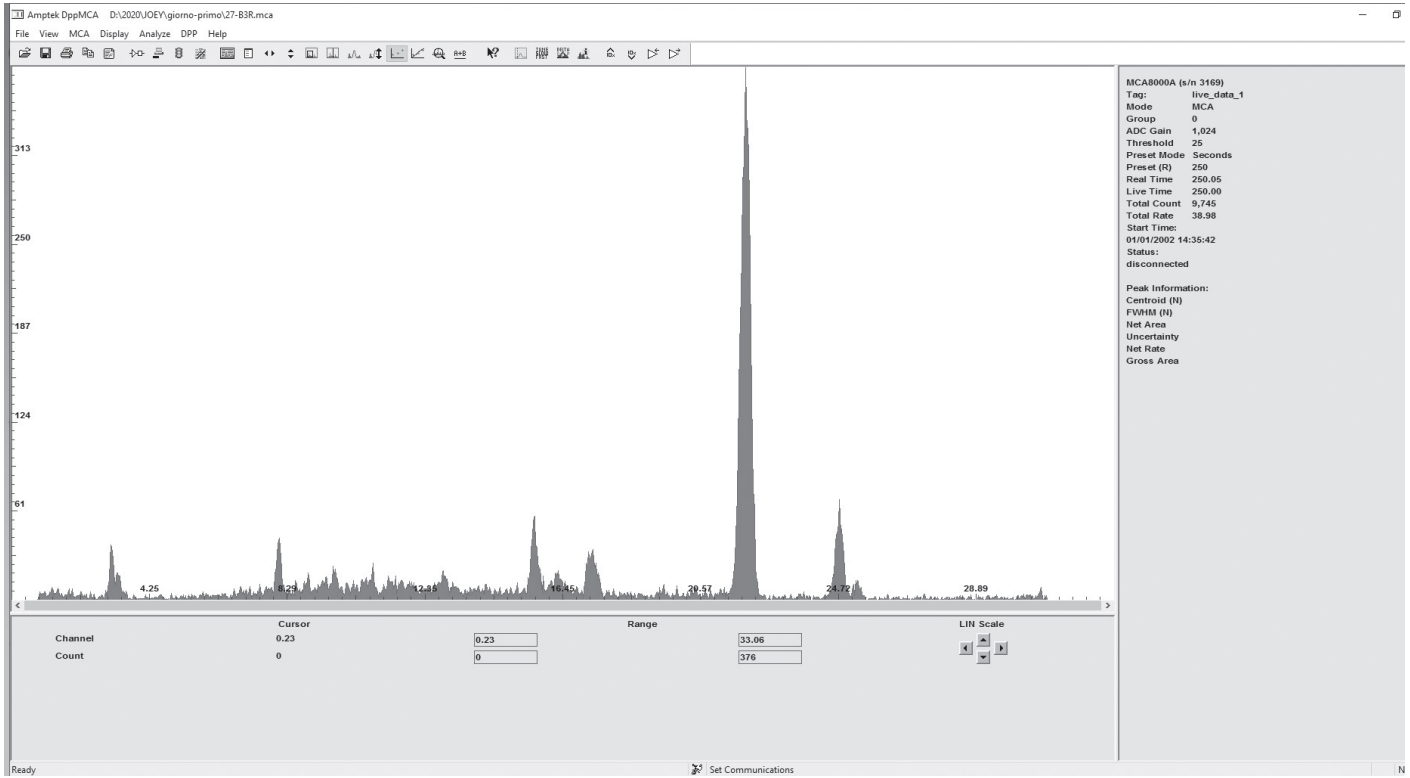

Figure 5b. Graphic representation of the metallic composition of Hippalektryon inv. 111020 (reverse).

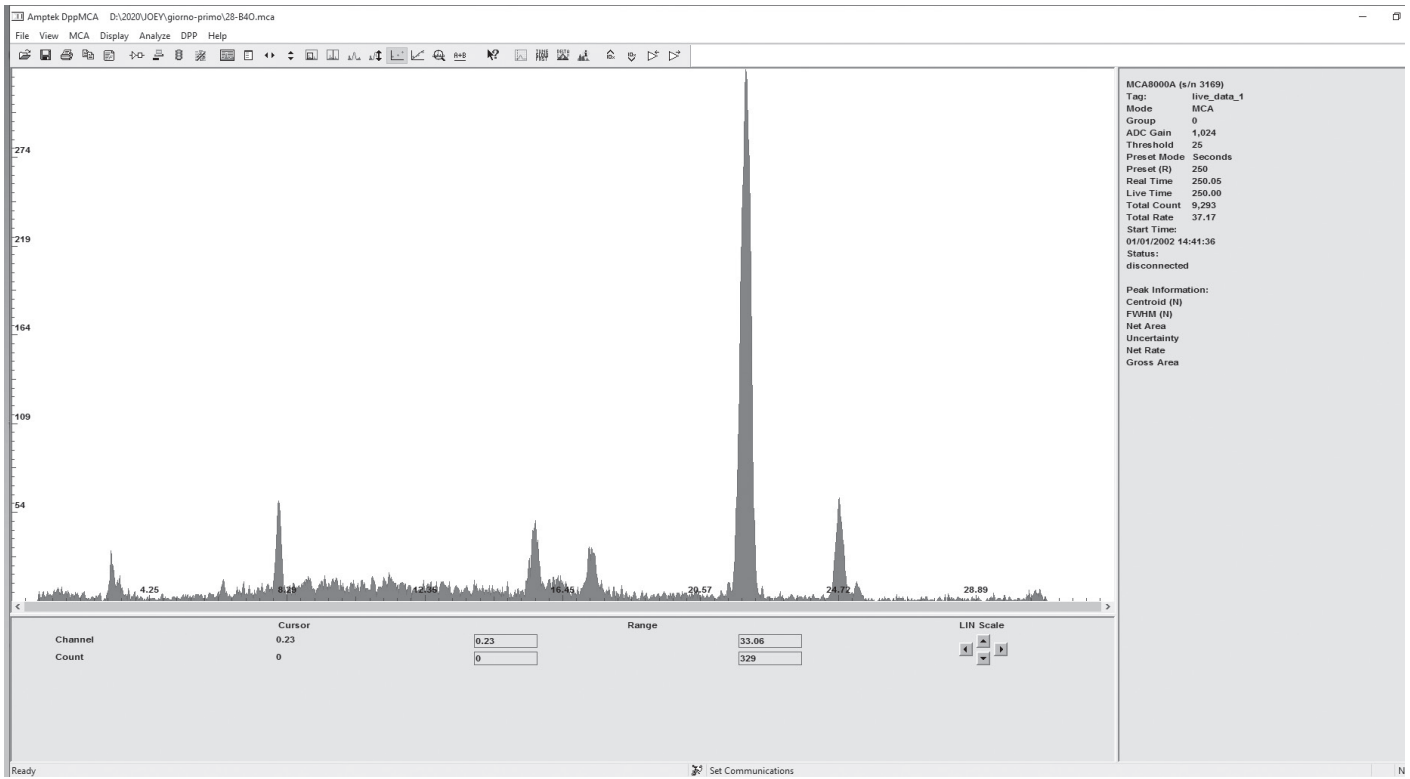

Figure 6a. Graphic representation of the metallic composition of Gorgoneion inv. 83099-14 (obverse).

