Baroque silver from central Europe

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Thilo Rehren, Jadwiga W. Łukaszewicz, Michal Woźniak

Thilo Rehren

Institute for Archaeo-
Metallurgical Studies
UCL Institute of Archaeology
London, Great Britain.

Introduction

Silver has been used for more than five thousand years to create jewellery and beautiful objects, and to this day artists and art lovers alike all over the world cherish the unique colour and quality of this metal. Some shapes and forms are timeless in their elegance; others evoke the special feeling of times gone by. Archaeological and antique objects appeal even more to our senses with their combination of exclusivity and eternity.

In Antiquity, gold and silver were symbols of wealth and power, as the noble nature of these metals protects them from the signs of decay typical for base metals such as copper and iron. However, only very few gold and silver objects survive the passage of time intact, as the noble metals have been re-melted and recycled over and again, not only in times of need.

Much of this is true also for historical objects, those which have been kept in collections rather than buried in the ground for much of the time. Even though there are often many more historical objects surviving than their archaeological cousins, they are still rare and valuable, not only for their metal value, but also their beauty, historical significance, and not least due to their individual life history, their personality. Archaeological metal objects can often only be assigned to a particular period and culture.

However, from the Renaissance onwards, many objects can be linked to individual artists, owners, or both. This intangible heritage adds a unique quality to their cultural importance. They are not just individual, special objects; they are objects whose individual life histories can be documented. Preserving and understanding the many facets of this individual history of the object is at the heart of the term 'authenticity'; only an object with a full life history is a true part of our common cultural heritage.

Nautilus cup

An elaborate piece of art, combining the delicate shell of a nautilus with silverwork in marine motifs. The same object, newly created, would probably be seen as kitsch.

From Artist to Museum:

steps in the life history of an object

Metal objects have their own life histories, similar to humans. Maybe their lives are running at a slower pace than a human life; but like us, they evolve and develop, accumulating scars, layers of history. Metal objects are shaped and formed by their creators in much the same way as human beings are raised, with hopes and intentions. As the objects grow older, their fortunes may change. They pass from one owner to another; their role may differ from what they were meant to do initially. Wear and tear will take their toll; repairs may be done. Like a mature face tells of a rich life of its owner, traces of all these different experiences will accumulate as marks which will remain in the object, and can tell us about their changing fortunes. This chapter presents some of the ways in which we can decipher these marks to fill in gaps in our knowledge of the life histories of historic silver objects.

Artists and patrons – the object is born

When the artist starts out making the object, casting the metal into its mould and working it into its final shape, at this stage the metal has already a long journey behind it. Ore has been mined and smelted, the silver refined to high purity, and alloyed with copper to the desired fineness. It may well have been recycled silver, gone through repeated episodes of casting, alloying, refining and re-melting. Accordingly, it will have specific trace elements in it, in different concentrations and combinations. At this stage, the authenticity of the object is not in question; but it inherited during its creation the unique signatures, the trace element fingerprints, which will stay with it until it is re-melted again. After the object is finished, the quality of the metal is tested by an official assayer who removes a small amount of metal and determines the quantity of silver present. If it satisfies the prescribed requirements, the object is marked or stamped with the sign of the assay office, as well as of the maker. A birth certificate has been issued. Typically, the test material is removed in an unobtrusive, but aesthetically pleasing way; this deliberate scar becomes part of the hall mark.

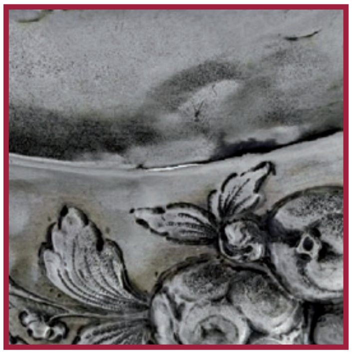
Assay line

Assay line showing where some of the metal was removed to determine the quality of the alloy, maker's mark (IM, left) and assay office hall marks (fruit, right). The small circular mark is the centre point where the object was fastened on the lathe during its manufacture. *Part of the tankard shown on page 69.*

Besides its chemical authenticity, the object acquires its unique physical identity when it is made; the hand of the artist is imprinted onto the metal's very shape, structure and surface. This physical authenticity combines two dimensions: an art historical one, outwardly visible and accessible to the art historian, and an internal one, reflecting the technical steps of the manufacture, only visible to the experienced craftsperson or metallurgist.

Owners and users – the use life of the object

Most objects are made to be used; they have a practical function as well as a spiritual meaning. A grail is used in church to offer wine during communion, but it is also a sacred object fit for religious use. It is well looked-after and will show little wear even if it is in constant use over long periods of time. A tankard, used in more rustic drinking events, will likely suffer more wear and tear, particularly as the guests become more cheerful.



Baroque dish

MAIN: made by Peter Ra(h)m in Augsburg, 1695-1705. *National Museum, Poznań, 2360.*
INSETS FROM THE TOP: rim of dish 2361, with faint remains of gilding just about visible.
Note also the long crack where the border meets the well; this is a weak point due to the thinning of the metal when the well is sunk.
Relatively crude repair on the underside of the dish MNP 2360, sealing a crack between the sunken centre or well and the broad decorated border. Date of repair unknown.
Gilded rim of dish MNP 2360, with maker's mark PR clearly visible.

Thus, repairs are a common and necessary feature of many objects, and can be made at nearly every stage of the object's life. Some flaws can appear already in the workshop, requiring the addition of a small patch or similar; often, these repairs are expertly done, using the same or a very similar alloy as was used for the main object, and are difficult to detect. Others may be done much later, and by less skilled artisans, using what metal is at hand.

Tankard

Partly gilded. *Augsburg 1653-1655, by Hans Christoph I Mehrer.*

Other use wear can manifest itself in less drastic ways than cracks or breaks. Many silver objects are partly gilded, either to highlight certain areas or to protect the surface from corrosion. The dish 2360 (page 68) has a well-preserved gilded rim and well.

However, most gilding does not withstand cleaning very well, and after centuries it can be almost completely worn off (see rim of dish 2361, top of page 68).

A later owner may decide to restore the original gilding. Alternatively, the taste may have changed, the plain silver colour now preferred, and efforts made to remove the last remains of gilding.

Conservation and restoration – preserving objects for the future

Most silver objects of significance eventually reach the point when they are no longer in regular use, but are kept as heirlooms, collectors' items, or in public museums. At this stage they undergo a transformation from a 'living' object to a more static existence. They also normally receive some conservation and restoration treatment: depending on the circumstances, by more or less experienced conservators, silversmiths, or laymen. Over the last century, the philosophy of conservation and restoration has repeatedly changed. Modern approaches aim to be as minimally invasive as possible, securing the long-term stability of the object, including its unique modifications acquired over time, but avoiding full restoration to a former pristine state. Thus, at this stage the object and its history are recognised as part of our common cultural heritage, safeguarded for the enjoyment and education of future generations.

Unravelling the life history – discovering authenticity

An object without history has no cultural value; it is not more than a lump of metal. It may be beautiful, or valuable for its metal content; but its real significance as part of humankind's cultural heritage lies in its unique history, its origin and authenticity. Hardly any object comes down to our times with its full biography recorded and documented. Painstaking research is necessary to piece together what information can be found: identifying its makers, tracing its successive owners, re-constructing events, reading the scars and modifications, in short, creating cultural significance through the discovery and analysis of intangible aspects of its heritage. Traditionally, two main approaches have been used for the study of early modern metalwork: archival research and art historical assessment. Increasingly, technical studies contribute to the reconstruction of an object's history and authenticity, first as an aspect of conservation and restoration, and more recently applying materials science and other analytical methods. Each of these approaches will contribute its own particular type of information to the emerging overall picture.

Archival research tries to trace the object as an individual item back through time. It may have been sold in the past, and documented in an auction catalogue. It may have been part of a public or large private collection, and recorded in the inventory or purchase list. Sometimes, artefacts displaced or stolen during the last century can be identified in old photographs taken by their previous owners, for insurance purposes or simply appearing in the background of a family picture. Gold and silver objects have a unique additional element that assists in this kind of research: the maker's marks and hall marks mentioned above. For most major guilds and cities there exist comprehensive lists of these marks, detailing the years of their use and the names of the makers.

The art historical assessment depends on a high level of individual scholarship, accumulated experience from the detailed study of numerous such objects, often looking at very subtle traits and characteristics. In the end, it allows to place the object in a certain geographical and chronological context, possibly identifying the likely author or maker of the object under study. Most people will have heard of discussions about the authenticity of newly-discovered paintings attributed to famous painters; the same approach can be adopted with regard to important silversmiths and their often very personal styles.

The technical study of manufacturing methods is part of conservation research, and necessary to ensure appropriate treatment. Hammered metal can corrode differently from cast metal; different gilding methods react differently to cleaning, and any conservation treatment has to take this into account. However, at the same time, it is important to note that certain technical treatments or production methods are specific for certain periods. Thus, in addition to enabling proper documentation and conservation treatment, the investigation of manufacturing methods can reveal a

The marks on silver and gold

The main aim of marking silver and gold objects is to provide an item with a sign that officially approves trade turnover. This entails a guarantee for the purchaser from an individual maker, and a confirmation guarantee given by supervisory institutions, authorizing the secondary trade turnover of an object.

Authorization and guarantee are necessary because of the usage (in silver- and goldsmithing) of noble metals (gold, silver, platinum) alloyed with other metals. The value of these metals, and the pure metal content as a percentage of the total weight, decide the material worth of an object. The practice of counterfeiting alloys and deceiving customers, and the ensuing complaints to supervisory institutions, led to the introduction of a clear guarantee system.

Confidence in gold- and silversmith hall marks as a means of authenticating an object is relative. They always require – just as any other signs, such as inscriptions, coats of arms, signatures – careful analysis and authentication, because of the danger of forgery. For modern museology, collection and art market purposes, knowing the exact alloy composition is not as important as is the consistency of the actual, real alloy with the information about it provided by a hall mark. There is the danger of using hall marks for deliberately giving misleading information concerning the time and place of manufacture of an object, and its authorship. We can distinguish several kinds of counterfeit marks: illegal usage of old punches and usage of punches with newly made heads, as imitations of earlier, ancient marks, or as newly 'invented', false marks. In case of suspicion of forgery, the most important procedures are: observation of difference (or lack of difference) in the stage of dilapidation, scratches on the surface in the place where the mark is imprinted and around it, and the method used for imprinting the mark.

certain 'technological style' which can be characteristic of a particular cultural context, school of artists, or period. This is also the most likely point when later repairs or other modifications to the original object are discovered, and assessed.

Finally, materials science and chemical analysis can contribute a broad range of detailed information complementary to the information accumulated so far. The most basic question is that of metal composition: is the silver pure, or alloyed? Then, which trace elements are present, and in what concentrations? Refining methods for gold and silver have changed over time, and certain levels of trace elements can be diagnostic of certain periods or geographical regions of origin. On the other hand, the never-ending recycling and the age-old long-distance trade in gold and silver metal leads to widespread mixing and blurring of such characteristics. However, an authentic old object should not be made from a modern alloy, and even complex pieces assembled from many different parts should not be made from widely different metal types if they are supposed to come from a single workshop.

Authenticity – the final answer

Combining the results of such diverse approaches as archival research, art historical assessment, technical and chemical analysis will inevitably reveal more or less detail about the history of an object. The information will not necessarily be consistent, and often large gaps will remain in our knowledge of the object and its history. Discussing the authenticity of an object will involve a balanced interpretation of the various pieces of information gathered. There may well be conflicting interpretations; an unusual alloy may have been used at times, when fresh silver was in short supply, or a less known workshop may have produced objects in a style not easily recognised. On the other hand, a skilled artist today can create objects using traditional methods and materials, imitating styles of past centuries. These can be innocent copies, hall marked by today's standards, or they can be fraudulent objects, stamped with old marks to deceive collectors. Genuine ancient objects may have been 'improved' to enhance their appeal and hence value. The boundary between restoration and deception may be as thin as the provision of documentation about the work done.

In the end, authenticity is often impossible to quantify. An object will always be seen as authentic as scholarship can agree upon at any given time. Copies, fakes and forgeries will always be present next to genuine objects of historical origin, and the quest to determine an object's particular life history will remain at the heart of any study, art historical or otherwise, of ancient and historic works of art. The 'arms race' among collectors, scholars, dealers, scientists and forgers will continue as long as there is a

Gilding methods

The most common gilding method in early modern times is known as fire gilding. For this, a grey paste of gold-mercury alloy, called amalgam, is applied to the object's surface. Upon heating, most of the mercury evaporates, leaving behind a thin layer of gold. Depending on the length and temperature of firing, more or less mercury remains with the gold. The results have shown two different examples from the collection of Baroque silverware analysed as part of our study; in one object, the mercury content is almost as high as the gold content, while in the other, only a trace of mercury can be detected. Such differences, invisible to the naked eye but clearly recorded through scientific analysis, can indicate different workshop practices, or possibly later re-gilding events.

market for such items, which means forever. The information that new approaches generate when authenticating genuine items and detecting fraudulent pieces will immediately be used by the next generation of fraudsters to produce even better copies. It is imperative for scholarship to stay ahead in this, through creativity and collaboration, to safeguard our common cultural heritage against the debasement, in terms of quality and quantity, that comes from the activity serving the interests of the fraudsters only.

The art historical approach to authentication:

some boxes and dishes in the National Museum of Poland

Jadwiga W. Łukaszewicz, Michał Woźniak, Renata Sobczak-Jaskólska,
Alina Tomaszewska-Szewczyk, Maria Rdesińska

Jadwiga Łukaszewicz

Fine Art Department
Nicolaus Copernicus
University Torun, Poland.

Introduction

In the struggle against art forgeries and illicit art trade, the ability of distinguishing between original and counterfeit artefacts plays an important role. The issue concerns not only painting and sculpture, but also small mobile objects such as jewellery or ancient functional objects. These minor items, with not only historical but sometimes also artistic value, were often richly decorated and not always used according to their function, but mainly as representative showpieces.

The authentication of an artefact is a complex process that requires the cooperation of specialists from many different fields. Until today, the main responsibility of categorizing an object as authentic or not lay with the art historians, or, in the case of ancient objects, archaeologists, who with their knowledge of the development of form, type and style, as well as of iconography and the evolution of ornaments, are able to assess the conformity of the characteristics of the object (and sometimes of the manufacturing technique) with the suggested time and place of origin. Such considerations need to be supported by composition analyses and by the determination of manufacturing techniques and technologies. The physico-chemical examination and research are conducted by natural scientists, contributing an independent aspect to the assessment. The opinion of art conservators, who with their knowledge of ancient manufacturing and decoration techniques, as well as of possible damages an object may have incurred, can further contribute to the conclusions concerning the authenticity of the object, and may also be very helpful for distinguishing between authentic and counterfeit artefacts.

This text aims to illustrate the application of the approaches mentioned above for the authentication of metal objects on two pairs of silver artefacts – two dishes and two boxes – chosen from a set of silverware with baroque features that was an object of examination within the AUTHENTICO project.

Art history approach and methods

Dish 3773

MAIN: Abraham Grill, Augsburg, about 1670-1674. *National Museum, Poznań.* INSET: town mark and maker's mark.

The methods used for the examination of historical artefacts in art history are fundamentally based on visual and tactile inspection. This includes the identification of various components of the object and the stratification of its structure, the interpretation of forms and identification of images, symbols and other means of conveying ideas, the determination of the meaning of the object itself and all representations contained therein, as well as the recognition of its function within the original context of execution – all based on extensive standards of comparison. The knowledge and experience of an expert combined with the necessary precision of observation and an appropriate interpretation enable the formulation of a judgment on the authenticity of the object. This will be illustrated here on two pairs of superficially similar objects, pretending to be in the style of the late Baroque.

The two dishes

Formal description:

Abraham Grill, Augsburg, about 1670-1674; MNP 3773; measurements: major axis 284 mm, minor axis 239 mm.

The marks placed near the edge of the rim (from right):

- Town mark – a pine cone with a cross or T(?) letter in three-part base
- Maker's mark – used by silversmith Abraham Grill, active around1672 to1682

Alloy composition: silver with c 6 weight percent copper. Fire gilding with a gold to mercury ratio of around 1.

August Schleißner (1825 – 1891), "J. D. Schleißner Söhne" company; Hanau, 4th quarter of the 19th century; MNP 2756; measurements: major axis 635 mm, minor axis 565 mm.

The marks placed on the bottom part of the well:

- Town mark similar to the mark of Augsburg
- Eagle in a shield, turned left in oval shield with cut top angels, similar to the mark of Frankfurt am Main
- Number 13 in a shield

Although the marks are clearly different from historical ones, they give the object some features of antiquity and historicity.

Alloy composition: silver with c 6 to 7 weight percent copper. The same composition was used for the solder.

The dishes constitute a type of vessels particularly popular in the 17th century, during the Mannerism and Baroque periods. They could be used to serve fruits or sweets, but their main role was often representative. They were placed on sideboards and sometimes decorated with elaborated ornamentation and figural scenes, meant to demonstrate the splendour of the owner. In this respect they differ from paintings and bronze reliefs only in terms of material and technique used. They were being produced from silver metal sheet, with decorations obtained by usage of repoussé work, chasing and, sometimes, engraving. The texturing of the surface and gilding of some parts of the objects allowed the silversmith to emphasize chosen sections of the dish.

The profile of Grill's dish presents a gentle transition between the well and the rim, high relief, softly shaped, with chased contour, with big, rather compact, figural and ornamental motifs, texturing with usage of hollow punches that gives the effect of flattened balls, and wavy edges. These are features typical for the silversmith's work in the second half of the 17th century, especially between 1660 and 1680. The rim is decorated with a wreath of flowers with short stems, designed in a manner characteristic for the period around 1660-1675.

