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The Society of JEWELLERY HISTORIANS

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The Golden Age of the Etruscans: a modern goldsmith's practical experiments in the style of the ancient masters

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ULDERICO GIUSEPPE PETTOROSSI is a practicing Italian goldsmith, born in 1970 in Perugia and now based in Torgiano (PG) corso Vittorio Emanuele II, 10. It is his admiration for the spectacular jewellery of Etruscan goldsmiths of the 6th-5th centuries BCE that influences the style of his jewellery and has driven him to develop techniques and tools to produce fine granulation and goldwork that emulates the jewellery from Antiquity.

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Front cover:

Earring made by Ulderico Giuseppe Pettorossi, based on an early fifth century BCE Etruscan earring from Vulci. Diameter 6 cm, 22 carat gold, glass, rock crystal ©Pettorossi

The Golden Age of the Etruscans: a modern goldsmith's practical experiments in the style of the ancient masters

ULDERICO GIUSEPPE PETTOROSSI

As a practising goldsmith, I have long admired ancient jewellery, made without the equipment familiar to modern goldsmiths. I have recently had the opportunity to study the structural and decorative details of original Etruscan jewels in the National Archaeological Museum of Perugia under magnification and from this I have hypothesized how they could have been made, although it is important to stress that this is not necessarily how they were made.[1] To pass from hypothesis to practice is not easy because, as with all artisan practices, the success of an artefact depends on the experience and repetition of an action that must become as natural as breathing, moreover, I had to partly abandon my modern goldsmithing practices and transport myself back to a time where materials and chemical technologies were different from now.

The decorative elements listed below are characteristic of Etruscan goldsmithing and were used throughout the ancient Mediterranean basin at various places and periods. I will focus only on my own methods of manufacturing these elements. Secondly, I will briefly comment on the work of the Castellani family of goldsmiths who, in the first decades of the nineteenth century, were able to observe the elaborate Etruscan funeral objects discovered at that time in the Papal States.

Making gold components

In ancient jewellery, the casting of gold was seldom practised because it wastes too much metal and the thickness of the casting is too great. Furthermore, the resulting casting could exhibit unwanted porosity. The primary component from which all parts of the jewel can be created is a thin gold sheet, made as follows:-

After melting a high-carat gold alloy in a crucible in a charcoal furnace it is cast into an ingot. The ingot is flattened by hammering with bronze or iron hammers with, in the last phase of flattening, a piece of leather interposed between the gold sheet and the hammer. From a gold sheet some 0.20 - 0.15mm thick it is possible to make varied components for jewellery. Thin strips can be cut to produce wires of various sizes that are used for decorative filigree or to produce suspension rings for pendant elements of the jewel (typically *amphorae*, satyr heads, etc.).

Using very thin sheet saves on raw material, but more importantly, bringing such thin metal to about 920°C with a charcoal oven or with a blowpipe is easier and faster. This is the temperature needed for soldering with copper salts (see below).

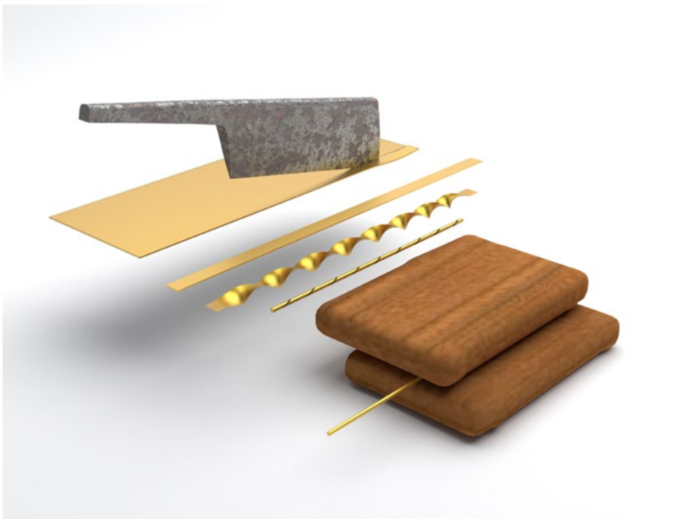
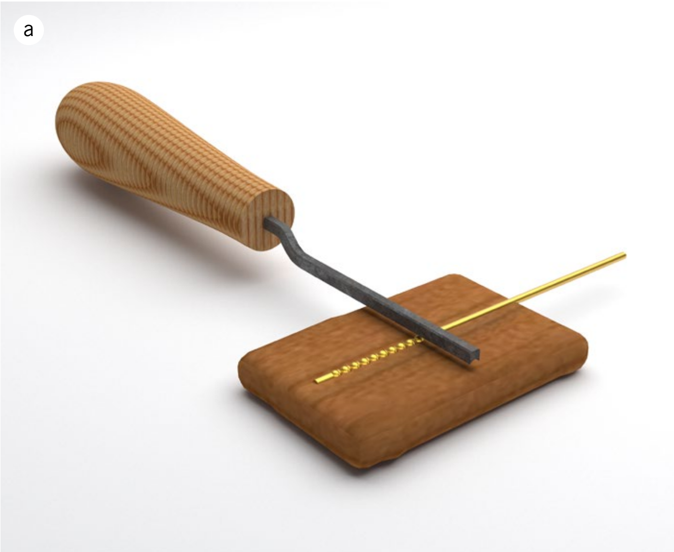


Fig. 1
Schematic diagram of the stages in making strip-twist wire. From left to right, a strip cut from gold sheet is tightly twisted helically, forming a tube. The wire is finished by rolling between two smooth, firm surfaces. Diagram © Jack Ogden

Wire

The first stage of my work in making a wire is to cut a thin strip, approximately 1mm to 2mm wide, from the gold sheet. The strip must be twisted helically to form a tube and then rolled between two plates of bronze, iron, wood or polished stone, to compress the tube, closing the coils (fig. 1). The tube is regularly annealed to red heat during the work. In the final stages of rolling the wire,

1 For information on early goldsmithing practices see Further Reading p.21.



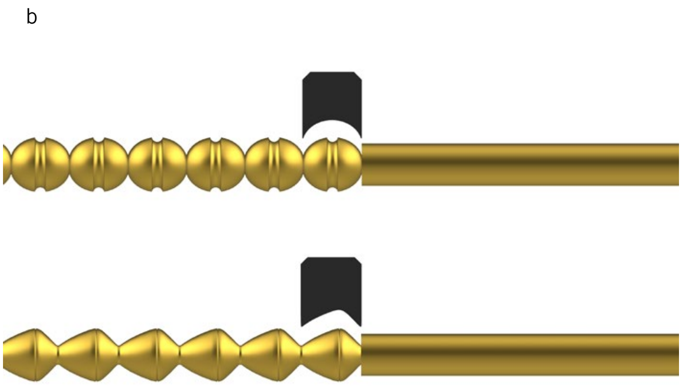


Fig. 2
a) Schematic diagram of the use of a simple grooved beading tool on wire.
b) Examples of bead shapes made by two different profiles of beading tool.
Diagrams © Jack Ogden
c) Experimental length of 22 carat gold strip-twist wire with beading.
Wire diameter 0.9mm. Maker and photograph Ulderico Giuseppe Pettorossi.

