

# INTERPRETING PLINY'S GILDING ARCHEOLOGICAL IMPLICATIONS \*

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## *Abstract.*

Pliny's description of mercury gilding has a clearer meaning if interpreted in terms of a gilding process quite different from the usual fire amalgam gilding. Other related passages of Pliny's text support this interpretation. Qualitative laboratory tests and additional references emphasize the important role played by the purity of the base metal in gilding operations.

## *Introduction.*

The progress of a research-study started several years ago on the surface features of the golden S. Marco horses<sup>1</sup> led me to investigate the gilding techniques used by the ancients.

The unusual composition of the S. Marco horses (practically pure copper), implying exceptional casting difficulties, finds a possible explanation in the light of the results of research carried out by P. Craddock.<sup>2</sup> He suggests that the pure copper constituting the base metal of some gilded artifacts of the classical age, examined in the British Museum Laboratory, is the result of objective difficulties encountered by the ancient goldsmiths in gilding a base metal of a copper alloy not particularly poor in tin and lead. He quotes Theophilus as a support of his interpretation. His findings, as well as other recent ones concerning ancient gilt bronzes,<sup>3</sup> appear to present a real guide for a re-examination of what the ancient authors state on this matter.

The present work applies this line of approach to Pliny's N.H. It aims at showing that a critical

investigation of Pliny's text concerning «aes» gilding, leads to an original interpretation of a method of mercury gilding possibly used during his time.

The proposed method and some related laboratory tests are presented and discussed in this paper. Some additional references concerning the composition of the base metal, as associated to gilding, are also given.

## *Statement of Pliny's problem concerning gilding.*

Pliny's *Naturalis Historia* is the richest source of technology that reached us from the classical world. The vicissitudes the N.H. manuscripts experienced through the centuries, partly justify the difficulties encountered by students in interpreting some of their parts. The difficulties are further enhanced by possible fallacies of Pliny himself in reporting some technical terms.<sup>4</sup>

The reconstruction of Pliny's manuscript by the various commentators, appears particularly weak as far as book XXXIII of his N.H. is concerned. Although it has been the main reference for metallurgists for many centuries, even today it shows several ambiguities that the sporadic emendations made to the text, most of philological character, have clarified only in part. These ambiguities are mentioned, more or less explicitly, by those experts who quoted Pliny in questions concerning metallurgy and chemistry known by the ancients.

The passages that Pliny devotes to gilding, are typical examples of the above. They are (from the Loeb edition<sup>5</sup>).

XX. On marble and other materials incapable of being raised to a white heat gold is laid with white of egg; on wood it is laid with glue according to a formula; it is called leucophorum, white-bearing; what this is and how it is made we will explain in

XX. Marmori et iis, quae candefieri non possunt, ovi candido inlinitur, ligno glutini ratione composita, leucophorum vocant. quid sit hoc aut quemadmodum fiat, suo loco docebimus. aes inaurari argento vivo aut certe hydrargyro legitimum erat, de quis, ut

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its proper place. The regular way to gild copper would be to use natural or at all events artificial quicksilver, concerning which a method of adulteration has been devised, as we shall relate in describing the nature of those substances. The copper is first subjected to the violence of fire; then, when it is red hot, it is quenched with a mixture of brine, vinegar, and alum, and afterwards put to a test, its brilliance of colour showing whether it has been sufficiently heated; then it is again dried in the fire, so that, after a thorough polishing with a mixture of pumice and alum, it is able to take the gold-leaf laid on with quicksilver. Alum has the same cleansing property here that we said is found in lead.

XXXII. There is also a mineral found in these veins of silver which contains a humour, in round drops, that is always liquid, and is called quicksilver. It acts as a poison on everything, and breaks vessels by penetrating them with malignant corruption. All substances float on its surface except gold, which is the only thing that it attracts to itself; consequently it is also excellent for refining gold, as if it is briskly shaken in earthen vessels it rejects all the impurities contained in it. When these blemishes have been thus expelled, to separate the quicksilver itself from the gold it is poured out on to hides that have been well dressed, and exudes through them like a kind of perspiration and leaves the gold behind in a pure state. Consequently when also things made of copper are gilded, a coat of quicksilver is applied underneath the gold leaf and keeps it in its place with the greatest tenacity: but if the gold-leaf is put on in one layer or is very thin it reveals the quicksilver by its pale colour. Consequently persons intending this fraud adulterated the quicksilver used for this purpose with white of egg; and later they falsified also hydrargyrum or artificial quicksilver, which we shall speak about in its proper place. Otherwise quicksilver is not to be found in any large quantity.

XLII. At the present time silver is almost the only substance that is gilded with artificial quicksilver, though really a similar method ought to be used in coating copper. But the same fraudulence which is so extremely ingenious in every department of life has devised an inferior material, as we have shown.

The generally accepted interpretation of the above passages is that in them Pliny refers to the gilding technique that we call gilding by mer-

dicemus illorum naturam reddentes, excogitata fraus est. namque aes cruciatur in primis accensumque restinguitur sale, aceto, alumine, postea examinatur, an satis recoctum sit, splendore deprehendente, iterumque exhalatur igni, ut possit, edomitum mixtis pumice et alumine, argento vivo inductas accipere bratteas. alumen et in purgando vim habet qualem esse diximus plumbo.