Dish 2756

August Schleißner,
"J.D.Schleißner Söhne"
company, Hanau,
4th quarter of the 19th century.
Archdiocesean Museum
in Poznań, Poland
Dish Marks: standard hallmark
and false town mark.

Box 3760

Andreas III Wickert,
Augsburg, about 1705.
Town mark, maker's mark
and assay scar.

Schleißner's dish represents an example of the type of dishes popular between 1680 and 1700, but with clear irregularities and differences in the execution. The relief decoration is shaped with some stiffness and fragmentation, showing a higher density of figural and ornamental motifs. The rim is cast, not repoussé worked; the metal sheet is relatively thick; the inner border of the rim decoration is encircled with a row of circular motifs with sharp edges. The edge of the rim is hard, thickened and sharply linear-profiled, like in original late baroque dishes from the end of the 17th and the first third of the 18th century. A few ripples look artificial and are unnecessary in this type of border, introduced only for the purpose of imitating baroque techniques. Moreover, the edge was shaped through placing a tape from the outside, an aspect which is different from baroque techniques.

In the figural scene in the well, the striking elements are the hardness, stiffness, and linearity of moulding. Acanthus leaves, typical for dishes and other baroque objects, are not present on the rim, replaced by a compact weave of plant ornaments. The shape and layout of panoplies are analogous to those of historical compositions from the second half of the 19th century.
The object is only seemingly and at a superficial glance similar to dishes from the 4th quarter of the 17th century. A number of differences in composition and technique provide indications on the two hundred years later date of execution. Relatively significant bends of the metal sheet appear to be intentional. A number of small holes are also present; in such baroque dishes, with high relief, repoussé worked in relatively thin metal sheet, cracks are a very common occurrence. The holes in this object may even have been made intentionally, because the metal sheet is slightly thicker than in many baroque vessels, and thus not so soft and prone to bending and cracking. The solder used to repair some of the cracks is of very similar metal to the dish itself, supporting the idea that it was made at the same time as the dish itself, in the same workshop.

The two boxes
Formal description
Andreas III Wickert; Augsburg, about 1705; MNP 3760 RM; measurements: length 87 mm, width 68 mm, height 19 mm.
Marks placed on the exterior of the bottom:
- Town mark of Augsburg – pine cone (with six scales) on two lines, similar to the mark used in 1705
- Maker's mark – AW in ligature indicates the work of Andreas III Wickert (born 1664, master 1694, marriage 1696, died 1728)

The marks are hardly visible inside, and were perhaps punched on hard ground. The marks have soft edges, a frequent feature in old, functional silver objects.
Alloy composition: The different pieces from which this box has

BOX 3569

"Ludwig Neresheimer & Co": Hanau, after 1890. Standard hallmark, town mark and company mark.

been assembled have slightly different alloy compositions, ranging from silver with about 5 weight percent of copper to around 10 weight percent. Some of this may be related to corrosion or excessive cleaning; some parts were green from copper salts, indicating that copper is selectively removed from the surface of the alloy. The gilding has a gold to mercury ratio of around 4 to 5. Some mercury was found in the silver inside the box, without gold, possibly due to diffusion of the volatile mercury over time.

"Ludwig Neresheimer & Co": Hanau, after 1890; MNP 3569 RM; measurements: length 90 mm, width 60 mm, height 10 mm.
Marks:
- Town mark – pine cone on trapezoid base in oval shield, unrecorded, similar to the town mark of Augsburg
- Company mark – gothic N in triangular shield
- Number 13 in rounded square – assay mark

Alloy composition: Silver with consistently c 7 to 8 weight percent copper; occasionally traces of gold were found.
Small boxes such as these were used for hygiene and toiletry pur-

poses, or to store tobacco (snuff boxes). They had different shapes and sizes and were popular in the 18th century.Wickert's box is made of silver. It was gilt, lost wax-cast, chased and hard soldered. The sides are soldered. A profiled slat, decorated with kymation, is attached to the outer sides of the box. On the inner side of the cover there is a plate covering the reverse of the relief. The entire cover is decorated with clearly segmented battle scenes in a fashion characteristic of late baroque reliefs from the end of the 17th and beginning of the 18th century. The representation is similar to the compositions in Flemish and French painting. The type of relief, its softness and precision have an equivalent in the objects made in Augsburg under French influence.

The Neresheimer box is made of silver metal sheet. The relief, covering both the cover and the bottom of the box, was stamped on a matrix that was cracked in a few places. The relief is shallow and small, hardly elaborated. On the cover and on the reverse of the bottom there is an identical figural scene with a representation of a group of ladies bathing in a spring, in rocaille scenery, referring to 18th century French compositions.

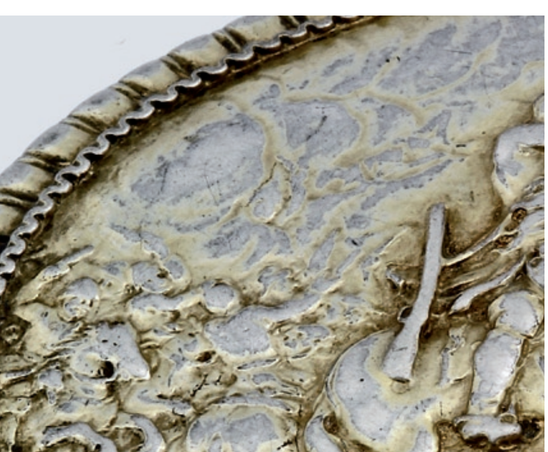
The ornament, despite similarities and references to rococo patterns, is segmented and articulated differently. The rocaille loses its shell-like character for an indefinable and very simplified plant ornament. There is a lack of otherwise typical water plants, and floral motifs are hard to identify. All the observed details confirm that the object was created in neo-rococo style.

Conservator/restorer approach

Conservator/restorer approach

Box 3760

Detail of the oval box surface.



One of the main criteria in the authentication of an object is the evaluation of its state of preservation, which enables us to establish whether we are dealing with an ancient or contemporary object. During the analysis of the state of preservation, it is important to determine potential causes for changes in the object. At this stage, it has to be established if changes are the result of corrosion processes or due to the use of the item, or whether they are only their imitation, made with the purpose of giving the object the appearance of antiquity.

On the oval box, we can observe deep wear of the fire gilding and scratches on the surface. Their diversity and the partial loss of sharpness indicate that they are the effect of long-time use of the object. The baroque origin confirms the hypothesis of changes resulting from galvanic corrosion, which occurs at the junction of the gold layer and silver base.

The data concerning the history of the object can also be complemented by traces on the object of materials used in conservation, left after the clearing process (polish paste was identified on the dish 3773 shown on page 74) or of materials used in anticorrosion protection in the form of layers (the objects were covered with acrylic resin).

The choice of the substance used for protecting the object is influenced by developments in resin technologies, as well as informed by specialist literature, which outlines trends in conservation practice. The assessment of the stage of decay of the layers, their colour, brittleness or solubility, together with the conservator's documentation, allow the dating of the item.

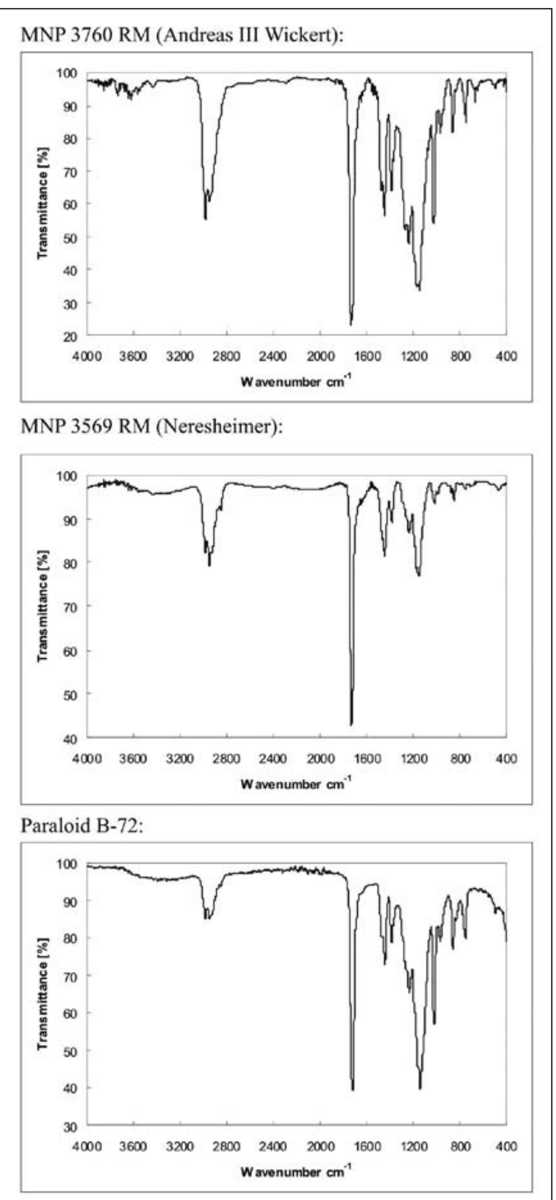
Natural science approach

UV fluorescence

UV fluorescence of acrylic resin layers on the surface of the Andreas III Wickert's (large photo) and Neresheimer's boxes.

Infrared spectroscopy

FT-IR spectrum of acrylic resin layers on silver surface and reference spectrum of Paraloid B-72. (Andreas III Wickert's and Neresheimers's boxes).



Contemporary methods for the examination of works of art use mainly nondestructive techniques that allow the analysis of material without taking samples.

Visual analyses that make use of electromagnetic radiation in the visible range are used by art historians and conservators for the purpose of describing the artefacts. These analyses are expanded to the use of other parts of the electromagnetic spectrum, particularly using infrared, ultraviolet and X-ray radiation. These various radiations are used in depicting the work of art, and for qualitative and quantitative analyses of materials used in its production. The effect of UV-radiation on the surface enabled the observation of fluorescence of polymeric layers and to trace their distribution on both examined boxes: the oval box created by Wickert and the Neresheimer box, applied (not very carefully) during the conservation work. With the use of X-ray fluorescence analyses of the surface of the objects, the composition of the silver alloys was established, the occurrence and range of the gilding was confirmed, and the hypothesis of the occurrence of goldlack was invalidated[1].

Another method – infrared spectroscopy (FT-IR) with reflection attachment – enabled us to determine the chemical structure of acrylic layers applied on the surface of objects during conservation[2]. The authentication of an artefact can be a difficult and complex issue. It is often much easier to prove that an item is a forgery or pastiche than that we are dealing with an authentic, historical object. To date, none of the methods or analyses used, either in the humanities (art history, archaeology) or in the field of natural science, can guarantee the validity of a result with complete certainty. This is why it is so important to combine different approaches and methods in the attempt to authenticate an object, since only the similarity of conclusions drawn from the results of different analyses can guarantee a high level of certainty of the authentication.

In this case, it is interesting to note that the non-invasive surface analysis using a portable X-ray fluorescence instrument found no diagnostic differences in composition between the two objects made in the late 17th and early 18th century, and their later imitations made in the late 19th century. All objects were made from silver metal with around 5 to just under 10 weight percent copper, and not trace elements were found using the non-invasive instrument, above concentrations of around 0.1 percent. This is consistent with early modern silver, which is typically well refined.

To determine the remaining trace elements a more powerful instrumental analysis would be necessary, possibly involving the removal of a small sample of metal, or the movement of the object to a large-scale laboratory elsewhere. Similarly, lead isotope analysis could be done in order to identify the geological origin of the silver used here. However, this not only requires a small sample to be removed from the object in question, but also depends on the availability of a large data base of comparative analyses from other objects, and from geological and metallurgical samples from possible production areas for this silver.

Another aspect potentially indicating a certain period of manufacture is the gilding method. The older objects have several areas fire-gilded, as indicated by the presence of relatively high mercury concentrations together with the gold. However, fire gilding was done well into the 20th century, and can still be made today; thus it does not date the objects. A more detailed investigation might identify differences in the details of this gilding process, such as the firing temperature and length, which both affect the level of mercury in the final gold layer. But as with the lead isotope or trace element analyses, these investigations can only add indications, but rarely provide clear and decisive answers.

Conclusion

The investigation of early modern silver objects involves a number of different approaches. Stylistic and art historical investigations offer a very powerful method to identify possible periods and regions of production, often enabling to date the object to within a few years. This not only relies on the assessment of the artistic workmanship, but is supported by a careful study of the various marks and use traces. The scientific investigations adds further elements to the picture, but the final assessment has to consider all aspects and bits of information individually and jointly.

ILLUSTRATIONS AND ACKNOWLEDGMENTS:

All the objects illustrated in these pages are from the National Museum in Poznań, Poland, with ecceptions of page 75 from Archdiocesan Museum in Poznań, Poland. Photographs by A. Skowronski. Acknowledgements for National and Archdiocesean Museums in Poznań for making their collections available for AUTHENTICO project.

1. Analysis conducted by Prof. Thilo Rehren.

2. Analysis conducted by Mgr. W. Topolska on the Bruker Alpha FT-IR device. The authors would like to acknowledge the Bruker-Optik GmbH company for allowing them to use the device.

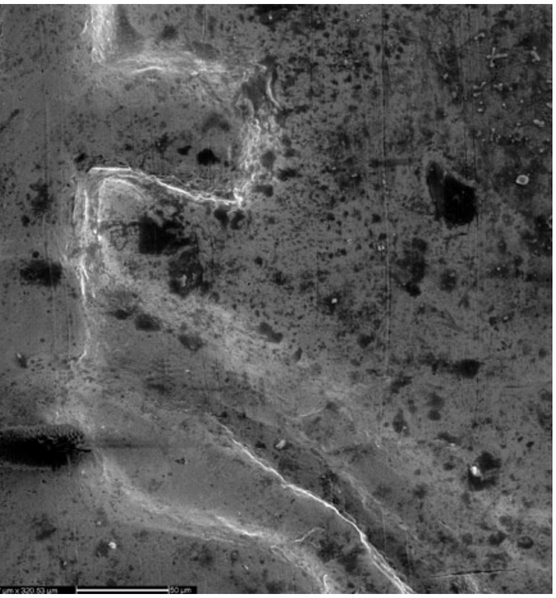
Andrej Ŝumbera

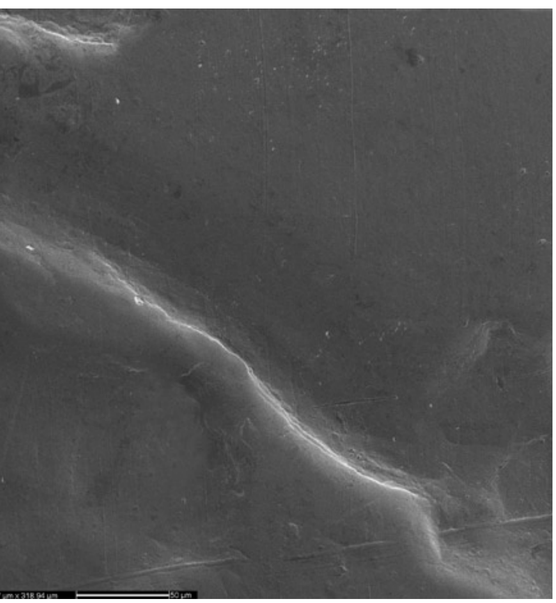
Hallmarks, which are special marks stamped onto precious metal articles, provide different information about these products (where and when they were made, who made them). In particular, they guarantee the declared fineness of the used material; for brevity, the following text uses several times the term "hallmark" including maker's mark or responsibility mark as well, which are explained later on. Even in today's era of precision manufacturing, every new hallmarking die is unique; it is impossible to make an exact reproduction. The production of hallmarking dies is a highly professional activity requiring, on purpose, a good portion of manual work. Traces left by engraving tools are the reason why we can

Andrej Ŝumbera

EDU-ART.

Conservation & Restoration of Prague Castle Royal Jewellery, Czech Republic.





Characterisation

PAGE 83: hallmark embossed on silver plate. ABOVE: right side under the cross mark. UNDER: embossed edge shaping, right under the cross mark. SEM magnification. Assay Office, Praha.

find many unique characteristics even on the minute area of the hallmark embossment. When the surface is magnified, we can see these distinctions and identify the differences of seemingly identical hallmarks (in this page, first photo from the top). This was and still is the way to discover forged, illegal hallmarks.

Legal hallmarks were often registered and samples kept in different places as reference marks, imprinted e.g. on copper plates (in this page, second photo from the top). In case of any doubt, it was possible to compare a suspicious hallmark with these samples and to discover a fake. Hallmarking of precious metals is an extremely effective weapon against fineness fraud. The system of hallmarks also makes the uncontrolled circulation of strategic materials, which precious metals have always been, more difficult.

Hallmark Forgery

Why are hallmarks forged? A fake hallmark makes it easier to sell poor quality products, the fineness of which is lower than that declared on the hallmark. A fake hallmark can also be used even when an article has the right fineness, because a false hallmark confirming an official inspection helps avoiding fees or custom duties. Unauthorized use of a maker's quality mark is a similar case: we can often see a fake maker's mark on imitations of successful products.

Counterfeits have always relied on the fact that it is practically impossible to tell the fineness of a metal from which an article is made without use of special devices. This is why different institutions and prominent individuals (rulers, goldsmiths' guilds, rich merchants) needed to have some way of making sure that besides a great look – which, in the case of fakes, often does not actually last – an artefact also has the declared value. This had been done for millennia with coins, stamped by the official mint. A similar system has gradually developed for jewels and other articles made of highly valued metals (initially gold and silver and, much later, also platinum and palladium): articles made of guaranteed precious metals were stamped with a small, but complicated and hard-to-imitate mark.

