Gold and silver technological traditions in San Pedro de Atacama (northern Chile), during the Middle Period (AD 400-1000)

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I, María Teresa Plaza, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

Date:

Signature:

I. Abstract

This project investigates gold and silver technologies in San Pedro de Atacama (northern Chile), a strategic node in the South Central Andes during the Middle Period (AD 400-1000). Nearly 200 gold and silver personal ornaments and ritual objects have been recovered as grave goods from cemeteries at San Pedro dated to this period. The aim of this research is to reconstruct the biographies of 140 gold and silver objects made of hammered sheets, considering their production, use and particular contexts to understand their technology and role within the San Pedro society.

This research is driven by the conceptual frameworks of *chaîne opératoire* and artefact life-histories, and supported by the materials science analyses of finished objects. The analytical methods employed include portable x-ray fluorescence, scanning electron microscopy coupled with energy dispersive X-ray spectroscopy, proton-induced X-ray emission, optical microscopy and macroscopic observations with a digital microscope to determine the alloy compositions, manufacturing techniques and technical sequences.

The results identify a heterogeneous assemblage where compositions, techniques and designs are varied, suggesting that the objects were most likely imported from different areas of the South Central Andes, such as Tiwanaku and northwest Argentina. Most importantly, evidence of two local technological traditions is documented: 1) a small-scale goldwork production and 2) a tradition of modifying and reusing imported objects, adapting them to local needs. These findings reveal different patterns in the material selection, transformation and further modification of the artefacts during their lives, challenging traditional assumptions that gold in San Pedro came exclusively from Tiwanaku.

The consumption of gold items show a differential distribution where some individuals were buried with gold or silver. The distribution of these items and the type of objects made in noble metals, indicate that gold in particular, embodied multiple levels of meaning that were used both to a) legitimise the social status of particular *ayllus*, and also to b) materialise long-distance social relationships among “common” people.

II. Impact statement

This study is the first systematic attempt at defining the characteristics of the gold and silver metalworking in San Pedro de Atacama during the Middle Period. Gold artefacts have been used to justify influential interpretations regarding social and political organisation in San Pedro, although they have not been studied until now. The technological study of gold and silver objects offers new insights into San Pedro society in two main ways. Firstly, it has exposed the cultural value given to these materials, revealing different depths of meaning related to San Pedro social and political aspects. Secondly, it has provided a more intimate view of the San Pedro community, by revealing a small-scale local production of funerary ornaments.

At a regional level, the relationship between San Pedro and its neighbours is still debated. The study of raw materials, manufacturing techniques and styles in gold and silver artefacts has helped to understand the social, political and economic associations between different communities that are intensively interacting during the Middle Period through well-developed exchange networks. Additionally, this research offers new insights into the metalworking of precious metals in the South Central Andes, providing technological markers to identify technological traditions that are distinctive of Tiwanaku, northwestern Argentina and San Pedro de Atacama.

This study moves away from traditional approaches to metallurgy in the Americas based on art-historical perspectives, often decontextualized. Instead, it is framed in a growing research area focused on the technological and contextualised study of metallurgy, employing archaeometric methods. This perspective has allowed to go beyond typological analysis, examining specific features associated to raw materials, technological traits and the use of these objects, providing a deeper and richer understanding of San Pedro society. The archaeometric approach is not yet common in Chile, and therefore this investigation constitutes a novelty. Hopefully, it will contribute to the development of the discipline in Chile, as it will be used as an example of the application of archaeometry to the study of metalwork and other archaeological materials.

Gold always attracts public attention, and is therefore an excellent means to promote general interest in Prehistory. Indeed, the figures and other content of this research can be used in San Pedro's museum (currently under construction) to explain how these artefacts were made, used and modified; and how - even small pendants - can contribute to the understanding of cultural aspects of San Pedro society and the socio-political landscape of its wider region. Moreover, these days that immigration is a trending topic, the information obtained from the gold objects can be used to discuss ancient regional relationships beyond current national borders, promoting the integration of San Pedro at a broader regional level.

Lastly, San Pedro de Atacama is an area with active and strong indigenous communities. In this context, this investigation contributes directly to the knowledge of their past and the construction of their modern identity. The identification of a local gold production introduces new conceptions about San Pedro's ritual and crafting practices. The latter may even promote new local craftsmanship.

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VI. Acknowledgments

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VII. Acronyms used in this research

%RSD	Coefficient of variation
Ag	Silver
Au	Gold
B.	Burial
BSE	backscattered electron detector
CA	Central Andes
CP	Casa Parroquial cemetery
Cu	Copper
dl	Below detection limits
IIAM	Instituto de Investigaciones Arqueológicas y Museo R.P. Gustavo Le Paige
LIT	site La Isla de Tilcara, Humahuaca Ravine
LFP	Late Formative Period (AD 100-400)
nd	not detected
MP	**Middle Period (AD 400-1000)**
NWA	**Northwest Argentina**
OM	Optical microscopy.
PCV	site Pueblo Viejo de la Cueva
PIXE	Particle-induced X-ray emission
PGE	The platinum-group elements: platinum, palladium, rhodium, ruthenium, iridium, and osmium
pXRF	Handheld portable X-ray fluorescence
SCA	**South Central Andes**
SD	Standard deviation
SEM	Scanning electron microscopy
SEM-EDS	Scanning electron microscope with energy-dispersive spectroscopy
SPA	**San Pedro de Atacama**
XRD	X-ray powder diffraction

PART I

Introduction and background

Chapter 1. Introduction and research gap

This research is proposed as the first systematic science-based approach to the production and consumption of gold and silver metalwork in San Pedro de Atacama ("SPA") during the Middle Period ("MP"; AD 400-1000). The town of SPA is located in the Atacama Salt Flat basin at the eastern limit of the Atacama Desert - one of the driest deserts in the world - in northern Chile. During the MP, the *San Pedrinos* were a sedentary society, based on a village lifestyle. They were agriculturalists, *llama*[1] and *alpaca* herdsmen and caravaners participating of a dynamic regional traffic system (Nielsen, 2013).