I sprinkled it with copper salts to solder the coils so that the walls of the tube would not split when it is flexed and bent, although there is no clear evidence that this was done in antiquity. I aimed to create a solid wire by completely closing the tube by rolling. In this way, I made round wires with diameters ranging from 0.30 to 1.0 mm. Ancient gold wires made using the so-called strip-twist process can be as narrow as 0.1 mm although these were not used for structural purposes.

Decorative wires

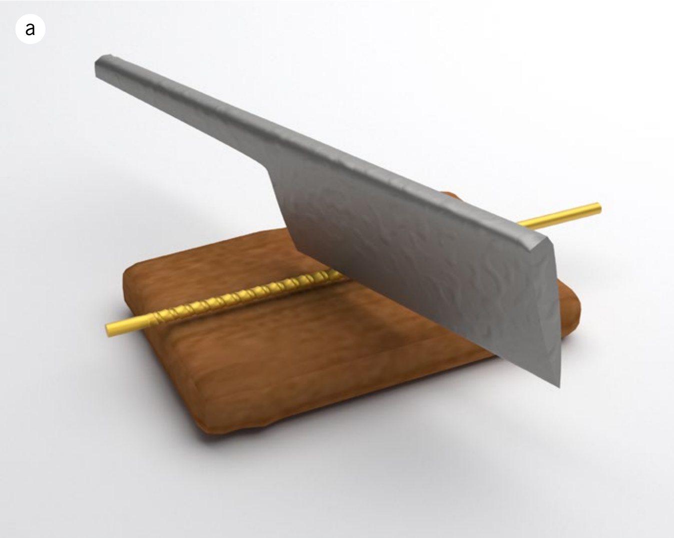
This plain wire made from a twisted strip was used for various applications and was decorated in different ways. I produced beaded wire by rolling a wire under a tool consisting of a narrow iron blade with a groove cut along its length (fig. 2a).The edges of the groove must not be too sharp otherwise they will break. The profiles of beading tools could vary to produce various forms of beaded wires in antiquity (fig. 2b); there are wires with almost spherical beads, others are bi-conical, symmetrical or asymmetrical, and others with narrow or wide lozenges, termed spool-beaded wires. The principle of the beading tool is the displacement of metal through the movement of the instrument back and forth, not the removal of metal.

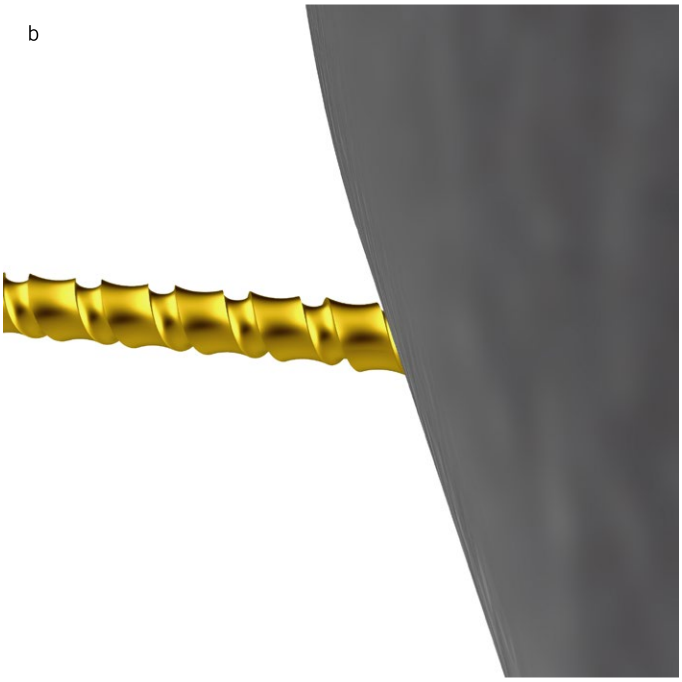
The blade of my beading tool was inserted into a wooden handle to have a firm and comfortable grip. The support under the wire must be yielding, but not too much, otherwise the bead will not be produced. The perfect material for this purpose is thick, hard leather. Using a beading tool is not easy, it requires strength and experience; it must always be rolled at right angles to the axis of the wire or you risk ruining the work. Hold the beading tool with one hand – I use the right – and the other can use a wooden strip as a guide to ensure the wire and tool stay at right angles.

Another decorative form of wire is spiral beaded wire (fig. 3). Here the wire is rolled under a thin but not too sharp iron blade at an angle to the axis of the wire, typically 30-45 degrees. The effect made by the blade on the wire is that of a spiralling groove which, depending on the pressure of the tool and the consequent displacement of the metal, is more or less marked. For this technique too you need experience and having an assistant to keep the wire aligned contributes to a better result. The neatest spiral grooves are created by keeping the same inclination of the blade on the wire throughout the process.

Serpentine strip

Between the Etruscan Orientalizing and the Archaic periods (seventh to fifth centuries BCE), this type of decoration was used above all on disc earrings. It is a very thin and narrow reeded strip, with two parallel ribs along its length, bent into a serpentine form, If you look at it from above you see what look like ribbed cylinders side-by-side while from the side you see regular serpentine bends (fig. 4).The most difficult part of producing the decoration is the ribbing of the strip, due to the very small size. The S-strip used to decorate the pair of disc earrings from Vulci of the early fifth century BCE, now in the Metropolitan Museum of New York, has a width of just 1.0 mm (fig. 5). It is difficult to create two parallel ribs in such a space. In my experiments reproducing this type of decoration, I tried three methods: for the first I produced a 6cm bronze punch with parallel grooves along its end, to create the ribs. Interposing the gold sheet between a base of lead and the punch, and hitting the punch with a hammer, I got a good result. In the second I engraved two parallel grooves in an iron block to make what is called a swage and attempted to press a thicker gold sheet into this with a hammer. Here, I did not obtain a very satisfactory result because it is not easy to keep the thickness of the sheet sufficiently even, retaining the stability of the strip while it is being hammered is problematic. The third method requires a single blunt blade, positioning the gold sheet between the lead sheet and the blade which is struck with a hammer to obtain a thin rib. This is repeated to create a second rib parallel to the first. The result is good with practice. In all three cases, I found that the lateral spread of metal had to be trimmed with a cutter once the ribbing had been completed. To form S-shapes from the ribbed strip insert pairs of pins into a wooden surface, positioned at the required distance and bend the strip around them (fig. 4c).





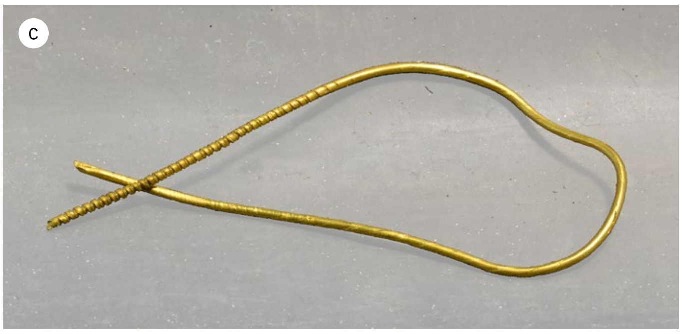


Fig. 3
a) Schematic diagram of the method of forming spiral beading.
b) Detail of the appearance of spiral beading as formed under a blade.
Diagrams © Jack Ogden
c) Experimental length of 22 carat gold strip-twist wire with spiral beading. Wire diameter 0.3mm. Maker and photograph Ulderico Giuseppe Pettorossi.

