Metallurgical Case Studies from the British Museum's Collections of pre-Hispanic Gold

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Abstract: *A program of scientific and technological study of the collection of Pre-Hispanic gold at the British Museum has recently begun, using optical and scanning electron microscopy, radiography and X-ray fluorescence analysis. Interesting case studies, showing a range of goldworking practices, will be illustrated. These include gilding, the use of stone matrices in mould making and the identification of fakes.*

Resumen: *El Museo Británico ha comenzado recientemente un programa de estudio científico y tecnológico de su colección de objetos de orfebrería prehispánica. Para este programa se usa microscopía óptica y electrónica de barrido, análisis radiográficos y de fluorescencia de rayos X. En este artículo se presentan estudios de caso interesantes que muestran un rango de prácticas de orfebrería que incluye dorado, uso de matrices de piedra para la elaboración de moldes e identificación de falsificaciones.*

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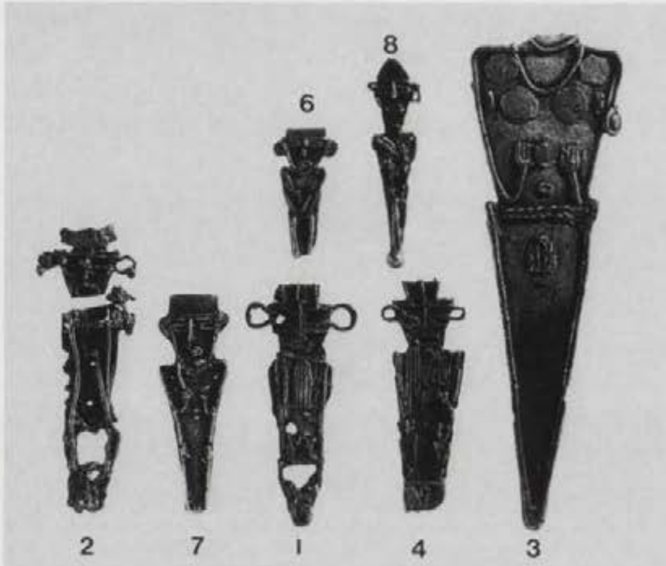
Acknowledgements:

Warmest thanks are due to Professor Jean Thomas, Colin McEwan, Nigel Meeks, Sheridan Bowman and John Mack at the British Museum ; to Clemencia Plazas, Sonia Archila, Juanita Sáenz, Luz Alba Gómez, and all the staff at the Museo del Oro, Bogota ; to Warwick Bray, Institute of Archaeology, University College, London ; Patricia Estévez, Banco Central del Ecuador ; Cecilia Bakula, Banco Central de Reserva del Perú and Paloma Carcedo de Mufarech.

I am especially grateful to the Royal Society of Great Britain for a research travel grant. Also to The Historical Metallurgy Society for a contribution to conference expenses.

The British Museum's collection of South American metalwork has been accumulated over nearly 200 years, but until recently few of the pieces had been analysed or studied metallurgically. The objects came from Peru, Ecuador, Colombia, Panama, Costa Rica and up to Mexico and this ongoing study has been set up to provide technological information for the catalogue of the collection.

Analysis of alloy composition is an obvious avenue for research, but as yet there is not a large database of analyses (see Rovira 1994 for a review of gold) . As the opportunities increase to have analysis done on pre-Hispanic metalwork, the database will become large enough to allow statistically valid comparisons and grouping of objects now scattered throughout international collections. However, without comparability in the analytical approach, there are likely to be some problems which are illustrated by the Muisca tunjos discussed below.



Photograph 1: Muisca tunjos (height of largest, 11 cm). The numbering correlates the objects to the analyses in tables 1 and 2, and figure 2. [photo A. Milton, British Museum].

Muisca tunjos

Muisca tunjos are miniature representations of artefacts, animals or (most commonly) human beings, singly or in groups. A few are made from pure copper or gold, but the overwhelming majority are cast in gold alloys. They were made as votive offerings by the Muisca of the altiplano of Cundinamarca and Boyacá, central Colombia, in the period between the 6th and 16th centuries AD, and are usually found (sometimes several together, in ceramic offertory vessels) at isolated landmarks such as lakes, peaks, and caves (Plazas, 1975 ; Lleras-Pérez,1997). They were made by the lost-wax method of casting ; the model was cut from wax sheet less than 1 mm thick and applied 'wires' of wax provided the detail as well as giving the sheet strength and doubling as runners and risers for the casting (photographs 1 and 2).