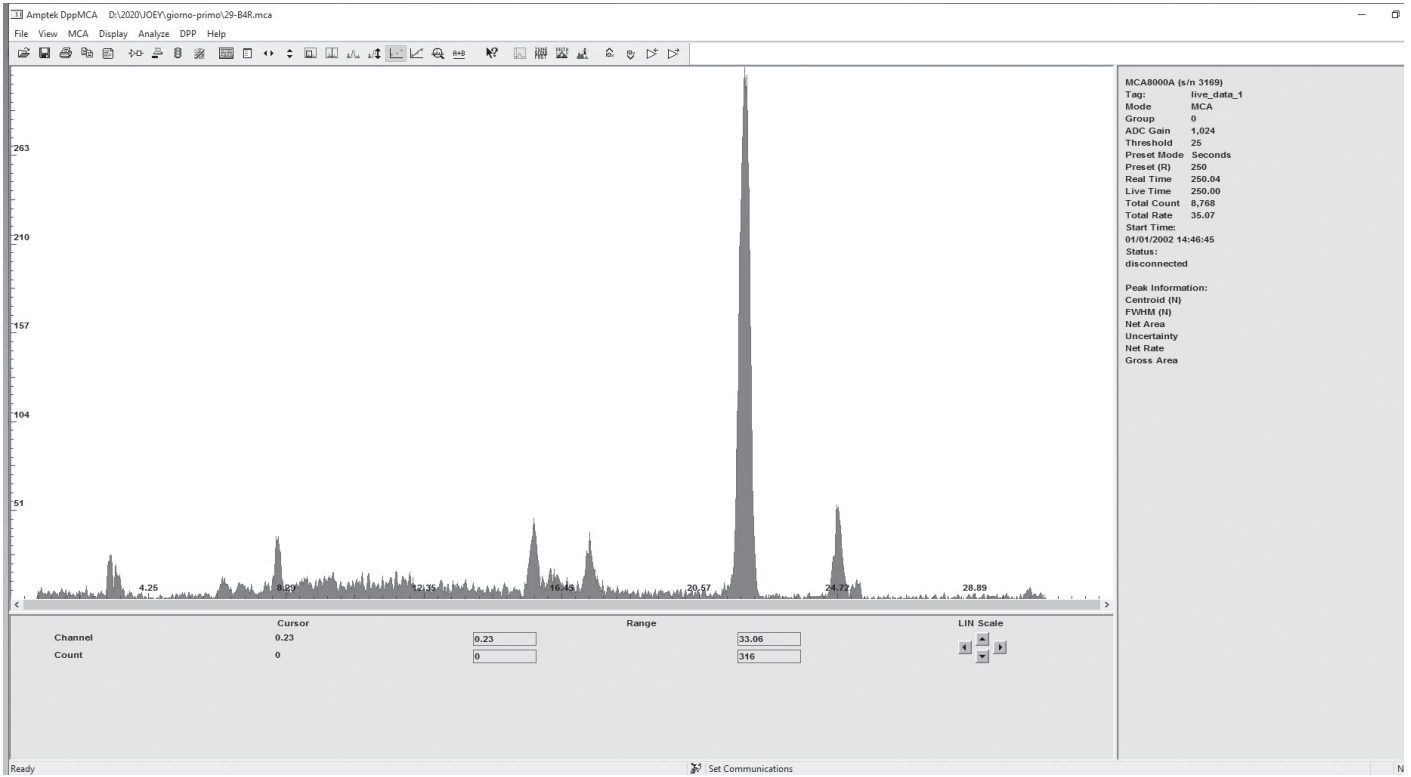

Figure 6b. Graphic representation of the metallic composition of Gorgoneion inv. 83099-14 (reverse).

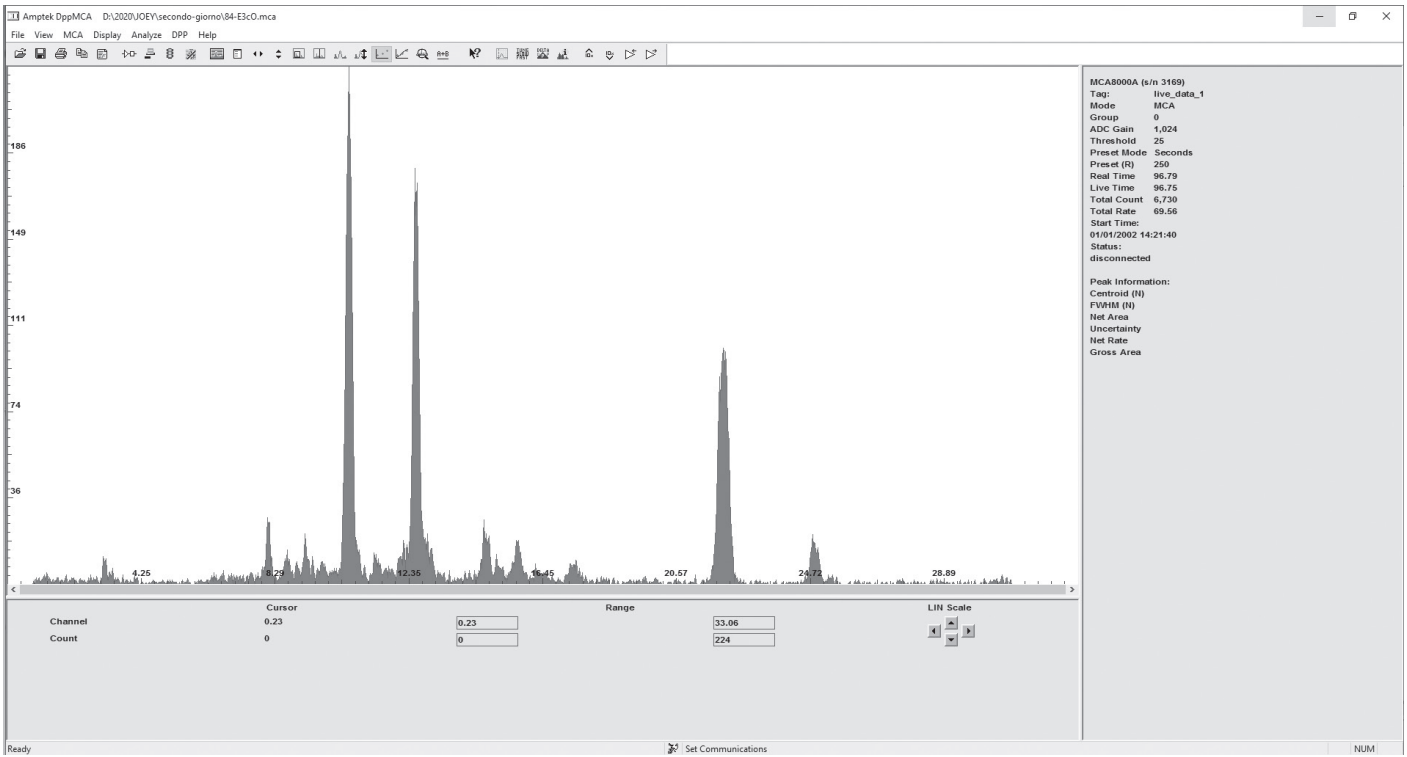

Figure 8a. Graphic representation of the metallic composition of Hippalektryon inv. 83099-31 (obverse).