Fig. 4
Experimental serpentine strip made by Ulderico Giuseppe Pettorossi. 22 carat gold, foil thickness 0.3mm, width 1.57mm, height 1.6mm.
a) Top and b) side view.
Photo, © U.G. Pettorossi
c) Schematic diagram of the sequence of steps in forming serpentine strip – from back left to front right:-

1. The bronze punch with a pair of parallel grooves along its base
2. Positioning the gold sheet between a base of lead and the punch, and striking the punch with a hammer
3. Trimming the excess foil
4. Bending the strip around pairs of pins

Diagram© Jack Ogden

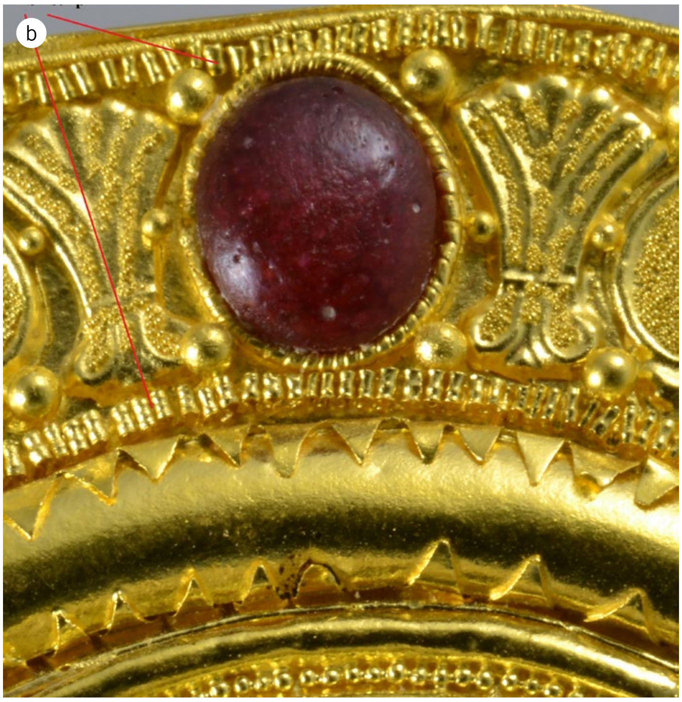


Fig. 5
a) A copy, made by Ulderico Giuseppe Pettorossi, of an Etruscan earring (fig. 5c). Diameter 60mm, 22 carat gold, glass, rock crystal. Applied beaded wire and serpentine-strip arrowed.
b) Enlarged detail showing serpentine strip (arrowed).
Photo, © U.G. Pettorossi
c) Pair of Etruscan disc earrings from Vulci, early fifth century BCE. Diameter 61mm, gold, glass, rock crystal, agate, carnelian. Metropolitan Museum of Art, New York, accession Number: 40.11.7–.18. Harris Brisbane Dick Fund, 1940

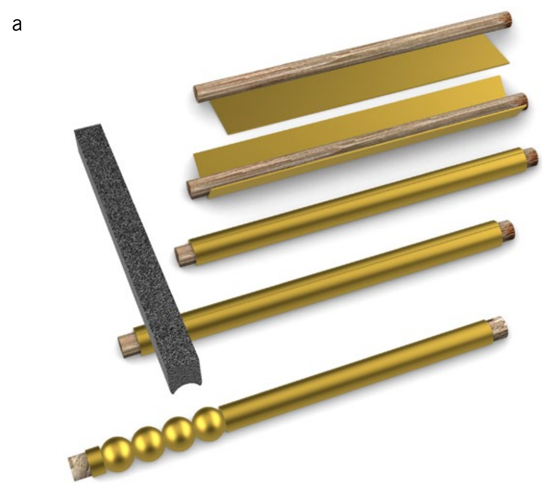


Fig. 6
a) Schematic diagram of the formation of smooth and beaded hollow tubes. From top to bottom, gold foil is rolled around a wooden stick then rolled under a beading tool. Diagram © Jack Ogden
b) Experimental undecorated and beaded hollow tubes. Diameter 1.7mm, 22 carat gold
c) Combination of experimental strip-twist wire (top) and beaded hollow tube, made by Ulderico Giuseppe Pettorossi. Photos © U.G. Pettorossi

Smooth and beaded hollow tubes

In the Classical Hellenistic period, hollow tubes were used, both plain and decorated, for example for tube earrings with pendants. To make the tubes it is necessary to cut a gold strip of the appropriate dimensions for the diameter of the tube you want. The tubes I made have a diameter of about 1.7mm, and a length of about 15cm, so the area of the gold sheet required is approximately 0.7 x 15cm. This sheet is wound around a flexible wooden stick and then rolled between two hard plates to close the tube (fig. 6a). In my approach, the internal wooden core was burned out and the edges of the sheet were joined with copper salts to make a smooth tube. For the ribbed hollow tube, before removing the wood core, I used the same tool as for the beaded wire but with a larger section. Once the grooves had been created, the tube could be bent as required, before burning out the wooden core and soldering the edges, then positioning and soldering to the jewel (fig. 6b and c). It has been suggested that in antiquity the wood core was left in place and burned to charcoal during soldering of the seam of the tube. The charcoal then acted as a core to support the tube when it was beaded.

Decorative punches, formers and dies

Many decorative elements in Etruscan jewellery were likely produced with punches to impress sheet gold placed over a lead support (fig. 7). The ends of these punches could be of various forms, from a simple hemisphere to highly sophisticated lotus flowers and palmettes. Punches are easier to produce in copper alloy rather than iron. The decoration is worked in low relief on the face of the punch to form a low-relief impression when hammered onto the reverse of the foil. This is a 'positive' punch and is struck while the gold sheet to be decorated is supported on a lead sheet.[2]

In many cases a punch is used indirectly: the decoration is punched into the sheet, cut out and then soldered onto the jewel. For example, I made a circular impression with a ring punch formed of a pair of twisted rods (fig. 8) and a further form using two juxtaposed twisted rods for a herringbone decoration. I used this type of punch in making my copies of two different types of disc earring (fig. 5a) and (fig. 9).[3]

Formers or dies for shaping gold sheet are generally deeper (fig. 10). They are often more complex than punches; they can be in the form of human faces, animals, birds and so on, and these tools can be single or a matched pair, as in the case of the manufacture of *protomes* or three-dimensional figures. I have used the techniques and tools outlined above to make a copy (fig. 11) of the fourth century BCE Etruscan earring from Santa Caterina Vecchia, Perugia, now preserved in the National

2 Still called a *piombarola* today in Italian.

3 Earrings from Cetona of the sixth century BCE preserved in Berlin Antikenmuseum Inv. No. GI. 413 and 414 (Misc. 3025, 3026).