XXXII. Est et lapis in iis venis, cuius vomica liquoris aeterni argentum vivum appellatur. venenum rerum omnium est perrumpitque vasa permanens tabe dira. omnia ei innatant praeter aurum; id unum ad se trahit. ideo et optime purgat, ceteras eius sordes expuens crebro iactatu fictilibus in vasis. it vitiis eiectis ut et ipsum ab auro discedat, in pelles subactas effunditur, per quas sudoris vice defluens purum relinquit aurum. ergo et cum aera inaurantur, sublitum bratteis pertinacissime retinet, verum pallore detegit simplices aut praetenuas bratteas. quapropter id furtum quaerentes ovi liquore candido usum eum adulteravere, mox et hydrargyrum, de quo dicemus suo loco. et alias argentum vivum non largum inventu est.

XLII. Hydrargyro argentum inauratur solum nunc prope, cum et in aerea simili modo duci debent. sed eadem fraus, quae in omni parte vitae ingeniosissima est, viliores excogitavit materias, ut docuimus.

cury amalgam or fire-gilding. (Vitruvius is also quoted in support of it<sup>6</sup>). This interpretation also holds that both Pliny and Vitruvius had omitted

to mention the final operation of the process which consists in heating the piece in order to remove the mercury.

A few commentators are more careful. Moran is, to my knowledge, the most evident example of an objective attitude in this respect.<sup>7</sup> He says: «But whether or not Vitruvius was definitely referring to the fire-gilding process we cannot say. And Pliny, though mentioning mercury as being used in the gilding of copper, seems definitely not to be referring to the fire-gilding process in the ordinary meaning of that phrase».

#### *Approach to an interpretation of Pliny's gilding technique.*

Actually, by a careful examination of what Pliny reports, as compared with any description whatsoever of the fire-gilding, one can perceive that, apart from the ambiguity of some words, they refer to techniques that are substantially different. The fire-gilding process is reported by many authors. Cellini's description<sup>8</sup> seems to be the most complete. Moreover many of the more recent authors were probably influenced by him.

In Cellini's gilding, the layer of gold is formed «in situ». He speaks of gold leaves but as used only in order to promote a good and quick amalgamation of gold with mercury inside the crucible. The gold-mercury ratio in the amalgam (which is prepared separately) varies between fairly wide limits.<sup>9</sup> It is reached step by step by the artist and it is established on the basis of his experience, taking into account both the size of the artifact and the desired type of gilding. He makes use of further «operations for spreading the amalgam» if he considers the result unsatisfactory. The heating by fire (requiring continuous control of the piece and adjustments by hand for a better distribution of the amalgam on its surface) is a fundamental operation since *it is indispensable in order to form the gold layer*.

Pliny speaks of gold leaves attached directly to the base-metal by mercury. I suggest that the process of mercury gilding reported by Pliny has to be interpreted exactly as he describes it<sup>10</sup> and therefore consisting in the following successive operations:

- a) Mercury is rubbed on the surface of the base metal (i.e. copper) when the latter is cold. Copper amalgamates with mercury. A very thin layer of copper-mercury amalgam forms. At room temperature the copper does not become soft in the presence of mercury.<sup>11, 12</sup>
- b) The excess of mercury is mechanically removed. This operation leaves the surface shining and smooth as a mirror.
- c) The gold leaf is pressed upon the surface. Gold absorbs mercury from the copper but does not soften. We cannot refer to it as an «amalgam» in the «classical» sense. Even if the gold leaf absorbs all the mercury from the copper-mercury amalgam, it remains solid and consistent. It keeps its original leaf form while it is «tenacissime» attached to the base metal.
- d) The gilden artifact is not subjected to fire.

This gilding technique (I will refer to it as «cold-mercury gilding»)<sup>13</sup> does not appear to present operational difficulties since the amount of mercury to be used is independent of the choice of the goldsmith. The working conditions are fixed since they are defined exclusively by the «solubility» of mercury in copper. The goldsmith cannot make mistakes since the operation is satisfactorily reproducible. Moreover, it offers the advantage of a minimum consumption of mercury.

Heating to remove mercury is an optional operation and basically unnecessary. It appears reasonable to assume that the removal of the mercury by heating would present, in this method, different physical aspects from those concerning the classical gold-mercury amalgam. In the latter the mercury is removed by fire through evaporation. In the former, since the mercury is beneath the gold leaf (the gold layer is already present), it would be transferred into the environment mainly by diffusion though the gold layer and therefore by a lower rate process. This gilding method cannot be discussed by comparing it with the «classical» method. However Cellini seems to confirm that there is a difference in the mercury removal rate in the two cases. He describes the classical fire-gilding process and, referring to the spreading of the gold-mercury amalgam he adds: «... and although somebody does this by using

quicksilver itself and then lays the grounded gold upon it, this is not a good method since that excess of quicksilver spoils the colour and the beauty of the gold...». It appears that even Cellini, who knew how to remove mercury by fire, could not do very much in this case.

