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Modern and ancient gold jewellery attributed to the Etruscans: a science-based study

Orfèvrerie moderne et ancienne attribuée aux Étrusques : une étude scientifique

Anna Rastrelli*, Marcello Miccio*, Lore Troalen**,
Marcos Martinón-Torres***, Maria Filomena Guerra****, Salvatore Siano*****,
Andrej Sumbera****** and Maria Luisa Vitobello*******

Abstract: A fibula with a lion and a pair of cluster earrings from the collection of the Florence National Museum of Archaeology, attributed to the Etruscans and said to originate from Populonia but suspected to be modern productions, were studied in the framework of the European project AUTHENTICO. They were compared to genuine objects from this same collection and from the collection of the National Museums Scotland. The study was carried out *in situ* in Florence with a stereomicroscope equipped with a digital camera, a handheld XRF spectrometer, and the portable LIPS prototype developed by AUTHENTICO. Some objects were studied with SEM and X-radiography. The aim of the study was to show that portable techniques of examination and analysis provide information on gold jewellery that allow the differentiation of modern and ancient productions.

Résumé : *La fibule au lion et les boucles d'oreille à motifs floraux de la collection du musée national d'Archéologie de Florence, attribuées aux Étrusques, provenant de Populonia, mais suspectées d'être des productions modernes, ont été étudiées dans le cadre du projet européen AUTHENTICO et comparées à des objets originaux de cette même collection et de la collection des Musées Nationaux d'Écosse. L'étude a été réalisée* in situ *avec une loupe binoculaire équipée d'un appareil photo numérique, un analyseur de fluorescence X portable miniaturisé et le LIPS portable développé dans le cadre du projet AUTHENTICO. Certains objets ont été sélectionnés pour analyse au MEB et par radiographie. Le but de ce travail est de montrer que les informations obtenues grâce aux techniques portables d'examen et d'analyse permettent de différentier les productions modernes des anciennes.*

Keywords: Etruscan, fakes, goldwork, XRF, LIPS, SEM, stereomicroscope.

Mots-clés : *Étrusque, faux, orfèvrerie, FX, LIPS, MEB, binoculaire.*

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1. Introduction

The high skill of the Etruscan goldsmiths is largely revealed by the incomparable quality, delicacy, and complexity of the filigree and granulation patterns of their jewellery, as well as by the thinness of the gold foils employed and the excellence of the joining techniques. Among the most representative objects of the 6th century BC fine Etruscan gold work, the *bauletto* (basket) earrings can only be fully appreciated with a magnification lens.

Accurate observation at low and high magnification of Etruscan gold items produced around the 6th century BC shows the following characteristics (Guerra, 2006; Guerra *et al.*, 2007): plain and hollow granules may reach several millimetres but, in the case of dust granulation, their diameter may be as small as 120 µm; different wires – beaded, twisted, spooled, strip-twisted, etc. – may reach diameters of about 150 µm; and the gold foils used in the small pendant decorations are often about 100 µm thick. The dimensions of the added decorative elements can be observed under the stereomicroscope in Figure 1 for one *bauletto* earring from the collection of the National Museums Scotland (NMS).

In Etruscan gold objects, joining is usually carried out by copper diffusion (Mello *et al.*, 1983); the technique is described by Pliny, Theophilus and Cellini (Wolters, 1981). However, hard-soldering was also used for the application of large elements. The use of both techniques can be found in a single object, when, for example, decoration patterns are made with elements of different dimensions, such as the reels from Vulci (reference I.8 in Gaultier and Metzger, 2006), dated to the beginning of the 4th century BC (Guerra *et al.*, 2007).

In spite of the technical difficulties inherent to the reproduction of Etruscan work (Rudoe, 1991), partly owing to the lack of knowledge regarding Etruscan art, at least in the 19th century, copies and imitations, as well as invented items of Etruscan inspiration, have been produced since the 18th century for the antiquities market (Guerra, 2008a). The Pasinati cista and the Praeneste gold fibula, both attributed to Francesco Martinetti (Gordon, 1982; Williams, 1992), are known Etruscan fakes. The sarcophagus with the inscription of the gold fibula from Chiusi (Borrelli, 1992) purchased by the British Museum (Williams, 1992), the bronze chariot said to originate from Orvieto, and the colossal Etruscan warriors of Orvieto, purchased by the Metropolitan Museum of Art (Duchêne, 2006) are but three more examples of famous Etruscan fakes created by restorers who worked in the Campana workshop (19th century, Rome). The Campana collection included nearly 15,000 objects according to Borrelli (1992), some genuine, other fantasist and unscrupulous fakes.