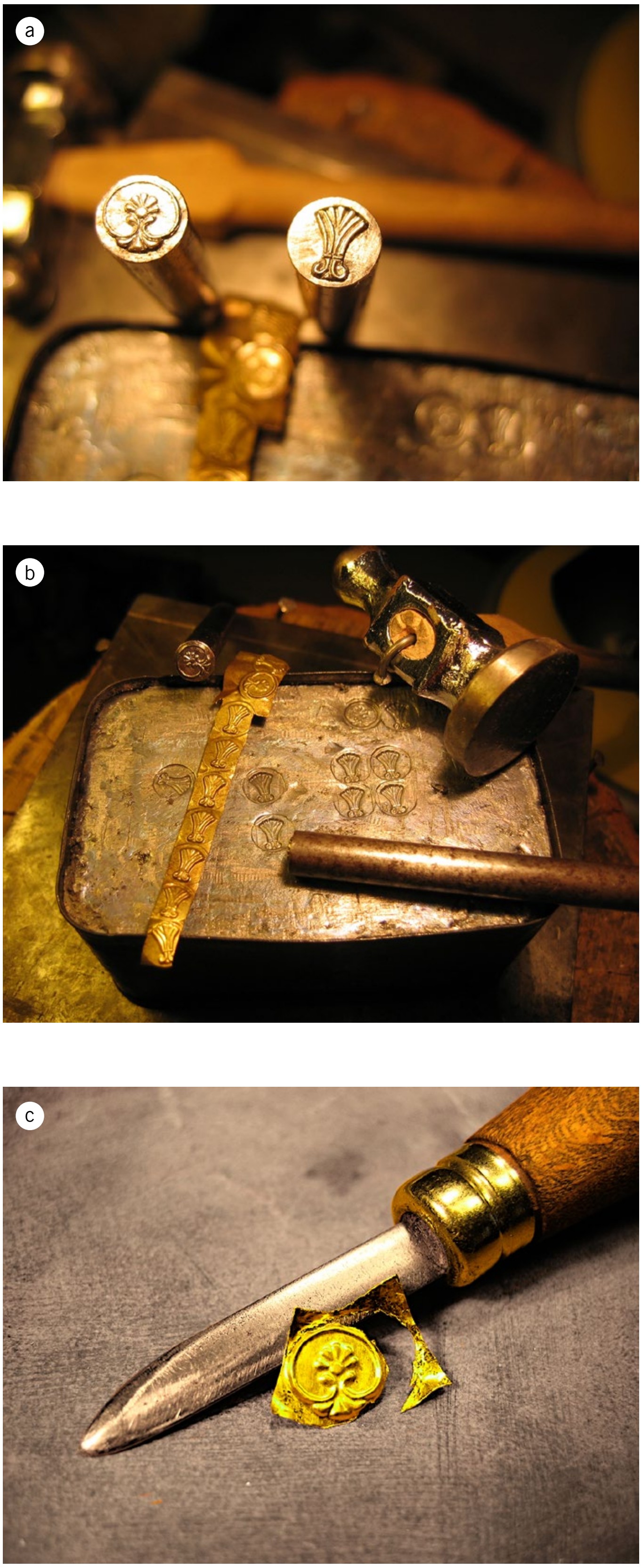


Fig. 7
a) Punches with palmette and lotus flower designs (bulino engraving). Punch diameter 0.9mm
b) Punching a gold foil with palmette designs, on a lead backing
c) Trimming the excess foil around the punched lotus flower design
Made by Ulderico Giuseppe Pettorossi. Photo, © U.G. Pettorossi

Fig. 8
Circular twisted rod punch: bronze, diameter 25mm, ring section 1.8mm
a) Left bronze punch, right pure silver foil, resting on a lead sheet
b) Punch hammered into the silver foil
c) Left to right - the resulting sheet-silver form; indentation in the lead; bronze punch
d) Trimming the excess silver foil
Finished decorative element, e) back and f) front
Made by Ulderico Giuseppe Pettorossi. Photo, © U.G. Pettorossi

Fig. 9
Copy, made by Ulderico Giuseppe Pettorossi, of an Etruscan earring from Cetona of the sixth century. B.C.E. Originals are in Berlin Antikenmuseum. Inv. No. GI. 413 and 414 (Misc. 3025, 3026)
Photo, © U.G. Pettorossi
The decorative elements created with circular punches are indicated by the red arrows

Fig. 11
Copy, made by Ulderico Giuseppe Pettorossi, of an Etruscan earring from Santa Caterina Vecchia, fourth century BCE. Original in the National Archaeological Museum of Perugia.
22 carat gold, height 13cm. Photo, © U.G. Pettorossi

Fig. 10
A simple bronze punch with pre-formed negative mould for shaping flat foil into the 3-dimensional form of an arch of a typical Etruscan sanguisuga (safety pin) fibula.
Height 20.8mm Length 37.5mm
Made by Ulderico Giuseppe Pettorossi. Photo, © U.G. Pettorossi

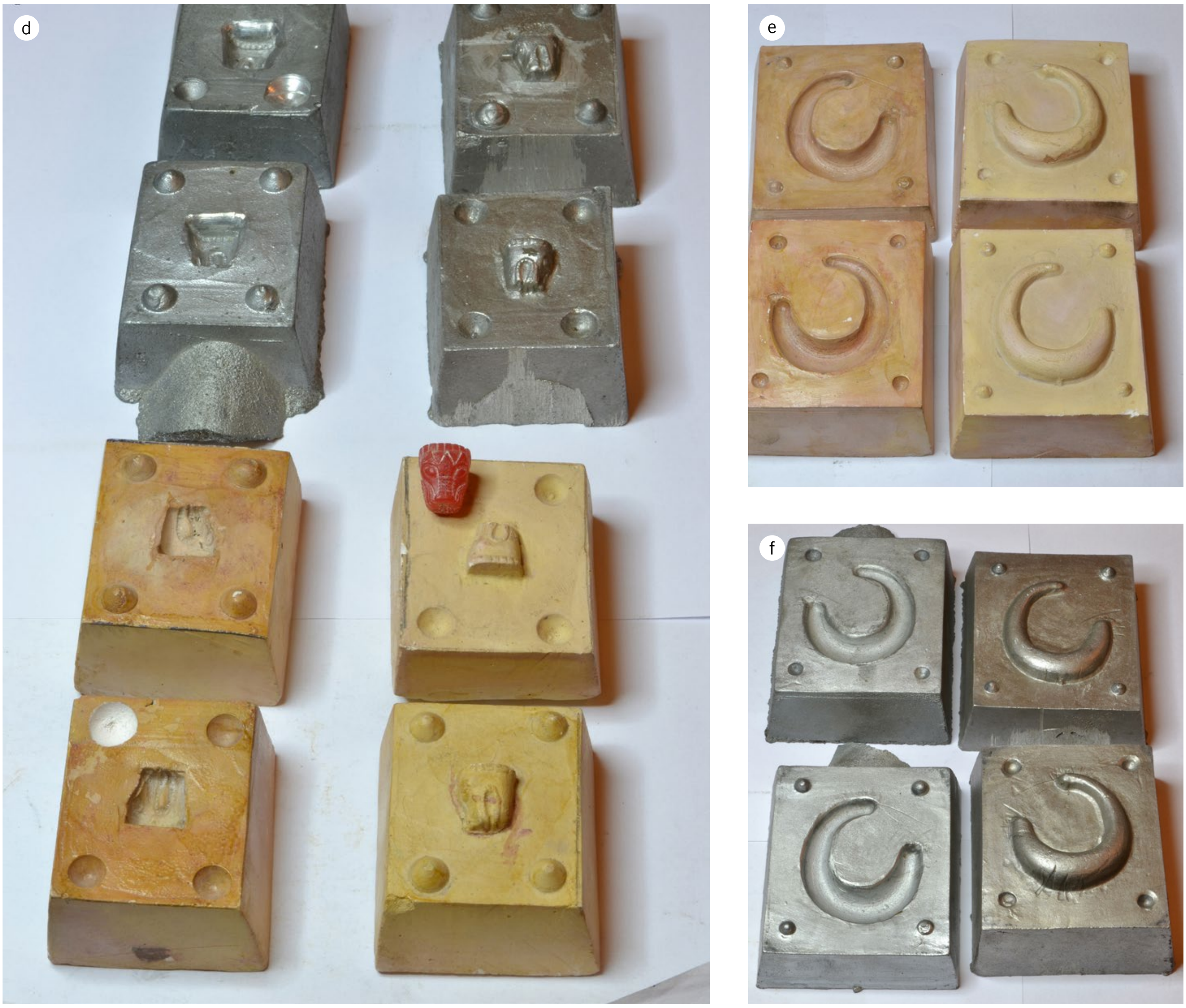
Archaeological Museum of Perugia.[4] The material I used for the model was wax, to cast by the lost wax method, but wood can be used to proceed to clay mould casting. In both cases, the result is a positive bronze former or punch to impress the sheet gold into the shape of the face.