This fact is all the more true in Pliny's cold-mercury gilding where: «...if the gold leaf is put on in one layer or is very thin...it reveals the quick-silver by its pale colour...». In other words Pliny states that the «pallor» of the gilded surface points out the presence of mercury.

Pliny himself seems to confirm the above, in the passages that describe the fraud. A critical analysis of what he writes results in a reasonable interpretation of the fraud that supports the above gilding method.

We derive from the text that the fraud refers to the mercury, not to the gold. At Pliny's time mercury, both the native and the «hydrargyrium» (artificial quicksilver), must have been relatively expensive and not easily found.<sup>14</sup> On the other hand, the «recte» of Vitruvius as well as the «legitimus erat» of Pliny, mean that only the gilding made by means of mercury was considered good and durable. This explains the purpose of the fraud. According to the cold-mercury gilding process, the «pallor», and that particular type of «pallor», appears to be the only element that objectively indicates (and in some way proves to the purchaser) the use of the expensive mercury by the goldsmith. If the «pallor» were removed by heating, as occurs in classical fire-gilding, the association between «pallor» and fraud reported by Pliny would have no sense. Therefore, the fraud appears to consist in gilding with another method and in simulating the «legitimus» gilding process by imitating the «pallor» left by mercury. The latter aspect of the fraud, Pliny says, is performed by the use of egg-white.

Some laboratory tests clearly show that the simplest and the most banal of the possible interpretations of the production of the «pallor» by egg-white can be the correct one.<sup>15</sup>

A little egg-white is smeared on a metal surface previously gilded by a method that does not imply the use of mercury (hot pressing). The excess egg-white is removed from the gold surface. If the temperature of the gilded piece is relatively high (we shall see below how this high

temperature is consistent with the «fraudulent gilding»), the gold surface becomes pale turning into a colour very similar to that observed in a surface gilded by the cold-mercury process. The similarity concerns both the colour (in terms of purity and brilliance) and its surface pattern.

The «albumen», hardened by cooking on the gold surface, cannot be removed by washing nor by scraping. The latter aspect seems to depend on the real physical structure of the gold leaf. The thinning of gold (both by ancient hammering and by modern rolling) does not result in a layer of uniform thickness as seen at the microscopic scale. The leaf is actually studded by small thickness defects even when applied by not pressing to the base metal. The egg-white infiltrates these microscopic spaces and, embedded there by the cooking, cannot be reached by scraping. It is worth mentioning that the thinner the leaf, the larger the surface fraction covered by thickness defects and the stronger the «pallor» produced by the white of egg. The structure of the «pallor» due to mercury in samples which have been cold-mercury gilded is governed by the same parameters. Microprobe examination of a sample gilded by the cold-mercury process shows that mercury which gives the «pallor», is distributed on the outer surface in spots 10-100 micron in size. The naked eye does not resolve them.

The use of egg-white, as described above, has a further important aspect that renders it more effective with respect to the fraud. We can observe that the «pallor» due to mercury fades after some time. The pale colour, as simulated by egg-white, behaves in the same way. Since it is an organic substance exposed to the air, it undergoes a biochemical attack, then decomposes and disappears after some days. According to the spirit of the fraud this behaviour of the egg-white, as compared with another inorganic white, was such as to assure the goldsmith that his long term credibility too could not be questioned.

At this point, if the above schema is acceptable, further examination of Pliny's text is necessary. The original sentence concerning the fraud (XX) starts with «Fraud excogitata est etc. ...». Bailly<sup>16</sup> does not accept it (the presence of «argento vivo» does not fit the fraud) and adjusts it as it is now in the Loeb edition reported above. But even emended in this way, its initial «namque» does not appear to alter the previous mean-

ing, i.e. Pliny begins to say how the gilding with fraud is performed. Actually the sentence, as it is now in the Loeb edition, as well as in its unemended form, looks like a repetition, with further operative details, of a gilding process performed by using both gold leaves and mercury. We have seen that the use of mercury is incompatible with the fraud. Therefore by this sentence Pliny is expected to describe the other way of gilding, that is a leaf-gilding without mercury. The following points support this thesis:

a) the unemended manuscript says «mixtis pumice alumine argento vivo» generally translated in «with a mixture of pumice, alum and quicksilver». Bailey states that it is an impossible mixture: from the chemical point of view it has no sense. On this ground Bailey justifies his emendation included in the Loeb edition. The original sentence is therefore wrong.

b) Pliny's description of the preparation of the base metal to be gilded, appears to have been learned from an expert (XX). «Splendore deprehenste» is typical evidence of good annealing for a metallurgist. A modern metallurgist would say the same with the words: «growing of large metal crystals». The liveliness of the description includes the distinction Pliny makes between native and artificial quicksilver.