Hallmarks started being widely used after the first goldsmiths' guilds were founded in the 13th century. As time went by, every goldsmith has created his own mark, usually with his initials that were engraved in differently shaped frames to distinguish them (next page, first photo from the top). Some records of these early hallmarks still exist and thus, even after many centuries, we can often identify the author of a specific article from the hallmark. The guilds were very particular about their reputation and made sure that the products made by all their members were of good quality in every aspect, and usually guild members themselves inspected these products. The objective was to guarantee the quality of the work as well as the metal for its customers. This guarantee was especially important for products exported to other regions. Maker's marks and hallmarks of a goldsmith or guild not only guaranteed fineness and good quality work, but also provided information about where the articles were made, which helped to promote the good reputation of their makers.

Several factors helped to create an environment that radically limited illegal practices. A new goldsmith could not become a member of the guild unless he had many years of experience as a journeyman, passed difficult tests and was vouched for by one of the current guild members with a good reputation. It was not possible to work as an independent goldsmith without being a member of the guild. There were several levels of punishment for those who failed to honour guild regulations, the worst punishment being expulsion from the guild. Guilds were very protective of their territory, and whenever foreign products were sold in their territory, they tried to find any potential discrepancy and thus to limit competition.

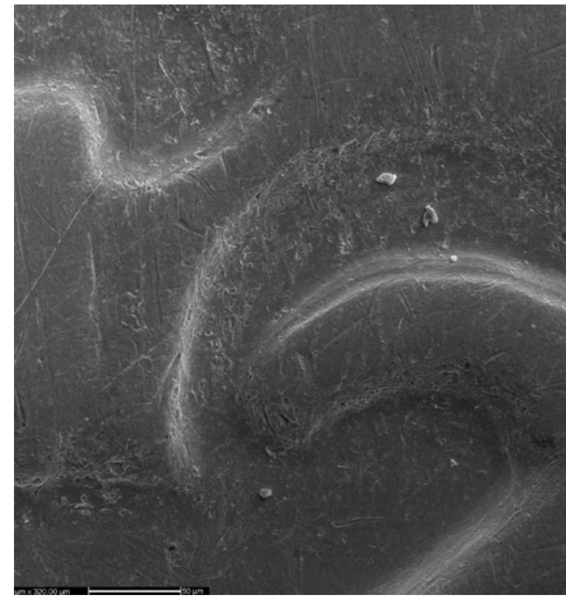
Assay Offices

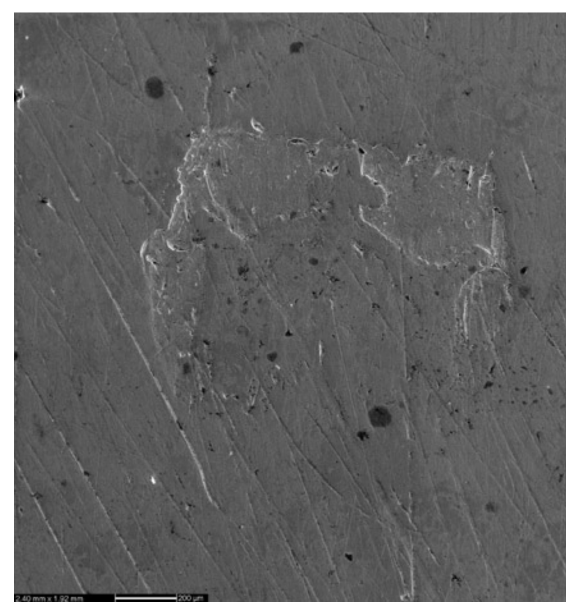
Prior to the industrial revolution, it was difficult to abuse hallmarks on a large scale thanks to the implemented practices. With the onset of a new era, the situation has changed: cheap batch production and an easy circulation of goods affected the goldsmith trade as well. The traditional structure of guilds and business relations kept changing and the tried and tested guarantees were no longer sufficient – there was more room now for fraud.

It was necessary to stop these bad effects in the dynamic and chaotic atmosphere of the industrial revolution, and it was in the state's best interest to implement effective inspections of goldsmith products. Therefore, most European countries established specialized offices – assay or guild institutions – and provided them with the necessary regulatory authority. Since the time of their foundation, their task has been practically the same: to test the fineness of all precious metal articles, to inspect fineness marks and maker's marks that are mostly imprinted by the actual makers, and to imprint hallmarks proving the inspection. Strictly speaking, the term "hallmark" means only the mark imprinted by an inspection institution independent from the maker (in this page, second photo from the top).

The separate fineness marks and maker's marks are also stamped onto precious metal articles and are often included in the term, although they do not carry the same official authority. Today, most countries have a sophisticated system of marks from which we can easily find out the necessary information about the met-

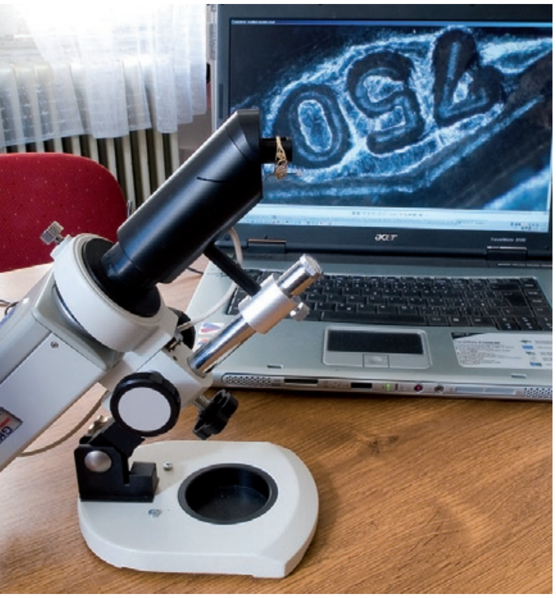
BELOW: surface after mechanical cleaning inner edges remain intact. UNDER: even a seemingly completely damaged hallmark can contain signs for identification in the recesses.

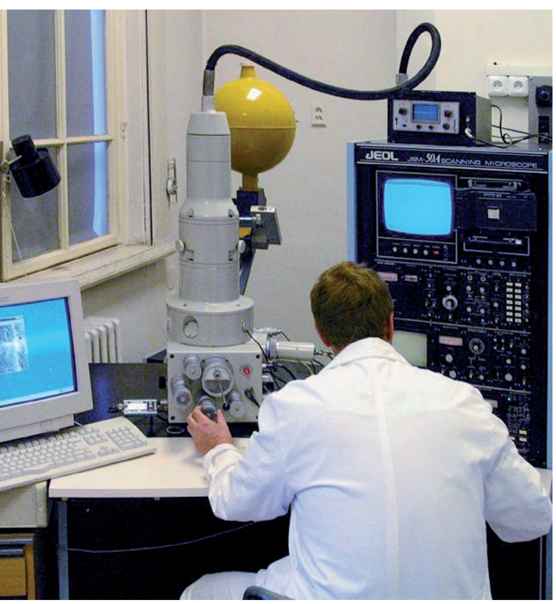




al and its fineness, the maker and the place of inspection. The assay offices keep records of all these marks.
Assay offices often have the right to perform random on-site inspections to check whether the products that are being sold have been properly inspected and do not carry false hallmarks or incorrect marks. The inspection systems in many countries are similar but not uniform.

Assay offices seek modern devices that would help them to discover any discrepancy. Touchstone testing that provides good basic information is the simplest and oldest method. Fire assay by cupellation, i.e. the separation of precious metals from other metals by oxidizing fusion, is a very accurate method of checking the contents of precious metals in an alloy. This method, known since medieval times, allows us to determine fineness with the accuracy of up to two ten-thousandth.





Microscope

ABOVE FROM THE TOP:
portable microscope
and visual documentation.
SEM, Assay Office Praha.

Modern non-destructive methods of analysing precious metal alloys include, besides others, elemental analysis by an electron beam with energy-dispersive analysis, EDA, or the more commonly used X-ray fluorescence analysis (XRF). High quality optical or electron microscopes are used to check hallmarks, and are indispensable for conclusive identification in court.

Thanks to the cooperation of assay offices in different countries, the best offices share their experience with other offices. The Assay Office in Prague, founded in 1806 as c.k. Affiliated Assay Office Prague, is also involved in such cooperation. The following experiments were carried out in cooperation with its laboratory.

Identification of Hallmarks with Different Levels of Damage

We hardly ever see a totally clean and undamaged surface when examining hallmarks and other marks on old precious metal articles. The purpose of these experiments was to find out whether or not it is possible to find unique characteristics on damaged (partially worn) hallmarks.

The experimental samples consisted of silver metal plate strips with six different hallmarks imprinted on them.

The strips were then subjected to four different ways of degradation of a different degree (wear, repair by fire, corrosion and mechanical cleaning of an article); the goal was to find the ideal way of looking for unique characteristics that survive such treatment, and to determine the limit where the identification of unique characteristics is no longer possible or possible only with great difficulty.

The surface of the samples imitating regular wear was sanded and polished to a different degree. Hallmarks are usually stamped deep enough and therefore even significant wear does not change the hallmark embossment. Yet, there are cases where e.g. wearing a ring for a long time may cause such loss of the metal that damages the hallmark embossment. The sample imitating this situation proved that it was still possible to identify the unique characteristics of the hallmark in the bottom part of the embossment.

The next sample imitated a repair of the jewel by fire: the metal was annealed to the temperature that causes oxidation of the surface due to the presence of copper in the alloy. When the oxidized layer was chemically removed it was obvious that the imprinted hallmark had lost its most delicate characteristics but was still in a state good enough for examination of the embossment.
Subsequently, a thick layer of patina on the sample imitating an archaeological find was artificially created. By its chemical removal, a situation was imitated where the surface of a jewel is usually damaged even if corrosion is removed very carefully. In this case, the entire surface, including recesses, of the hallmark was damaged. Identification was difficult. In such cases the size and especially the characteristics of the damage must be assessed. Damage by corrosion is easy to recognize.

However, few archaeological finds of artefacts that would today require hallmarks are from periods when hallmarks were used, and the difficulty to make a fake archaeological find with a fake hallmark looking real minimizes the risk of circulation of such imitations.

On the samples imitating mechanical cleaning, the effects of cleaning with fine abrasives using fine nylon, brass or glass brushes with a different level of intensity were examined. After having applied regular force necessary to clean the surface, one could still see enough areas, especially in the recesses of the embossment, to identify the hallmark.

After all these tests representing regular degradation, repair and cleaning, it was still possible to see the identification characteristics of hallmarks in the electron microscope. In reality of course, identification is much more complicated due to the large number of marks that have been used, where especially the old ones are often not registered. Nevertheless, the tests have shown that the traditional way of hallmarking still provides efficient protection against the different types of fraud mentioned above. Thus, there are good reasons for creating a comprehensive database of currently known hallmarks so that newly examined hallmarks could be easily and quickly compared.

The samples artificially damaged in such an extreme way making identification impossible show signs of obvious tampering. If

Testing

ABOVE FROM THE TOP: cupellation method; non-destructive testing of the crown jewels at the Prague Castle.

someone wanted to disguise forged hallmarks this way, such extreme damage of the embossment can be discovered by a regular optical microscope. If we see similar damage in real life, we can most likely assume that the damage was done on purpose to make identification impossible.

Detection of Reproduced or Moved Hallmarks

Another way of forging hallmarks is taking a mould of the entire original, including its hallmarks, and reproducing it using lost-wax casting, which makes accurate reproductions. The fact that a hallmark must be metal stamped and not cast is crucial for distinguishing the original from the reproduction. The surface of a casting is completely different from that made by the hallmarking die and, when magnified, it is easy to see the difference. This is demonstrated by another experiment comparing the surface of a stamped hallmark with that of a casting.

It is also possible to deceive customers by moving a legal hallmark to another jewel. The traces of soldering can be carefully effaced and, in such a case, it is difficult to discover a fake. The goal of this rather rare type of forgery is to make an imitation of an especially valuable artefact look real.

Conclusion

The fight between counterfeits and inspection continues and has become more and more sophisticated on the part of both sides. Counterfeiting is becoming more frequent and precise, and is being discovered by more and more sophisticated techniques. Cutting-edge devices are used to discover imitations, and it is often necessary to cooperate at an interdisciplinary level in order to assess them. A stamped hallmark will remain a good identifying characteristic in the future, although counterfeits will undoubtedly continue imitating them. The goal of the experiments made as part of the AUTHENTICO Project was not only to help to improve the method of detection but also to find simple methods of initial inspection that could be widely applied.

ILLUSTRATIONS AND ACKNOWLEDGMENTS:

Pp. 83, 84, 85
SEM views Assay Office Praha.

Pp. 86, 87
Photos by Andrej Ŝumbera.

The author wishes to thank and acknowledge Ing. Martin Novotny, Director, Praha Assay Office, for his learned contribution and for granting availability of facilities and SEM equipment.

Gold studies

Maria Filomena Guerra

Found in a free state in nature, as nuggets, dust and pellets in alluvial deposits and auriferous quartz, gold is amply malleable and ductile, allowing it to be cold hammered, rolled and shaped to form simple objects. However, native gold is an alloy of gold where silver and copper are present in variable contents. The first known production of pure gold dates from the time of King Croesus (6th century BC), and was identified in the archaeological remains of a gold refinery unearthed in Sardis, the capital of the ancient Lydian Kingdom. Since then, gold alloys could therefore be produced with the colour and the mechanical and physical properties required for the final purpose of the item.

Maria Filomena Guerra

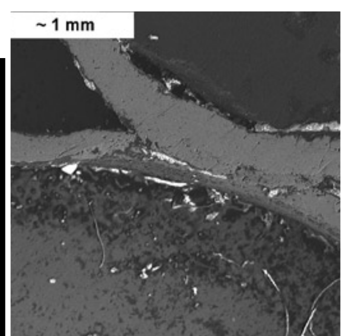
C2RMF,
Centre de Recherche
et de Restauration
des Musées de France.

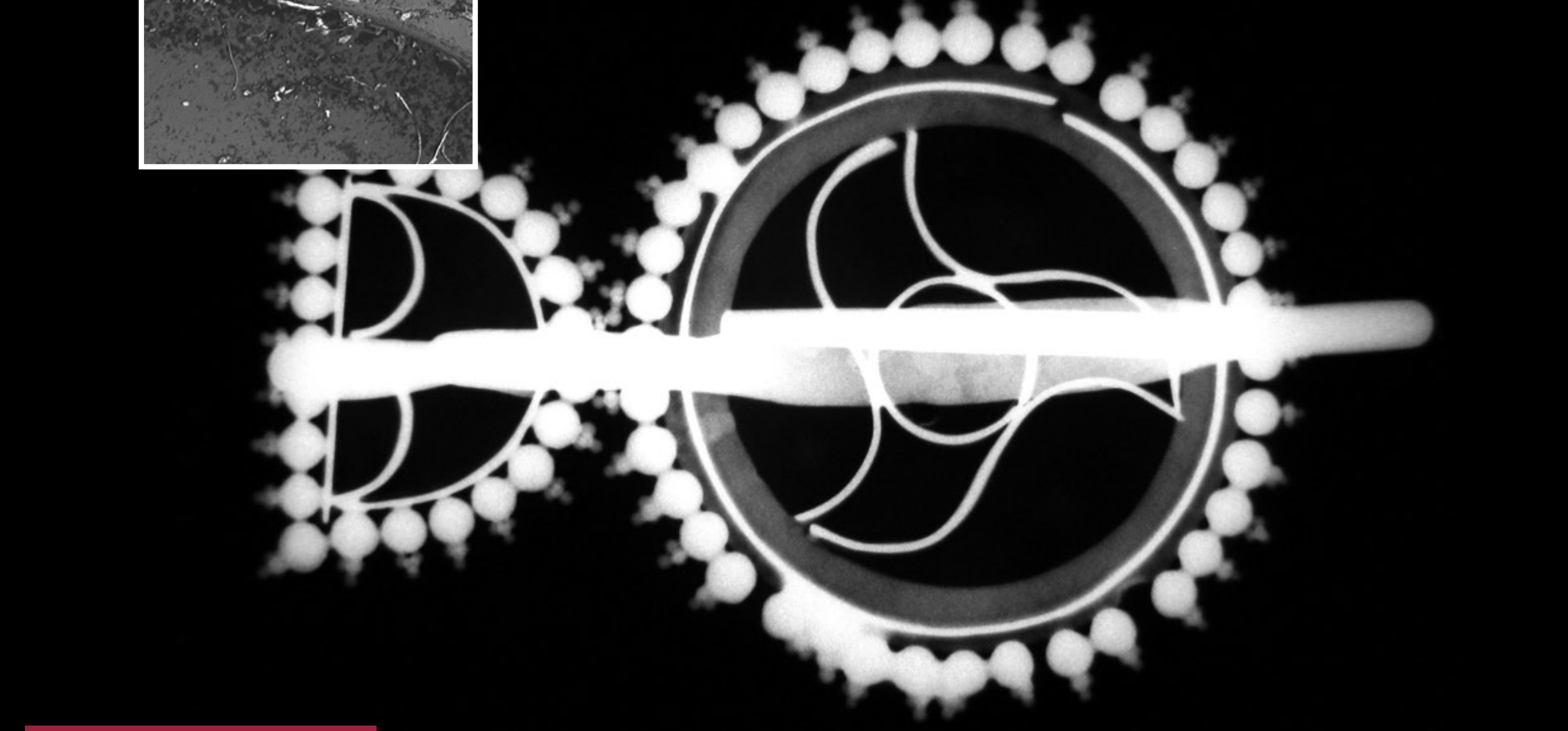
Volterra brooch

PAGE 89: jewellery items are a construction of many different joined parts and materials. The decoration of a gold item can be obtained by chasing, stamping, engraving, etc. or by addition of materials by gem setting, niello inlaying, enamel application and so on.