For symmetrical three-dimensional shapes, it is often necessary to create matching dies or formers for the right and left sides, or front and back.[5] There are various ways in which this can be done. The process I used to produce the leonine *protome* for the pendant with the female head (fig. 11) and the tube of the earring, was as follows (fig. 12). I carved the lion in wax and

4 A similar earring, perhaps its pair, was purchased from the Alessandro Castellani sale in 1884 and is in the British Museum (Accession no. 1884,0614.10).

5 Copper alloy formers for producing the two sides of the body of a seated sphinx, and the front and back of a lynx head, both for producing Hellenistic earrings, are published in Ogden, J. M. 2024. *Jewelry technology of the ancient and medieval world.* Brunswick: Brynmorgen p. 106.

Fig. 12
The manufacturing of components for the earring in Fig. 11 by Ulderico Giuseppe Pettorossi.
a) Detail of the finished gold leonine protome terminal to the tube
b) and c) Model in wax of the leonine protome



d) Left and right plaster moulds for the metal formers (top) for the leonine protome
e) Tube: left and right plaster moulds produced from a clay model of the tube
f) Tube: left and right metal formers cast from the plaster moulds - fig. 12e

g) Exploded view of all the components of the earring, some not yet trimmed.
Photos © U.G. Pettorossi

then pressed one side of the wax model into a soft clay sheet. Next, I formed a box around the clay sheet and poured in plaster. Once the plaster had dried I removed the wax from the clay and repeated the same operation with the opposite side of the wax lion model. At this point I had a negative cast of the left and right sides of the lion, I then made a box around them and filled it with plaster and once dry I had a pair of positive casts of both sides of the lion. I used these four plaster casts, two positives and two negatives, to impress their shape in casting sand to reproduce them in metal.[6] This gave me the choice of pressing the gold sheet into the dies or using the positive cast tool to impress the gold into lead. The latter method is designed to produce multiple shapes, all identical. I wanted to create a pair of earrings, so I needed to produce identical shapes of identical measurements.

The finishing process is to work around the shapes with chisels, working on pitch, to cut off the excess gold sheet and then to join together the two halves using copper salt soldering. The structural curved tube, the female head pendant, the leonine *protome* and the amphora pendants of the ancient original are all hollow and have a centreline where the halves were joined, almost certainly with the copper salt soldering technique. It is necessary to refine the detail on them by chiselling on a pitch support, for example, to define the details of the face and hair, because the moulds I produced in this way did not give sufficiently fine definition. Pitch is also used to fill the joined halves, to support them while finishing the seam line.

6 I produced the metal moulds through sand casting, a technique used today. For ease of casting, I used a zinc-based alloy called Zamak which melts at about 380 ° C. Bronze would have been the metal chosen in ancient times if this technique was used [NOTE: there is no clear evidence for sand casting in moulds before Medieval times See: La Niece, Susan. 2016. Sand casting in the Islamic world. In Barbara Armbruster, Heidemarie Eilbracht, Oliver Hahn, Orsolya Heinrich-Tamáska (eds). *Verborgenes Wissen: Innovation und Transformation feinschmiedetechnischer Entwicklungen im diachronen Vergleich*. Berlin Studies of the Ancient World 35. pp. 263-276].

Granulation

The art of creating, positioning and soldering tiny gold spheres dates back to the third millennium BC in Mesopotamia, where gold was used to produce sumptuous jewels and ornaments for the ruling classes. In Egypt, granulation came a little later. It may be that the discovery of copper salt soldering occurred accidentally like many other discoveries. I can only imagine the disappointments and errors ruining the almost finished jewel, and until the object has been washed and cleaned the goldsmith will not know if the granulation operation was successful or if there is collateral damage.[7]

Experiments using copper salts[8]

The combination of copper and wine vinegar produces the copper salts that I use to solder the granules. It is known that they used copper salts in ancient times but we do not know precisely which substance or compound: Pliny gives a very detailed recipe in his *Naturalis Historia*,[9] In my first experiments of soldering with copper salts I used many compounds, carbonates, oxides, sulphates and acetates. I also reconstructed Pliny's recipe by grinding malachite (copper carbonate) and indeed found some usefulness with all these substances, and I even attached granules with nothing other than heat, by so-called autogenous welding.

To experiment with all these substances and recipes based on copper salts I used 2x2 cm sheets of 22 carat gold with the ratio of copper to silver 50:50, though the limitation was that it was not applied to a three-dimensional jewel. I found vinegar mixed with the copper salts reacted to produce a green, transparent liquid, without any solid matter. In the beginning, not being a chemist I did not know what compound I had created, but I knew what I was aiming for. Subsequently, on reading of Henry A.P. Littledale's work of 1936 I realized that I had made cupric acetate.[10] In Littledale's description of the behaviour of the compound cupric acetate plus organic glue when heated, it is the organic glue that is given the greatest importance as it produces the reducing atmosphere that triggers the transformation from cupric acetate into metallic copper. However, in my experience, cupric acetate transforms into metallic copper even in the complete absence of organic glue, whether using a torch or the oven. However, a reducing environment is essential (absence of oxygen).

7 Even if you work with a modern electric oven, you have the same anxiety.

8 The term 'copper salt' simply means a copper compound, such as copper oxide, copper carbonate or copper acetate.

9 Pliny the Elder. *Natural History*, Book 33, chap. 29.

10 Littledale, Henry, 1936. 'A new process of hard soldering and its possible connection with the methods used by the ancient Greeks and Etruscans'. In *The Scientific and technical factors of production of gold and silverwork: A course of lectures held under the auspices of the Worshipful Company of Goldsmiths 1935 – 1936*. Lecture 4, February 24th, 1936. London: Goldsmiths' Company. Pp. 44-63. See also Littledale's UK Patent *Improvements in Hard Soldering mixtures and hard soldering processes*. 415181 of 1934.

