Depletion gilding, innovation and life-histories: the changing colours of Nahuange metalwork

Juanita Sáenz-Samper[1] & Marcos Martinón-Torres[2,*]

[1] *Museo del Oro, Banco de la República, Calle 16 #5-41, Bogotá DC, Colombia*

[2] *Institute of Archaeology, UCL, 31–34 Gordon Square, London WC1H 0PY, UK*

[*] *Author for correspondence (Email: m.martinon-torres@ucl.ac.uk)*

*The technique of depletion gilding is well evidenced in pre-Columbian Andean gold work. Artefacts from the Nahuange period in Colombia (*c. *AD 100–1000) were subject to metallographic, chemical and microscopic analyses to provide regional comparative data on metalworking traditions. Results suggest that depletion gilding may have been an accidental discovery and, contrary to widespread assumptions, not always a desirable feature. This research illustrates how technological innovation may not always be immediately adopted, and considers how the life-history of gold artefacts may affect their appearance and microstructure. It also offers directions for future studies of depletion gilding elsewhere.*

Keywords: South America, Colombia, pre-Columbian, archaeometallurgy, depletion gilding, gold, life-histories

Analytical methods and results of chemical analyses

Full SEM and EPMA methods and results of the analyses performed at the UCL Institute of Archaeology are reported in Sáenz-Samper (2015), and therefore they are only succinctly summarised here.

SEM examination employed a Hitachi S-3400N and a Philips XL30. SEM-EDS was conducted on an Oxford Instruments EDS attached to the Philips, operating at 20kV, working distance of 10mm, spot size of 5.2 and acquisition time of 70s. Calibration with cobalt was carried out every 30 min. Analytical results always ranged between 95 and 102 weight percent (%), owing to small beam fluctuations and microporosity, especially in more corroded samples, but they were normalised to 100% to facilitate comparisons.

EPMA analyses were carried out on a JEOL JXA-8100 calibrated with pure standards, running at 20kV with a beam current of 5×10^{-8} and an acquisition time of 50s. Three crystals were employed (TAP, PET and LIF) and the following elements were sought: Si, S, Cl, Mn,

Fe, Co, Ni, Cu, Zn, As, Ru, Rh, Pd, Ag, Cd, Sn, Sb, Os, Ir, Pt, Au, Pb and Bi. The results reported are averages of 8 to 10 measurements per sample, typically conducted on areas of ~80 by ~120µm, though sometimes smaller if the artefacts were severely corroded.

For portable XRF analyses we used an Olympus Innov-X Delta Premium portable X-ray fluorescence spectrometer (pXRF), with a Rh anode and equipped with a silicon drift detector (SDD), providing a typical resolution of 145-155 eV FWHM for 5.9 kV X-rays (on an AISI 316 standard). The factory-built Alloy Plus method was employed, which uses a fundamental parameters algorithm for quantification, optimised through the analyses of certified reference materials. Analyses were performed at 40kV with a beam current of 100µA and using the so-called Beam 1, which includes a 2mm Al filter in the X-ray path, for livetimes of 15 seconds. The X-ray beam was collimated to an analytical spot of ~3mm in diameter. Analyses of reference materials by pXRF are provided in Table S1 below, and these are a reflection of the data quality behind the values labelled as pXRF/UCL in Table S2.

The legacy data acquired by the Departamento Técnico Industrial (DTI) of Banco de la República includes two XRF instruments: a Bruker AXS SR3000 used directly on objects' surfaces (reported as 'surface XRF / DTI') in Table S2) and a Kevex Omicron micro XRF at the Getty Institute in Los Angeles, used on polished sections (reported as 'section XRF / DTI'). No analyses of relevant certified reference materials are available for these instruments, but we can trust their overall reliability based on experience re-analysing objects with the newer pXRF at UCL and comparing the datasets.

Table S1. Results of pXRF analyses of reference alloys using the UCL instrument. Values in percentage by weight (%).

		Cu	**Ag**	**Au**	**Sn**
MAC1	given	1	4.6	93.9	0.5
	mean (n=3)	1.0	4.4	94.1	0.5
	SD	0.01	0.02	0.04	0.01
MAC2	given	5.1	19.2	74.7	1.0
	mean (n=6)	4.8	19.1	75.0	1.2
	SD	0.04	0.12	0.14	0.05
MAC3	given	9.1	29.7	59.2	2.0
	mean (n=4)	8.5	30.6	58.7	2.2
	SD	0.07	0.15	0.07	0.02

Table S2. Chemical analyses of Nahuange metalwork, in percentage by weight (%). The front/core analyses are the values used for the ternary diagram in Figure 8 in the main article. Back analyses refer to XRF analyses conducted from the back (gilded) surface and are presented for comparison. Note, however, that considering the penetration depth of the XRF analyses and the thinness of some of the sheets, it is possible that the part of the fluorescence detected during a 'front' analysis comes from the 'back' of the object.