The metal surfaces are conspicuously rough and unfinished, presumably because of the votive nature of these pieces. Ornaments made by the Muisca for wear, such as the necklace pendants in photograph 3, are also cast but they have a much smoother surface.

Photograph 2: Magnified detail of tunjo 6 showing the modelling of the face and cast structure.(width 1 cm). The black patches are residues of the casting mould [photo S. La Niece, British Museum].

Several of these tunjos have black mould material still adhering to them and no. 8 in photograph1 has the casting sprue, where the metal was poured in at the top of the mould, still attached to the foot (these figures were cast head downwards). It is not at all uncommon to find tunjos where the casting sprues and feeders for the molten metal have not been trimmed off (see Bray, 1982, nos. 59 and 60). Many also have major casting faults, for example the holes in numbers 1 and 2 in photograph 1.

The problems of analysing tumbaga alloys are well known (Scott,1995: 504); loss of copper from the surface occurs both by natural corrosion and, in the case of more finished objects, by deliberate treatment to improve the surface colour. Furthermore, the metal microstructure of tumbaga castings is frequently inhomogeneous (see paper by Meeks, this volume). Because of these problems, the choice of where to analyse the object is very important. The aim must be to analyse an area which is most likely to reflect the original composition of the alloy at manufacture. The surface metal is least likely to do so, and may not even accurately reflect the finished appearance of the newly manufactured object after it has suffered many years of corrosion. Any method which analyses the surface, and that includes most so-called non-destructive methods, can only produce semi-quantitative results at best. Table 1 gives the range of compositions obtained from analysis of different areas of two small Muisca tunjos (photographs 4 and 5) to illustrate the variations in composition which can occur.

TABLE 1

COMPARISON OF ANALYSES TAKEN AT DIFFERENT POINTS

	%Au	%Cu	%Ag
Muisca tunjo 7 (BM S1323) photograph4			
Surface	72	8	20
Abraded surface	73	8	20
Area at the centre of a cross-section	75	7	18
Muisca tunjo 1 (BM S1326) photograph 5			
Surface	56	36	8
Abraded surface	35	59	5
Area at the centre of a cross-section	28	67	5

The surface analyses were done by X-ray fluorescence analysis, the rest by energy dispersive X-ray analysis (in a scanning electron microscope). The precision is ± 1%.

Photograph 3: Muisca cast necklace pendants (length of largest, 1.27 cm) [photo A.Milton,British Museum].

Photograph 4: Detail of tunjo 7 (height 4.8 cm) [photo S. La Niece, British Museum].

Photograph 5: Detail of tunjo 1 (height 5.5 cm). [photo S. La Niece, British Museum].

Photograph 6: SEM micrograph of a polished section through the broken tip of tunjo 7. Note the continuity of the cast structure between the base plate of the tunjo, running horizontally across the bottom of the photograph, and the round sectioned "wire" on top of it. (BSE image. Width of section 1.2 mm) [photo S. La Niece, British Museum].

The first of these tunjos (no.7) has a relatively high gold content and low copper content. In this case the compositional difference between the surface analysis and analysis of metal at the centre of the casting is a few percent. The surface analysis of the tumbaga (copper-rich gold alloy) tunjo (no.1) is so different from the value for the core metal that it gives a completely false picture of the quantity of copper in the original casting alloy. To allow comparison of like with like it is therefore important when publishing analytical results to state how the analysis was done and on what part of the object and it has to be emphasised that surface analysis is worse than useless, it is positively misleading.

The problems outlined above are widely recognised and several sampling and analytical strategies have been evolved to produce meaningful analyses. Where the casting is thick enough, a successful method of sampling the core metal is to drill a sample using a 1 mm drill bit, discarding the unrepresentative turnings of the surface metal. If drilled into the base or a broken edge of an object, the resulting damage is minimal. However, the Muisca castings are often too thin to drill. The usual solution is to scrape away the surface of a small area for analysis, but the roughness of the surface of the tunjos required a very deep area to be abraded in order to remove all the surface inhomogeneity. The solution adopted in this case for the tumbaga tunjos was to take a small piece of metal and mount it in cross-section in epoxy resin (photograph 6) for analysis by energy dispersive X-ray analysis (EDX) in a scanning electron microscope (SEM).