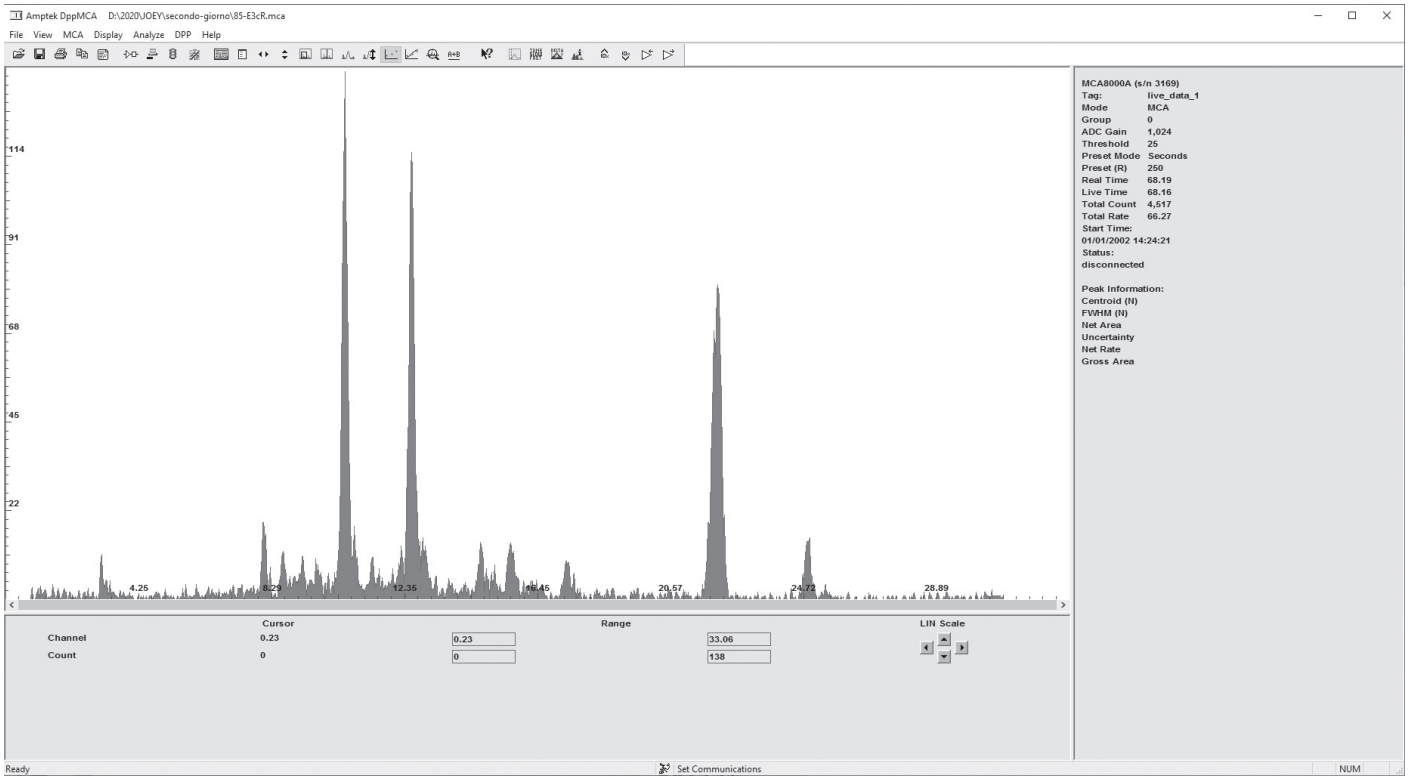

Figure 8b. Graphic representation of the metallic composition of Hippalektryon inv. 83099-31 (reverse).

suggests that the coin in question is a forgery made by a person who recognized an existing Etruscan expectation that some coins lack reverse types. Perhaps the maker himself did not think that coins needed a reverse type. This may indicate that the coin is a local forgery for an Etruscan audience, possibly made by an Etruscan unused to the notion of reverse types or punches. This counterfeit would thus have been most effective in the Etruscan market rather than as a coin circulating among Greeks, who likely would have noticed the lack of a punch. That it is unique suggests that it was a local forgery rather than an imitation produced en masse.

The lack of an incuse punch on this Etruscan-style forgery thus strengthens the argument against an Etruscan attribution for the rest of the Hippalektryones and Gorgoneia, because the rest share a reverse type, typical of Greek coins, while early Etruscan coins like the Monsters and Animals and First Metus do not have reverse punches. Taking into consideration both this technical difference and the discovery of similar coins in southern France, it is likely that the Hippalektryones and Gorgoneia were made in Gaul by Greeks or under strong Greek influence. Their presence in Etruria attests to the strong trade connections between the Greeks in southern Gaul and the Etruscans, reflected in the large quantity of Etruscan ceramics found in the area of Marseilles (Camporeale 2016, 78).

CASE-STUDY II: THE EARLIEST ETRUSCAN COINAGES

In order to provide a control against which the coins from the Volterra hoard could be compared, it was necessary to analyze specimens of confirmed Etruscan coinage.[6] In this case our sample consisted of examples of the Monsters and Animals Series and the First Metus. These coins were chosen on the basis of the geographic proximity of their mints to the hoard, their relative contemporaneity, and their availability at the museum. Only five were tested on account of time limitations and ongoing work at the Coin Cabinet that limited access to certain specimens.

XRF analysis was performed on three examples of the Monsters and Animals series held in the National Archaeological Museum in Florence: two tridrachms with the chimera (inv. 74179 and inv. 36254) and one didrachm with the lion-serpent hybrid (inv. 74069). They are consistent in terms of metallic composition. All are made from silver with a relatively high fineness, averaging 98% purity, but there was a slight divergence among them (2.9% divergence, more than among

6. Early Etruscan silver coinage is quite rare, and so our sample was limited to the coins available in the collection at the National Archaeological Museum of Florence, consisting of three examples of the Monsters and Animals series and two of the First Metus.

Figure 9. Chimera of Populonia, fifth century BC (inv. 36254).
Photo reproduced by permission of the Museo Archeologico Nazionale di Firenze (Direzione regionale Musei della Toscana).