By the simple addition of silver and/or copper to gold, and by using techniques such as annealing and quenching, as well as hammering and casting, a gold object with many different colours and many different joined parts and materials can be obtained. Objects based on lower quality alloys can be gilded to look like gold.
By using scientific techniques, the study of gold objects allows the tackling of all the different aspects covering their production and circulation: from the exploitation of the metal and any other raw material to the surface finishing of the object itself and its diffusion in a certain area of circulation.

When we consider the scientific study of gold objects, it is generally possible to define two main directions for enquiry: one pertaining to the manufacturing techniques used for making the objects, and the other addressing the circulation of the raw materials and of the finished objects. With regards to the first of these lines of research, the decoration, joining, mounting and surface finishing





Gold pendant

Observation of the nr. 267 gold cloisonné pendant from the Tajikistan National Museum of Archaeology dated to the Kushan Period, 1st to 2nd c AD. FROM THE TOP: stereomicroscope micrograph evidences the details of the cloisonné; SEM micrograph allows to show the finishing of the cloisons and estimate their dimensions; X-ray radiography shows all the different parts of the object and evidences their regions of joining.

techniques must be described. Analytically more elaborate, the second type of enquiry takes into consideration the origin and provenance (type and localization of the exploited deposits) of the gold by determining its geo-chemical characteristics.

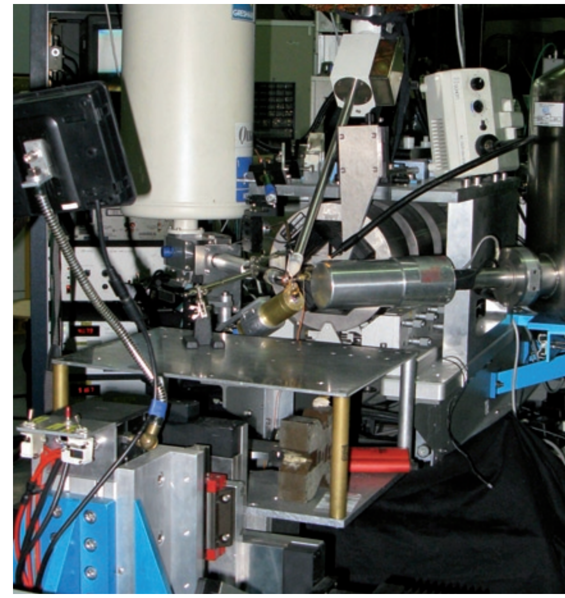
Depending on the goldsmith's techniques, on the complexity of the objects, and the questions to be solved, scientific methods of examination and analysis are selected and carried out in order to recover further information on the objects. Such information is added to the data on iconography, style, date and other pieces of evidence obtained by simple observation. It must however be noted that the criterion of non-destructiveness for the performed analyses is a requirement that restricts the range of available techniques.

Observation of the gold items under different lights and radiations allows the description of the mounting, joining, decoration and finishing techniques. Low and high magnification images of the surface morphology of a gold item are generally obtained by optical microscopy (OM) and scanning electron microscopy (SEM). The information is then complemented by X-ray radiography, which permits revealing the internal mountings and the regularity of certain processes, such as hammering. Decoration techniques such as repoussé, chasing, stamping, engraving, and so on, can be studied by high-resolution surface profilometry, providing information on the goldsmith's techniques, tools, and gestures.

Queries related to some production techniques, and to gold provenancing and circulation, are only achieved by analysis. Several scientific techniques of elemental, isotopic and structural analysis are available for the study of modern gold, but studies on ancient gold items must be undertaken with non-invasive techniques. For this reason, elemental analysis is usually preferred.

Non-invasive elemental analysis of gold work is carried out by techniques requiring the use of different tools, ranging from portable equipment to large facilities. The choice of the techniques depends on the type of query. For example, questions on the circulation of gold generally involve techniques with good detection limits, able to measure the concentrations of the few characteristic trace elements of gold that remain in the alloy after metallurgical processing.

Micro and macro major elemental analysis can be carried out with many techniques, such as X-ray fluorescence (XRF), energy or wavelength dispersive spectrometry (ED or WDS), SEM-EDX, or laser induced breakdown spectroscopy (LIBS). Trace element determination requires the use of large facilities; ion beam analysis (IBA) with particle accelerators and synchrotron radiation XRF



The analysis

ABOVE FROM THE TOP: analysis of the objects studied in the framework of AUTHENTICO: AGLAE accelerator, C2RMF; in situ, UCL portable XRF system at FNMA.

(SR-XRF) are at present the most convenient techniques for gold fingerprinting. These techniques are occasionally replaced by inductively coupled plasma mass spectrometry (ICP-MS).

ILLUSTRATIONS

P. 89

Volterra disc brooch. *Florence National Museum of Archaeology, purchased from Solaini on 1873. Reference catalogue nr. 70799. Photograph by M.F. Guerra, C2RMF.*

P. 90

Gold cloisonné pendant. *Tajikistan National Museum of Archaeology.Kushan period, 1st to 2nd c AD. Reference catalogue nr. 267.*

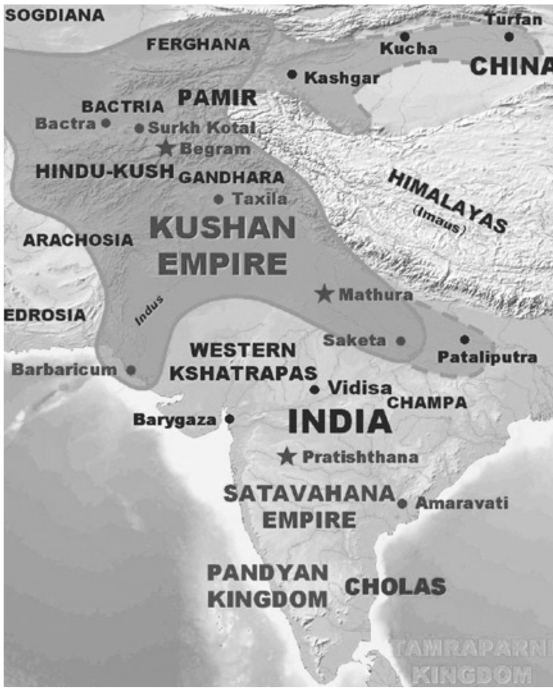
a) Stereomicroscope image by M.F. Guerra, C2RMF.

b) SEM image by M.F. Guerra, C2RMF.

c) X-ray image by T. Borel, C2RMF.

Kushan pendant and earring from Tajikistan

Kushan pendant and earring from Tajikistan



Kushan pendant

MAIN: the globular pendant from Tajikistan. INSET: the Kushan Empire circa 150 AD.

Kushan pendant

The Kushan Empire has its origins in the 2nd century BC, when a confederation of nomadic Indo-European Yuezhi tribes invaded the Sogdiana and the Bactria areas. These tribes first settled along the Oxus river and in southern Bactria, but later expanded to north-western India and Afghanistan.

The globular openwork gold pendant from the National Museum of Antiquities of Tajikistan was found in 1975, during the excavation at Beshkent cemetery V, situated in the Beshkent Valley (Southern Tajikistan) reference 6 at page 122 of NMAT. A blackish round bead is covered with thin wire openwork and connected to a solid gold jump ring, the basis of which is enriched with a ringlet of granules. The central pivot is completed by a pyramid of four small beads.

In detail

FROM THE TOP: the X-radiography of the pendant shows the use of rolled wires and a central plain wire. Micrograph obtained with a stereomicroscope shows the rough surface of the wires and discs composing the birdcage as well as the thin regions of junction of different parts.

Coupled, strip twisted wires are the starting point of the birdcage structure: the wires are bent to form loops, each loop jutting open to form the wirework net. At the junction points, when two wires touch each other at a 45° angle, small discs are placed and fused in order to contact the wires, providing strength and reinforcing the structure; the cage is maintained unfastened at the bottom, to allow the open birdcage to be gently folded over the inner stone bead, which, in turn, is threaded through the rod, connecting the birdcage to the bail.

The domed disc is centred right above the open wirework cage. The emerging wire, coiled around the bail, serves also as a central rod, ending with a pyramid made of granules; as a spacer, between the cage and the pyramid, a pearl is strung.

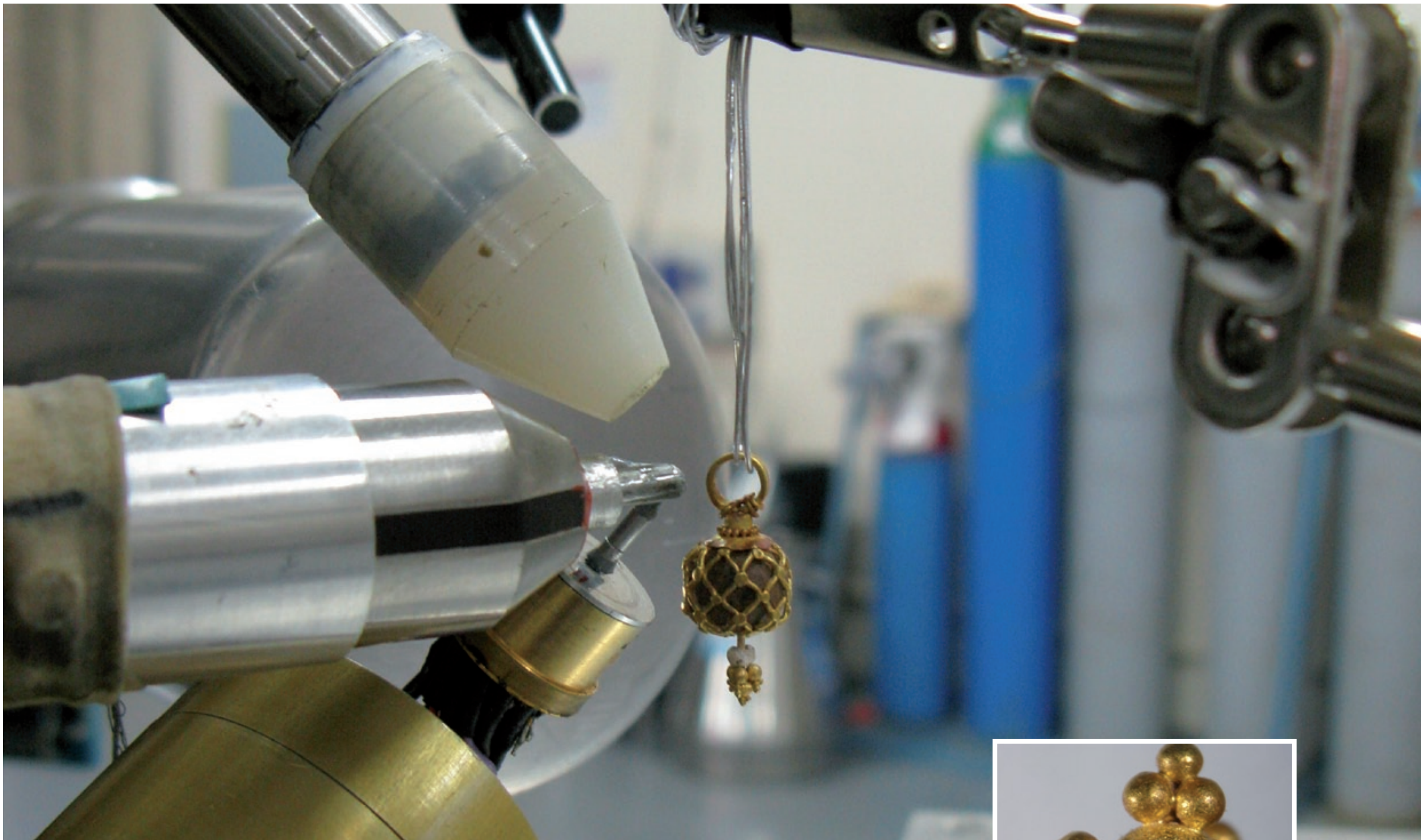
The pyramid, functioning as a finial, is fused to the central rod; it is obtained by placing three granules fused to each other in a triangular scheme, with a fourth granule centred on top of the three granules; additional smaller pyramids, obtained according to the same building scheme, are fused on top of each larger granule.

The elemental analysis of the pendant was carried out by PIXE at the AGLAE accelerator of the C2RMF, with a 3 MeV external proton beam of 30-50 µm in diameter and an intensity of 30-40 nA (Guerra 1994). The average composition of the gold alloy is 76% gold, 22% silver and 2% copper. This is close to the composition of some alloys used under Vasudeva II (after circa 261 AD) to strike concave dinars (Fussman 2003).

Khatlon earring

The pendant earring with turquoise and garnet from the National Museum of Antiquities of Tajikistan was found in the late 1970s, during the excavation at Ksirov cemetery III, mortuary enclosure nr. 19, situated in the Dangara district of the Khatlon region (Southern Tajikistan). The object is dated to the 4th-5th century AD (reference 17 at page 126 of NMAT). This earring is typologically very close to the elements of necklace 129 (Afghanistan catalogue) from Tilia Tepe, found in tomb V (1st century AD), as well as to other objects from Tilia Tepe. The earring is composed of four elements: in descending order, a suspension loop and ear hook, connecting the central body consisting of two bezel settings (one mango shaped and one round shaped), positioned on the same backplate, one below the other, and a round disc suspended with coiled wire from the main body lower box setting.

The suspension loop consists of a long rod, forged as a hook, joined to the back upper part of the jewel, and bent to fit into the ear. The lower part of the suspension loop is flattened for wider surface

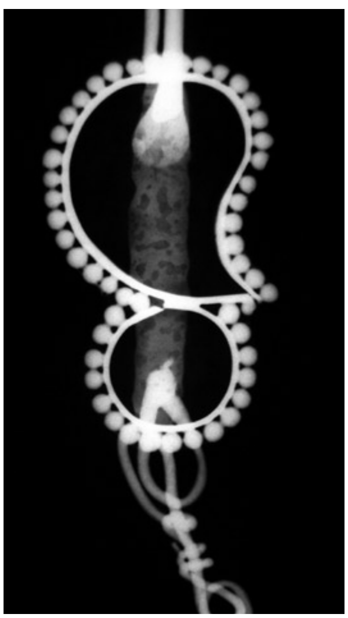


contact with the backplate. On the bottom end of the flattened rod, an oblong link is positioned, beaten flat at both ends, to allow for a wider contact surface with the backplate to which it is joined, thus resulting in a hook through which a length of strip-twisted wire is threaded, linking the pendant disc to the main body.

The mango shaped box setting consists of a flattened strip of gold, placed on the upper part of the supporting plate; it is surrounded by a row of granules. The setting encircles a cabochon turquoise (damaged), cut to fit into the bezel's mango shape. The round box setting consists of a flattened strip of gold, placed on the upper part of the supporting plate; it is also surrounded by a row of granules. A slightly damaged dark round cabochon garnet is set inside the box. The pendant disc hangs from the oblong link fused to the central body. The disc was obtained by beating a gold plate into thin sheet. A small jump ring, placed on the upper part of the disc, mechanically links the pendant disc to the central body by means of a suspension loop, made from strip-twisted wire, wound around both hooks. The elemental analysis of the earring was carried out by PIXE at the AGLAE accelerator of the

In detail

MAIN: analysis of the pendant by PIXE at the AGLAE accelerator of the C2RMF. INSETS FROM THE TOP: micrograph with a stereomicroscope shows the terminal pyramid of granules. At each side of the sphere, the wires make a loop.



Khatlon earring

FROM THE TOP: the earring; X-radiography shows the use of plain granules and the connection regions of the gold strips forming the cabochons.
RIGHT: SEM micrograph showing the construction: the rod joined to golden plaque, the granules surrounding the cabochon and the cabochon; the flattened rod; micrograph with a stereomicroscope shows the construction of the terminal disc.

C2RMF at the same experimental conditions described above. The average composition of the gold alloy is 72% gold, 26% silver and 2% copper. The earring is typologically close to the elements of necklace 129 (Afghanistan catalogue) from Tilia Tepe, found in tomb V (1st century AD). Objects from this period found at Tilia Tepe were made of an alloy of better quality, with 96% gold, 3% silver and 1% copper.

ILLUSTRATIONS

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Kushan pendant. *Total length: 24 mm, width: 10 mm; weight: 1,87 g. Tajikistan National Museum of Archaeology. Reference catalogue nr. 272. Photograph by D. Bagault, C2RMF.*

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Kushan pendant.
a) X-ray image by T. Borel, C2RMF.
b) Micrograph image by D. Bagault, C2RMF.

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Analysis of the Kushan pendant by PIXE. *Photograph by M.F. Guerra, C2RMF.*
Kushan pendant
a) Micrograph image by M.F. Guerra, C2RMF.
b) Micrograph image by D. Bagault, C2RMF.

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Khatlon earring. *Total length: 5.9 mm, disc diam. 1.8 mm; width: 10.5 mm; weight: 2.48 g. Tajikistan National Museum of Archaeology. Reference catalogue nr. 286. Photograph by D. Bagault, C2RMF.*
a) X-ray image by T. Borel, C2RMF.
b) SEM image by M.F. Guerra, C2RMF.
c) SEM image by M.F. Guerra, C2RMF.
d) Micrograph image by D. Bagault, C2RMF.