TABLE 2 : ANALYSIS OF MUISCA METALWORK

BM reg. no.	%Au	%Cu	%Ag
1. Tunjo S1326	28	67	5
2. Tunjo S1324	30	64	7
3. Tunjo S1327	33	60	7
4. Tunjo S1328	38	55	7
5. Necklace pendant 1937-7-5,11	46	46	8
6. Tunjo BMRL 6732-43-R	55	29	17
7. Tunjo S1323	75	7	18
8. Tunjo S1322	74	5	22

Analysis of body-metal by EDX and XRF analysis. The precision for the major elements is ± 1%. The sensitivity of detection is 0.01 or 0.02% for most elements. Tin, arsenic, platinum, lead and nickel were sought but not found.

The disadvantage of this method is that the sample preparation takes time, so it is unsuitable for large numbers of objects. The advantage is that the SEM imaging allows examination of the microstructure to find a representative area for analysis, avoiding corrosion zones and inclusions. The results of the analysis by EDX and X-ray fluorescence analysis (XRF) of the core metal of seven tunjos is given in table 2, together with the composition of the core metal of a Muisca necklace pendant.

The above results show a very variable copper content, between 5-67% copper in the casting alloy. This is above the level that would normally be considered likely to occur naturally with gold and it is reasonable to say that the copper was a deliberate addition. The wide range of values for copper suggests that there was no standard recipe for how much copper to add to the melt. Interestingly, by plotting the results on a ternary diagram (figure 1) it is clear that the quantity of copper added to the alloy in these cases does not significantly lower the melting point of the alloy; all but number 6 would melt at above 900°C, whether they have 5% or 67% copper in the alloy, though those with a greater copper content have a longer freezing range, which would aid casting. However, the most likely reason for adding more copper was for economy.

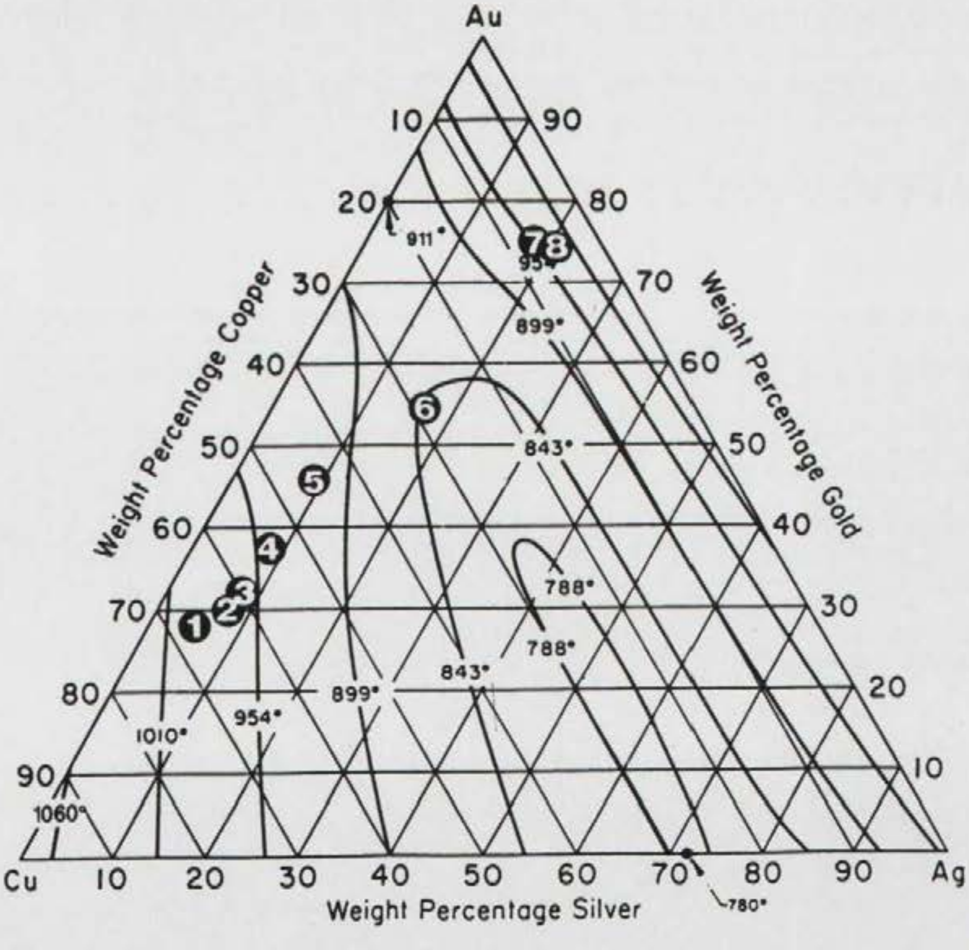


Figure 1: Analyses from table 2 plotted on a section of the phase diagram for the ternary alloys of gold-copper-silver. The lines indicate the liquidus contours for alloy composition.