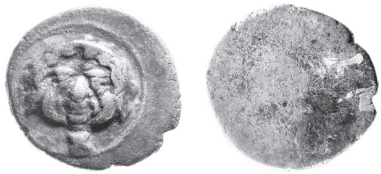

Figure 10. First Metus of Populonia, 450–400 BC (inv. 74044).
Photo reproduced by permission of the Museo Archeologico Nazionale di Firenze (Direzione regionale Musei della Toscana).

the coins of the Volterra hoard). One tridrachm (inv. 74179) was 96.4% and the other (inv. 36254) (Fig. 9) was 98.6% silver, while the didrachm (inv. 74069) was 99.3%. The levels of purity, as well as the composition of the alloy, displayed by the latter two are consistent with good-quality coinage of this period (Pitarch and Queralt 2010). Tridrachm 74179, on the other hand, contains 3.1% copper, which may suggest either that copper was added to the alloy or that metal containing more copper than would occur naturally was recycled to produce this coin.

Finally, we undertook analysis of two examples of the Populonian First Metus series (450–400 BC). One (inv. 74044) (Fig. 10) was 97.9% silver (Fig. 11, below), while the other (inv. 36259) (Fig. 12, below) was only 89.2% silver, with 10.2% copper (Fig. 13, below). The former is what we might expect of coinage in the region (Pitarch and Queralt 2010). The latter, however, is quite low. This coin has a provenance dating to 1775, when it was listed among coins belonging to the Cabinet of Medals of the Uffizi Galleries as part of the Granducal Collection (*SNG Florence*, 16; Pelli 1787, I:87, no. 3; Migliarini 1850, no. 464).

The alloy of roughly 90% silver and 10% copper is an outlier, and differs significantly not only from every coin in the Volterra hoard, but also from all four other examples of early Etruscan coinage. This alloy is not at all typical of Archaic

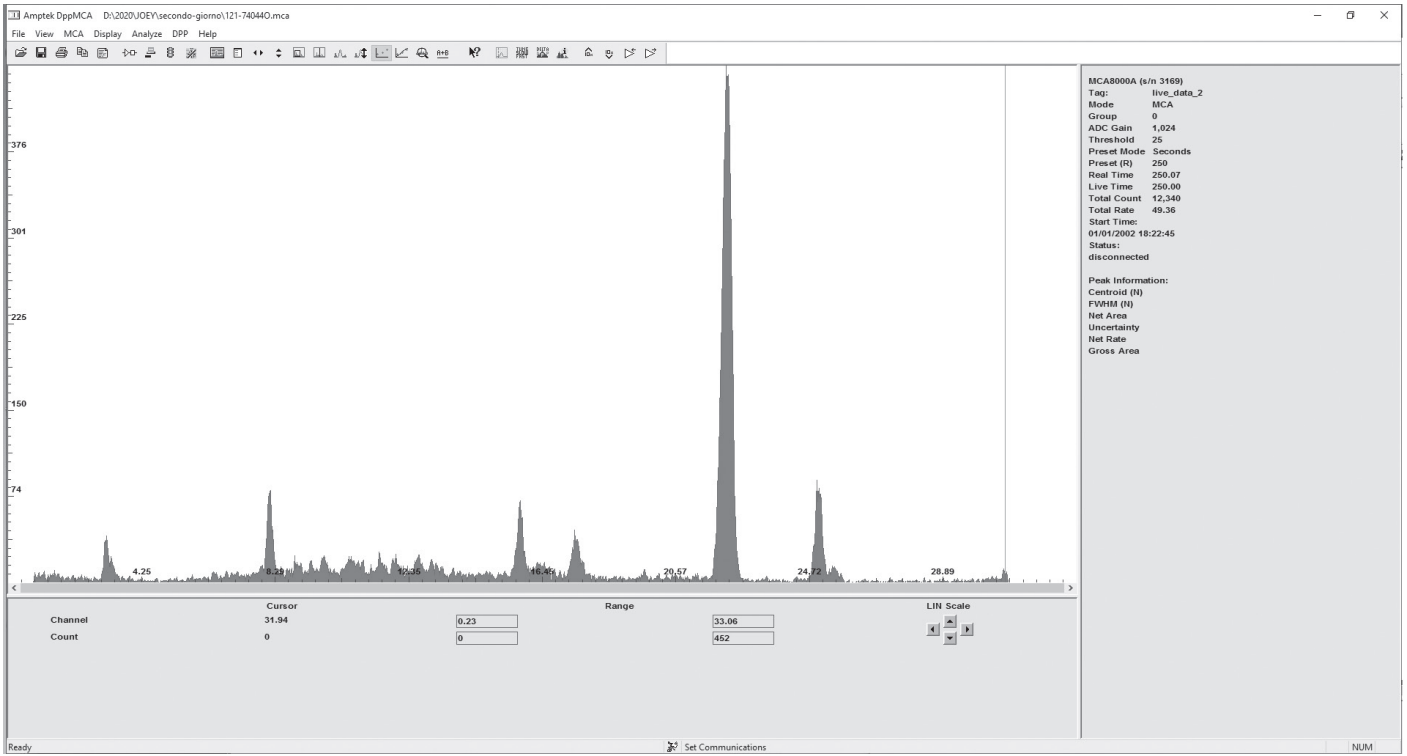

Figure 11a. Graphic representation of the metallic composition of First Metus inv. 74044 (obverse).