Production of granules

I shall not dwell on the gold alloys used in ancient times; for the most part in Classical times, they are alloys of about 22 carat with varying proportions of silver and copper. To produce small fragments of gold to be made into granules, an iron or bronze file can be used, or a gold wire can be cut into small enough pieces but I found this latter technique more difficult.[11] The method of production of the granules is well described in various publications, but in any case, I will describe what I did which, of course, is not necessarily what was done in antiquity (fig. 13). The size of the filings from a piece of gold depends on the size of the teeth of the file and the pressure that is applied. Collect the filings in a container; any iron particles coming from the file should be separated with a magnet, although I doubt a magnet was so used in antiquity. A layer of powdered charcoal is placed in a crucible of refractory clay then, with your fingers, begin adding the gold powder, like a pinch of salt when seasoning a dish, working close to the gold, resting on the surface of your charcoal layer. This operation is repeated, a layer of charcoal then a pinch of gold, then charcoal and so on, until the crucible is filled or the gold dust is exhausted. The crucible must be sealed before placing it into a cold oven. The oven must then be brought to at least 1050° C to melt the filings. Once this temperature has been reached, turn off the oven and allow it to cool before removing the crucible. When fully cooled, pour the contents into a bowl.

Fig. 13
Gold granules made by Ulderico Giuseppe Pettorossi. 22 carat gold, Diameter from 0.23mm to 0.05mm. Photo © U.G. Pettorossi

11 Another method to control the size of the granules could have been to cut squares from a very thin sheet. Cut narrow strips in a longitudinal direction, without detaching them completely, then cut across the strips, so as to obtain squares. With constant practice you can control the size of the squares and consequently of the size of the granules.

To separate the granules from the charcoal there are various methods suggested. Firstly water, but the charcoal is so fine that it becomes like oil when combined with water, so I have not found it practical, especially as there is always the concern that the smaller, lighter granules would get lost in the various washes.

The second method uses calibrated sieves. This is a modern method although perhaps in the past they created sieves by piercing small holes in thin sheet (fig. 14), an idea that came to me when looking at ancient graters. The third method is to blow gently, in the open air but not against the wind; the contents of the crucible are poured onto a paper tray and shaken to spread it out. Tilt the tray towards you and the spheres will begin to group at the edge; at this point blow gently to disperse the charcoal. This is a tiring and uncomfortable task but only in this way have I managed to recover the smallest granules from the crucible and I would like to believe that in ancient times it was done like this. I produce about 10 grams of granules at a time; therefore the quantity of charcoal needed is not excessive. The ancient goldsmiths probably selected the size of granules by eye. On many ancient ornaments the spheres are of different sizes, even when positioned artfully; on others the granules are well selected and of even size.

Positioning granules

The granules are separated by size, cleaned and collected in a small vessel. The positioning on the surface of the jewel is done with a fine brush (fig. 15). The liquid or viscous mediums that were used in ancient times could have been oils that did not boil during heating, which would move the granules and ruin the work. We can hypothesize the use of lavender oil (it was used for enamels in the nineteenth century by the Castellani), quince seed oil (mentioned in old goldsmith manuals) or vegetable gums such as tragacanth.

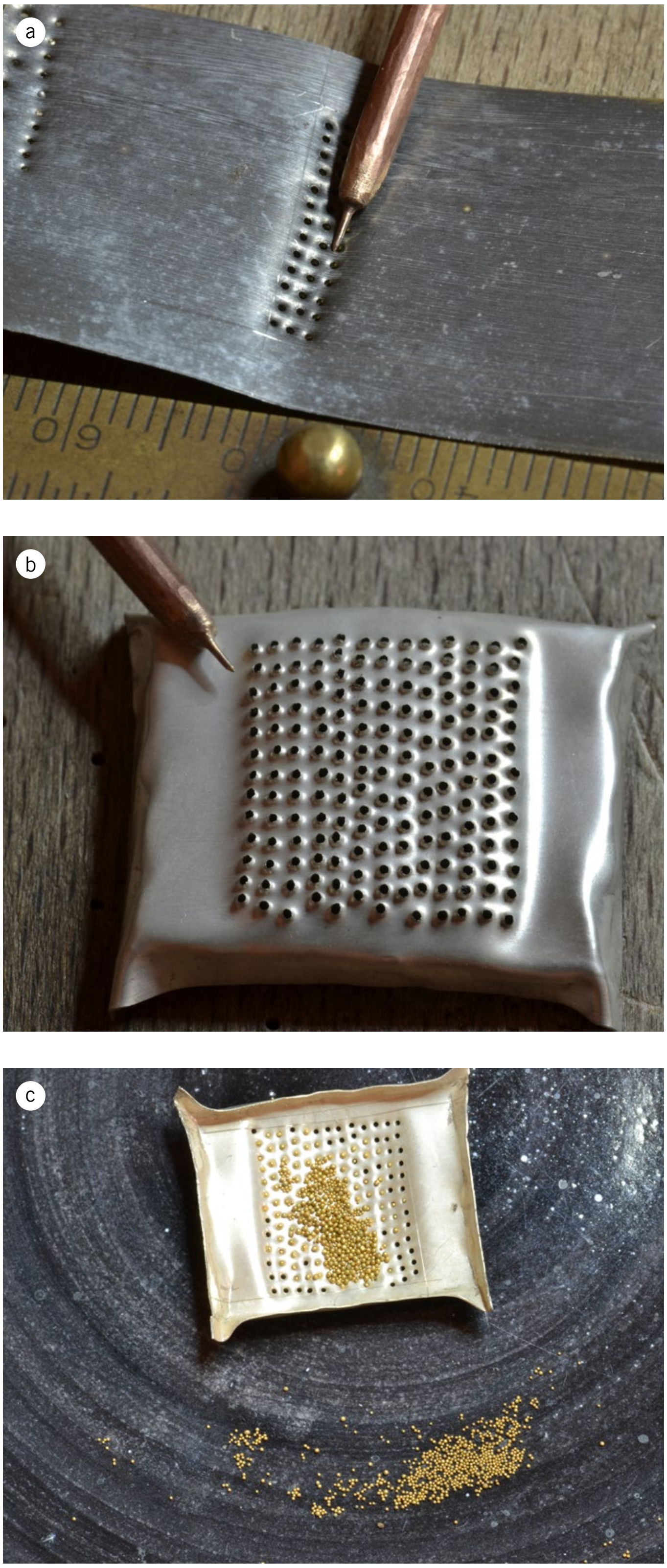


Fig. 14
Testing the hypothesis of using a seive for sorting granules by size:
a) punching a silver sheet with a bronze tip, diameter 0.42mm to make a seive
b) reverse of the seive
c) using the seive to retain the larger granules, the finer granules fall through the perforations
Photos © U.G. Pettorossi

Fig. 15
Positioning granules on a palmette inspired by those of an Etruscan necklace from Palestrina of the fifth century BCE. Made by Ulderico Giuseppe Pettorossi. 22 carat gold. Photo © U.G. Pettorossi

Fig. 16
a) A complex jewel created by Ulderico Giuseppe Pettorossi in the year 2001: inspired by an Etruscan fibula of the seventh century BCE of unknown provenance, 22 carat gold, length 10cm
b) Gold granules positioned on the gold bow of the fibula. The copper salt was applied as a solution
c) As the solution dries it takes on an opaque appearance, when it is ready to be placed in the furnace

In my view, there are two main ways of positioning the granules, which I have named 'Field' and 'Silhouette' granulation.