The proportion of gold is three to five times that of silver. This ratio falls well within the range of analyses given by Rivet and Arsandaux (1946) and Newman et al (1991) for Muisca metalwork, and also the range of compositions which are seen in naturally occurring alloys of gold and silver found as grains and nuggets in river bed sands and gravels. The small number of results presented here agree with the hypothesis that the Muisca were alloying copper with native gold panned from rivers. Interestingly the necklace pendant (number 5) is indistinguishable in composition from the tunjos, and although it looks very golden because it has been depletion gilded, it is made of a baser alloy than several of the tunjos.

Photograph 7: Cast gold Quimbaya lime-flask (height 30 cm). BM 89-10-1.1. [photo A. Milton, British Museum]

Photograph 8: Detail of the head of the standing male lime flask, showing that the burnishing stops short of the relief details of the headdress [photo S.La Niece, British Museum].

Photograph 9: Radiograph of the standing male lime-flask showing constructional details as well as casting faults and secondary casting runs (see text for interpretation) [S. La Niece, British Museum]

Quimbaya lime-flasks

Two lime-flasks of the Quimbaya culture of Colombia have been examined so far. They are a standing male figure, 30 cm high, 640.5 g in weight (photograph 7), which had suffered some damage from crushing, and a small gourd-shaped flask, 10.8 cm high, 122.6 g in weight. The latter is almost identical in form to one from the 'Treasure of the Quimbayas' in the Museo de América, Madrid, but smaller (Rovira Lloréns, 1992: Cat no. 52), and there are a number of flasks of similar vegetable forms in collections in Colombia and Europe. This flask is paler in colour than other well-known Quimbaya pieces and shows little evidence of wear, and consequently it has been suggested that it is a fake. This study provided an opportunity to compare the two flasks and address the question of authenticity.

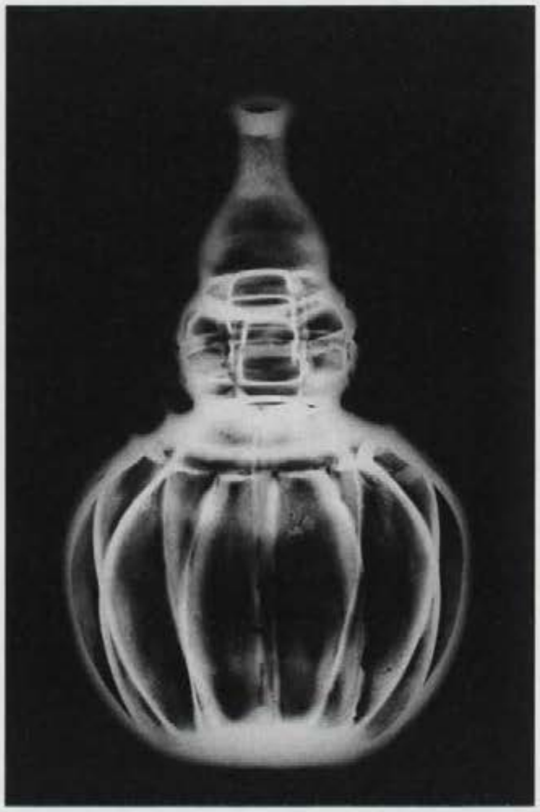
The standing male flask was made by the lost-wax method and is a hollow casting. The wax was built up around a shaped clay core, incised and appliqué details added, together with the casting sprue, feeders and air vents. The internal core was held in position with pegs, probably of wood, pushed through the wax into the core and the whole was invested in a clay casing. The wax was melted out and the metal poured into the resulting void. The clay casing was broken off, the remains of the pegs removed, the metal surface finished and the core was usually extracted (Bray, 1978: 34). Some of the grey casting core can still be seen inside the male figure, and there are two round holes for core-supports in the shoulders, one of which is plugged. There are rectangular openings on the base of the feet which are larger than the round holes for core supports. It has been suggested that these holes may have been used to extract core material from inside the casting (Bray, 1978: 191 no.375) but an alternative explanation is that the rectangular holes are openings through which the core and the investment connect, avoiding the need for pins. This type of hole has been reported on late hollow-cast figures from the Tairona region of northern Colombia, on cast human figures from Costa Rica and on a late Quimbaya pendant, but not from the classic Quimbaya period to which this figure belongs (Howe, 1985: 197). The small gourd-shaped flask has a plugged round hole for a core-support in the centre of the base and presumably the core could have been also held in place through the mouth of the flask. There are several lines on the surface of the gold which could either be joins in the wax model or soldering of the metal, particularly lines running around the neck, down the fluted sides and around the base. These features were investigated using radiography (see below).