Many gold objects held in museum collections were repaired in the past. Others are either pastiches produced using heteroclite ancient parts, or fully modern inventions (Guerra, 2006; Guerra *et al.*, 2007; Guerra, 2008b). This is the case of some of the objects presented in this paper: the fibula with a lion and a pair of cluster earrings from the collections of the Florence National Museum of Archaeology (FNMA). Purchased in 1911 from Maruzzi and assumed to originate from Populonia, they can be confidently revealed as modern fakes.

The aim of this work – carried out in the framework of the European project AUTHENTICO – is to provide analytical information on these objects, to compare their production technology and the composition of their alloys with genuine objects and pastiches from the FNMA, and to show how portable equipments can be used to provide criteria for the identification of modern jewellery. A small number of objects from the NMS were also analysed for comparison.

The study of the objects from the FNMA was carried out in the museum. They were examined under a SMZ1000 Nikon stereomicroscope equipped with a digital camera, and by X-radiography. The analysis of the alloys was carried out with a handheld X-ray fluorescence (XRF) spectrometer, Innov-X Systems Model Alpha 8000 LZX, with a silver tube, and operating at 40 kV, 29 µA. The area of analysis was of about 6mm^2. Precision and accuracy were tested against a set of gold standard alloys (Table 1). The majority of the results provided are averages of 2-3 measurements and they have been normalised to 100 wt%.

The objects studied at the NMS were examined using an Olympus stereomicroscope (Olympus SZX12 x 7-90) equipped with a digital camera (Olympus DP70), a CamScan Scanning Electron Microscope and a 300 kV Pantak X-radiography system. They were also analysed by X-ray Fluorescence with an Oxford Instruments ED 2000 system, with a Rhodium target X-ray tube at 46 kV. Details on this equipment can be found in Troalen *et al.* (2009).

A few objects were selected for analysis with the portable low-cost laser induced plasma spectroscopy instrument (LIPS) developed in the scope of the European project AUTHENTICO, based on a compact Q-switched Nd:YAG laser (further details in Agresti *et al.*, 2009). In this case, measurements were carried out with a spot of about 70 µm diameter. Based on the different results obtained for the gold alloy standards of Table 1, the ablation could be limited to 100-200 µm laser pulses, which prevented major deposition of Cu and Ag oxides around the ablation hole, and allowed observing the saturation of the elemental depth profile towards the composition of the bulk. The total ablation

depth was of about 60 µm. The calibration for quantitative elemental analyses was carried out with a set of gold alloy standards.

2. Results

The bow-shaped fibula with a lion and the pair of cluster earrings were purchased by the FNMA in 1911 as Etruscan jewellery from Populonia. The objects and their mounting, revealed by X-radiography, are shown in Figure 2. The fibula was produced in two parts: (1) the lion obtained by joining two embossed metal sheets decorated with granules; (2) the shank obtained by decorating a gold sheet with a line of five animals in granulation, outlined by two rows of granules. The 1 mm diameter spring is coiled one and a half times and soldered to the fibula under the lion. The cluster earrings consist of a horseshoe-shaped central element with a wide oval single piece clasp on the back. The central element is decorated with knurled and wavy wires, ropes, flowers with five petals and gold dust granulation, and it is adorned with hollow globules with a diameter ranging from 220 to 3000 µm.

The observation of the fibula under the stereomicroscope shows that the granules of 300-500 µm diameter forming the granulation patterns are joined by hard-soldering. Figure 3a reveals some solder left over on the metal sheet. In spite of being obtained by cutting small pieces of wires in an Etruscan tradition (Nestler and Formigli, 1994), as illustrated in Figure 3b, the granules are far too irregular to be considered as ancient work. Comparison of the granulation patterns from an ancient earring (Fig. 1) and the modern fibula (Figs. 3a and 3b) clearly shows this aspect. Formigli's (1985) assumption of a modern fabrication and our analytical results are confirmed by the observation of the spring, for which the use of a modern drawn wire, characterised by its mechanical seams (Oddy, 1977; Ogden, 1991; Swadling *et al.*, 1991), is obvious (Fig. 3c). We also note that the section of the spring terminal is reduced by cutting with a chisel instead of being hammered, as expected for an ancient fabrication.