This distinction appears, at least in this sentence, to refer to mercury only as far as its use for gilding is concerned. The term «certe» attributed by Pliny to the artificial quicksilver with respect to the native one is a marginal detail of the gilding operation that only the goldsmith had experienced. «Certe» can be explained by the better purity of the artificial quicksilver with respect to the native one, so that the former enabled the goldsmith to gild with greater security. In conclusion, the property of the technical terms used by Pliny in this passage and the effectiveness of the description renders the «impossible mixture» less acceptable.

c) Pliny's text could have been altered by the addition of the term «argento vivo» that does not fit with the rest. It may be a correction made by the copyist in order to make Pliny consistent with himself (the use of mercury for gilding as described elsewhere) according to a cursory interpretation of the passage. I can quote two authors

of the past, Pancirollus and Zasius, who read one of Pliny's manuscripts reporting the fraud as consisting in gilding with no mercury and with egg-white as the instrument of the fraud.<sup>17</sup> These two author's interpretation of the purpose of the fraud is misleading, but their description of the no-mercury gilding technique, as taken directly from Pliny, leaves no doubts. Indeed Pancirollus speaks of a «modum vero inaurandi vel adulterandi» (a method for both effectively gilding and for making the fraud). The «modum vero inaurandi» to which Pancirollus refers is the cladding or hot pressing. It requires a preparation of the base metal through careful purification by fire followed by a cleaning of the surface to make it ready to receive the gold leaf (the same terms used by Pliny could be taken directly to describe it!). The gold leaf is attached directly to the base metal by «hot pressing».

d) As the gilding by cladding or hot pressing requires the base metal to be at a high temperature, Zasius' and Pancirollus' interpretation of the discussed sentence throws indirectly a new and clarifying light on the debated<sup>18</sup> first sentence of Pliny's XX paragraph: «Marmor...». On the basis of the present interpretation its meaning becomes clear. The gilding by hot pressing, Pliny says, cannot be performed on marble or other substances that cannot be raised to high temperatures by fire.

e) Two of Pliny's outstanding codices do not contain the term «argento vivo». «Argumenta» is the word substituting it. This implies that the passage has at least an alternative version.

In order to clarify these points I collected all the available comments directly and indirectly related to the matter and I submitted them to the authority of Prof. Silvio Ferri.

He kindly permits me to summarize here the conclusions of his analysis:

- 1) There is no doubt that Pliny mentions the fraud referring to mercury.
- 2) There is no doubt that the original passage in paragraph XX concerning the fraud, has to be interpreted as the way in which Pliny tells the reader how to make the fraud (the emendation introduced by Bailey does not change substantially this meaning).

- 3) From 1) and 2) the term «argento vivo» has no sense.
- 4) Mayhoff reports that the Pliny's R and V codices contain the word «argumenta» instead of «argento vivo».<sup>19</sup> They are both very good codices and cannot be underestimated or ignored. In Pliny's texts parenthetical clauses are often encountered. They look like marginal glosses written by copyists or readers and in later times included in the text itself. Therefore they have to be taken as parenthetical clauses whose purpose is to clarify the text. In this specific case the term «argumenta» is perfectly acceptable as a parenthetical clause coming from a marginal glosse. Since its meaning requires an interpretation of the Pliny passage which implies a technical evaluation having no immediate evidence, its function in the text could have escaped past students. «Argumentum» has various meanings. Two of them are consistent with this case and moreover typical of it. The first meaning subordinates «the attaching of the gold leaf to the base metal» to «the effectiveness of the purification and cleaning operations» previously described. This meaning can be concisely expressed as «and the proof of it is that» or «and this is verified by the fact that». The second can be found in Middle Age Latin, where «argumentum» has also the meaning of «instrument for, means for, operation for». Both the meanings of «argumenta», as a parenthetical clause, aim at emphasizing what Pliny said in the text, that is a *good* joining of the gold leaf to the base metal by hot pressing necessarily depends on the *good* fire-working of the piece and on the *good* cleaning of its surface. The latter operations are, according to the above interpretation, the «argumenta».

#### *Some laboratory tests.*

I tried to substantiate the above by some additional information having a more objective character. I could rely on proper collaboration, namely that of Dr. Luigi Rigosi of the Physical Institute of the University of Ferrara, who very ably performed all the operations concerning the

fraud, the mercury gilding and the finishing of the gilt samples.

The cold-mercury gilding was performed in the laboratory. It is a technique which does not present any problem. The spreading of the mercury on the copper surface, the polishing of the amalgamated surface that becomes like a mirror and the application of the gold leaves are both simple and reproducible operations. The gold leaf remains compact. The mercury which contaminates the gold, is detected by its characteristic «pallor». This gilding operation can be satisfactorily performed on both copper and bronze (7% tin).

Some explorations of the boundary between the gold leaf and the base metal, performed by microprobe analysis, showed that the boundary itself is very sharp, both with copper and bronze.

But the most interesting aspect of the cold-mercury gilding operation, as described above, concerns the finishing of the gilt surface.

While the gilding performed on pure copper can be very easily finished by the burnisher both at a high and room temperature, it is not so with bronze. In the latter case the burnishing acts as a destructive operation of the gold layer. The gold leaf attached by mercury to a bronze base metal does not resist when submitted to burnishing. Even under the first brushes it gets chapped, crumbles up and breaks. It is extremely fragile.