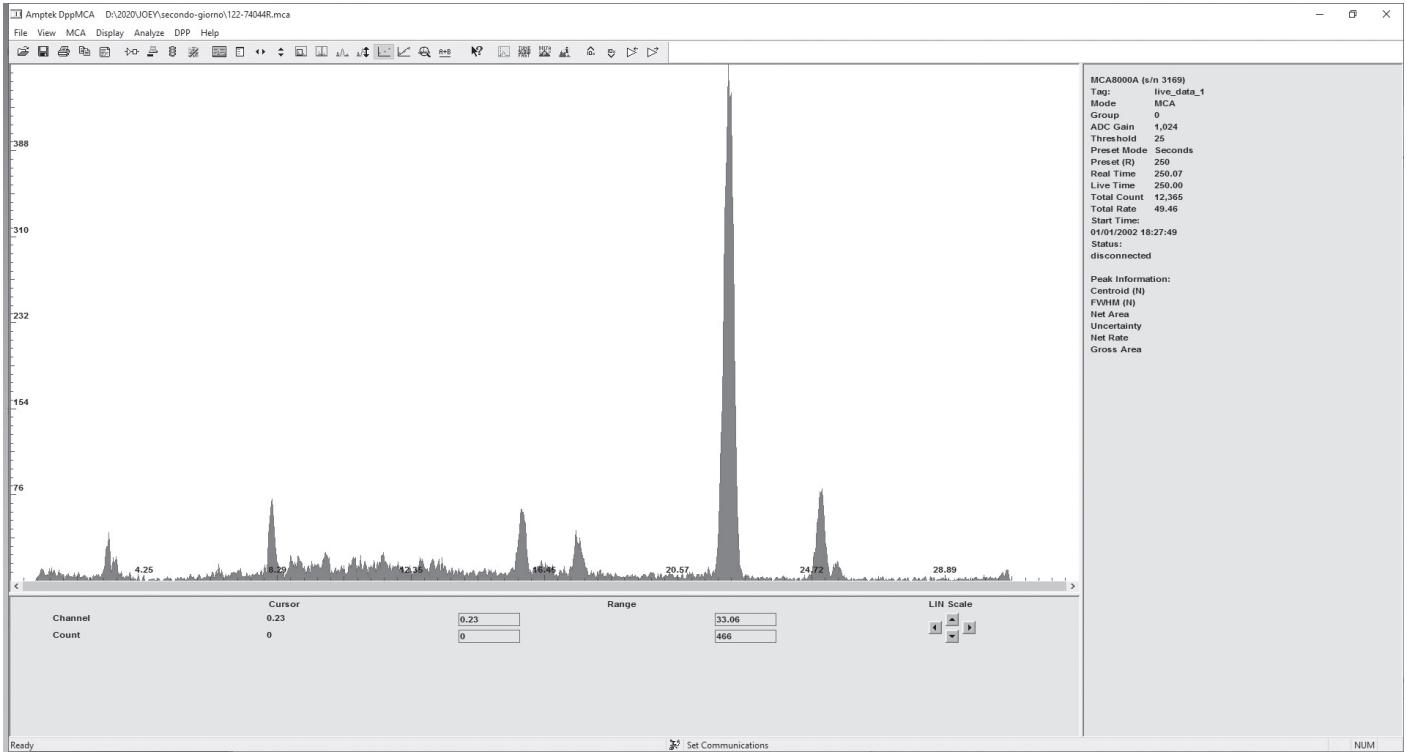

Figure 11b. Graphic representation of the metallic composition of First Metus inv. 74044 (reverse).

Figure 12. First Metus of Populonia, 450–400 BC (inv. 36259), interpreted by the author as an eighteenth-century forgery.
Photo reproduced by permission of the Museo Archeologico Nazionale di Firenze (Direzione regionale Musei della Toscana).

and early Classical coinage in the region, but is similar to some intentionally-debased Roman coins of the third century BC (Westner et al. 2020, 587).

In fact, the alloy is consistent with several varieties of eighteenth-century Italian coinage. For example, the currencies of the Duchies of Savoy and of Parma were minted at 0.900 fineness, or 90% silver and 10% copper, from about the middle of the eighteenth century (Michels 1884, 98). An example is the silver *scudo* of Carlo Emanuele III of Savoy (minted 1755–1769, Krause-Mishler #48). While not definitive, the fact that this First Metus is a significant outlier in terms of alloy and has a metallic composition more typical of modern Italian coinage than ancient might suggest that it is a forgery. By its appearance alone, one is drawn to suspect that this coin is a modern forgery that made its way into the collection. The quality of the engraving and the preservation of the coin are significantly better than most other examples of the First Metus. The level of detail is far superior, in particular the precise rendering of the teeth. The beaded border is both complete and relatively well-centered, which sets this coin apart from many of its fellows. The patina, too, appears suspect in that it is heavily blackened around the edges of the details while it is bright and clean where the design is raised, for example the cheeks, nose, and hair.

Suspect, too, that this coin is exactly identical to another rather questionable-looking example held in the Bibliothèque nationale de France (*SNG Paris* 3) and first attested in the de Luynes collection in 1840 (Vecchi 2012a, 1:86, no. 8.42) (Fig. 14, below). These coins appear to have been struck from the same die, which strengthens the likelihood that this is the work of a modern forger. In addition to all of the suspect elements listed above—shared as they are by both coins—it is extremely rare to have such an exact die-match in such a limited issue as the First Metus. The mid-nineteenth-century provenance of the second coin (*SNG Paris* 3; Vecchi no. 8.42) should not deter us from tentatively identifying it as a modern fake, along with its eighteenth-century fellow (inv. 36259; Vecchi

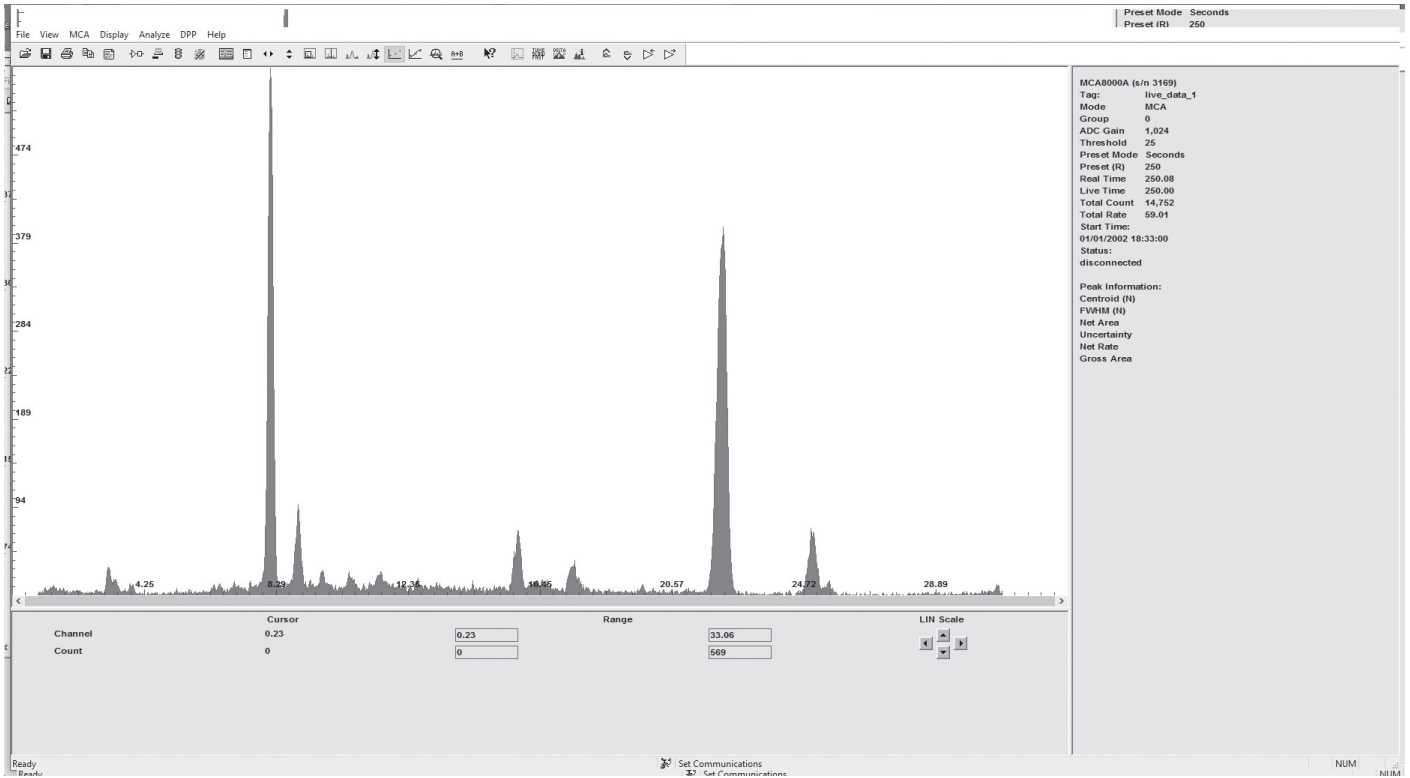

Figure 13a. Graphic representation of the metallic composition of First Metus inv. 36259 (obverse).