The cluster earrings show a quality of work very similar to the one of the lion fibula. Figure 4a shows details of the earring: the use of hard-soldering can be identified by observation only and the thick gold sheets with marks of file polishing on the borders that contrast with the delicacy of the lion's head and the flower of the genuine *bauletto* earring are shown in Figure 4b.

The filigree patterns are also of very dissimilar quality in modern and Etruscan productions (Ogden, 2004), such as

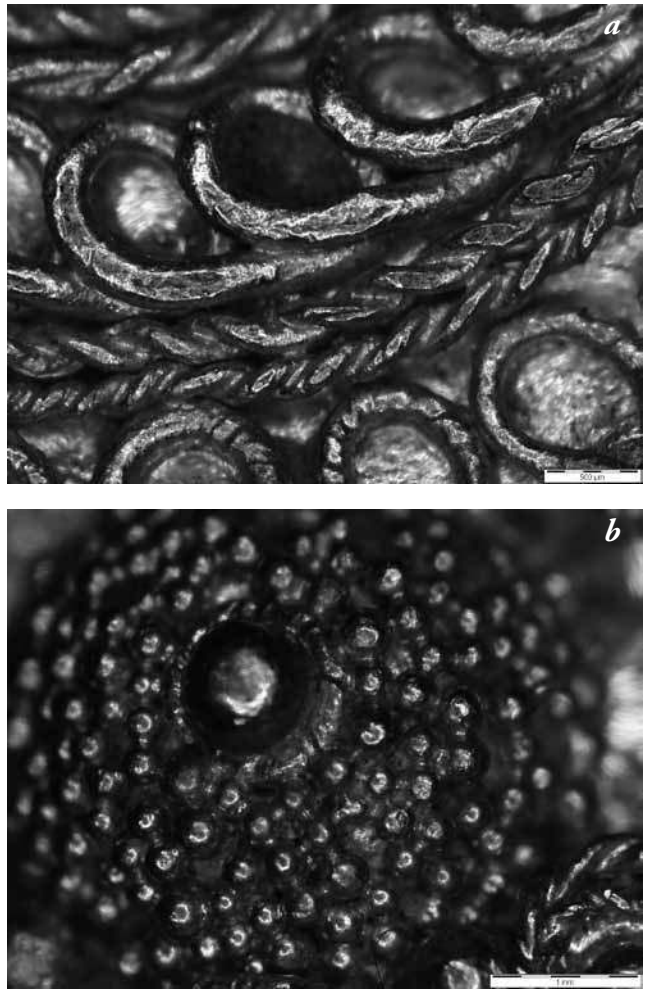


Figure 1: Details of a *bauletto* earring (reference K2004.40.1) from the NMS collection showing (a) filigree and (b) granulation patterns.
Figure 1 : Détails des motifs en (a) filigrane et (b) granulation de la boucle d'oreille à baule (référence K2004.40.1) de la collection du NMS.

in several objects belonging to the Campana collection held in the Louvre museum (Bagault *et al.*, 2006). In order to illustrate these aspects, Figure 5 shows SEM-SEI images of earring A.1905.914.2 from the collections of the NMS. This earring consists of modern and ancient beads. The quality of the strip-twisted wires of the ancient granulated beads on Figure 5a, certainly joined by copper diffusion, contrasts with the quality of the beaded and block-twisted wires of the modern beads in Figure 5b, which were joined with thick hard-solder.

If we exclude some particular cases (such as the use of modern 18 carat gold alloys, Guerra *et al.*, 2007), the composition of the modern and ancient alloys are in most cases

			Au %	Ag %	Cu %
Standards NMS	Oxford rolled gold	XRF	79.4	10.6	10.0
		Theoretical Value	80.0	10.0	10.0
	Oxford GCS5 gold	XRF	80.0	17.1	2.9
		Theoretical Value	79.4	17.9	2.7
Standards AUTHENTICO	Authentico A1	XRF	92.1	6.7	1.2
		Theoretical Value	92.0	6.0	2.0
	Authentico A2	XRF	71.3	25.1	3.6
		Theoretical Value	70.0	27.0	3.0
	Authentico E1	XRF	47.0	53.0	
		Theoretical Value	50.0	50.0	
	Authentico E2	XRF	51.9	47.7	0.5
		Theoretical Value	55.0	44.0	1.0
Standards C2RMF	Lyon Allemand A	XRF	91.6	4.1	4.4
		Theoretical Value	92.0	4.0	4.0
	Lyon Allemand 6917	XRF	74.2	18.9	7.0
		Theoretical Value	75.0	18.0	7.0
	Lyon Allemand 6907	XRF	75.8	5.0	19.2
		Theoretical Value	75.2	5.7	19.1
	Lyon Allemand 6905	XRF	74.4	6.8	18.8
		Theoretical Value	75.0	6.0	19.0
	Lyon Allemand 6906	XRF	73.5	14.0	12.5
		Theoretical Value	75.0	12.5	12.5