This behaviour appears to support the hypothesis presented at the outset of this paper concerning the difficulties in mercury gilding bronze with respect to pure copper. The alloying of tin with gold that should easily take place in the gold-bronze interface in the presence of mercury (mercury amalgamates well with tin), appears to be the cause of the observed fragility.<sup>20</sup>

But tin contained in the base metal alloy can pass into the gold leaf even when no mercury is present. Mr. Canal, an expert in archeology who in his Venetian firm reproduces artworks by using ancient techniques, kindly contributed to this research by making some practical tests. In particular he performed some experiments by attaching gold leaf to both copper and bronze by hot pressing. The burnishing gave results similar to the previously mentioned ones. This type of gilding, an operation where the use of the burnisher is of fundamental importance to attach the leaves

to the hot base metal,<sup>21</sup> gave good results on pure copper but ruinous on bronze.<sup>22</sup>

The above operations concerning both cold-mercury gilding and hot pressing have been carried out on several samples and the results are perfectly reproducible. In the cladding operation the high temperature of the metal can cause tin to be transferred from the base metal alloy into the gold.

Although the above tests cannot result in a conclusive picture, the ability and the experience of the experimenters give them great validity. We have to bear in mind that in many cases the burnishing of the gilded surface is an important artistic part of the gilding.

*Pure copper - gilding association. Further literature evidences.*

I wish to conclude this contribution by presenting a few elements selected among a large series of references. The elements that I report below do not throw sure light on the matter concerning the composition of the alloy to be gilded, but they strengthen Craddock's suggestions. The main references worth mentioning in this respect are:

1) The pure copper - gilding association found in ancient artifacts belonging to the classical age, is further confirmed by the metal objects found on the Nemi ships. The Roman ships were brought to light from the bottom of Lake Nemi.

There is a book, edited by the Italian government,<sup>23</sup> in which the various stages of this archeological and technical operation are reported. In the appendix of the book there is a list of metal artifacts found in the ships. Those of interest are classified under «Pure Copper» and «Bronze». All the «pure copper» artifacts are reported to be gilded while only one of those under «Bronze» is gilded. Nothing more is reported about the composition of the alloy nor how the parameter for the classification was chosen. However a well known metallurgy laboratory is reported to have performed the analysis.<sup>24</sup>

2) The fragility that the gold experiences when contaminated by tin and lead seems to have been known in the past. It is mentioned in some

old Encyclopedias. Biringuccio Vannuccio should be quoted here as he speaks about the effect of contamination on gold by other metals in the contest of gilding.<sup>25</sup>

3) D'Arcet's opera<sup>26</sup> on the gilding of bronze by fire amalgam is generally considered one of the most outstanding works of the recent past. It does not contain clear statements concerning the best alloy to be bilded. The purpose of his investigation is the search for an alloy which could meet the needs of the various artisans. However the answers given by the goldsmiths (they are among the artisans he consulted in his investigation) clearly show that, according to them, the freer the alloy is from tin and lead, the better the gilding is.

A deeper analysis of the metallurgical aspects of gilding techniques is contained in Bonazzi's «Guide to the goldsmiths».<sup>27</sup> It is a very accurate summary of what was known at his time about gilding. His technical and chemical terminology is excellent. He describes the «classical fire gilding technique» and the preparation of the base metal (bronze and brass) to be gilded. The piece has to be previously placed on a fire «with its surface completely covered by coal» or by using other materials «that burn well producing a fire more uniform and less intense than coal». This preparation, he adds, is justified by the goldsmiths, «according to their own vision of the gilding», as having the purpose of cleaning the metal surface by taking the crease off of it. Then he writes: «They (the goldsmiths) attribute the beautiful colour of the gilding to this perfect cleaning. But things are different. D'Arcet thinks, and he is right, that this operation results in a burning of part of the zinc contained in the alloy, namely in its surface. Consequently the surface itself goes back again to a more or less red copper state, and that is why it better retains the gilding and acquires a brilliant colour».<sup>28</sup>

On the basis of this reference and of the ambiguity of other authors more or less his contemporaries, who generally speak about gilding of bronze and brass but they use the term «copper» just when they reach the point in which they describe the gilding operation, it appears that this technical point was actually not clear even among the artisans themselves.

Some further statements concerning this matter can be reported. They are not justified by the authors but confirm the existence of a problem that concerns artifact composition as related to gilding, referring to ancient gilding techniques.

Winkelman<sup>29</sup> states that some ancient statues are made of bronze and some of copper. Then he adds: «the ancients preferred to use copper rather than bronze when they wanted to gild the statues since the former can be gilded much more easily than the latter».

Bossi<sup>30</sup> discusses the operations for «aes» refining according to Filon from Bisanzio description. Then he says: «It is worth mentioning that whatever kind of fire refining was used by the ancients it was applied only to those pieces that had to be gilded...». He suggests that for some special artistic purposes «the ancients could also use the few available veins of native copper». Bossi is quoted by several authors of the XVIII century as an outstanding expert in ancient techniques.