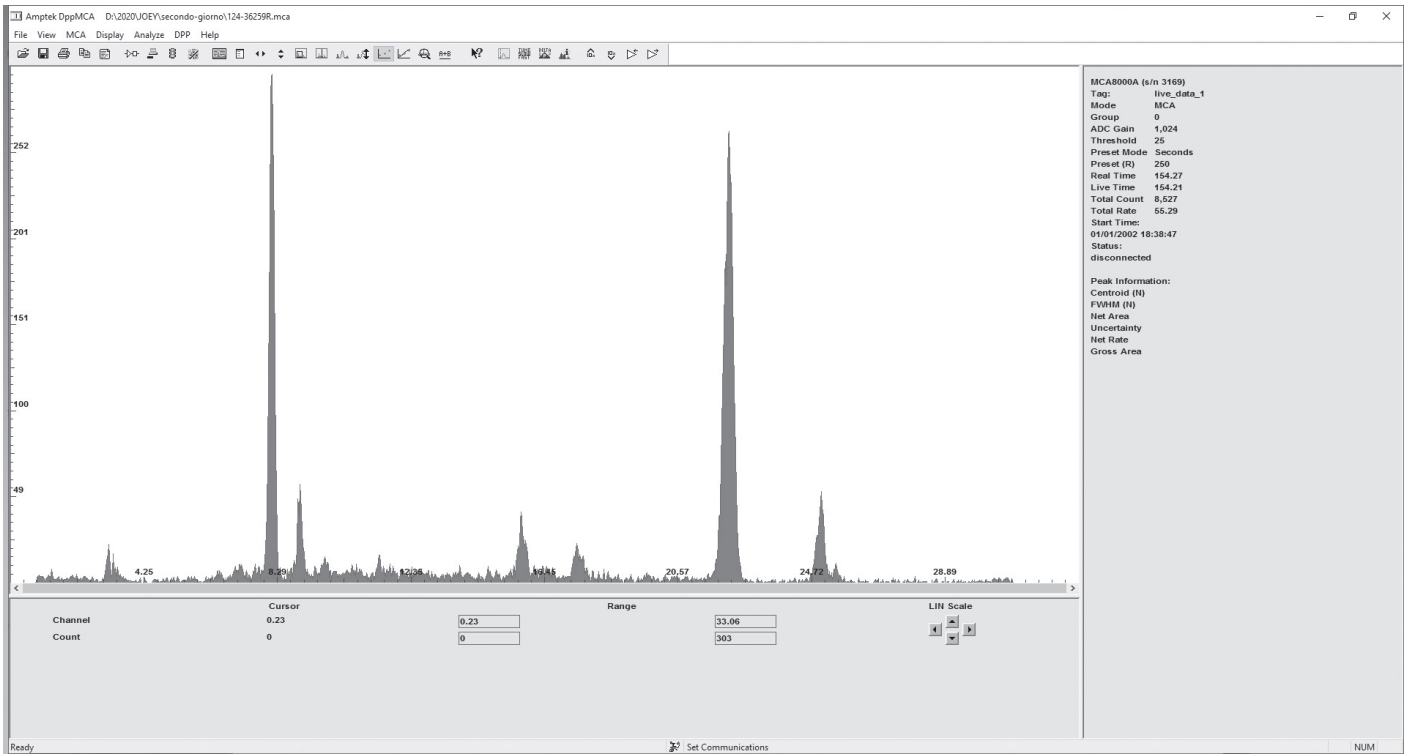

Figure 13b. Graphic representation of the metallic composition of First Metus inv. 36259 (reverse).

Figure 14. First Metus of Populonia, 450–400 BC (*SNG Paris* 3; BnF identifier ark:/12148/btv1b11315162h; Vecchi 2012, 2:613, pl. 13, no. 8.42), interpreted by the author as an eighteenth-century forgery.
Source gallica.bnf.fr / Bibliothèque nationale de France.

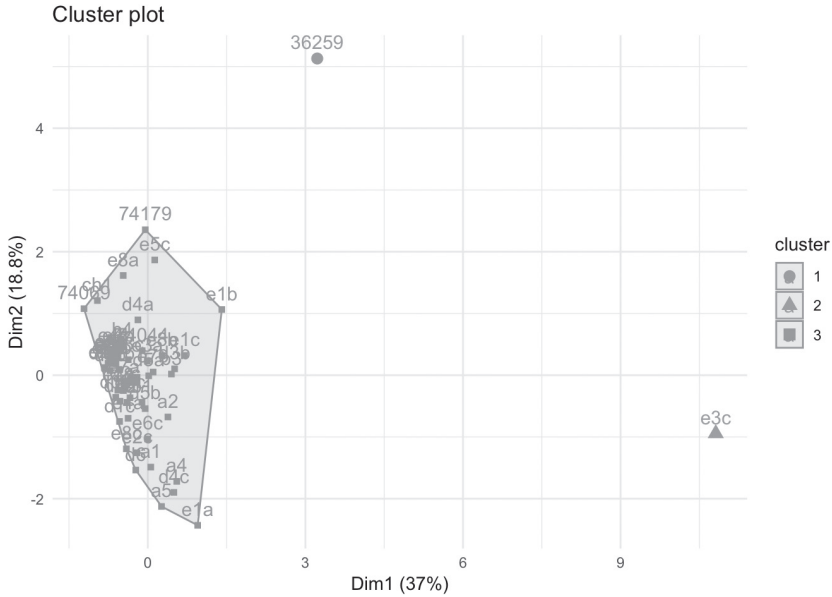

Figure 15. Clustering analysis of all of the coins of the Volterra hoard in addition to the three Monsters and Animals and two First Metus.

no. 8.39), as the falsification of Etruscan coins in Italy dates at least to the late eighteenth century (Lanzi 1825, 3:559). It is not beyond the realm of possibility that the duc de Luynes purchased a forgery prior to 1840, and that the Florence forgery made its way into the Uffizi by 1775. These coins were likely made from the same die, perhaps by the same forger. Neither of these coins have any sort of archaeological provenance that would serve to contradict a tentative identification as modern fakes. It should be noted that Vecchi does not identify either of these coins as fakes, but he did not have at his disposal the XRF results that revealed the coin (inv. 36259) as an outlier.

The XRF results may support the hunch that this coin is an eighteenth-century forgery. Here, the clustering analysis of our results (Fig. 15, above) is invaluable, as it presents a consistent cluster contrasted starkly with two major outliers.[7] The point marked "e3c" corresponds to the heavily-leaded Hippalektryon (inv. 83099–31) that I have interpreted as an ancient forgery, while the point marked "36259" is the First Metus that I have identified as a modern forgery (inv. 32659).