Table 1: Results obtained by stationary and handheld XRF for the gold alloy standards.
Tableau 1 : Compositions obtenues par fluorescence X fixe et portable miniaturisée pour les standards d'or.

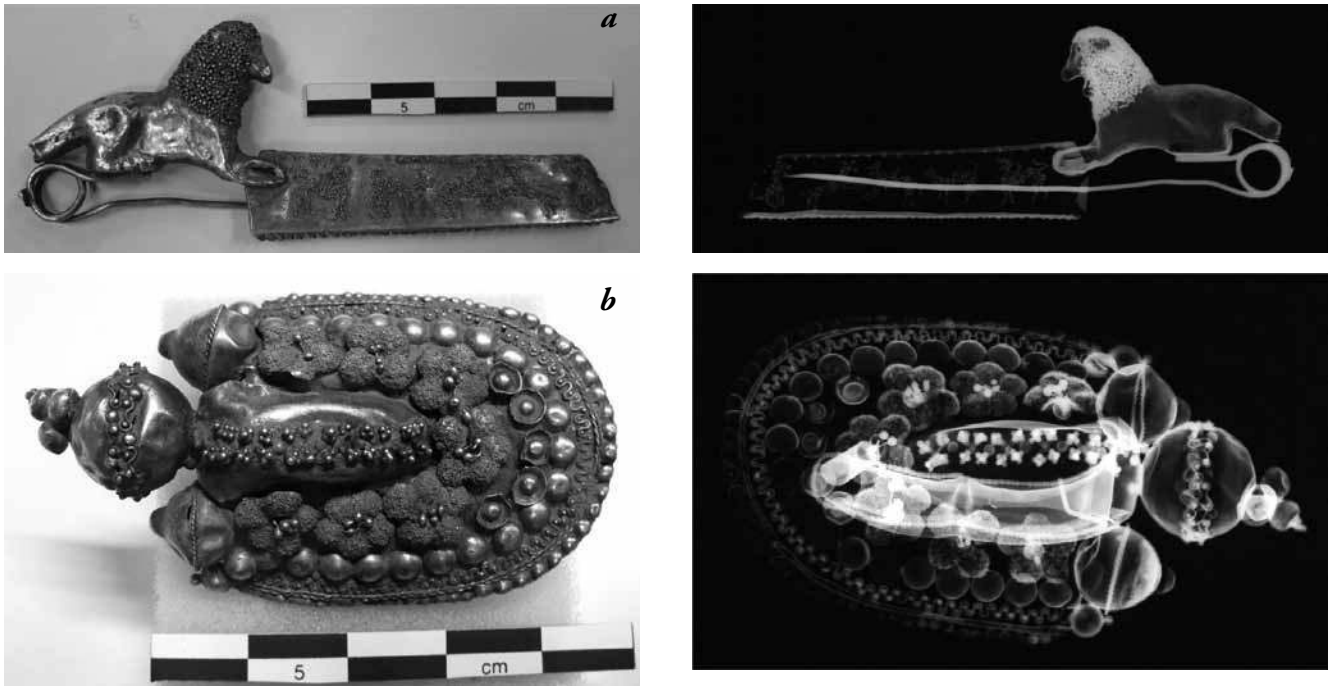
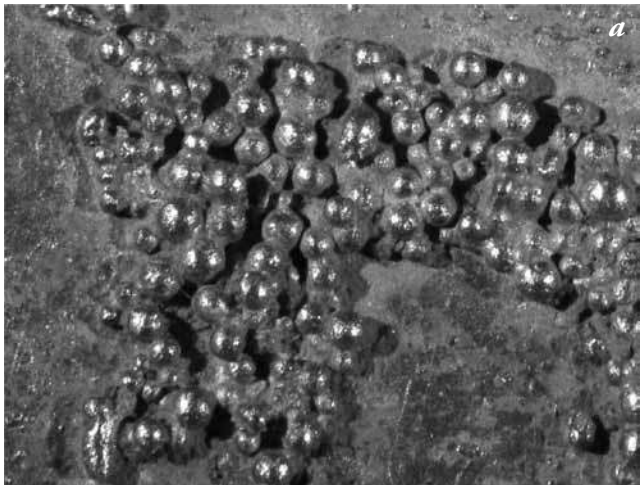
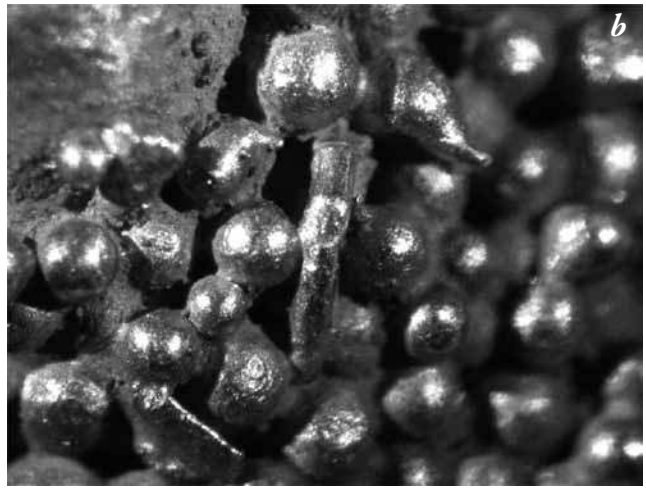