Brenni<sup>31</sup> examines and comments a large series of historical documents concerning the Italian goldsmith associations. In these documents among other pertinent information there is the following report: «On July 25<sup>th</sup>, 1669 the gilders claim against the goldbeaters who reduce the gold leaf to a thickness smaller than the usual one. In such a way they make difficult the gilding also because of the formation of an alloy (of gold) with less precious metals».

Biringuccio<sup>32</sup> says about copper alloyed to tin: «But this (the alloy with tin) is not proper when you want to work it by hammering since in this case the copper must be pure and odourless, otherwise it cannot be made thin, nor can it be fired, *gilded*, etc.

4) One Pliny's passage seems to imply an association between the composition of the artifact and the gilding. In the XXXIV book of his N.H. he tells of a bronze statue brought to Rome from Greece that Nero wanted to be gilded, and so it was. In a later time the gilding was removed. The passage ends: «...in this state it (the statue) is looked upon more precious, even if one can still see on its surface the cuts and scars made in order to fix the gold on the bronze». The famous French sculptor E. Falconet<sup>33</sup> trans-

lates: «les hachures et les cicatrices». He clearly refers to the gilding technique known in France as «à l'haché». Blummer<sup>34</sup> gives Pliny's passage the same interpretation. He also discusses the application of this mechanical gilding process to various artifacts according to their shape. This gilding technique is mentioned in several old Encyclopedias.<sup>35</sup> It consists in producing deep cuts on the base metal and then hammering a gold sheet (apparently relatively thick) upon its surface made hot. According to what we know about gilding, this technique appears to be the only one (using fire) that does not require a proper chemical composition of the base metal as «a priori» established in order to obtain stable gilding. The bronze alloy of the Greek statue, cast with no idea that it had to be gilded at a later time, was prepared through the usual casting technique. Therefore it could not be mercury gilded nor gilded by hot pressing. This can explain the apparently unusual way used in Rome to gild it. I discussed this point with A. Oddy of the British Museum Laboratory, and it appears that in the past there were several ways of performing mechanical gilding.

### Conclusions.

The matter discussed in this paper concerns a very broad field of fundamental importance in Science and Technology with relation to Archeology.

I am presenting this work as an attempt to put together only a few of the intriguing aspects of the ancient gilding techniques. Mercury gilding in ancient times is a very complicated matter and needs further research in order to be clarified.<sup>36</sup> My conclusions are implicitly contained in the various steps of this paper. Their validity is limited by the large variety of the themes concerning the matter so that necessary oversimplifications are made. However some considerations can be presented.

It appears reasonable to assume that the casting of practically pure copper artifacts in the classical age is the result of a technical necessity rather than an ignorance in casting techniques. The association pure copper-gilding found in artifacts of the classical age is not casual and it



appears as the most logical explanation of the purity of the base metal.

The possibility that in Roman times there was a shortcoming in alloying copper, has been assumed by some authors on the ground of a Pliny's passage (Book XXXIV, 46) where, after mentioning the clay model of a statue in personally have seen in Zenodorus studio, he writes: «This statue has shown that skill in bronze-founding has perished, since Nero was quite ready to provide gold and silver, and also Zenodorus was counted inferior to none of the artists of old in his knowledge of modelling and chasing». E. Falconet<sup>37</sup> goes through this passage and comments it on the basis of his own competence on the matter. He presents a series of valid arguments against its superficial interpretation. He says for instance: «I do not believe that in a country where to make statues to the emperors was a frequent habit, the art of bronze-founding had enough time to be lost». But he does not clarify or justify what Pliny writes. This may have been a source of confusion even if the interpretation of this Pliny's statement, as accepted today, is not only based on a philological analysis. Its meaning however is derived from a previous passage in the same book XXXIV, 5, where Pliny writes: «Formerly copper used to be blended with a mixture of gold and silver, and nevertheless artistry was valued more highly than the metal, but nowadays it is doubtful point whether the workmanship or the material is worse, and it is surprising thing that, though the prices paid for these works of art have grown beyond all limit, the importance attached to this craftsmanship or working in metals has quite disappeared and the process of casting precious bronze has so gone out that for a long time now not even luck in this matter has had the privilege of producing a work of art». S. Ferri<sup>38</sup> clarifies both passages.

On the other hand we know that, at least in the recent past, artifacts of copper-tin-lead alloy were gilded by mercury amalgam, a technique that by several authors is assumed as having been known since the beginning of advanced metallurgy. But we know very little even about relatively recent operations and this too does not seem to be casual. In many documents concerning the goldsmith corporations of some Italian cities, having a high reputation in their past gild-

ing art, the term «secret» is very often associated with gilding operations.<sup>39</sup>

Since the gilding process, that is the classical amalgam process, was common knowledge, it appears that such a reputation and therefore the «secrets» had to concern the preparation of the objects to be gilded and the «beauty» of the resulting gilding, the latter being a parameter subject to the criticism of high level connoisseurs.