Field granulation is constructed within filigree wire or embossed or stamped relief. In the Silhouette granulation, the granules lack such borders and are used almost like pigment; careful placement of the little grains forms flora, fauna, people and other figural forms, or complex geometric decoration. The important thing in both techniques is the quantity and viscosity of the medium used in the soldering. For the Field granulation this needs a greater quantity and liquidity; for the Silhouette higher viscosity of the liquid is essential to control the granules especially on curved surfaces. In any case, whether an oil or simple water is used, the copper salts must be added at the same time in the Silhouette, in the Field they can also be added afterwards, the reason is that if you add the salts at the end of the Silhouette the granules could move, having nothing that contains them. In both cases, the salts are always added with the same brush as is used to position the granules

Observations on the soldering process with copper salts in a muffle furnace

I will describe the process of creating a complex jewel inspired by an Etruscan fibula of the seventh century BCE of unknown provenance.[12]

The granules are positioned and the copper salt solution covers the granules (fig. 16). Where they are in contact with each other and the foil, the green is more intense. The solution is transparent and as it dries it takes on an opaque appearance. The piece is

12 In the Providence Museum of Art, Rhode Island School of Design, Museum Appropriation Fund 30.051.

placed in the centre of the furnace on a porous refractory brick which offers a secure support so that nothing moves, not even a granule. The oven is at about 920°C. I observed that the copper salts immediately turned black and caught fire, producing an imperceptible green flash. At this point, I close the door and wait for the oven to return to temperature before inserting dry wood sawdust, quickly re-closing the oven door. The wood does not burn but makes smoke which creates a reducing environment, which prevents the gold from oxidizing and reduces the salts to metallic copper. The temperature increased by up to about ten degrees compared to the programmed one. When it came back down I opened the peephole and observed that the smoke inside was still dense and I could see nothing, but after a few minutes the smoke cleared and I could see the piece was almost white. Oxygen enters through the peephole and it is at this precise moment that we observe the surface of the gold become reflective like a mirror; I could even see the roof of the muffle reflected in it. This appearance is the key indicator that the copper salts have lowered the surface melting temperature of the gold by alloying with it, causing the liquid metal to move into the contact points between the granules and the foil, exploiting the phenomenon of capillary action. Without the copper salts, temperatures at the limit of melting of the whole object would need to be reached to obtain this process (autogenous welding), so their use is essential to be able to solder safely without the risk of melting the last group of granules and destroying many hours of work in a single instant. Some have tried their hand at experimental tests of autogenous welding with refractory earth furnaces powered by coal and bellows, including myself, but they were unable to go beyond the creation of simple, flat specimens with few granules. The construction of a complex 3-dimensional jewel is another matter. I suggest that the ovens used for granulation from the earliest times are of the same type used in medieval enamelling workshops, of which some drawings and descriptions of that period have passed down to us. The firing and melting environment of the fired enamel powders needs the same environment that is used for granulation (with a higher temperature), i.e. reverberatory [13] and extremely clean, except for one aspect, the reducing environment (absence of oxygen). I believe that the ancient goldsmiths and metallurgists were perfectly aware of how to create a reducing environment; in the ceramic production of the Etruscan black Bucchero ware for example, the potters knew perfectly well that they could remove oxygen by combustion of wood sawdust to obtain the desired result. In addition, there is another aspect we must not overlook – temperature control. In ancient times this must have relied on the recognition of the various shades of colour of the fire and the objects in it. The goldsmith had to observe the object while it underwent heating and maintain a constant flow of air from the bellows. The main problem is not how to reach the temperature for the reduction of copper salts, but the stability of the heated surface and granules. The object to be granulated needs an environment protected from sudden movements, dust or drafts that could come from the bellows that feed the coal. I have found that an oil lamp with olive oil as fuel in conjunction with a blowpipe can be used for annealing or welding foils together, for filigree wire, for spheres formed by two spherical caps, and rings of twisted strip wire for the construction of looped chains. There is no evidence, however, that there was such a use of lamps in antiquity.

It is worth emphasising that the thinness of the gold sheets used, as well as being economical, was also practical, since whether in the oven or with the lamp, the temperatures for soldering with copper salts are reached more easily. How did they achieve this fine work? The answer is always the same – experience. Close observation of Etruscan jewels shows that perfection was not always obtained. Some granules are not well joined, the surfaces of the gold sheet often show signs of bubbling and holes indicating that they had almost reached the point of fusion, and there are gaps in the granulated surfaces. They often resorted to assembling a jewel with mechanical methods such as pins, folded sheets and rivets to avoid, where possible, the repeated heating of the object.

Cleaning and pickling of the jewel

Each time a metal, including gold, is heated in the presence of air it oxidizes to form a black patina, and it must be cleaned. In the ancient world modern acid pickles were not available but various mixtures, often with vinegar, were used. In my experiments, I boiled the jewel in a mixture of vinegar, soda and coarse salt. This was so effective that it dissolved the bottom of the steel saucepan I use for goldsmith's acids. The gold came out perfectly clean but, if oxides persist, the piece can be left in the solution, even overnight. To brighten the finished jewel after pickling, it can be brushed with a hard and firm bristle brush with a little water.

Brief considerations on Castellani goldsmithing methods

To conclude, the Industrial Revolution of the eighteenth and nineteenth centuries made great leaps forward in jewellery production, but a casualty of mass production was the loss of many craft skills. The Italian family firm of Castellani, in the first decades of the nineteenth century, had access to new archaeological finds from peoples of their land, jewellery of types hitherto never seen. They, together with an illustrious list of artisans, revived decorative elements that had disappeared from jewellery. For example, their jewellery creations incorporate micromosaics. Sometimes they include authentic Roman and other intaglios and cameos in their jewellery – or reproduced these too. Alessandro Castellani (the youngest of Fortunato Pio's children) was fascinated by granulation but he appears not to have known the ancient copper salt method of granulation. The method that the Castellanis used to solder the granules and the filigree was equally ingenious, essentially that used since the Renaissance for filigree work. They used powdered anhydrous borax as a flux, mixed with finely divided solder and gum tragacanth. Through this technique, their granulated reproductions turned out to be as beautiful as the ancient ones. I have reproduced this method and used it on 18-carat and 22-carat gold and silver. The result is a practical joining method for filigree and granulation, but I did not find it comparable in quality and

13 A reverberatory furnace is a metallurgical furnace that isolates the material being processed from contact with the fuel, but not from contact with oxygen.