Figure 2: Photography and X-radiography of the FNMA (a) lion fibula (reference 85037: 14.05 g; 9.4 cm long) and (b) one element of the pair of cluster earrings (reference 85036: 27.70 g; 6.1 cm height and 3.5 cm large).
Figure 2 : Photographie et radiographie à rayons X de (a) la fibule au lion (référence 85037 : 14,05 g; 9,4 cm de longueur) et (b) d'une des boucles d'oreille à motifs floraux de la paire du FNMA (référence 85036 : 27,70 g; 6,1 cm de hauteur et 3.5 cm de largeur).





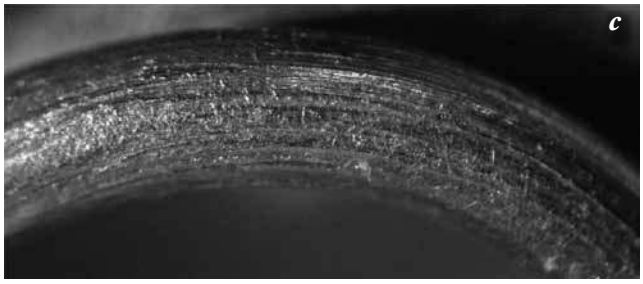


Figure 3: (See colour plate) The lion fibula: (a) granulation pattern, (b) detail of the granulation pattern, and (c) seams characteristic of the use of a modern drawn-plate to produce the spring.
Figure 3 : (Voir planche couleur) La fibule au lion : (a) motifs en granulation, (b) détail du motif en granulation et (c) lignes caractéristiques de l'utilisation d'une filière pour fabriquer le ressort.

Figure 4: Details of the (a) modern cluster earring with indication of the file marks; (b) ancient *bauletto* earring reference 15718 FNMA (Currie's collection, 1836).
Figure 4 : Détails de la boucle d'oreille à (a) motifs floraux modernes avec localisation des traces de lime et (b) baule étrusque référence 15718 FNMA (collection Currie 1836).