The fact that this First Metus is of suspect appearance and that it has a metallic composition exactly consistent with eighteenth-century coinage (roughly 90% silver and 10% copper) allows us to tentatively identify it as a forgery made from melted-down eighteenth-century coinage. Such a phenomenon would not be unlikely in Etruscan-obsessed Italy of the eighteenth and nineteenth century, following the posthumous publication of T. Dempster's *De Etruria Regali* in 1720. During this period some of the earliest Etruscan fakes were known to have been created by the prolific Italian forgers of the time (Vecchi 2012b, 2:433; Hansson 2020).

CONCLUSION

XRF analysis of the Volterra hoard and the earliest Etruscan coins indicate that the vast majority of the coins are of nearly pure silver, consistent with high-quality Archaic and early Classical coinage. The analysis also distinguished two significant outliers. One, a Hippalektryon from the Volterra hoard, is heavily leaded and lacks an incuse punch, suggesting that it is an ancient (perhaps Etruscan) forgery of the Greek coin type. If correct, this coin (inv. 83099–31) holds great significance for it would be the earliest extant coin produced in Etruria, as the hoard in which it was found is dated to 500 BC. Another, a First Metus (inv. 36259), has a metallic composition more similar to eighteenth- and nineteenth-century European coinage than to ancient coinage. Given this fact, as well as its suspect appearance and its lack of archaeological provenance, it may be that this coin is a modern Italian forgery. While the original question of the attribution of the Gorgoneia and Hippalektryones may remain uncertain, these two case-studies demonstrate the value of XRF as a first-wave, non-destructive, affordable means of metallurgical analysis in detecting outliers among coin assemblages, as well as indicating that further analysis is necessary to adequately address the problems related to the Volterra hoard.

7. Thanks to Doctor Evan Stein, Statistical Consultant with the Department of Statistics and Data Sciences at the University of Texas at Austin, for his invaluable assistance in visualizing this data.

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Table 1. XRF Results*

Obverse	Reverse	Weight (g)	Inv. Nos.	XRF Nos.	References	Ag (%)	Cu (%)	Pb (%)	Zn (%)	Au (%)	Bi %)	Fe (%)	Br (Y/N)
Goat head†	Incuse square	0.65	83099–3	a6	Cristofani Martelli 7 (this coin)	98.5	1.1	0.2	0	0.2	0	0.1	N
Bird head†	Incuse square	0.64	83099–1	a7	Cristofani Martelli 8 (this coin)	98.4	1.2	0.2	0	0.2	0	0.1	N
Female head†	Incuse square	0.61	83099–4	a8	Cristofani Martelli 10 (this coin)	98.8	0.9	0	0	0.3	0.1	0	N
Female head†	Incuse square	0.64	111006	e1b	Cristofani Martelli 9 (this coin)	97	1.3	0.3	0	0.3	0.2	1	N
Female head†	Incuse square	0.63	111026	e6b	Cristofani Martelli 11 (this coin)	98.7	1.1	0	0	0.2	0	0.1	N
Ionian helmet†	Incuse square	0.54	83099–5	b1	Cristofani Martelli 13 (this coin)	98.4	1.1	0.1	0.1	0.2	0.05	0.1	N
Ionian helmet†	Incuse square	0.60	83099–6	d4c	Cristofani Martelli 12 (this coin)	98.4	1	0.1	0.2	0.3	0.1	0	N
Ram head†	Incuse square	0.65	83099–2	a5	Cristofani Martelli 6 (this coin)	98.1	1	0.2	0.4	0.2	0	0.2	N
Seal†	Incuse square with cross	1.30	83099–11	a1	Cristofani Martelli 1 (this coin)	98.1	1.3	0	0.2	0.3	0	0.1	N

*The presence of the † symbol indicates that the coin is part of the Volterra hoard. The full results of my analysis are available as a web supplement, but DPPMCA Display & Acquisition Software for Windows is required to open the files. The column labelled "XRF Nos." contains the temporary numbers given to the coins during XRF analysis, and which are necessary for the interpretation of the supplemental data.

Obverse	Reverse	Weight (g)	Inv. Nos.	XRF Nos.	References	Ag (%)	Cu (%)	Pb (%)	Zn (%)	Au (%)	Bi %)	Fe (%)	Br (Y/N)
Seal head†	Incuse square	0.64	83099–8	a2	Cristofani Martelli 2 (this coin)	98.1	1	0.2	0	0.4	0.1	0.2	N
Seal head†	Incuse square	0.69	83099–7	a3	Cristofani Martelli 4 (this coin)	98.4	1.1	0.3	0	0.2	0	0.1	N
Seal head†	Incuse square	0.66	83099–10	a4	Cristofani Martelli 3 (this coin)	98.2	1.2	0	0.2	0.3	0.1	0.1	N
Seal head†	Incuse square	0.66	83099–9	e2c	Cristofani Martelli 5 (this coin)	98.5	0.9	0.1	0.1	0.4	0	0.1	N
Gorgon†	Incuse square	0.56	83099–14	b4	*HN Italy* 94; *SNG Firenze* 47 (this coin)	98.2	1.3	0.2	0	0.2	0	0.2	N
Gorgon†	Incuse square	0.55	83099–16	d1c	*HN Italy* 94; *SNG Firenze* 48 (this coin)	98.8	0.6	0.2	0	0.4	0	0.1	Y
Gorgon†	Incuse square	0.51	83099–17	d2c	*HN Italy* 94; *SNG Firenze* 54 (this coin)	98.4	1.1	0.2	0	0.3	0	0.1	N
Gorgon†	Incuse square	0.65	111008	d3b	*HN Italy* 94; *SNG Firenze* 43 (this coin)	98.3	1.2	0.1	0	0.2	0.2	0.1	N
Gorgon†	Incuse square	0.40	111009	d3c	*HN Italy* 94; *SNG Firenze* 57 (this coin)	98.4	1.4	0	0	0.2	0.1	0	N
Gorgon†	Incuse square	0.53	111012	d5a	*HN Italy* 94; *SNG Firenze* 50 (this coin)	98.4	1	0.1	0	0.3	0.1	0.2	N
Gorgon†	Incuse square	0.50	83099–13	d5b	*HN Italy* 94; *SNG Firenze* 55 (this coin)	98.7	0.8	0.1	0	0.3	0.1	0.1	Y
Gorgon†	Incuse square	0.52	111013	d5c	*HN Italy* 94; *SNG Firenze* 52 (this coin)	98.8	0.8	0	0	0.3	0.1	0.2	N