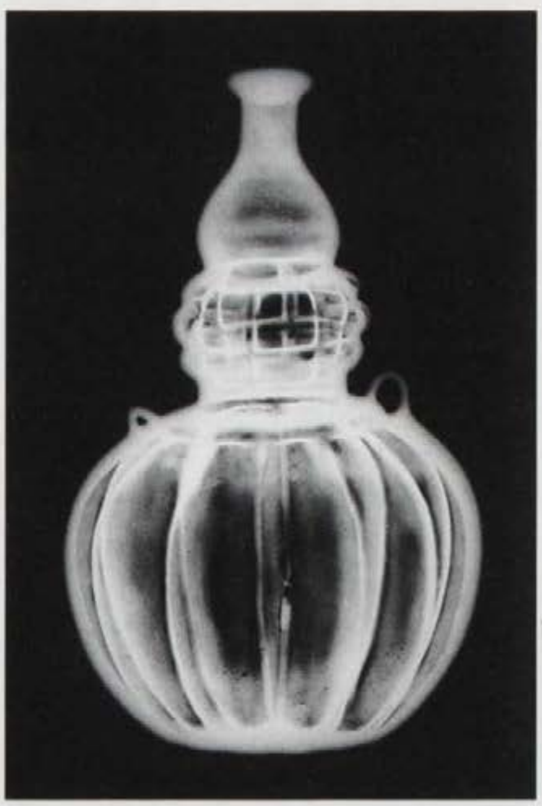
X-ray fluorescence analysis was carried out on a clean area abraded on the bottom of the foot of the standing male flask, and two small samples were taken of the metal of the gourd-shaped flask and mounted in cross-section, as discussed above, for analysis by EDX analysis in a scanning electron microscope with the following results (the precision of the measurements is ± 1 %) :

	% Au	% Ag	% Cu
Standing male	54	13	33
Gourd flask	56	14	29

These analyses are of the core metal, ie. represent the original alloy composition. However, the surface of both flasks is richer in gold (up to 75% gold) at the expense of copper, than the core metal. The silver composition reaches a maximum of 20% at the surface in some areas of both flasks. The main difference between the two appears to be that the gold rich layer covers the whole surface of the gourd-shaped flask but it only survives in protected areas on the standing male, close to relief features (for example in photograph 8), where polishing, cleaning or wear could not reach ; although the figure appears pinkish in colour, there are the remains of a matt golden coloured layer in these protected areas. The plugs in both flasks differ in composition and colour to the body metal. The apparent lack of effort by the Quimbaya to conceal these plugs has been commented on by Howe (1985: 195).

The polished samples from the gourd-shaped flask were examined under polarised light and some copper oxide was seen in cracks in the metal. This is often an indicator of antiquity, but the quantity of oxide formation required to prove antiquity is uncertain, and it cannot be considered conclusive in this case.





Photograph 10a and b: Radiogaphs of Quimbaya gourd shaped lime-flask at two orientations (height 10.8 cm).BM Am1910.12-2.6. [S. La Niece, British Museum].

Both flasks were radiographed to look for further information about their manufacture and as a means of examining the inner surfaces. The radiograph of the standing figure shows a number of features (photograph 9). The white areas are dense, blocking the X-rays from the film, in this case indicating where the metal is thickest. The neck ornament, for example, appears white because it is cast in relief and is therefore thicker. Because the radiograph records both back and front of a three-dimensional object, as if it were transparent, the back of the neck ornament can also be seen in the image. The dark areas are where there is little or no metal shielding the film from the X-rays. The most important dark features on this radiograph are the rectangular holes in the bottom of both feet (the radiograph shows the shadow of the toes superimposed), the casting porosity, which appears as a speckled texture over the whole figure, and the very obvious cracks in the metal. The quality of the casting is poor ; not only is there considerable porosity in the metal, with many pores of 0.5 mm, but there are large areas where the metal did not flow at all, leaving holes in the solidified casting. These were then filled by running in additional molten metal. This can be seen on the radiograph as the white areas on the inside of the figure's left leg, and on the right shoulder and neck.

