Characterization of pre-Columbian South American gold wires

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Figure 1. Map of the Calima cultural region.

ABSTRACT/SUMMARY

In this study, excavated gold wire and other small gold objects from the Calima cultural region in Colombia have been analyzed with x-ray fluorescence spectroscopy (XRF), scanning electron microscopy equipped for energy-dispersive spectroscopy (SEM-EDS), as well as with conventional metallographic techniques. The results show that these gold artifacts are made from ternary gold/silver/copper alloys, where no surface enrichment of gold has taken place. A number of small circular wires were studied with respect to the manufacturing technique. Although some had been cast to shape, the majority had been created with the block-twisting method. These results improve our still limited understanding of pre-Columbian gold working and metal wire manufacturing.

INTRODUCTION

Gold working in the Calima region began around 300 BC, making it the location of the earliest gold-working in Colombia (Figure 1). The early Calima style is characterized by large objects, such as beads, discs, nose ornaments and face masks, made from pure gold that was either hammered or cast (Figure 2). The gold was obtained mainly through placer mining, and whole rivers appear to have been diverted in order to reveal alluvial gold deposits. The understanding of metal working and mining in this region is however far from clear, partially due to the lack of systematic archaeological excavations in the area - many hitherto studied artefacts have been looted and lack proper dating or context.

In addition to gold, copper was also mined. Neither tin nor silver ore is present in the region, and consequently bronze- or silver-working was never developed. Some silver is however present in the gold ore, which allows for creation of the gold-silver-copper tri-metal alloy known as tumbaga. By mixing the three metals together, the resulting alloy is harder than pure gold, and has a lower melting point than each of the constituent metals alone, making it easier to cast. The tumbaga alloy also allows for depletion gilding, where acidic plant juices are used to remove copper from the outer surface, making it more gold-rich.

Figure 2. Two early Calima lime dippers in gold, showing how gold wires were incorporated into works of art. These objects are examples only, and were not analyzed in the present study.

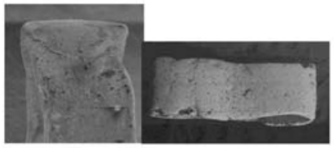

Figure 3. SEM images of the gold ring 1A. SEM-EDS analysis indicates no presence of a soldering material at the join.

THE GOLD OBJECTS

In this study, a total of 17 small gold objects were investigated: 2 rings, 8 wires, and 7 objects of other various shapes (Table 1, Figure 4). All objects were excavated in the Calima region in Colombia, South America, and date from pre-Columbian times.

The two rings (1A and 1B) are made from rectangular strips which were bent into rings, with overlapping ends that have been joined without a solder (although the use of a solder with a material composition identical to that of the rings cannot be completely ruled out) (Figure XX).

The wires (2A, 3A, 5B, 5C, 5D, 6A, 6B, and 6C) are either circular or rectangular, and some of them have been given pointed ends. Most likely, the wires were made to be incorporated in works of decorative art, (such as Figure 1) although the pointed ends suggest that they could have had some more utilitarian use, such as chisels or hooks. The manufacturing technology of the wires is discussed below.

Of the other objects, the two irregular fragments 3B and 3C and the drop-shaped object 4, appear to be waste from casting processes. Also the fragments 2C, 5A and 5E appear to be waste materials. Object 2B has the shape of a coffee bean, which may or may not be an intentional design.

Figure 4. The excavated gold objects.

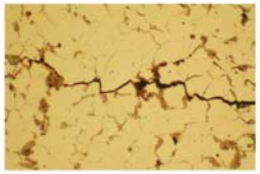

Figure 5. Close-up of the cross-section of 5D, showing age-related intergranular cracking.

DETERIORATION

The objects are made from Au/Ag/Cu tri-metal alloys, with few signs of deterioration. No corrosion is visible on the objects, although some are covered with red iron-rich soil. Although gold itself is a noble metal, alloys with a gold content below 70% readily corrodes. During sampling, it was observed that for some objects, the interior is a lighter colour than the surface, suggesting that some surface oxidation has taken place. Some objects also display traces of modern red and green lead-based paint, of an unknown origin. The microstructure of some of the samples reveal age-related irreversible intergranular cracking (Figure 5). Under SEM examination, some wires look spongy, porous, or have small holes all over the surface due to dissolution or damage of the surface during burial. The resulting appearance is likely due to dissolution of grain boundary precipitates.

Figure 6A. Polished and etched cross-section of sample 2A, showing that this wire was cast to shape, without further modifications.

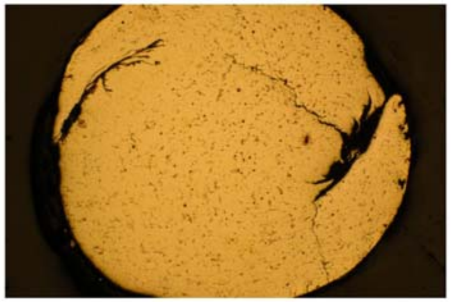

Figure 6B. Polished and etched cross-section of sample 5D, showing that the block-twisting method has been used to shape the wire.