The objective difficulties that the artisans encountered in using the amalgam or fire gilding process were, in some places to a greater degree and in some others to a lesser one, overcome, through experience, by the various goldsmith corporations, so that a large variety of alloys could be satisfactorily gilded. It therefore appears that an artifact of practically pure copper should be justified not only by the gilding», but also by a particular gilding technique in which the purity of the base metal is a very critical condition for the gilding operation.

If Pliny's method herein presented is accepted, its lack of flexibility is a proper parameter for justifying the purity of the copper found in artifacts of the classical age. The introduction of the classical fire-gilding process, as we know it today, could have occurred in a later time. It promoted a larger variety of choices that were to bring gilding operations to such a high technological level as to explain the formation, through the centuries, of a large ability selection among the goldsmith's corporations.

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<sup>1</sup> O. VITTORI and A. MESTITZ, *The Burlington Magazine*, CXVII, March 1975, pp. 132-139.

<sup>2</sup> P. CRADDOCK, *J. of Archeol. Sci.*, 4, 1977.

<sup>3</sup> W. A. ODDY and P. A. LINS, *J. of Archeol. Sci.*, 1975, 2, pp. 365-373; M. PICON, J. CONDAMIN, S. BOUCHER, *Gallia*, XXIV, 1966, pp. 189-215; M. PICON, J. CONDAMIN, S. BOUCHER, *Gallia*, XXV, 1967, pp. 153-168.

<sup>4</sup> H. BLÜMNER, *Technologie und Terminologie der Gewerbe und Künste bei Griechen und Römern*, Leipzig 1884, Band III; PLINY, *Naturalis Historia*, XXXII, xix, 61; E. D. VON LIPPMANN, in *Mitteil aus dem Osterlande*, N. F. 5, 370-418, 1892 (repeated in *Abhandlungen und Vorträge zur Geschichte der Naturwissenschaften*, Leipzig 1906, pp. 1-46); S. FERRI, *Plinio il Vecchio, Storia delle arti figurative*, Roma 1946; K. C. BAILEY, *The Elder Pliny's chapters on chemical subjects with Eng. trans. and notes*, 2 parts, London 1929-1932; Id., *Hermathena*, XLIV, 1926, pp. 73+83 (comments of XXXIII, 13, 61, 65, 79, 83, 87, 88, 89, 94, 109, 121, 123, 126, 130, 143); PLINIUS SECUNDUS C. «*Hist. natur. de l'or et de l'argent*», extr. de Plinie I. XXXIII (translated by D. DURAND FOL, London 1729); M. BERTHELOT, *Introduction à l'étude de l'archéologie et histoire des sciences*, Paris 1906; J. BECKMANN, *A concise history of ancient institutions, inventions and discoveries*, London 1823; T. T. READ, *The Archeol. Inst. of America*, 1934, X, 18, 5, pp. 382-389; E. SELLERS-STRONG, *The Elder Pliny's chapters on the history of arts*, London 1896. A good source for books and articles on Pliny N.H. after 1914 is published in M. MAROUZEAU, *Année Philologique*.

<sup>5</sup> Loeb series with English translation by H. RACKHAM and N.H.S. JONES (1938).

<sup>6</sup> VITRUVIUS, *De Architectura*, VII, 8. He says: «*Quicksilver is useful for many purposes. For instance, neither silver nor copper can be properly gilded without it*».

<sup>7</sup> S. F. MORAN, *Artibus Asiae*, XXXI, 1969, 1, p. 55, footnote 3; see also: G. WINGELMAN, *Storia delle arti del disegno presso gli antichi*, (translated in Italian by C. FEA) p. 38, Roma 1783; H. BLÜMNER reports several of the debated interpretations of the Pliny's gilding. He quotes Lenz, who states that a clear picture of the gilding operation reported by Pliny cannot be given. (*op. cit.*, p. 314).

<sup>8</sup> B. CELLINI, *Trattati della scultura*, Firenze 1568; see also: «*Liber sacerdotum*» 168, p. 28, in M. BERTHELOT, *La Chimie au Moyen Age*, tom. I, Paris 1889.

<sup>9</sup> M. D'ARCET, *Mémoire sur l'art de dorer le bronze au moyen de l'amalgame d'or et de mercure*, Paris 1818; *Enciclopedia della Chimica Guareschi*, under the item «oro» p. 438.

<sup>10</sup> A. Jacob suggests that, after Pliny, both the base metal and the gold leaf could be covered by mercury before applying the second on the first. (DAREMBERG SAGLIO, *Dict. des Ant.*, under the item «hydrargy-

rum» p. 311, footnote 23). This operation does not hold since a gold leaf smeared with mercury cannot be handled in any way.

<sup>11</sup> W. J. HUMPHREYS, *J. Chem. Soc. Trans.*, 1896, 69, p. 243 and p. 1679.

<sup>12</sup> P. RAYSON and C. CALVERT, *J. Inst. Metals*, 87 (3), 1958-1959, p. 88.

<sup>13</sup> B. Bearzi independently suggests that the ancients could use a cold-mercury gilding technique (Personal communication).

<sup>14</sup> The last sentence of the paragraph XX (N.H. XXXIII) «*Alias etc...*» has also implicitly this meaning.