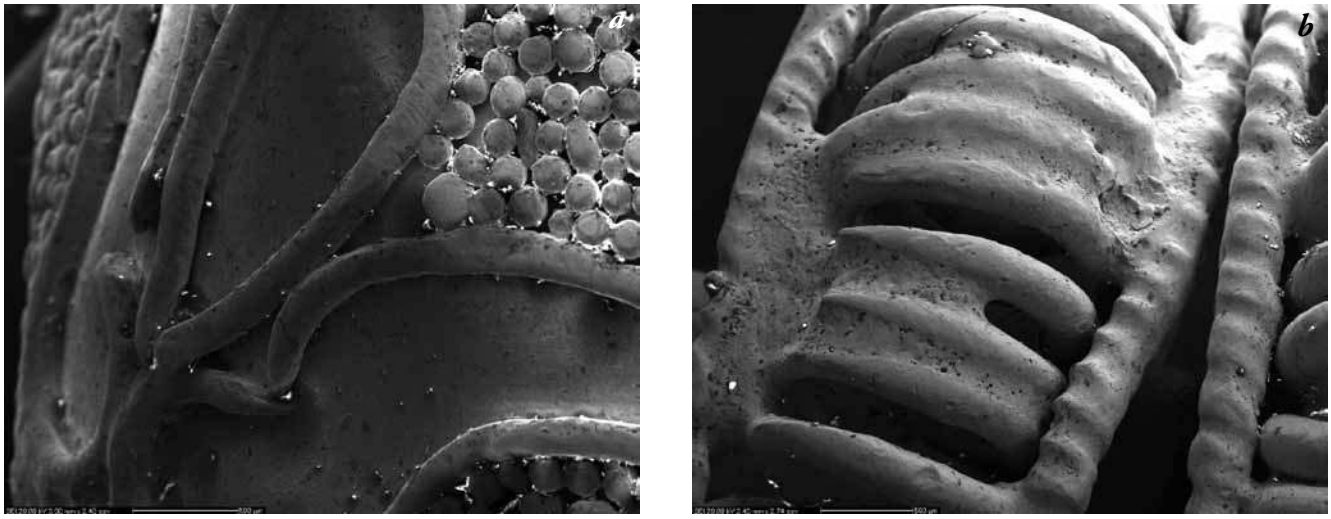


Figure 5: SEM-SEI micrographs of earring A.1905.914.2 from the NMS, showing the difference in quality between the (a) ancient and (b) modern gold work (scale: 500 µm).
Figure 5 : Images MEB-SE de la boucle d'oreille A.1905.914.2 du NMS, montrant la différence de qualité du travail d'orfèvrerie (a) ancien et (b) moderne (échelle: 500 µm).

barely different (Guerra, 2006; 2008b). In the present work, we analysed the lion fibula and the cluster earrings by portable XRF and LIPS. A few Etruscan *bauletto* earrings from the collections of FNAM and NMS, and a genuine pendant and a pastiche from NMS were also analysed for comparison. The results obtained are shown in Table 2.

Considering the fact that LIPS analysis is carried out on a small region of the object while XRF analysis is carried out on a large zone, which may include the region of interest (plate, granule, etc.) together with the solders, we can say that the results provided in Table 2 for the two techniques applied to the FNMA jewellery are in good agreement. The largest differences are observed for the *bauletto* earring 15718, which includes many decorative parts.

The results obtained for the lion fibula and the cluster earrings show the use of different alloys to produce their different parts. These alloys consistently have Ag values lower than 10%, and Cu values lower than 3.5%. Within the relative compositional variation, we can tentatively identify an alloy containing about 7-9% Ag and 2-3% Cu, another containing about 5% Ag and about 1% Cu, and a third one containing about 2% Ag with variable contents of Cu. We also note the use of different alloys for the production of the two elements of the pair of cluster earrings. The results obtained for the lion fibula and the cluster earrings are significantly different from the composition of the genuine objects analysed in the present work. They are also different from the results obtained for the modern parts of several published Etruscan pastiches (Guerra, 2006; Guerra *et al.*, 2007), such as cartouche finger-rings (74-79% Au, 15-21% Ag, and 3-6 Cu%, Guerra, 2006).

The high concentrations of silver and copper detected in the granulation applied to the lion's head are explained by the presence of leftover solder. Of potential interest is the notably high iron content detected on the earrings' surface (with one reading reaching a Fe concentration of 11%): this is possibly due to a surface coating with iron oxides, which might be explained by the goldsmith's intention of giving to the modern productions the aspect of objects originating from archaeological excavations.

Earring A.1905.914.2, suspected to be a modern mounting of ancient and modern parts, shows a very homogeneous composition, with an average of 10.4% Ag and 2.6% Cu. This composition is distinct from the other published genuine objects, such as the Vulci reels, made with an alloy containing 97.5% Au, 1.5% Ag, and 1% Cu, and the ancient parts of the hinged bracelets made with an alloy containing 94% Au, 4% Ag and 2% Cu, while the alloy of the modern parts contains 98 % Au, 1.3% Ag and 0.7% Cu (Guerra *et al.*, 2007). However, the granulated bead is without a doubt ancient. These results seem to indicate that the other beads could be partially ancient, but restored before being assembled in a modern mounting. The higher silver contents of this alloy are explained by the use of a silver-rich solder.