WIRE MANUFACTURING

One particularly utilitarian class of gold objects is wires, and gold wires were used in the Calima region to fasten pieces, attach adornments and to repair broken objects (Figure 2). The question then, is, how were these very thin and perfectly circular wires made, using only simple tools? Generally speaking, there are six known methods to create circular metal wires: casting, hammering, block-twisting, strip-twisting, swaging, and drawing. Drawing is arguably the most efficient method, and the only one employed in modern society. In Europe, the draw-plate was invented around the 6th century A.D., whereas in South America the draw-plate appears to be introduced with the arrival of the Spanish conquistadors. Although all the different methods of wire-making produce circular wires, a careful examination of the wire, and particularly the cross-section, will reveal the mode of manufacture. Although cross-section analysis requires destructive sampling, the information gained is necessary in order to accurately determine the manufacturing process. The other way to study wire-making technology, e.g. *via* archaeological finds of tools (for example, draw-plates), must be considered secondary – the best evidence will always come from the wires themselves.

In the present study, the etched cross-sections revealed that two methods for wire-making had been employed. The dendritic structure of sample 2A shows that this wire was cast to shape, without modifications after casting (Figure 6A). Casting of such fine wires (1.1 mm diameter) has previously been shown to be a specialty of neighbouring cultural regions (Scott, 1992). For the other wires, many of them display evidence of block-twisting, in form of spiral-shaped voids extending into the bulk material, and which result from the twisting of the originally rectangular block/wire (Figure 6B). The somewhat flattened surfaces of some of the samples, together with hammer marks, suggest that these specimens were first block-twisted into a circular shape, and then hammered to their final form.

Sample	Type	Color	Dimensions	Au	Ag	Cu
1A	ring	Moderate yellow	thickness 0.1 mm	58.0%	21.0%	21.0%
1B	ring	Moderate yellow	thickness 0.1 mm	75.8%	14.0%	10.1%
2A	circular wire	Yellowish white	ø 1.1 mm	53.4%	32.3%	14.3%
2B	bean-shaped object	Moderate yellow	n/a	72.1%	15.0%	12.9%
2C	flat fragment	Light yellowish brown	thickness 0.7 mm	56.9%	11.2%	31.9%
3A	circular wire with pointed end	Strong yellow	ø 0.5 mm	76.3%	22.4%	1.2%
3B	irregular fragment	Strong yellow	n/a	82.0%	10.9%	7.0%
3C	irregular fragment	Pale orange yellow	n/a	58.4%	16.9%	24.6%
4	drop-shaped fragment	Moderate yellow	n/a	81.7%	17.4%	0.9%
5A	rectangular strip	Strong orange-yellow	n/a	87.2%	10.4%	2.3%
5B	circular wire with pointed end	Strong yellow	ø 1.0 mm	88.9%	10.6%	0.5%
5C	rectangular wire with pointed end	Light yellow	0.7 x 0.5 mm	78.2%	15.2%	6.6%
5D	rounded wire	Pale orange yellow	ø 1.4 mm	85.9%	13.6%	28.2%
5E	folded rectangular strip	Strong orange-yellow	thickness 0.2 mm	85.9%	13.6%	0.4%
6A	rectangular wire with pointed end	Light yellowish brown	1.2 x 0.5 mm	62.4%	11.2%	26.3%
6B	circular wire with flattened end	Brilliant yellow	ø 0.9 mm	84.7%	14.8%	0.5%
6C	square wire with pointed end	Moderate orange-yellow	0.8 x 0.8 mm	85.4%	13.9%	0.7%

Table 1. Table of properties of the studied samples.

ELEMENTAL COMPOSITION

The elemental composition of the metal wires was analyzed with XRF and SEM-EDS (Figure 7). The results revealed that they all were made from ternary gold/silver/copper alloys, with varying proportions of the different elements. The gold was in the range 50–90%, the silver in the range 10-30%, and the copper in the range 1-30%. The varying amounts of the metals have an obvious impact on the colour of the wires – while most of them are a standard golden yellow, the silver-rich wire 2A is a pale yellow, and the copper-rich samples 2C, 3C, 5D, and 6A a darker orange-brown (Figure 8). Most likely, the variation in elemental composition is intentional in order to create these different shades of yellow. The elemental composition appears to be uniform through the samples, indicating that no surface enrichment of e.g. gold has taken place, neither as a result of deterioration processes in the soil, nor as a result of intentional depletion gilding.

Figure 8. Objects 2A, 2B, and 2C, showing differences in colour due to different proportions of gold, silver, and copper.

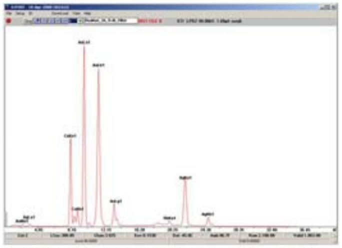

Figure 7. XRF spectrum of sample 2A, showing peaks for gold, silver and copper.

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