The radiographs (photographs 10a and b) of the small gourd-shaped flask also shows porosity, typical of casting, but much finer than that of the male figure. This porosity is coarsest towards the bottom of the flask (up to 0.25 mm) and much finer at the top. This supports the view that this type of vessel was cast in the inverted position (Plazas and Falchetti, 1978: 35), the gases having less opportunity to escape from the last part of the pouring before the metal solidified. One of the main reasons for radiography of this flask was to investigate lines running around the neck, down the fluted sides and around the base. Superficially these lines looked like joins. Radiograph (a) in photograph 10 has one of these lines running down the centre of the fluted base (the image is confused by the radiographic superimposition of both sides of the flask). Although two holes (black) and a dense area (white) can be seen in the radiograph at the mid-point of this line down the fluting, there are none of the features which would be expected of soldered metal joins and there is no break in the pattern of casting porosity across the line. This line therefore seems more readily interpreted as a join in the wax components of the casting model, rather than soldered metal, and the holes and dense area as misalignments of the wax join which was reproduced in the cast metal. The bipartite construction of the fluted body suggests that a template was used to form two identical halves of the casting model and presumably also its core. None of the lines on this flask appear from radiographic and microscopic examination to be soldered.

Photograph 11: Detail of depletion gilded penannular ornament from the Esmeraldas region of Ecuador. BM 1938-10-25,31 [photo S. La Niece, British Museum].

In summary, the small gourd-shaped flask is a hollow lost-wax casting and the wax model was built up from several components, as might be expected of a genuine piece. The metal composition is very similar to that of the standing male lime-flask, and falls within the very wide range of Quimbaya alloy compositions given by Rovira (1994). The main difference is the surface finish, which is

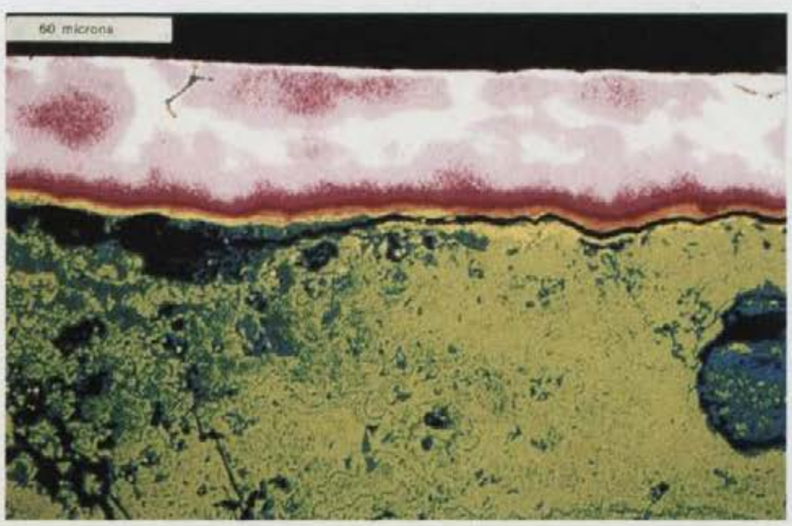
Photograph 12: Detail of fusion gilded penannular ornament from the Esmeraldas region of Ecuador. BM 1938-12-25,28 [photo S. La Niece, British Museum].

Photograph 13: False colour SEM image of a cross-section through he fusion gilding of the ornament in photo 12.The gilding layer is seen as pink and white, the corroded copper alloy appears green and blue, and the yellow islands are the vestiges of relatively sound metal. [photo S. La Niece, British Museum].

extremely polished and pinkish in colour on the standing male and also on other fine Quimbaya pieces, but is matt and golden in appearance on the gourd-shaped flask. There are two possible explanations for this difference. The first is that the gourd-shaped flask was made of the same alloy as ancient Quimbaya castings, but with different finishing, perhaps recently. The second is that the Quimbaya pieces like the standing male flask, which now are pinkish in colour and very polished, were once golden but have been polished since excavation, largely removing the thin golden surface, except where it is protected by raised areas in the design. Stone burnishing tools will give a fine polish to gold, but the finish on many Quimbaya flasks is unusually bright. This question can only be resolved by study of more of these flasks, especially their construction and finishing.