	Cu %	Ag %	Au %	Fe %
FNAM XRF				
Fibula 85037				
lion's body	0.4	2.7	96.3	0.6
granulation neck*	3.4	17.4	77.0	2.2
spring			100.0	
shank	2.2	8.7	88.4	0.7
Cluster earring 85036/1				
back plate	2.8	2.0	95.2	≤0.5
three globules top	3.5	9.7	85.6	1.2
side sphere top	0.5	2.0	95.8	1.7
central sphere top 1	1.1	2.3	94.5	2.2
2	2.7	8.8	77.5	11.0
Cluster earring 85036/2				
front flower	2.0	6.7	89.1	2.3
back hook	1.1	≤0.2	98.2	0.7
three globules top	1.3	7.4	88.1	3.2
side sphere top	1.0	4.9	93.4	0.7
central sphere top	1.2	5.4	92.7	0.7
front flower	1.9	5.7	88.8	3.6
Bauletto earring 15718				
main barrel	3.1	4.4	91.5	1.0
Bauletto earring 15751				
main barrel	2.7	17.8	78.5	
side plaque	2.1	16.6	80.7	
Bauletto earring 7746				
main barrel	2.0	4.5	92.9	
side plaque	2.9	4.5	92.2	
FNAM LIPS				
Fibula 85037				
lion's body	0.2	1.4	98.4	
Cluster earring 85036/1				
back plate	2.8	2.5	94.7	
Bauletto earring 15718				
clasp	2.0	3.5	94.5	
big granule	1.9	2.9	95.2	
NMS XRF				
Bauletto earring A.1956.381				
Front plate	1.9	1.9	96.2	
Lateral plate	1.8	2.1	96.2	
Bauletto earring A.1956.381 A				
Front plate 1	2.3	1.9	95.8	
2	1.9	3.0	95.1	
Lateral plate	1.7	1.8	96.5	
Earring A.1905.914.2				
Granulated bead	2.7	11.3	86.0	
Small bead 1	2.7	11.7	85.6	
2	2.5	10.7	86.8	
3	2.5	7.7	89.8	
4	2.7	10.7	86.6	

*granules and solder together

Table 2: Compositions obtained for the different objects from FNMA and NMS collections analysed in this work by handheld XRF, stationary XRF, and portable LIPS
Tableau 2 : Compositions obtenues pour les différents objets appartenant aux collections du FNMA et du NMS, analysés pour ce travail par fluorescence X avec système portable miniaturisée et fixe et par LIPS portable.

It is at this stage impossible to establish convincing criteria for the differentiation of modern and ancient productions by measuring only the elemental composition of the objects. Only the results published by Cesareo and Von Hase (1976) on the compositions of the reproductions of gold Etruscan objects made by Castellani in the 19th century showed the use of different gold alloys, containing 2.5-6.6% Ag and 0.6-2.2% Cu. Some of these alloys are close to those obtained for the lion fibula and the cluster earrings. In any case, it has to be acknowledged that, given the variable compositions documented, it is not possible to discriminate modern from ancient gold items based on Au/Ag/Cu ratios only.

3. Conclusion

The analytical information obtained in the framework of the European project AUTHENTICO using portable equipment for the study of the lion fibula and the pair of cluster earrings from Populonia, attributed to the Etruscans and belonging to the collections of the FNMA, provided convincing evidence that they are fakes. Examination of these objects showed the use of thick gold sheets finished by file polishing, drawn wires, and big granules joined by hard-soldering. The delicacy of the Etruscan filigree and granulation patterns, the thinness of the gold foils, and the excellent joining techniques are not matched in the modern pieces.

The elemental analysis of Etruscan genuine gold items and pastiches from FNMA and NMS revealed the variety of the ancient and modern alloys, showing that composition alone does not provide sufficient criteria for distinguishing between ancient and modern productions. Etruscan genuine objects, pastiches with modern and ancient parts, and 19th century reproductions of Etruscan objects published by different authors were also taken into account for this comparison.

Further comparison of the technical aspects of ancient and modern goldsmithing, as well as further analysis of the alloys used in the manufacture of modern and ancient gold items, should allow the establishment of an useful database for authentication assessment. In the present work, we note how both XRF with stationary and portable systems and LIPS can be successfully used in this type of study, even taking into account the error introduced by the analysis of non-flat surfaces and the different degrees of surface damage.

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