<sup>15</sup> H. Blumner interpretes this point in a very strange and questionable way. He suggests that the «pallor» should be attributed to the effect of the base metal! (*Op. cit.*, p. 314, footnote 2).

<sup>16</sup> K. C. BAILEY, *op. cit.*

<sup>17</sup> PANCIROLLUS GUIDUS, *Rerum memorabilium sive deperditorum libri commentariis illustrati*, Francoforti 1660 (under the paragraph: *De Auricalco*); ZASIVS, *De obligationibus*, v. dal Zasius in ss. nouum, p. 518.

The Pancirollus book is easy to be found. The Zasius opera is very rare at least in Italy. I could find it in the Padova Central Library under the item Zasius. The passage of interest of Zasius is reported below:

«*Legice Plin. libr. 33 cap. 3, 6...: quia incendunt aes ut ardeat, deinde estinguunt aceto et alumine, postea inducunt bracteolas auri et istas bracteolas aes sic preparatum accipit in se quod strictissime harent*».

<sup>18</sup> H. BLÜMNER, *op. cit.*

<sup>19</sup> N. H., Ed. C. Mayhoff, Leipzig-Teubner, libri XXXI-XXXVII (1897).

<sup>20</sup> Guareschi describes the properties of both gold-lead and gold-tin alloys. The fragility of the alloy containing even traces of the two metals is emphasized. Concerning the fragility of the gold-lead alloy, Guareschi writes: «... such a curious effect of the lead on gold has to be taken continuously into account by goldsmiths in order to avoid that even the smallest particle of lead joins the gold». (*Enciclopedia della Chimica Guareschi*, under the item «oro» p. 428).

<sup>21</sup> H. MARYON, *Welding in ancient times (Welding and metal fabrication)*, London 1955, pp. 383-389.

<sup>22</sup> E. CANAL reports: «The pure (commercial) copper results to be the 'easier' metal on which to make the gold leaf to adhere by cladding. A slight adherence can be observed even at 100-120°C. From 250-280°C the adherence can be defined good. At 350-380°C the optimal condition begins. Both brass and bronze (having a relatively high proportion of tin) present serious difficulties for obtaining an adherence at various temperatures: from 150°C to 500°C the gold leaf is not retained by the base metal, very often is scratches and it is removed by the

burnisher even if one acts with lightness and carefulness ». (Personal communication).

<sup>23</sup> G. UCELLI, *Le navi di Nemi*, Roma 1940.

<sup>24</sup> The Chim. Ital. Minero-Metallurgico di Milano. One composition analysis is reported: copper 99.60 per cent.

<sup>25</sup> VANNUCCIO BIRINGUCCIO in book IX pp. 280-281, describes « l'arte del fabro orefice ». The variety of problems the goldsmith had to face is lively described. The operations the goldsmith must know, « that (in the people mind) are considered like secrets...: and primarily, the way of softening gold, when, because of some smell of lead, or other metal, it has taken, does not hold up the hammering... » (BIRINGUCCIO VANNUCCIO, *De pirotechnia*, libri X, Venezia 1540, pp. 280-281).

<sup>26</sup> M. D'ARCET, *Op. cit.*

<sup>27</sup> BONAZZI, *Guida per i doratori*, Bologna 1811.

<sup>28</sup> This is in agreement with Teophilus when he describes the purification of copper. He advises to cover the piece with fine ashes and coal « ... and you will at once see the burnt lead adhere to these ashes like glue » J. G. HAWTHORNE and C. S. SMITH, *On divers arts. The treatise of Theophilus*, Chicago 1963, p. 125.

<sup>29</sup> G. WINCKELMANN, *op. cit.*, in the Introduction to the Lib. VII, Cap. II.

<sup>30</sup> L. BOSSI, *Memoria sulle patine dei bronzi antichi*, (Opuscoli scelti sulle scienze e sulle arti, Tom. XV, p. 271).

<sup>31</sup> L. BRENNI, *L'arte dei battiloro ed i filati d'oro e d'argento*, Milano 1930, VII, p. 56. (It can be found in Venice, Biblioteca Museo Correr).

<sup>32</sup> VANNUCCIO BIRINGUCCIO, *op. cit.*, Chapt. 2, Lib. V.

<sup>33</sup> PLINIUS, *Traduction des XXXIV, XXXV, XXXVI livres de Pline avec des notes par Etienne Falconet* (II<sup>e</sup> edition) 2, Tom. 8, La Haye (Amsterdam 1772) 1773, Dan. Monnier.

<sup>34</sup> H. BLÜMNER, *op. cit.*, p. 311.

<sup>35</sup> See i.e. DIDEROT and D'ALEMBERT, *Encyclopedia*, under the item « dorure ».

<sup>36</sup> W. A. ODDY and P. A. LINS, *op. cit.*

<sup>37</sup> E. FALCONET, *op. cit.*, note 24.

<sup>38</sup> S. FERRI, *op. cit.*

<sup>39</sup> Several old documents are available. (L. BRENNI, *op. cit.*