Museum ID	Analysis / laboratory	Type	Technique	Front/core			Back		
				Cu %	Ag %	Au %	Cu %	Ag %	Au %
O08647	section EPMA/ UCL	Breast plate	H	81.4	3.2	15.6			
O08678	surface XRF / DTI	Nose ornament	C	49.5	8.1	42.4			
O09502	section XRF / DTI	Bird shape pendant	C	96.0	<1	<1			
O10333	surface XRF / DTI	Nose ornament	H	39.0	9.0	52.0			
O10342	surface pXRF / UCL	Nose ornament	H	22.2	12.5	65.4	21.4	12.5	66.1
O10526	surface XRF / DTI	Nose ornament	H	64.5	5.0	30.5			
O10946	surface XRF / DTI	Nose ornament	H	57.0	8.0	35.0	57.0	6.0	37.0
O11037a	section SEM-EDS / UCL	Nose ornament	H	59.0	5.0	35.6			
O11140	surface XRF / DTI	Nose ornament	H	57.6	4.8	37.7			
O12278	surface pXRF / UCL	Nose ornament	H	38.7	8.3	53.0	40.3	8.1	51.6
O12611	section XRF / DTI	Bird shape pectoral	C	31.0	7.0	62.0			
O13706	surface pXRF / UCL	Nose ornament	H	37.2	9.5	53.3	41.5	9.2	49.3
O14580	surface pXRF / UCL	Nose ornament	C	44.5	8.1	47.4			
O14839	surface XRF / DTI	Nose ornament	H	61.0	5.0	34.0			
O14840	surface XRF / DTI	Nose ornament	H	61.6	6.1	32.3			
O14841	surface XRF / DTI	Nose ornament	H	48.5	7.1	44.4			
O15463	section XRF/ DTI	Bird shape pectoral	H	98.0	<1	<1			
O15612a	section EPMA/ UCL	Frog pendant	C	55.9	6.0	37.1			
O16195	surface pXRF / UCL	Nose ornament	H	47.4	7.7	44.9	42.8	7.5	49.7
O16196	surface XRF / DTI	Nose ornament	H	58.0	7.0	35.0			
O16197	surface XRF / DTI	Nose ornament	H	57.0	7.0	36.0			
O16519	surface pXRF / UCL	Belt	H	50.4	8.1	41.5	35.8	8.8	55.3
O16520	surface pXRF / UCL	Belt	H	47.5	10.3	42.2	46.2	10.7	43.1
O16971	section XRF / DTI	Bird shape pectoral	C	56.0	10.0	34.0			
O17033a	section EPMA/ UCL	Ear ornament	H	62.6	6.1	29.5			
O17116	section XRF / DTI	Bird shape pendant	C	22.0	19.0	58.0			
O17161	surface pXRF / UCL	Nose ornament	H	44.9	10.5	44.7	42.6	11.0	46.5
O17463	surface pXRF / UCL	Nose ornament	H	36.7	8.0	55.3	35.1	10.6	54.4
O18124	surface pXRF / UCL	Nose ornament	C	47.9	6.8	44.9	47.7	8.1	44.2
O19707	surface pXRF / UCL	Nose ornament	H	36.0	7.8	56.2	26.2	9.9	63.9

O22845	surface XRF / DTI	Nose ornament	H	50.0	9.0	41.0
O26159	surface pXRF / UCL	Nose ornament	C	47.5	6.5	46.0
O26820a	section EPMA/ UCL	Breast plate	H	58.5	5.9	33.7
O26820b	section EPMA/ UCL	Ear ornament	H	56.3	6.7	36.0
O29603	surface XRF / DTI	Nose ornament	H	56.0	7.0	37.0
O33857	surface XRF / DTI	Frog shape pendant	C	48.7	9.6	41.7
			Mean	**52.4**	**7.4**	**39.9**
			Median	**50.2**	**7.0**	**41.3**
			SD	**15.9**	**3.2**	**13.9**
			Max	**98.0**	**19.0**	**65.4**
			Min	**22.0**	**<1**	**<1**