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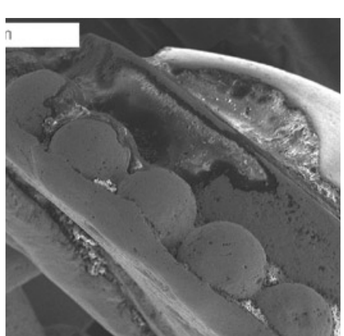
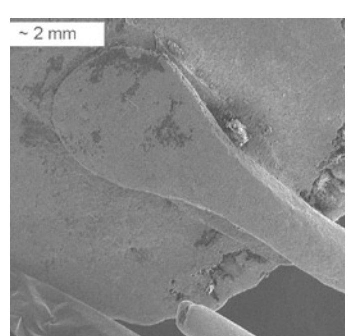
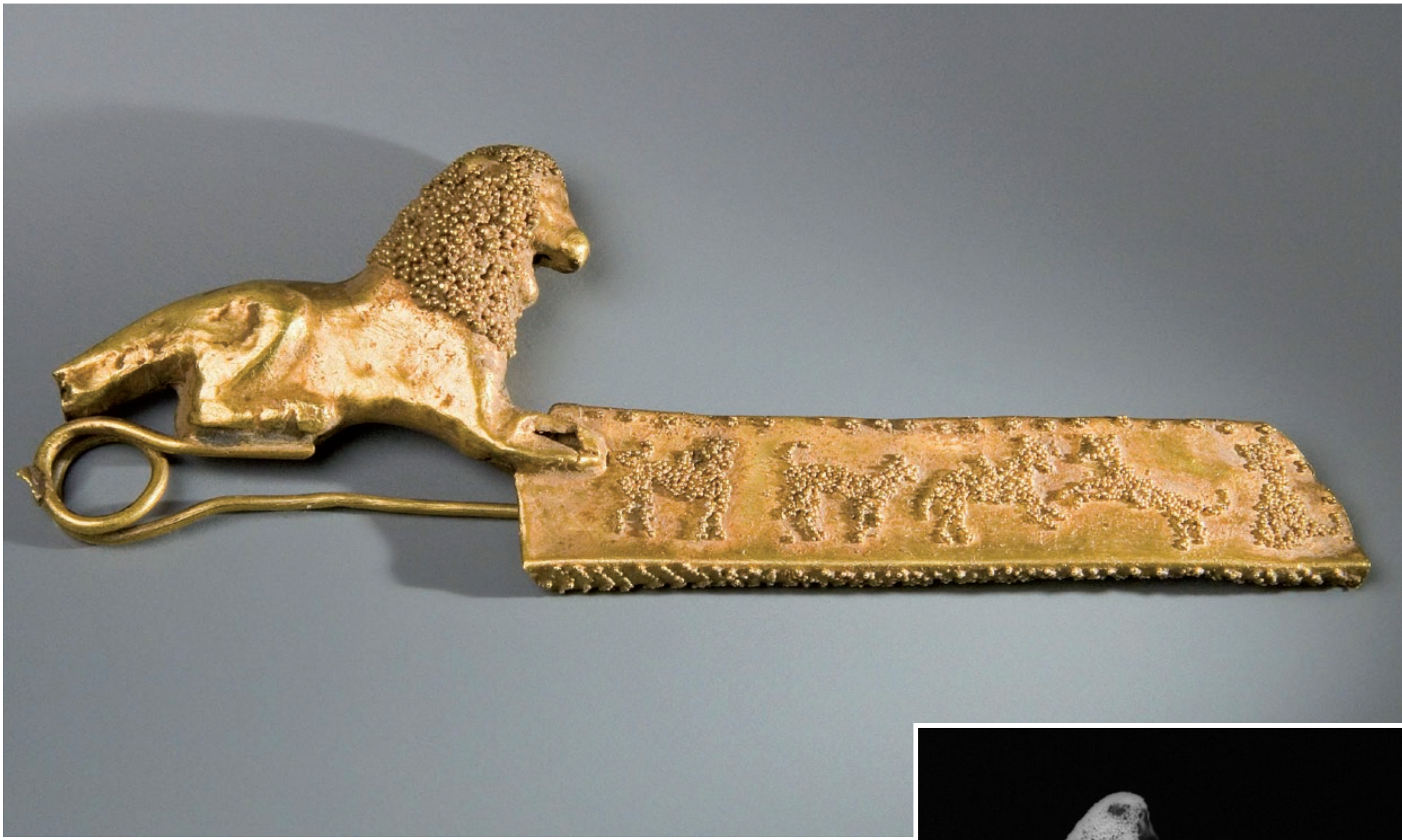
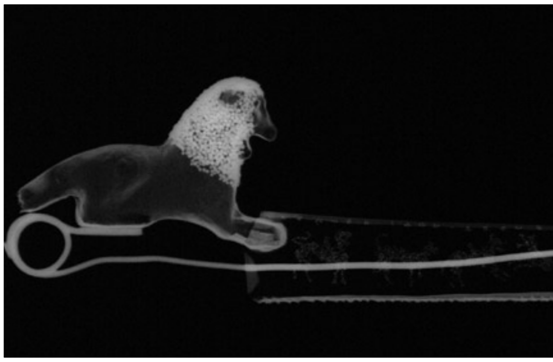




Etruscan lion fibula

Etruscan lion fibula





Lion fibula

MAIN: the fibula.
INSET: the X-radiography shows a wire that is sharpened by cutting instead of hammering.

Etruscan art is particularly attractive for museums and private collectors. The lack of knowledge about the art of this civilisation created new possibilities for forgers, who, since the 18th century, also produced ‘invented’ items, in addition to copies and imitations (Guerra 2008). The sarcophagus based on genuine sarcophagi, and forged by adding the inscription of the gold fibula from Chiusi (Borrelli 1992), purchased by the British Museum, London (Williams 1992), and the colossal Etruscan warriors of Orvieto, purchased by the Metropolitan Museum of Art, New York (Duchêne 2006), are just two examples of famous Etruscan fakes.

These were fabricated by restorers working in the 19th century workshop of the Marquis Giovanni Pietro Campana di Cavelli, whose collection comprised nearly 15,000 objects, some genuine,

'Baule' earring

ABOVE: micrographs show the different forms and dimensions of the granules used in the production of the lion fibula motifs and residues of hard soldering.
BELOW: 'Baule' earring.

some fantasist and unscrupulous fakes (Borrelli 1992), and others modified and enhanced by additions (Guerra et al 2007, Guerra 2005). The fibula with a lion from the collection of the Florence National Museum of Archaeology was purchased in 1911 from Maruzzi and assumed to originate from Populonia.

The construction of this fibula can be easily described using X-radiography. It is a bow-shaped fibula in the form of a lion, obtained by joining two embossed metal sheets. The lion has small, slightly outlined ears and a short, slender muzzle; the forepaws are lengthened and joined on to the shank immediately underneath the upper part of the object; the tail is shortened, with a hole drilled in it, and the thick mane has been made by granulation.

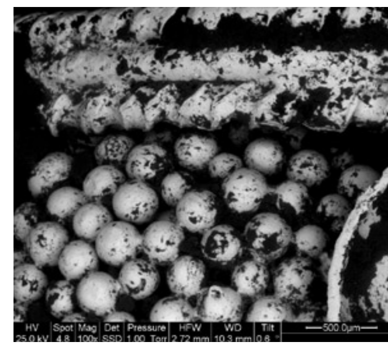
The spring, wound round one-and-a-half times, is welded under the lion. The elongated shank terminates in an oblique cut at the rounded end and is decorated with a procession of five animals made in gold dust. Following two representations of what are probably winged lions passant dexter, there are two unidentifiable animals rampant and another lion passant traversed, bordered by two rows of granulated dots.

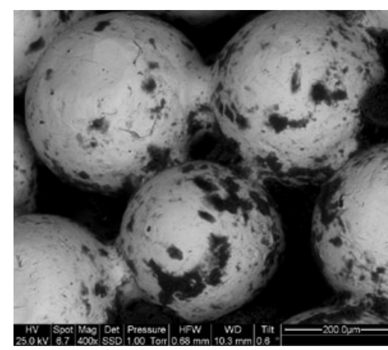
The observation of the decoration motifs with granulation under the stereomicroscope shows that the fibula is of modern fabrication. This fibula had already been declared a fake by Formigli (1985). The granules were obtained by cutting small pieces of wire according to Etruscan tradition, with those granules taking the expected forms, from cylindrical to spherical, when exposed to high temperatures (Nestler and Formigli 1994). However, the granulation is far too irregular to be considered as an ancient work and the granules are joined by hard soldering.

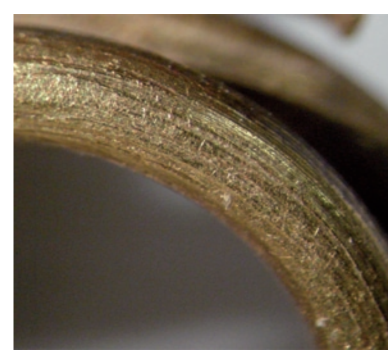
When we observe the granulation motifs applied on a genuine Etruscan 'a baule' earring, the regularity of the ancient production of powder granulation and the fine granulation and filigree work of the decoration motifs are obvious. One of the Etruscan 'a baule' earrings from the Florence National Museum of Archaeology collection, dated to the second half of the 6th century BC (unknown provenance), and belonging to the Currie's Collection (1836), was studied for comparison. The hypothesis of a modern fabrication for the lion fibula is confirmed by the observation of the hook: it clearly shows the use of a modern drawn wire, recognizable by their characteristic parallel striations (Ogden 1991), caused by passing the wire through the holes produced by irregularities in the perforation of the drawn-plate.

The analyses were carried out using a handheld XRF spectrometer, Innov-X Systems Model Alpha 8000 LZX, with a silver tube, operating at 40 kV and 29 μA. The analytical spot/focus of the instrument is about 5 mm in diameter, and therefore some analyses of small parts of a composite object may have included adjacent parts. The results are averages of 2-3 measurements (normalised to 100 wt%). The composition of the lion fibula was compared to the composition of the 'baule' earring nr. 15718, as well as to another earring (inv. nr. 85036), also purchased in 1911 from Maruzzi and supposed to originate from Populonia. The observation of this earring under the stereomicroscope leads to the conclusion that it is also of modern production, and perhaps from the same workshop as the fibula.

The results obtained by XRF indicate the use of different alloys to produce the lion fibula: 87.8% Au, 8.7% Ag and 2.2% Cu for the plaques, and 75.6% Au, 17.4% Ag and 3.4% Cu for the granulation. The modern earring was also produced with different alloys: 92.7% Au, 5.4% Ag and 1.2 % Cu for the plaques, and 88.1% Au, 7.4% Ag and 1.3% Cu for the big granules. The presence of iron oxides on the earrings' surfaces (iron reaches up to a concentration of 4%) is explained by the intention of giving an 'archaeological' aspect to the fakes. The genuine 'baule' earring shows a very different composition from the alloys used in the modern productions: 91.5 % Au, 4.4% Ag and 3.1% Cu.

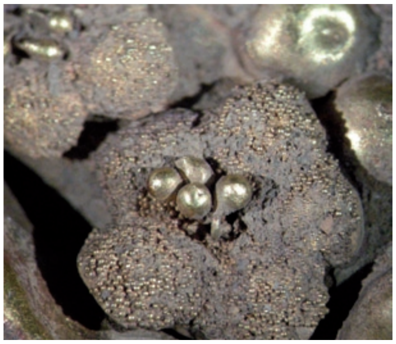






In detail

FROM THE TOP: SEM micrographs showing details of the powder granulation that decorates the big granules and half-granules of earring 15718, and the plain and twisted wires surrounding the motifs.
LAST: under the stereomicroscope, the gold hook reveals the use of a modern drawn-plate.



Earring

ABOVE FROM THE TOP:
earring from Florence National Museum of Archaeology.
UNDER: stereomicroscope micrograph.

ILLUSTRATIONS

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Lion fibula. *Total length: 94 mm; width: 10 mm; weight: 14,05 g. Florence National Museum of Archaeology. Inv.nr 85037. Photograph by A. Ŝumbera.*
X-ray *image by M. Miccio, SBAT*

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Lion fibula. *Micrographs by M.F. Guerra, C2RMF.*
'Baule' earring. *L. 1,4 cm. Florence National Museum of Archaeology. Inv.nr 15718. Photograph by A. Ŝumbera.*

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'Baule' earring.
a) Photograph on the top of the page by G. Demortier, C2RMF.
b, c) BSE images by S.Siano, IFAC.
d) Micrograph by M.F. Guerra, C2RMF.

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Earring. *Height: 6 cm; length: 3,5 cm; weight: 27,70 g. Florence National Museum of Archaeology. Inv.nr 85036. Photograph by A. Ŝumbera.*
Micrograph *by M.F. Guerra, C2RMF.*

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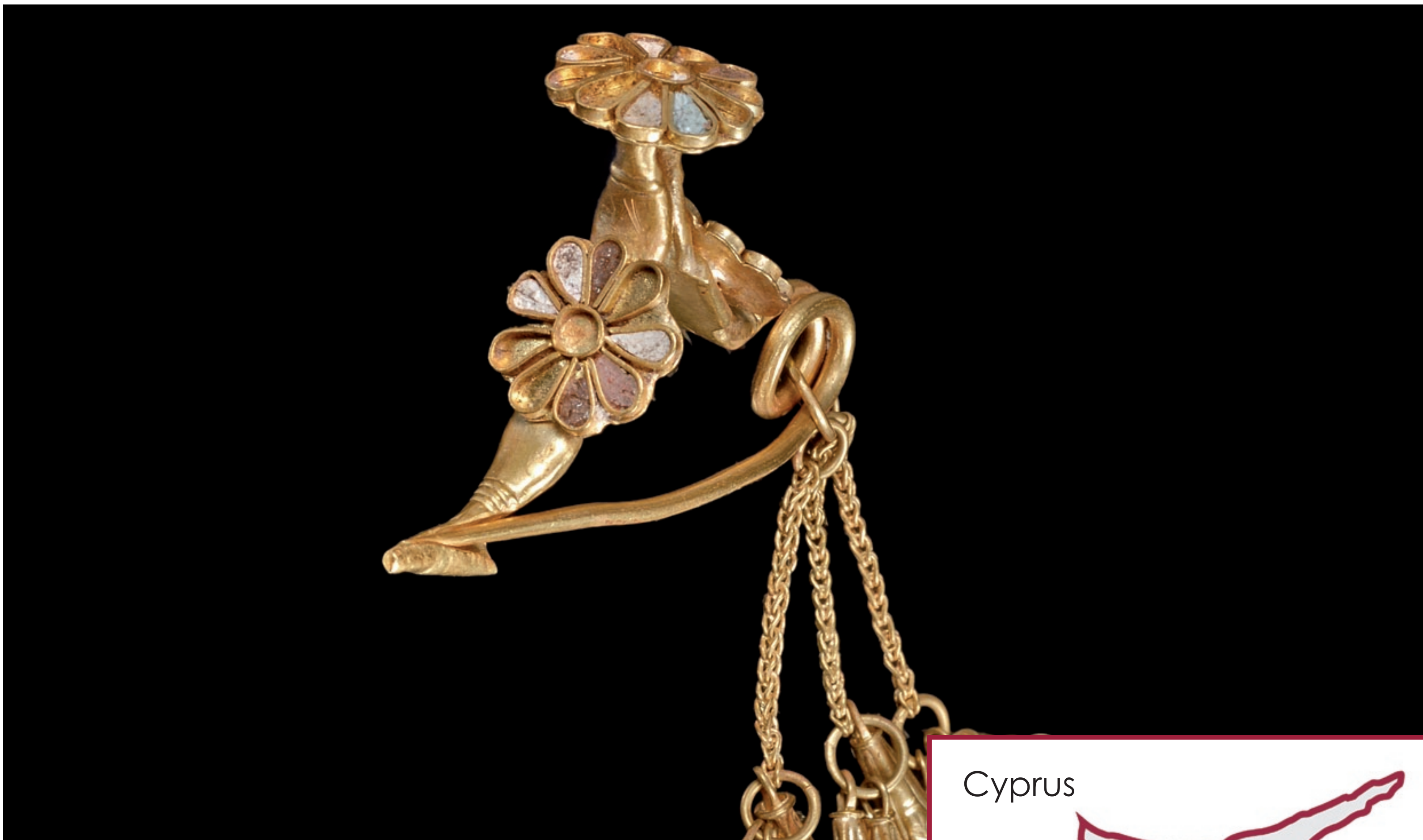
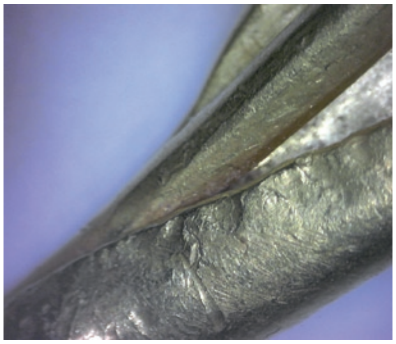
Kition Fibula



Among the high quality jewellery items from the 8th-7th century BC Phoenician tomb found in Kition MΛA 1742 near Larnaka in 1998 (Hadjisawas 1999) and kept at the National Museum of Archaeology of Nicosia (Cyprus), the gold elbow triangular fibula is the most representative both of the goldsmith's skill, and of the relations of Cyprus with other Mediterranean civilisations. Usually made of bronze, triangular bow fibulae are very popular from the 8th century BC to the 1st century AD in Cyprus (Äström 1972), Egypt and Persia, and are widely distributed in the Mediterranean area (Stronach 1959).
The decoration of the Kition fibula – consisting of rosettes, chains and bells – is typical of Phoenician jewellery. This type of decoration is illustrated in the 8th century BC earrings discovered at

Kition fibula

MAIN: the fibula from the Phoenician tomb of Kition.
INSET: the map of Cyprus showing the localisation of the Kition site near Larnaka.



Cloison

FROM THE TOP: detail of the clasp showing the faceted surface due to hammering; detail of the cloison of the inlaid rosettes.
BELOW: one of the cloisonné glass paste inlaid rosettes.

Camyrus in Rhodes (Salzmann 1863), in several items from Tharros (Acquaro 1984), and in earrings dated to the 6th century BC found in Liomilya near Kouklia (Brunet and Moretti 1990).