Gilded penannular ornaments from Ecuador

The collection includes a number of small penannular ornaments, either nose- or ear-rings which were acquired in 1938 with the provenance "from ancient graves discovered when working for gold on the shorelines of the Máte and Ostiones rivers, Ecuador" inscribed in the Museum register. The Máte (or Mátes) and Ostiones are two minor rivers running into the North Pacific between the towns of Esmeraldas and Valdez in the Department of Esmeraldas. This places them within the cultural area of Tumaco-Tolita, but the date of these pieces is unknown and they may belong to a later culture. The ornaments are a heterogeneous collection of forms and materials, varying in diameter from 1 to 4 cm;



Photograph 14: High magnification detail of nage in photo 13. The gilding layer is very sharply defined and ows some coring. The : pink/orange junction tween the gilding and copper body indicates iat diffusion has taken ce [photo S. La Niece, British Museum].

some are round in section, some flat and some are hollow C-sectioned gold sheet, some are gold, some gilded and the rest are copper, usually with trace levels (less than 1%) of arsenic and gold detectable by X-ray fluorescence analysis. One is certainly modern, being made of machined brass tube.

Two corroded but gilded ornaments were selected from this group for closer examination and identification of the gilding technique. As has been pointed out by David Scott (1986a: 318) it is not easy to determine from examination at low magnification whether a layer of gilding over copper is foil gilding (covering with a layer of gold foil) or fusion gilding (coating with molten gold), or, as is illustrated below, depletion gilding (enriching the surface of a base gold alloy by removing copper). Metallographic examination is the only way to conclusively resolve the problem. A small sample of metal was taken from each of the ornaments and mounted in epoxy resin in cross-section, to allow study of microstructure of the gilding layer (cast or worked) and examination of the junction between the gilding and the body metal of the ornaments. The sections were polished and then examined using a JEOL 840 scanning electron microscope with analytical facilities.

Penannular ornament 1938-10-25,31 (photograph 11) has a bright, gilded surface, bubbling up in places because of the corrosion beneath. At the damaged tip, the core metal appears dark and corroded. The polished section reveals a distorted cast structure with corrosion zones deep inside the core metal. The composition of a relatively uncorroded area of the core metal is 44% gold, 52% copper and 4% silver (EDX analysis, ±1% accuracy level), rising to about 78% gold at the surface, with corresponding decrease in copper content. The gold enriched surface is very uneven in thickness, at most only a few microns deep. It has been burnished. The conclusion from examination of this section is that the ring is depletion gilded, that is, it is cast from a low gold alloy from which copper has been deliberately oxidised and dissolved out of the surface. The resulting gold-enriched surface has been burnished to give a shiny golden appearance. The distortion in the cast structure suggests that some work was done at the tip of the ornament after casting, perhaps to bend it round.

The second ornament (BM 1938-12-25,28) under low magnification looks very similar (compare photographs 11 and 12). It has a bright gilding layer, which is peeling away in places to reveal the dark, corroded body metal. Photograph 13 is a false colour SEM image of the polished section through this object seen at high magnification; the width of the field of view is 2 mm. In this photograph the grey-scale of the black and white SEM image is replaced with a spectrum of colours which provide more contrast than a range of greys. In this image the brighter end of the scale, ie. the gold-rich layer on the surface appears pink. It varies in thickness between about 60 microns and 25 microns. The darker end of the scale, that is the copper, appears green.

Analysis of this section shows that the ornament has a heavily corroded copper core with only about 5% gold and less than 1% silver in the alloy. The dark blue areas are the most deeply corroded, and interestingly, these areas are where the few percent of gold in the core metal are concentrated (see paper by Meeks for further examples of the preferential corrosion of gold-rich zones in tumbaga alloys). The yellow areas on the image are islands of relatively sound metal.