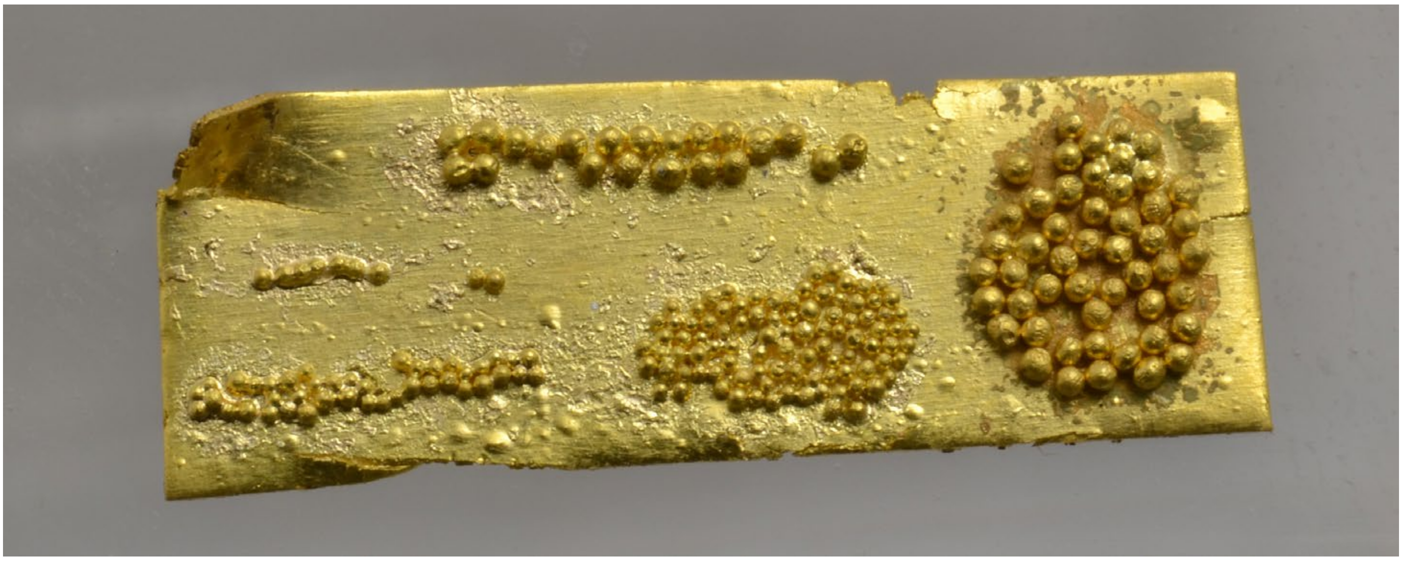


Fig. 17
Cleaning and pickling with hydrochloric acid of experimental granulation applied by the Castellani method (heating with filings of gold solder and powdered, vitrified borax). Made by Ulderico Giuseppe Pettorossi. Photos © U.G. Pettorossi

beauty to work made using copper salt soldering, especially for very small granules. In addition, with the ancient method, I found it easier to position the granules and create complex decoration. More difficult than the Castellani method, however, is the use of the oven compared to the blow torch, whether with gas and mouth or gas only. I have pondered whether the Castellani and others at the time used hydrochloric acid for pickling since there was industrial production of this chemical agent in the nineteenth century. I believe it likely and produced 22-carat gold specimens that show the success of this (fig. 17).

Fig. 18
'Odysseus'- Double-sided pendant by Ulderico Giuseppe Pettorossi.The decorative motif was inspired by a Castellani brooch from the Campana collection which in turn takes up a decorative foliage motif of an Etruscan brooch from the 5th/4th century BCE now in the Musée du Louvre. Filigree, granulation, fired enamel, nephrite jade, 22 carat gold. Soldering with copper salts. Pettorossi. Photo, © U.G. Pettorossi

In the creation of decorated wires, the Castellani used drawn wire of a larger diameter than the Etruscan wire made from twisted strips that I used. The Castellani beaded wire tends to have narrower 'beads' relative to the wire diameter than the ancient. I tried to replicate this with the hand-held beading tool as described above. This proved satisfactory with pure silver and 22-carat gold but I failed with 18-carat gold as it was too hard. The Castellani may have used a more industrial type of machine.

More recently, I have produced some jewels inspired by the style of nineteenth century archaeological jewellery, taking a cue from some Castellani jewels (figs 18-23). I used copper salt soldering for objects in 22-carat gold for the granulation and filigree whereas

Fig. 19
Pendant 'The nineteenth century' by Ulderico Giuseppe Pettorossi. Filigree, granulation, fired enamel, handmade loop-in-loop chain, 22 carat gold. The outermost beaded wire of the decoration is solid and produced by drawing. Photo, © U.G. Pettorossi

Fig. 20
Pendant 'Heaven, beauty and earth' by Ulderico Giuseppe Pettorossi. Filigree, granulation, fired enamel miniature grisaille, handmade loop-in-loop chain, 22 carat gold. Photo, © U.G. Pettorossi

Fig. 21
Two pendants in gilded silver with micromosaic elements typical of Castellani designs
Produced by Ulderico Giuseppe Pettorossi. Photo, © U.G. Pettorossi
Micromosaics by Elena Lo Presti

Fig. 22
a) Pendant in 22 and 18 carat gold by Ulderico Giuseppe Pettorossi, inspired by a Castellani-made brooch. The filigree decoration and the beaded wire are bonded with copper salts, the micromosaic element was built within cells, in this case in pure silver, and is an innovation of the Castellani
Diameter of the micromosaic 3.8cm, total diameter 5.3cm
b) Silver strips that form the cells and define the design of the subject, the owl and the leaves.
Thickness of the strips for the wings of the owl 0.14mm, for the rest of the decoration 0.08mm and height 2.75mm
c) Structure of the design completed, the silver cell walls enhance the contours and allow the inlaid glass tesserae to follow the design
Photo, © U.G. Pettorossi. Micromosaics by Elena Lo Presti

for the silver I used the Castellani recipe with borax, powdered solder and gum. In two recent cases, I created two 'reconstructions from originals', using mixed soldering techniques. Copper salt for the upper part with 22-carat gold filigree, but the powder solder method for structural parts in 18-carat and 22-carat gold structural parts. These two jewels included micromosaic in collaboration with an excellent artisan who has experimented with this 'lost art' and has renewed the Roman micromosaic tradition.

I am a goldsmith craftsman, inspired by the work of ancient goldsmiths. My experimentations have shown me some of the ways in which the ancients may have made their jewellery and I hope that the results may be intriguing to craftsmen of today and of interest to jewellery historians. It has been an exhilarating and humbling journey. The more I have learned and experimented, the more I have come to respect the extraordinary skills of my Italian predecessors. They show that artistic sensitivity coupled with amazing experience, perhaps gained over generations, can create miracles.

Acknowledgements

My thanks are to Jack Ogden for his encouragement to write this article and especially for his technical diagrams of my tools and methods. Thanks also to Aude Mongiatti, British Museum Department of Scientific Research for initially translating my work and Susan La Niece for shaping my enthusiastic words into this article.

Fig. 23
a) Pendant in 22 and 18 carat gold, by Ulderico Giuseppe Pettorossi, inspired by a Castellani-made set exhibited at the Musée des Arts Décoratifs Paris. The filigree decoration is bonded with copper salts. The micromosaic is made within a cell structure, in this case in 22 carat gold, the halo of the dove is made up of 22 carat gold tesserae. Diameter of micromosaic 3.1cm, total diameter 3.9cm
b) Construction of the dove: thickness of the 22 carat gold cell walls 0.18 mm, height 2.55mm; 22 carat gold tesserae 0.5 x 0.5mm
c) Overview of the work
Photos © U.G. Pettorossi. Micromosaics by Elena Lo Presti

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