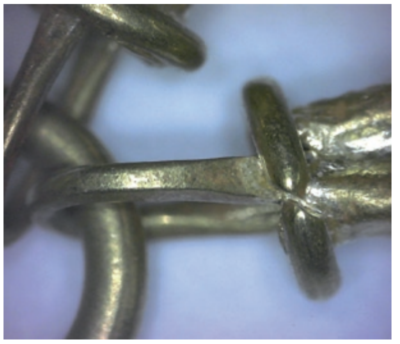
The Kition fibula consists of a main body made out of a single rod of about 2000 μm diameter, forged skilfully to the desired shape, and decorated with three rosettes. Hanging from the spring coil, and connected with jump rings, there are three chains ending with three bell-shaped pendants each. The rosettes are placed on the upper side of the fibula: the top rosette consists of 11 cloisons, the right one towards the coil consists of 10 cloisons, and the left one towards the catch-plate consists of 9 cloisons. Similar rosettes can be found on several Egyptian headbands, and the most ancient representation of this type, dating to the 4th dynasty (3rd millennium BC), was worn by Rahotep's wife Nofret (Tait 2006).

The flowers consist of a plaque of gold cut and polished on the borders, and decorated with strips of gold filled with coloured glass paste. In the centre of each rosette, a round cloison of 500 μm thickness is positioned in order to complete the decorative effect. On the rear side of the backplates, a reinforcing ring is positioned centrally to improve the contact surface connecting to the fibula's body.

The catch-plate, opened towards the locker, is positioned on the left side of the fibula, forged to a thinner and flatter surface of 2000 µm width, and folded over to host the needle. Aligned horizontally with the catch-plate, the needle is coiled one-and-a-half times to form the spring. A large connecting ring is inserted into the coil; into this ring, three smaller jump rings are inserted to connect the three loop-in-loop chains.

At the end of each chain, connected by the suspension rings of about 700 µm diameter, are three sets of bell-shaped pendants, decorated with chased stylized lotus flowers. At the bottom and top end of each bell, a thin flat border of gold of about 600 µm is fused, in order to protect the foil edges, as well as to reinforce the connecting area, where a suspension loop is inserted and fused.

The analysis of the alloys was carried out with a handheld XRF spectrometer at the National Museum of Archaeology of Nicosia. The fibula is fabricated of a gold base alloy containing an average of 16% silver, with average concentrations of copper of 1% for the main body and the rosettes, and of 2% for the bells and the chains.



Chain

FROM THE TOP: the loop-in-loop chain obtained with a wire of about 500 µm diameter and the bell shaped pendants and the suspension rings.

ILLUSTRATIONS

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Kition fibula. *Photo: National Museum of Archaeology of Nicosia, Cyprus. Published with the permission of the Director of the Department of Antiquities, Republic of Cyprus, Ministry of Communication and Works.*

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Kition fibula. *Micrographs by M.F. Guerra, C2RMF.*

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Authentication of copper alloy statuettes

Florence's antiquarian collections

Salvatore Siano, Anna Rastrelli, Andrea Mencaglia, Marcello Miccio, Juri Agresti

Salvatore Siano

CNR IFAC, Istituto di Fisica Applicata "Nello Carrara", Sesto Fiorentino, Italy.

The general problem

The archaeological dating of copper alloy statuettes of ancient styles belonging to private antiquarian collections from the past centuries is often very controversial. Usually, no information about their excavation origin, history before acquisition, or previous restoration works is available. This is in particular the case of the small and large bronzes collected in Florence by the House of Medici since the early Renaissance and afterwards by the House of Lorraine.

These collections include several hundred copper alloy statuettes of Greek, Etruscan, and Roman styles, preserved at the Florence National Museum of Archaeology and the Museo Nazionale del Bargello. Most of them show clear evidence of restoration work, such as joining of independent pieces, and brown patinations. Inventory numbers from the past centuries are often still visible on the statuettes, providing information concerning their history from archival records. However, the latter never document the circumstances of the statuettes' initial acquisitions.

The development of objective analytical methodologies for recognising copies or imitations of ancient subjects, genuine artefacts, and pastiches represents an important contribution to our knowledge of metal heritage, relevant for many museum collections around the world, which over the centuries acquired copper alloy artefacts of unknown or uncertified provenance.

Examples of authentication problems

Four statuettes were selected as case studies. For each of them, the archaeological examination identified specific authentication problems within a preliminary attribution hypothesis. These problems have been approached by means of technological and material characterisations, according to the IAM presented earlier in this book. Eventually, all the data collected are critically evaluated and synthesised in multidisciplinary conclusions.

The Statuettes

FROM THE LEFT:
Grotesque figurine. *Florence National Museum of Archaeology (FNMA), Inv. nr. 2332, height 23 cm. First quoted in Uffizi Inventories in 1784*.

Venus. *FNMA Inv. nr. 2570, height 23.5 cm, first quoted in the Uffizi Gallery's Inventories in 1769.*

Naked man seated. *FNMA Inv. nr. 2282, height 27.5 cm. First quoted in Uffizi Gallery's Inventories in 1704.*

Bacchus. *FNMA, Inv. 2287, height 38 cm.*

Grotesque figurine

This figure has an almost bald head apart from a forelock and a kind of hair pigtail above the upper limit of the occipital region (p. 107). He wears a very short mantle, with a hood descending on the shoulders.
A functional hole with a diameter of about 2 mm can be observed on the back, at the vertex of the hood. The figure holds a fruit in his left hand, while the right arm is slightly raised.

This kind of grotesque subject is typical of the Alexandrine artistic production (p. 107, inset).
A small bronze similar to the present one (the figure wears the same mantle, but the gestures are rather different), with a hole on the hood, was found during an excavation in the neighbourhood of Rome in 1759, not too long before the first reference to the present figurine in the Uffizi Inventories in 1784.

From the archaeological standpoint and general appearance of the surfaces, the bust seems ancient. In contrast, the arms and feet which are soldered to the bust could be modern additions, making this artefact a pastiche. However, it is evident that the contribution to the object's authentication provided by archaeological examination is based on the stylistic coherence of the present figurine with a Hellenistic archetype, whereas all the rest requires further technological and material characterisations.

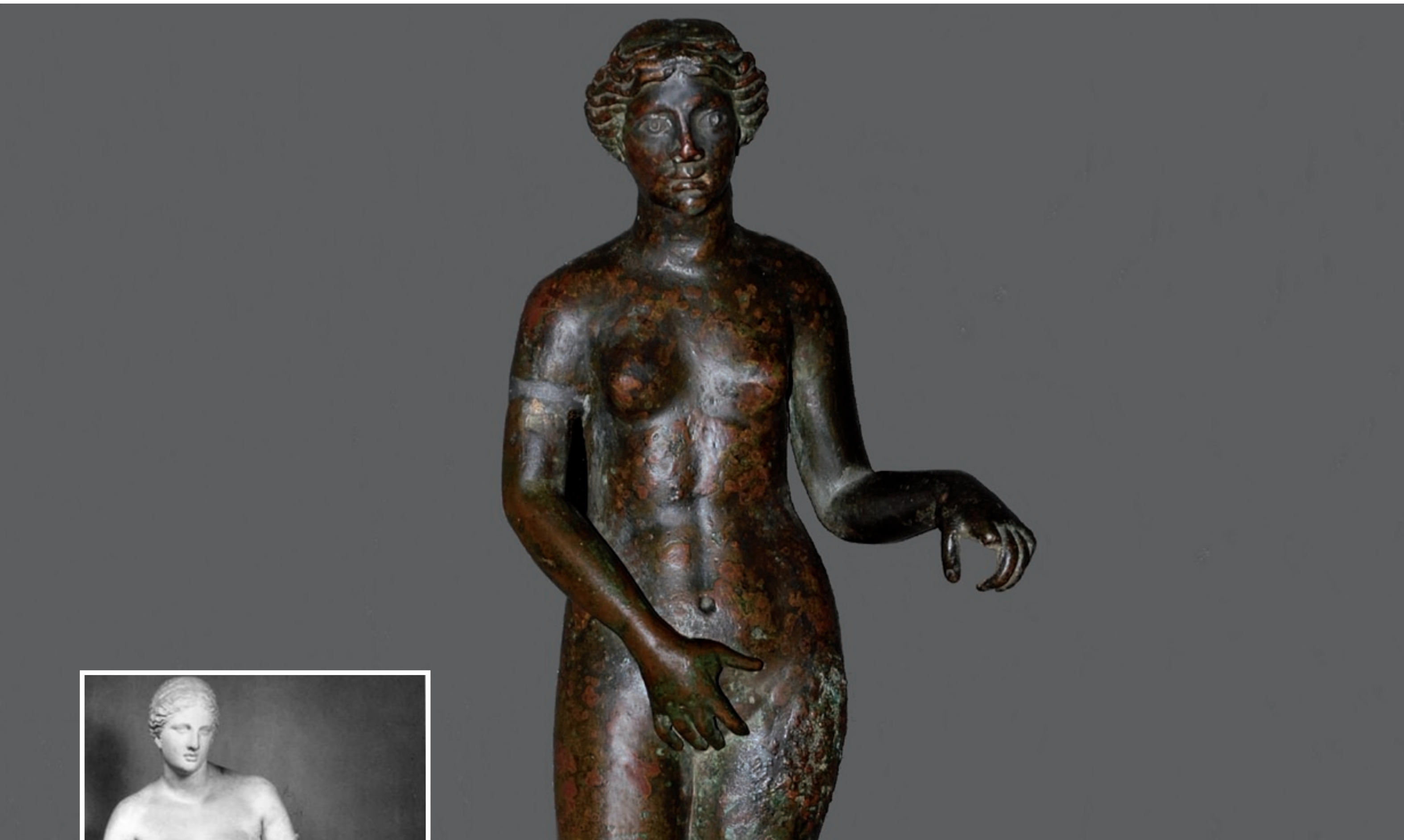
Venus

This small bronze represents a naked Venus, standing on her left leg, covering her pubes with the right hand, and aiming at something with the left forefinger (p. 108). The former gesture is typical of a popular iconographic type of this goddess dated to the 4th century BC, the so called *Venus pudica* (p. 108, inset), whereas there are no comparisons for her gesture with the left hand. The prototype of this statuette is the famous Cnidian Aphrodite by Praxiteles, which holds a towel in her left hand.

From the archaeological standpoint, the present figurine could be a Roman replica of a Greek original, with a stiff appearance and the body slightly out of proportion. It has both arms soldered to the body.
Thus, the material characterisation should allow distinguishing whether they are genuine or later integrations. If they are the result of modern restorations, only the right arm would be philologically correct.

Grotesque figurine

MAIN: detail of the upper part of the body.
INSET: ancient type of the Grotesque figurine: small Roman bronze.



Venus

MAIN: view of the upper part of the body.
INSET: ancient type of Venus: Cnidian Aphrodite.

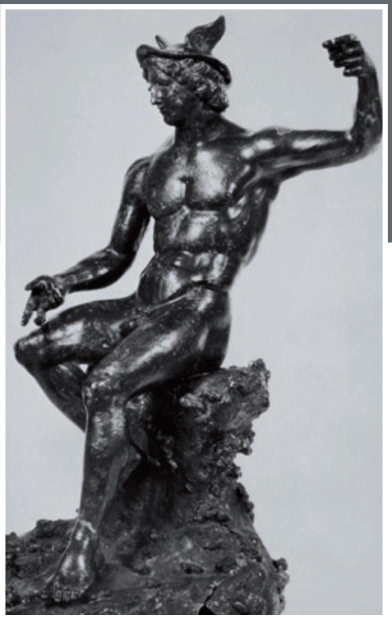
Naked man seated

The naked young man represented in this statuette has a wreath of flowers over his head and holds some fruits in his left hand, while the right arm is resting on the thigh (p. 109). The head seems out of proportion, being too small with respect to the body, but the overall appearance of the bronze is of high quality.

It is impossible to identify the present sculptural subject because of the lack of diagnostic attributes. He is not a god, nor a hero, nor a prince, which is very rare in ancient art; the fruits in the left hand are meaningless, and the gesture is the one of a figure holding a spear or a similar weapon, like the Capitoline Zeus or the representation of Alexander the Great on coins. Perhaps the fruits, or more likely the entire left arm, have been added later on. A statuette similar to the present one was found in Augst (Switzerland) in 1923 (p. 109, inset). It represents a seated Hermes, stylistically heavily based on the famous Hermes from Herculaneum in Naples.

The god wears his typical winged cap and has his left hand empty: probably it held the *caduceus*, manufactured separately.

The present small bronze belongs to a group of four larger size statuettes, all borrowing much stylistically from ancient Greek sculp-



ture, but showing some features of the Renaissance style; another example is presented below. Once again, they could quite possibly be pastiches including ancient fragments heavily integrated with more recent additions. Technological and material characterisations should assess which parts of the statuette are genuine, in order to identify the proper iconographic type.

Bacchus

This small bronze represents the naked god Bacchus (the Greek Dionysus) with a heavy ivy wreath on his long hair, standing with both arms raised and holding bunches of grapes in his hands (p. 110). Similarly to the previous statuettes, it seems to be a pastiche. Perhaps only the torso, which is mentioned in the Uffizi Tribuna since 1553, is ancient. The torso could well be a replica of an archetype by Praxiteles, being very similar to his famous "Resting Satyr" (p. 110, inset). The statuette is quoted as a torso in the Uffizi inventories until 1570, and with its present appearance since 1589; clearly, some restoration was carried out during the intervening time period. For a long time, this integration of a head similar to an ancient Dionysus head, arms, and legs was believed to be the work

Naked man seated

MAIN: view of the upper part of the body.
INSET: seated Hermes found in Augst.

of Benvenuto Cellini. The gesture of the statuette is a modern innovation: the merriment and joy expressed by this figure are in the spirit of the Renaissance and Mannerist styles. However, such an attribution hypothesis appears difficult to support, since the famous sculptor died in 1571.

A small bronze torso preserved at FNMA (Inv. nr. 2280) is a replica of the ancient part of the present figurine. In 1980 it was believed to be ancient, and considered to be a Roman work dated to the 1st century BC, stylistically based on the Apollo Lykaios

Bacchus

MAIN: view of the upper part of the body.
INSET: the "Resting Satyr".

by Praxiteles. A subsequent technological examination in 1984 pointed out it could be a Mannerist artwork, according to the smoothness of the outer surface and the absence of corrosion of the inner one. Furthermore, the appearance of the edges suggests they are the result of casting rather than due to corrosion of the metal. There is historical evidence showing that Anticaglie (ancient fragments or copies of them) were used by Cellini and other Renaissance and Mannerist artists to make pastiches, copies, or reinterpretations. Such an intriguing problem asks for a systematic multidisciplinary investigation.

Technological features: execution techniques

Following the archaeological and art historical assessments, the second step of the IAM (Integrated Authentication Methodology) foresees the interpretation of manufacturing techniques by visual and radiographic examinations. Understanding the processes used in the production of the artefacts provides fundamental complementary information for the authentication of copper alloy sculptures.

All the artefacts under investigation were cast using the lost wax technique. This involves the preparation of a wax model of the object to be cast in bronze. The model can be directly formed (direct method), or moulded from an existing sculpture (indirect method). The discrimination between these different processes is of crucial importance in authentication studies, since the direct method is unusual for objects from the Greek, Etruscan, and Roman periods, whereas it is frequently used during the Renaissance and Mannerism.

Grotesque figurine

The arms and feet of the grotesque figurine are joined to the bust by relatively rough soft soldering, where the solder is tin, lead, or a lead-tin alloy. The appearance of the surfaces of these limbs is rather metallic, without any evidence of corrosion phenomena. Conversely, the surface of the bust shows black and red areas, apparently due to surface mineralization and the formation of copper oxide. This suggests that the arms and feet are modern additions, whereas nothing can be said about the bust without a careful material analysis, since thin copper oxide layers can be easily produced in wet environmental conditions or by heating.

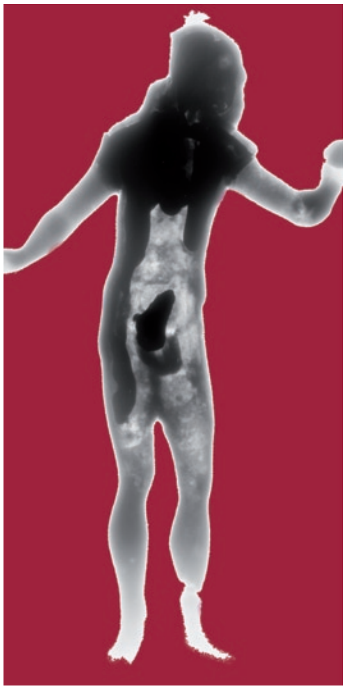
X-ray radiography shows the additions to be solid casts, as well as the legs and part of the thighs (image on the right). Conversely, the upper part of the bust has thin walls, even though this feature is partially concealed by a large amount of lead, here appearing as deep black zones, which flowed inside the figurine during the soldering process. However, the regularity of the thickness, the presence of typical meniscuses, and drips produced by slush casting of the wax are well-recognisable, and they all indicate the use of the indirect method in the production of the wax model for the bust.

Venus

The figurine is mostly a solid casting, apart from a strange internal cavity closed with a rectangular plug of difficult interpretation that can be seen at the level of the right hand (image on the left,

Figurine X-ray

Negative view of radiographic plate. X-ray imaging shows the difference between the upper and the lower part of the body.



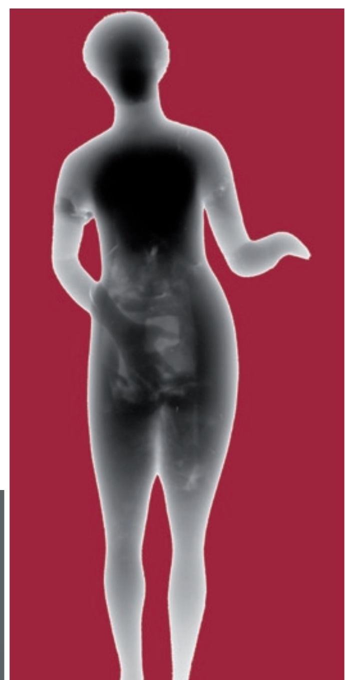
inset). The figurine is composed of three pieces, namely the two arms and the rest of the body. The right arm was joined to the body by soft soldering, whereas the left arm was added using hard soldering, that is using a copper alloy as the solder.