The gilding is a discrete layer of gold-copper-silver alloy, with a thin layer of copper corrosion over the top (green in the image). The gilding has a cored structure (the darker pink areas are richer in copper) suggestive of casting and shows no sign of working, certainly not the extensive working required to hammer out gold sheet or foil. Although the gilding layer is sharply distinct from the copper core it has flowed into every pit and hollow in the surface. The dark pink and orange band in the gilding at the junction with the copper is indicative of diffusion between the two zones due to heat. Area analysis of the gilding layer gave a composition of 40% gold, 56% copper and 4% silver. Photograph 14 shows the gilding layer at higher magnification. There is a very thin, discontinuous, gold-rich layer (white) at the surface of the gilding. The layer of copper corrosion seen in photograph 13 over the gilding suggests this is the result of corrosion during burial, rather than deliberate enhancement during manufacture.

The evidence of both the analysis and the microstructure eliminates most of the common gilding techniques. It is not depletion gilding as there is not enough gold in the core metal to produce that thickness of gilding and the gilding layer is too sharply distinct from the body metal. It is not foil gilding because it lacks the evidence of working and is very uneven in thickness. Mercury gilding can be discounted (no mercury detected), and electrochemical gilding (too thick and with a micro-structure not seen in electro-deposited metals). The microstructure and the close junction with the irregular surface of the copper indicate that the gilding was applied molten, so it is concluded that this is an example of what has been termed in the literature as fusion gilding or wash gilding (Bergsoe, 1938 ; Scott, 1986a and b). By reference to the ternary Au-Ag-Cu diagram it can be calculated that the gilding alloy of this ornament (44%Au, 56%Cu, 4%Ag) would have been molten at about 960°C, while the copper alloy core (estimated from analysis of the corroded metal as approximately 95%Cu, 5%Au) would not begin to melt until the temperature reached over 1060°C. This margin in melting temperatures of 100°C, while not great, is sufficient to have allowed the gilding layer to be molten without damaging the ornament.

The practical application of fusion gilding is still not fully understood. It was originally identified by Bergsoe (1938) on objects from the La Tolita area on the Pacific coast of Ecuador. More recently, gilded sheet copper fragments from the Department of Nariño, Colombia, have been studied by David Scott (1986, a and b). A cast Moche mace head in the form of an

Photograph 15: Gilded copper owl mace head.Moche (Peru) (height 6.5 cm). BM1949Am22.217 [photo A. Milton, British Museum].

owl's head from the British Museum's collections (Photograph 15) has also been found to have this type of gilding (Bowman et al 1997). The two methods which have been suggested for applying this gilding are dipping the copper object into a bath of molten gold alloy or applying the molten alloy to the heated copper ornament and allowing it to run over the surface. Neither of these methods would fully account for features seen on all of this class of gilded object. There are practical problems with dipping a copper-gold object into a molten gold-copper-silver alloy, not least the difficulty of controlling the temperature so that the item to be gilded does not melt in the crucible of molten gold. There is also the problem of holding it securely while coating the whole surface evenly. The Moche owl has strong relief decoration, which would have been flooded by either dipping in molten metal or running it over the surface, but the gilding on this piece is fairly evenly distributed over the flat areas and in the channels. How this was done is not known but perhaps fine grains of gold alloy were applied evenly over the surface in a paste with a flux to prevent oxidation and heated until the grains melted.

It is quite possible that different methods were used for different types of object. The fusion gilding of sheet metal, which requires further forming to make a finished object might well be applied by a different method from the fusion gilding on an object cast to its final shape. Scott (1986a: 322) has reported sheet copper which has been gilded on only one side, so could not possibly have been dipped in molten metal, but on other objects he found evidence of dipping, particularly a silvered copper nose-ring. Whatever the method used to apply the plating, it is apparently not a common technique. It seems to be largely confined to the coastal areas of Ecuador, reaching at its northern extent up into the Nariño area of Colombia and down as far as the Moche and Vicus regions of northern Peru. No fusion gilding has been identified anywhere else in the world though molten silver-copper alloy was a method used by the Celts and the Romans for plating copper (La Niece 1993:206). How far this reflects the real limits of the use of fusion plating, rather than the difficulty in identifying it, remains to be seen.

The results presented here form a part of a scientific study of the pre-Hispanic gold objects in the British Museum, which like most such collections lack any real archaeological context. The work is still in progress and will be published in the catalogue of the collection. The aim is to make the technological characteristics of the pieces available for comparison with stylistically similar pieces elsewhere. A broad database of analyses and manufacturing techniques will assist in the understanding of where these objects belong and will do something to ameliorate the loss of archaeological information.

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