Obverse	Reverse	Weight (g)	Inv. Nos.	XRF Nos.	References	Ag (%)	Cu (%)	Pb (%)	Zn (%)	Au (%)	Bi %)	Fe (%)	Br (Y/N)
Gorgon†	Incuse square	0.49	111016	d6	*HN Italy* 94; *SNG Firenze* 56 (this coin)	98.6	0.9	0	0.2	0.3	0	0.1	N
Gorgon†	Incuse square	0.56	111011	e1c	*HN Italy* 94; *SNG Firenze* 46 (this coin)	97.9	1.4	0.2	0	0.2	0.2	0.1	N
Gorgon†	Incuse square	0.51	111010	e2b	*HN Italy* 94; *SNG Firenze* 53 (this coin)	98.5	1.1	0.1	0	0.3	0	0.2	N
Gorgon†	Incuse square	0.53	111014	e4c	*HN Italy* 94; *SNG Firenze* 51 (this coin)	98.5	1.2	0	0	0.2	0	0.2	N
Gorgon†	Incuse square	0.55	83099–12	e6c	*HN Italy* 94; *SNG Firenze* 49 (this coin)	98	1.2	0.3	0.2	0.2	0	0.1	N
Gorgon†	Incuse square	0.59	83099–15	e7c	*HN Italy* 94; *SNG Firenze* 44 (this coin)	98.7	0.9	0	0	0.3	0	0.2	Y
Gorgon†	Incuse square	0.56	111015	e8c	*HN Italy* 94; *SNG Firenze* 45 (this coin)	98.8	0.7	0.1	0.1	0.3	0	0.1	N
Hippalektryon†	Incuse square	1.14	83099–24	b2	*HN Italy* 92–93; *SNG Firenze* 21 (this coin)	98.4	1.3	0	0	0.4	0	0.1	N
Hippalektryon†	Incuse square	1.00	111018	e5b	*HN Italy* 92–93; *SNG Firenze* 41 (this coin)	98.6	1.1	0	0	0.2	0	0.1	Y
Hippalektryon†	Incuse square	1.04	111020	b3	*HN Italy* 92–93; *SNG Firenze* 40 (this coin)	98.5	1	0.1	0	0.2	0.2	0.1	N
Hippalektryon†	Incuse square	1.10	111017	d1a	*HN Italy* 92–93; *SNG Firenze* 39 (this coin)	98.9	0.9	0	0	0.2	0	0.1	N
Hippalektryon†	Incuse square	1.10	83099–25	d1b	*HN Italy* 92–93; *SNG Firenze* 22 (this coin)	98.7	1	0.2	0	0.2	0	0	N

Obverse	Reverse	Weight (g)	Inv. Nos.	XRF Nos.	References	Ag (%)	Cu (%)	Pb (%)	Zn (%)	Au (%)	Bi %)	Fe (%)	Br (Y/N)
Hippalektryon†	Incuse square	1.14	111007	d2a	*HN Italy* 92–93; *SNG Firenze* 38 (this coin)	98.6	0.9	0.2	0	0.2	0	0.1	N
Hippalektryon†	Incuse square	1.03	111021	d2b	*HN Italy* 92–93; *SNG Firenze* 27 (this coin)	98.4	1.2	0.3	0	0.2	0	0	N
Hippalektryon†	Incuse square	1.14	83099–27	d3a	*HN Italy* 92–93; *SNG Firenze* 20 (this coin)	98.7	1	0	0	0.3	0	0.1	Y
Hippalektryon†	Incuse square	1.02	83099–21	d4b	*HN Italy* 92–93; *SNG Firenze* 29 (this coin)	98.6	1	0.2	0	0.3	0	0	Y
Hippalektryon†	Incuse square with cross	1.09	111025	e1a	*HN Italy* 92–93; *SNG Firenze* 24 (this coin)	97.9	1.2	0.1	0.1	0.6	0.1	0.1	N
Hippalektryon†	Incuse square	1.33	83099–18	e2a	*HN Italy* 92–93; *SNG Firenze* 35 (this coin)	98.9	0.8	0	0	0.2	0	0.1	N
Hippalektryon†	Incuse square	0.95	111019	e3a	*HN Italy* 92–93; *SNG Firenze* 43 (this coin)	98.3	1.1	0.2	0	0.2	0.1	0.1	N
Hippalektryon†	Incuse square	0.95	83099–30	e3b	*HN Italy* 92–93; *SNG Firenze* 34 (this coin)	98.6	1	0.1	0	0.2	0	0.1	N
Hippalektryon†	Smooth	0.85	83099–31	e3c	*HN Italy* 92–93; *SNG Firenze* 35 (this coin)	83.5	1.5	14	0.2	0.4	0.5	0.1	N
Hippalektryon†	Incuse square	1.00	111022	e4a	*HN Italy* 92–93; *SNG Firenze* 31 (this coin)	98.5	1.2	0	0.1	0.3	0	0.1	N
Hippalektryon†	Incuse square	0.95	111023	e4b	*HN Italy* 92–93; *SNG Firenze* 33 (this coin)	98.3	1.4	0.1	0	0.2	0	0.1	N

Obverse	Reverse	Weight (g)	Inv. Nos.	XRF Nos.	References	Ag (%)	Cu (%)	Pb (%)	Zn (%)	Au (%)	Bi %)	Fe (%)	Br (Y/N)
Hippalektryon†	Incuse square	1.14	83099–19	e5a	*HN Italy* 92–93; *SNG Firenze* 37 (this coin)	98.6	1.1	0	0	0.2	0	0.1	Y
Hippalektryon†	Incuse square	1.20	111024	e6a	*HN Italy* 92–93; *SNG Firenze* 19 (this coin)	98.7	1.1	0	0	0.2	0	0.1	N
Hippalektryon†	Incuse square	1.05	83099–28	e7a	*HN Italy* 92–93; *SNG Firenze* 25 (this coin)	98.4	1.3	0	0	0.3	0	0.1	N
Hippalektryon†	Incuse square	1.04	83099–22	e7b	*HN Italy* 92–93; *SNG Firenze* 26 (this coin)	98.6	1	0	0	0.2	0.2	0.1	N
Hippalektryon†	Incuse square	1.10	83099–20	e8a	*HN Italy* 92–93; *SNG Firenze* 23 (this coin)	98	1.8	0.1	0	0	0.1	0.1	N
Hippalektryon†	Incuse square	1.02	83099–23	e8b	*HN Italy* 92–93; *SNG Firenze* 28 (this coin)	98.2	1.4	0	0	0.2	0.2	0.1	N
Hippalektryon†	Incuse Square	0.98	83099–26	d4a	*HN Italy* 92–93; *SNG Firenze* 32 (this coin)	97.8	1.2	0.1	0	0.3	0	0.7	Y
Hippalektryon†	Incuse square	1.00	83099–29	e5c	*HN Italy* 92–93; *SNG Firenze* 30 (this coin)	98.1	1.1	0.1	0	0	0.2	0.6	N
Chimera	Smooth	16.52	74179	74179	*HN Italy* 111; *SNG Firenze* 58 (this coin)	96.4	3.1	0.5	0	0	0	0.1	N
Chimera	Smooth	16.43	36254	ch1	*HN Italy* 111; *SNG Firenze* 59 (this coin)	98.6	1.2	0.3	0	0	0	0	N
Lion-serpent hybrid	Smooth	10.80	74069	74069	*HN Italy* 113; *SNG Firenze* 61 (this coin)	99.3	0.2	0.2	0	0	0	0.3	Y
First Metus	Smooth	8.00	74044	74044	*HN Italy* 117; *SNG Firenze* 65 (this coin)	97.9	1.5	0.4	0	0.2	0.1	0.1	Y
First Metus	Smooth	7.38	36259	36259	*HN Italy* 117; *SNG Firenze* 66 (this coin)	89.2	10.2	0.3	0	0.3	0	0.1	N

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