The finishing of the three sculptural elements shows some differences. In particular, the cold working or chiselling of the head, left hand, and right foot is more refined than that of the right hand.
There is a significant difference between the corrosion effects observed on the bust and those on the arms (below). On the latter, a thin layer of copper oxides can be observed, sometimes referred to as a ‘passivating patina’, whereas deep corrosion spots that significantly altered the original surface are visible on the bust. However, the cleaning treatments of the past were rather aggressive, flattening most of the cuprite protuberances and exposing the metal surface in zones with a passivating cuprite layer.

Naked man seated
Visual examinations show that the statuette is composed of five independent pieces, namely the bust with the thighs, the left

Venus

MAIN: back of the Venus shows evidence of different corrosion phenomena.
INSET: negative view of radiographic plate.



arm, the right arm, the trunk with the right leg, and the left leg, all of which are assembled together by soft soldering (below). The surface of the bust is relatively smoother than those of the arms, legs, and trunk, a difference which suggests the latter were added well after the production of the bust, likely by another craftsman (below, insets).
No relevant corrosion phenomena are recognizable, apart from the thin greenish layer which can be seen over the front side of the bust, particularly on the chest and abdominal areas.
The endoscopic examination of the interior through the cavity of the trunk revealed the presence of an internal iron bar entering the bust of the figurine. It is fixed at the bottom part of the trunk by a transverse iron screw.

Naked man

MAIN: bust, left arm, right arm, trunk with the right leg and left leg are independent pieces assembled together.
INSETS: evidence of a more careful finishing of the bust compared to the other pieces.

X-ray

ABOVE: Naked man seated. Negative view of radiographic plate. INSET: a screw fixing the bottom part of the internal iron bar to the trunk.
BELOW: Bacchus. Negative view of radiographic plate.
INSET: one of the screws.

Several X-ray plates of the figurines at various orientations provide well-contrasted images of all the details of interest. X-ray image on the left of this page, shows that the internal iron bar starts from the bottom and has a length of about 22 cm. The cross-section of its top part is smaller than the one at the bottom and presents some profile modulations, which are compatible with possible mechanical deformations. It appears that this bar is a structural assembling element of the sculptural group rather than a core bar used for casting the bust, as is also confirmed by the presence of the screw mentioned above (inset image on the left).

The radiographic plates also revealed fundamental information on the joining of the different sculptural pieces, repairs, and preparation of the waxes. Six soft soldering zones joining the arms and legs to the bust, the bust to the trunk, and the left leg to the ground are clearly visible. Some plugs are also recognizable on the arms and legs, which probably replaced core nails. The five pieces composing the statuette were probably cast using the direct method, as shown by relatively strong thickness variations and the absence of typical morphological markers associated with wax forming in a mould, such as, for example, those observed in the case of the *Grotesque figurine*.

Bacchus

According to the archival information, it was a torso on which legs, arms, and head were integrated at some point between 1570 and 1589. All the pieces are hollow castings, even though the contours of the internal surface of the torso are not recognisable. Probably its interior contains a radio-opaque core material. However, as for the previous statuette, in this case also the noticeable thickness variations (image on the left of this page) are coherent with a direct modeling of the wax.

Very interestingly, all the visible plugs which close the holes left by core nails are screws (inset image on the left). This is a very peculiar repair methodology which was likely used also for the additions to the Naked man seated, as visible from the circular plugs of the arms. The technological similarities between the arms and legs of the two statuettes are very significant.

Material analysis

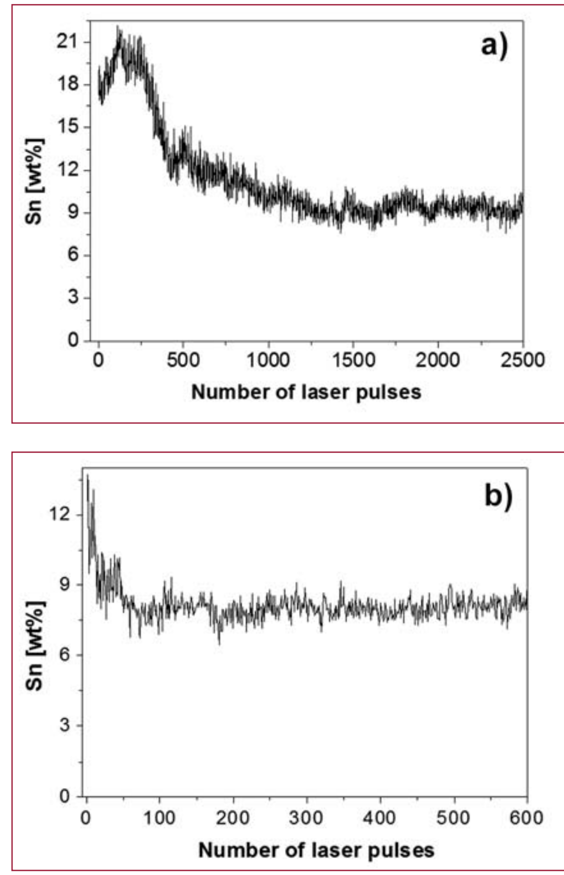
Compositional measurements using laser-induced plasma spectroscopy (LIPS) have been carried out on all the different pieces composing the four copper alloy sculptures. Elemental depth profiles were obtained for ablation depths up to several hundred microns, corresponding to several thousand laser pulses.
A depth profile of the tin (Sn) content of the left knee of *Venus* is given in graph a. It shows a large initial Sn-enrichment, which

reaches an almost stationary content of the bulk after about 1300 laser pulses. We have found such a depth profile only in genuine archaeological artefacts from excavations, whereas the surface enrichment peak is less pronounced for statuettes stored under indoor conditions for several hundred years, that is for Renaissance or later productions, and limited to a few tens of laser pulses for modern casts that were artificially aged (graph b).

These data, emerging from extensive and ongoing experimentations, potentially provide a direct solution for authenticating copper alloy artworks of ancient styles. However, the number of case studies carried out to date is not large enough for defining univocal temporal discriminations. The range of variability of the depth profile due to varying temporal and environmental conditions over the centuries needs further insights. However, a repeatable composition profile represents a very important marker which allows for a fast discrimination between modern counterfeits and artefacts naturally aged for centuries or millennia. This information can significantly contribute to the present comparative multidisciplinary approach. Before discussing the compositional depth profiles in more detail, it is necessary to present the results of the bulk compositions of the alloys.

Site	Sn (%)	Pb (%)	Zn (%)
Waist and hood	10.9-11.1	16.8-17.2	-
Head	10.4 ± 0.7	8.7 ± 0.5	-
Left thigh and right leg	11.0-13.7	10.7-11.6	-
Feet	5.2-5.3	4.9-5.5	3.3-3.6
Arms	5.2-6.7	3.8-4.2	4.9-5.3
Fruit in left arm	5.3 ± 0.5	5.0 ± 1.4	6.5 ± 0.8

Table above reports the alloy compositions of the Grotesque figurine. As presented in the table, the bust was made using a ternary copper with a significant content of tin and lead. The latter exhibits a strong variation among the individual measurements (between 9 and 17 wt% Pb), which is typical for lead and more pronounced for corroded artefacts. The arms and feet are made of a consistent quaternary alloy with about equal amounts of tin, lead, and zinc. This composition resembles the well known 85-5-5-5 alloy which was widely used during the last centuries.
The composition of the Venus is listed in table on the next page. In this case also, the body is made using a ternary copper-tin-lead alloy with a tin content similar to the previous figurine, but with a rather lower lead content (0.6-1.5 wt% Pb). The strong variations in tin content among individual measurements are compatible with the evidence of deep corrosion phenomena. Very surprisingly, the

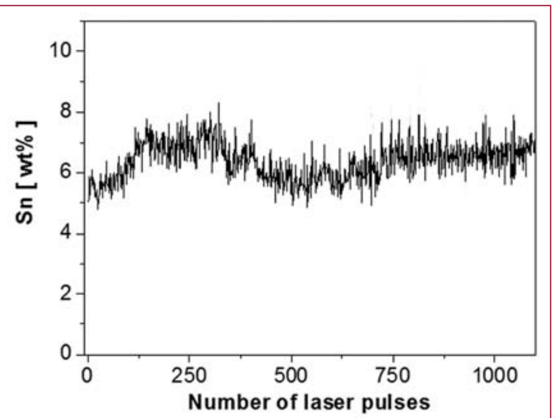


LIPS analysis

FROM THE TOP: representative Sn-depth profile measurements on the body of the Venus and on a modern figurine artificially aged.

left arm, which is questionable from an archaeological viewpoint, is coherent with the main alloy, whereas the right arm is decidedly different, being made of a quaternary alloy. Finally, we found that the central parts of the eyes (pupil and iris) were made of silver, now in an advanced state of mineralization, an aspect which is a further indication of authenticity.

Site	Sn (%)	Pb (%)	Zn (%)
Right thigh	15.2 ± 1.5	1.5 ± 0.3	-
Right shoulder, foot, and leg	9.2-9.9	0.6-1.0	-
Left arm	10.5 ± 0.8	1.4 ± 0.2	-
Right arm	1.1-1.6	1.4-1.4	2.9-3.5



Bacchus LIPS

The torso of Bacchus: elemental Sn-depth profile.

The bust of the Naked man seated was cast using a quaternary alloy, while all the other parts have a ternary composition of copper and tin with a small amount of lead. The Bacchus is entirely made from quaternary alloys, although the zinc content of the torso is significantly higher than in the other pieces.

The types of quaternary alloys identified for the four statuettes under investigation here are not documented in Etruscan and Roman artefacts. The systematic use of copper-zinc alloys, that is brass, started with coinage of the Imperial Period, using a zinc content around 20 wt%. Afterwards, during the Late Imperial Period and then again during the Middle Ages, the use of brass became common. However, the present types of relatively low alloyed quaternary metals only started to be documented in the Late Middle Ages, and they became frequently used during the Renaissance. In other words, the compositions of the arms and feet of the Grotesque figurine, the right arm of the Venus, the bust of the Naked man seated, and the torso of the Bacchus are not compatible with Roman or other ancient copper alloys. Conversely, the rest of the body of the Grotesque figurine and Venus are compatible with the available compositional data of alloys used for Roman statuettes. These conclusions are strengthened by the analysis of the elemental depth profiles.
A representative depth profile for the tin of Bacchus' torso is shown in this page on the right. The variation in the composition is moderate (between 6-8 wt%) compared to the one for the body of Venus, and limited to the first 200 laser pulses, which makes it unlikely for it to be of an archaeological provenance. The profiles of the further integrated parts are similarly almost flat, without significant enrichment and depletion phenomena.

Slight modulations only are also seen for all the pieces composing the Naked man seated, as well as for the arms and feet of the Grotesque figurine, whereas the body of the latter exhibits compositional profiles which are typical of deeply corroded genuine archaeological artefacts. The degree of corrosion of the body was independently assessed using time-of-flight neutron diffraction (TOF-ND), which showed a significant content of copper oxides (cuprite and tenorite) and copper chloride (nantokite). Conversely, no significant mineral contents were detected by TOF-ND for the Naked man seated, the arms and feet of the Grotesque figurine, and the right arm of the Venus.

Multidisciplinary conclusions

Grotesque figurine. The authentication study of this artefact, documented since 1784, is only apparently simple. Certainly the very metallic appearance of the arms and feet immediately suggests they are modern additions, but also the very red and black hue of the bust, which is relatively well-preserved, could raise some suspicion. However, the bust was shown to be actually genuine, based on the deep corrosion identified by LIPS measurements, and independently verified using neutron diffraction. It was cast using the indirect method, which is compatible with both a serial production and a Roman date.

Venus. The presence of deep corrosion, the shape of the elemental depth profiles, the silver inlay of the eyes, and the alloy composition all support the authenticity of the body and left arm. The right arm is a philologically correct 'modern' integration.

Naked man seated. Despite the lack of attributes, the similarity of the present artefact with the Hermes from Augst could suggest at least the bust to be genuine. The technological examination and alloy composition analyses, which revealed a direct modeling of the wax and the use of a peculiar quaternary alloy to cast the bust, are compatible with Renaissance and later productions rather than with Roman art foundry. Furthermore, none of the tin depth profiles measured is compatible with an archaeological provenance. No significant surface enrichment and depletion phenomena, which are typical for archaeological objects, were detected. These analyses, along with the archival information, which documents the presence of the statuette fully assembled since 1704, allow a tentative dating of the bust, as the most ancient part, between the 15th and 17th centuries. Furthermore, if the present artefact is considered as a modern creation rather than a copy of an ancient artwork, the temporal domain can be restricted to a period between the 16th and 17th centuries on the basis of stylistic considerations.

Bacchus. The torso of this figurine is documented since 1553, to which between 1570 and 1589 a head, arms, and legs were added. The latter were probably directly modelled and cast onto the existing torso. The holes likely left by core nails were filled using screws, an aspect which has a general technological importance. A careful examination of the radiographs of the Naked man seated has pointed out a similar repair methodology, although the threads of the screws are not clearly visible. The torso was cast according to the direct lost-wax method, using a quaternary alloy compatible with the Renaissance art foundry tradition. Its corrosion is moderate, and there is no evidence of the typical surface segregations observed in ancient objects, as shown by elemental depth profiles. The interior has a significant opacity to X-rays, which is unusual for the typical core materials used in ancient times (a mixture of quartz, clay, and organic fibres). We do not know whether the torso is a fake, intended as a fraudulent imitation of an ancient artefact, such as, for example, the "Resting Satyr" by Praxiteles. Conversely, it can be certainly considered a genuine Renaissance or Mannerist artwork inspired by the past and by the 'taste of the fragment' or 'of the relict of the Ancient World', which at the time was stimulated by the finding of many fragments of large statues.

REFERENCES AND ACKNOWLEDGMENTS:

Coauthors'affiliation*:*

Anna Rastrelli, Soprintendenza per i Beni Archeologici della Toscana, Firenze, Italy;
Andrea Mencaglia, Istituto di Fisica Applicata "Nello Carrara", Sesto Fiorentino, Italy;
Marcello Miccio, Soprintendenza per i Beni Archeologici della Toscana, Firenze, Italy;
Juri Agresti, Istituto di Fisica Applicata "Nello Carrara", Sesto Fiorentino, Italy.

Objects photographed are from the Florence National Museum of Archaeology, Florence, Italy. Inventory numbers are reported on p. 106.

Techniques

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TERM	DESCRIPTION
Agemina	Parts in different metal used to produce colour change; inlaying gold or silver over metal. See also Inlaying.
A-jour Filigree	Fine ornamental work using gold, silver or copper wire without the supports of a back-plate.
Alloy	1 A substance of two or more metals, intimately mixed and united, usually by being fused together and dissolving in each other while molten; for example, brass is an alloy of copper and zinc. Also applied to a similar substance composed of a metal and a nonmetal; for example, steel is an alloy of iron and carbon. 2 Any deliberate mixture of two or more metals to enhance the properties of one or other in some way,
Amalgam Gilding	1 Gilding method where an alloy of gold or silver mixed with mercury is applied to the surface of a base metal and fired to the point when the mercury vaporizes leaving a gold residue. 2 Powdered gold pulverized in a mortar and mixed with mercury until they amalgamated. The resulting 'paste' was spread over the metal and the mercury was subsequently vaporized, leaving the gold deposit.
Annealing	1 Process of restoring a metal to its soft state by heat after it has been made hard by working it, i.e. by rolling, hammering. The metal is softened by heat, care being taken not to overheat it, as this can result in upsetting the molecular structure and the metal may become brittle and crack or break on further working. Each metal has several critical temperatures and quenching schedules that result in annealing or softening work-hardened objects. 2 To treat a metal with heat and then cool it to remove internal stresses and to make the material less brittle. 3 A metallurgical process involving the heating and then slow cooling of metal during the course of working in order to increase the ductility and reduce the brittleness caused by hammering and bending,
Appliqué	A type of decoration made by affixing a design of one material to a base of another.
Aqua Regia	Strong oxidising solvent used chiefly in metallurgical analysis, composed of concentrated nitric acid (one part) and concentrated hydrochloric acid (three parts), it is capable of dissolving such metals as palladium, platinum and gold. The term literally means ruling water.
Arch drill	Drill made of an arch with a cord and a point.

Assay	1 Determination of the content of a specific component of a mixture, with no evaluation of other components. Such determinations are for example made on ores of various metals (especially precious metals) 2 The method to establish the purity of the alloy to ascertain its percentage of pure gold or silver.
Autogeneous welding	1 Method of joining metals using only heat. 2 A fusion weld made without filler metal.
Beaded wire	Decorative metallic wire looking like a sequence of spheres, obtained from a round wire with a comb-shaped instrument. The beads are characterised by a vertical groove.
Bezel	Metal strip surrounding and/or holding a stone.
Block twisted wire	Made by hammering out an ingot into a very thin square rod, then twisting it. Block twisted wire is produced and rolled between two smooth surfaces.
Blow pipe	1 Small tube used to provide air to a flame in order to increase the temperature. 2 Preferred term welding torch or cutting torch. A device used in oxygen cutting for controlling and directing the gases used for preheating and the oxygen used for cutting the metal.
Braided wire	Decorative metallic wire.
Brazing	1 A process that joins two pieces of metal using an alloy solder with lower melting point. Also called Hot Welding. 2 Method of joining and fastening metals and alloys. Brazing employs a nonferrous filler metal, usually in wire or paste form, to join metal parts at a temperature above approximately 800 F but below the melting point of the base metals being joined.
Burnisher	Tool with a smooth metallic surface or harder material like agate, etc.
Burnishing	1 Polishing metals by means of rubbing the surface with a hard, smooth object; agate was commonly used. 2 Finishing metal by contact with another, hardened, metallic surface that compresses the surface of the softer metal to produce a shiny surface.
Cabochon	A stone cut with a smooth, rounded surface, with no facets and highly polished. Cabochons are of various shapes, usually circular or oval, but sometimes rectangular or triangular. There are 4 basic forms: (1) the 'simple cabochon' with a dome and a flat base (2) the 'double cabochon' with a dome-shaped underside that is flatter than the upper dome (3) the 'hollow cabochon' with the interior cut away so as to make a shell-like form with increased translucency and often to have foil (4) the 'tallow-topped cabochon' with a shallow dome.
Cameo	1 A relief carving on a shell or stone. In multicoloured cameos, a layered substrate of a different colour exposed by the design which is carved or etched. 2 Originally a gemstone having layers of different colours carved to show in low relief the design and background in contrasting colours. 3 A Roman glass object made of two or more layers of different coloured glass bonded together, into the top of which is cut a design.
Casting	1 Teeming molten metal into moulds of sand or metal, and allowing them to cool into a solid cast piece. The temperature at which the metal is teemed is judged with maximum accuracy, and the rate of teeming is also closely controlled. The moulds have to be relieved at the earliest possible moment once casting has been concluded. 2 The process of producing metal artefacts by pouring molten metal into a hollow mould. The cast metal duplicates the object (wood, hard wax, etc.) originally impressed in the mould material. Some processes permit more than one reproduction. 3 The process whereby objects are made from a thermo-setting molten material poured into a former or mould of some kind. In metalworking, casting usually involves the use of a sand, clay, or stone mould, into which molten metal is poured to produce an object.

Casting-on	1 Method of joining two or more metallic items by pouring new metal on metal parts 2 Old method of salvaging damaged castings or parts of castings. Enough molten metal is poured on to the faulty area to fuse the metal in the immediate neighbourhood of the defect and reproduce the original form of the casting. Method also referred to as Burning-on. 3 A method used in a secondary stage of making metal objects in which a clay mould is made around part of an existing object. Molten metal is then poured in and fuses onto the original object. Used in adding handles, legs, and hilts to complicated artefacts.
Chain	A series of links connected with or fitted to each other.
Chasing	1 In chasing, the metal surface is patterned by striking with a hammer or other non-cutting tool. Applied to one surface of the metal only, this process is often combined with repoussé to achieve greater detail. 2 Chasing has been defined as the art of modeling (drawing, carving) the metal with a chaser and a hammer; it is different from engraving: engraving cuts into the metal, whereas by chasing one drives into the metal and embosses the surface without taking anything away.
Chiseling	The process of cutting or shaping a given pattern utilising a hand tool with a square bevelled blade, on a variety of materials.
Chrysokolla	Ancient name for copper carbonate used in copper salt joining.
Cire perdue	See Lost wax casting.
Cloisonné	A decorative technique involving a metal filament bent into a desired design form and then superimposed on an enamel surface.
Cloisonné enamel	Technique of decoration in which the cells (cloisonné) of the design are outlined with metal strips or bent wire affixed to a metal plate and the spaces are filled in with coloured enamels which are then fused.
Colloidal soldering	See Copper Salt Joining
Copper salt joining	Copper salts are applied as powder in the areas to be soldered and reduced to metallic copper in the reducing atmosphere of a carbon fire. The copper is alloyed on the surface with gold, forming a liquid film that is attracted into the contact points.
Corrosion	1 Gradual wearing away, decomposition or disintegration by oxidation of a metal. 2 An electrochemical change in a metal surface caused by reaction of the metal with one or more substances with which it is in contact for long periods; the effect is usually deleterious. As air is usually the environment to which metals are exposed, oxidation is one of the commonest forms of corrosion, as in the rusting of iron. This reaction (catalysed by moisture) forms ferric oxide, identical with the ore from which the iron was obtained. Thus, corrosion involves a return of a pure metal to its original state.
Cutting process	A process which brings about the severing or removal of metals.
Cutting stones	The process and art of shaping a precious stone or other gemstone by severing part of it from its original form so as to enhance its brilliancy, beauty and value.
Die	A punch or mould used to shape metals.
Diffusion bonding	1 Contact pressure, long time joining process, used to gild two metals together, such as gold leaf on a silver surface. 2 Preferred term diffusion welding (DFW). A solid state welding process which produces coalescence of the faying surfaces by the application of pressure and elevated temperature. The process does not involve macroscopic deformation, melting, or relative motion of parts. A solid filter metal (diffusion aid) may or may not be inserted between the faying surfaces.
Double braided wires	Decorative metallic wires arranged in fishbone form. Also called double fishbone braids.

Draw-plate	1 Plate with gradually decreasing holes to manufacture wire. 2 This is a steel plate with a range of diminishing holes (circles, squares, triangles, double half rounds, diamonds, and various other shapes). It is used to reduce or reshape wire, by pulling it through a draw plate.
Drill	A rotating cutting tool for creating or enlarging holes.
Embossing	1 A technique of producing relief decoration by raising the surface of thin metal from the reverse to form the design. The technique is the same as in repoussé work, but the term is sometimes strictly applied to work done by mechanical means, as distinguished from repoussé work that is done by hand by the use of punches and hammers. 2 A decorative technique in which a pattern is raised in relief, working with modeling tools on both sides of the metal sheet.
Engraving	1 Technique of decorating the surface of a hard material (e.g. metal or a gemstone) from the front by incised lines, characters, patterns, portraits, etc., cut into the surface. In modern times, engraving is done by hand by means of a sharply-pointed steel tool called a burin or graver. 2 The incision of a metal surface, requiring removal of metal for decorative purposes.
Filigree	1 Type of decoration on metalware made by use of fine wire, plain, twisted or plaited. The wire (usually of gold or silver) is used to form a delicate and intricate design. It is executed in two styles: (1) the wire was affixed by soldering to a metal base and (2) the wire was used without a metal foundation, thus forming an open-work design. For filigree work with the space filled in with enamel, see cloisonné enamel. 2 Fine ornamental work using either gold or silver or copper wire over a backplate. 3 A technique used in the manufacture of jewellery in which gold, electrum, or silver wire is bent into shape and then soldered onto an area of metal that is to be decorated.
Filigree enamel	1 Type of decoration in the manner of cloisonné enamelling but having the cloisonné made of twisted wire (rather than flat strips of metal) soldered to the base, and filled in with opaque enamel. After the powdered enamel in the spaces is fused and, upon cooling, has contracted, the wire shows above the surface. 2 The frame of the cloisonné enamel provided by decorative wires over a metal surface.
Finishing & Polishing	The use of different abrasive and polishing materials or tools to make a metal surface smooth and glossy.
Folded wire	Folding is a method of making wire by hammering a rectangular rod into a solid 'C' shape.
Forge welding (FOW)	1 A solid-state welding process that produces a weld by heating the workpieces to welding temperature and applying blows sufficient to cause permanent deformation at the fraying surfaces. 2 Welding process in which the parts to be joined are heated and then hammered or pressed together.
Forging	1 The shaping of metal by hammering while it is still hot. 2 In metal working, the shaping of a piece of metal by heating, to soften it, and then hammering.
Funnel wire	Decorative metallic wire obtained from a round wire with a comb-shaped instrument.
Gilding	1 The process of applying a finish of gold or silver onto base metal. 2 Process of overlaying or covering any metal, wood, etc., with a thin layer of gold or gold alloy. The methods include: (1) oil gilding or water gilding, by attaching gold leaf by means of an adhesive (called a mordant); (2) friction gilding, by rubbing the surface with ashes of linen rags soaked in a solution of gold chloride, then burnishing and polishing; (3) electroplating, by depositing a layer of gold by an electric current and (4) mercury gilding, see Amalgam Gilding. 3 The application of a thin layer of gold paint or gold leaf over a base metal, stone, plaster, wooden, or clay former or ornamental feature.

Gold thread	Gold strip cut from a hammered gold foil with a chisel or scissors and wound (or not) around a fibrous core.
Granulation	1 Metal decoration by means of granules joined to a back-plate. 2 A decorative process involving the making of patterns with minute grains of gold joined to a background. Grains can be massed to cover an entire ornament or part of one; they can be used to make simple linear patterns or geometrical shapes, a treatment known as decorative granulation. More elaborate employment of granulation are: (1) the outline style, in which lines of grains are used as an adjunct to embossed forms (2) the silhouette style, in which figures are rendered with solid masses of grains; and (3) the reserved silhouette style, in which the background is filled in with grains, while the main features are embossed but are otherwise left undecorated. 3 A technique used in the manufacture of jewellery whereby grains of gold, electrum, or silver are joined onto metalwork.
Granule	Tiny metal sphere. In examples of the finest Etruscan jewellery, the gold granules measure only 0.25mm to 0.14mm in width.
Hammering	1 A technique of working metal by beating up its surface so that it spreads to the required dimensions. 2 Process by which the metal is beaten to stretch and planish it in order to produce sheet metal.
Hinge	1 The fine hollow tubing known also as chenier provides a means of making the functional parts of jewellery, light, strong and unobtrusive. 2 Hinges are made from an uneven number of hollow tubes, i.e. cheniers, held together by a rivet. Each alternate tube is soldered to the side of the work piece, the other tubes to the lid of the piece in the case of a watch case and they revolve around the rivet.
Inlaying	Decoration of a surface by the insertion of one material into a ground of another; applied on metalwork, the process usually involves chasing or cutting grooves into the metal surface of the object and forcing gold, silver or copper into the grooves. Enamel and niello are also employed as inlays.
Intaglio	1 A method of decoration in which a design is cut into the surface. 2 Style of decoration (or an object so made) created by engraving or carving below the surface so that the apparent elevations of the design are hollowed out and an impression from the design yields an image in relief. The background is not cut away, but is left in the plane of the highest areas of the design. It is the opposite of a cameo. It is sometimes called hollow relief or coelanaglyphic. 3 A process of cutting a design into a surface of a small hard stone or gem. But also the object so created, usually used as seal or as stone to be set in a ring.
Joining	1 The process of holding two or more parts together. 2 The process, by various methods, of assembling the shaped sections of multi-piece objects, including soldering, colloid hard-soldering, diffusion bonding, pinning (by attaching small pins), clinching (by overlapping, folding and hammering down the edges), etc.
Lathing	A technique for shaping a workpiece by gripping it in a holding device and rotating it under a suitable cutting tool.
Leaf	1 Also foil; a very thin sheet of metal. 2 Very thin sheet of metal (usually 0.005 mm thick), thinner than foil and used for gilding.
Loop-in-loop chain	1 Single: each pre-joined link is passed through the previous one. Double: each link passes through the previous two, etc. 2 Type of chain whereby the round links are narrowed into an oval shape and are then bent back against themselves so as to form a U-shape, after which each link is threaded through the looped end of the preceding link. A more compact variation is the double loop-in-loop where each added link is slipped through the loops of the two preceding links.

Lost wax casting	1 Impressed into sand or surrounded with a special plaster to make a mould. The wax is burned out, and molten metal takes the form of the 'lost' wax. 2 Process is so named because it actually means the loss of the wax model, which will be melted away. The model is made in wax, enveloped in plaster, the wax is then melted out of the cavity filled with molten metal that provides the cast. The plaster mould is destroyed to retrieve the cast. 3 A method of casting intricate metal shapes by first modeling the required form in wax, then surrounding the wax with clay, firing it and draining out the melted wax, this leaves a high-quality mould for a single casting.
Melting	The process where the metal is heated until it becomes liquid.
Mercury gilding	See Amalgam Gilding.
Mould	1 A matrix into which molten metal is poured during casting. 2 The hollow former into which molten material (typically metal) is poured or soft plastic material is pressed to harden into a required pre-determined shape.
Mould casting	Casting method using two or more matrixes in which the molten metal is poured.
Opus interassile	1 A type of open work or pierced work, in which the design was produced by cutting away gold parts using a pointed tool. Eastern origin, revived in Roman times and flourished during the 3rd century AD, under the influence of Syrian workshops. 2 A style of open-work decoration of metal made by piercing the metal (usually gold) with a chisel or other tool to form an open-work pattern. Popular in Etruscan, Roman and Byzantine jewellery.
Overlaying	Decoration of one material by surface application of another; gold was often overlaid onto cut grooves in the surface of ornaments.
Oxidation	1 A chemical reaction in which a material, for example a metal, loses electrons to an oxidising material, like oxygen. 2 Reaction in which electrons are transferred from one atom to another, either in the uncombined state or within a molecule. The atom that receives the electrons is the oxidising agent, and the atom that gives up the electrons is the reducing agent. Thus, oxidation is always accompanied by reduction and such an electron transfer is known as a redox reaction.
Patina	1 The effect produced either naturally or artificially by oxidation on the surface of the metal. 2 A thin, greenish film or discolouration that forms, after long exposure to the atmosphere, on bronze and copper, sometimes on jewellery of such metals, adding a prized artistic effect. The natural patina is a carbonate of copper that forms to protect the metal from further oxidation. An artificial patina can be produced with acids. 3 Changes to the outer surface of an artefact that make its colour, texture, feel, or composition different from the main body of the piece, usually as a result of chemical, physical, or biological alteration through contact with the surrounding environment.
Piercing	A technique of decorating metal in which the decorative motives are created by perforating and removing parts of the metal sheet (making holes) with pointed tools.
Polishing	The process utilised in order to make all materials smooth and glossy. This usually follows all other processes adopted to fashion the piece and after it has been rubbed with any of various abrasives to give it its preliminary finishing. The polishing process involves the use of different abrasive materials and tools. Small areas are polished by burnishing.
Pressure welding	The application of high contact pressure for short periods of time.
Punching	The technique of punching involves a metal tool, at the base of which there is an image in relief. The tool is struck against the metal plate to imprint the image. With the metal plate now on a soft cushion, this technique is used either on the front or on the back. Punching is especially used in the continuous reproduction of a similar motif.

Pulviscolo	Granulation technique using extremely small gold granules.
Raising	Hammering a flat sheet of metal into a container type form.
Repoussé	1 Technique in which a pattern is raised in relief on a metal surface, working with modeling dowels to achieve the result on both sides of the metal. 2 Technique (often called embossing) of producing relief decoration on a metal plate by punching and hammering thin metal from the reverse in order to raise the design on the front. The metal plate is sometimes turned over so that some embossing can be done on the front to enhance the desired relief design. Hand punches and hammers are employed but sometimes the work is done by mechanical means. 3 Type of decoration used on cold sheet bronze, silver or gold, produced by hammering from the back surface against a pattern mould to create a relief effect. There are four types of repoussé: one done by hand on a cushion of soft material, another done on a positive mould, a third on a negative mould and a fourth one referred to as 'applied repoussé'. The applied repoussé is a decoration whose components are worked individually, then united at the surface of the object.
Ring punch	Tool used to produce small circles.
Rolled wire	Wire smoothened out by rolling between two wooden plates.
Rope braid	Decorative wire obtained by lying side by side two ropes spiralled in opposite direction (twisting a single square wire and a twist braid).
Soft soldering	1 Also called soldering. A joining method where the filler material has a melting point below 427° C. 2 Process of joining pieces of metal by the insertion of solder (molten metal) having a melting point lower than that of the metals to be joined. It is used in the making and repairing of jewellery. If the solder has a melting point only slightly below that of the metal pieces, it penetrates the metal and makes a firm join, called hard soldering or sometimes brazing; if its melting point is much lower, it makes a weaker join, called soft soldering.
Spiral groove wire	Decorative metallic wire obtained from a round wire pressed and rolled with an oblique instrument with smoothed teeth.
Spiral seam lines	Helicoidal furrows on metallic wire, visible only on strip twisted wires and not on drawn wires.
Spool wire	Decorative wire obtained from round wire with a comb-shaped instrument.
Square wire	Metallic square-section wire obtaining by hammering.
Stamping	The process of obtaining a given pattern on a metal sheet by various kinds of hammering (with a punch, into a die, etc.). The reproduction on a piece of metal, in relief or in intaglio, of a design with the help of a matrix; that is, a mould carrying a raised or negative image, or dies or stamps, or either type. The metal is worked cold or hot. Hot working is called matriçage.
Stone setting	The method by which a stone is secured in a finger ring, pendant, brooch, etc.
Striking	Thick gauges of metal stuck between two dies, both carved in intaglio (as in coin manufacture).
Strip spoolwire	Decorative metallic wire obtained from a twisted strip.
Strip twisted wire	Technique known as strip-coil or soda-straw twist. It involves cutting a strip of metal foil and wrapping it around an existing wire (or mandrel) which is then removed.
Tremolo	Engraving tool which can create a zig-zag motif on metal surfaces.
Tubular wire	Round hollow wire.
Twist braided wire	Decorative metallic wire consisting of two adjacent twists, one clockwise and the other counterclockwise.
Twisted square wire	Decorative metallic wire.

Welding	1 The union made between two metals. The joining of two pieces of metal at a temperature close to their melting point. 2 A joining process of materials which produces coalescence of materials by heating them to suitable temperatures, with or without the application of pressure or by the application of pressure alone, and with or without the use of filler metal. 3 The various processes of welding mostly involve heating the metal until it is sufficiently hot on the surface to become plastic, when it is brought into contact with the casting to be repaired and, without pressure, is united with it. A means of fusing together two or more pieces of metal with similar properties. In ancient times, welding was achieved by pressing heated pieces together at high temperature (hot but not melted), usually by hammering. This is commonly known as fire-welding.
Wire marks	Horizontal parallel scratches on metal wire.

Maria Luisa Vitobello - Thilo Rehren

A quest for Authenticity

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