The MP represents the most thriving moment in SPA prehistory. During this period, SPA reaches its maximum demographic expansion; local specialists produced monochrome pottery, baskets, textiles, mineral beads, wooden, bone and copper items; while a range of non-local artefacts and raw materials arrived to SPA from areas such as northwest Argentina ("NWA"), the Bolivian *Altiplano* and the Pacific coast (Castro et al., 2016; Knudson & Torres-Rouff, 2014; Salazar et al., 2014; Torres-Rouff & Hubbe, 2013; and references within).

Amongst non-local products, noble metals objects have captured both scholarly and public imagination. Nearly 200 gold and silver objects have been recovered from different cemeteries, including ritual vessels, axes and ornaments (Barón, 2004; Le Paige, 1961, 1964; Téllez & Murphy, 2007). It is noteworthy that these finds - gold in particular - are known to be exclusive to the MP; i.e., they are virtually absent in periods before AD 400, and after AD 1000 their consumption decreases until it almost disappears.

Because of the relatively large number of gold artefacts, the presence of ritual cups with Tiwanaku iconography, and the lack of evidence for local gold production, scholars during the 1980's and 90's assumed that these gold objects were of Tiwanaku origins, relating the social changes seen in SPA to a direct contact between the Tiwanaku State (a polity from the Titicaca Basin) and the San Pedro culture, including people from Lake Titicaca setting up colonies in SPA (Barón, 2004; Benavente et al., 1986; Le Paige, 1961; Tamblay, 2004; Thomas et al., 1985). However, biochemical analyses have ruled out that option (see more details in page 59), and the most accepted theory today is that the relationship with Tiwanaku was indirect, i.e., rather than colonies or administrators

[1] From here and onwards, the Andean or Spanish words highlighted in italics will be explained in the glossary of the appendix N°1.

coming from Tiwanaku, SPA remained independent and autonomous and their contact was articulated by dynamic trade routes (Berenguer et al., 1980; Castro et al., 2016; Dillehay & Nuñez, 1988; Llagostera, 2004, 2006a, 2006b; Núñez, 2006; Torres-Rouff et al., 2015).

Although gold is not the only material ascribed to Tiwanaku (e.g. snuffing implements, textiles and pottery are indicative of similar connections) it is the only one that is repeatedly related to this polity even if it has only been superficially and unsystematically studied (Benavente et al., 1986; Le Paige, 1961; Stovel, 2001; Tamblay, 2004; Téllez & Murphy, 2007; Thomas et al., 1985; Torres-Rouff et al., 2015). In the latest and most comprehensive study of SPA, Salazar and colleagues (2014) use metals as differential markers within the SPA society, where gold is thought to represent the highest ranks of a local emerging elite (see also Tamblay, 2004). They assume that all the gold was imported from Tiwanaku, and therefore local leaders were intentionally showing affiliation to the Tiwanaku sphere. However Stovel (2001; see also Torres-Rouff et al., 2015) notes that several gold and silver objects from SPA differ in design from their Tiwanaku counterparts, and they not always appear in “rich” burials (namely, burials with many grave goods). Stovel (2001, 2008) questions the assumed correlation between gold and Tiwanaku, but her arguments are only based on typological comparisons and she urges for more research on the matter, exploring potential connections with NWA and the southern *Altiplano*, from where pottery is circulating.

It is therefore surprising that a materiality used in major interpretations of social and political aspects of SPA society has not been properly assessed. The picture is rather incomplete and many questions remain about the collections of gold and silver items recovered in the area. For instance, what are the defining typological and material characteristics of gold and silver objects from SPA? How variable is the assemblage? Do they represent particular technological traditions? How do they relate to Tiwanaku metalwork? Is there evidence to argue for the existence of local metalwork? Were these objects used in life or were they especially made for the funeral? To what extent can we confirm the assumed relationship between gold and social status? So far, there has been no attempt to address these questions, and a perspective from the technology has been largely ignored (e.g. Salazar et al., 2014; Stovel, 2001; Tamblay, 2004). However, many of these issues - together with additional matters related to precious metal production and consumption; or the cultural aspects behind the actors making and using these items - can be explored by reconstructing in detail the technology and the choices made regarding raw materials and manufacturing techniques, as well as learning about the life-histories of the artefacts through wear-marks, repairs or modifications (Dobres, 1999; Martinón-Torres, 2002; Sillar & Tite, 2000).

Without a systematic investigation of these problems, it is difficult to discuss and interpret the role of these items in SPA society, and the relationship between SPA, Tiwanaku and other societies of the period. This project attempts to fulfil this gap by studying the objects in their context from an archaeometallurgical perspective, to reconstruct as far as possible their production technology and consumption patterns. Rooted in the assumption that technology is a social construct, I combine a detailed examination of the artefacts and laboratory-based analyses as a means to explore the social, political and economic influences behind the gold and silver technology (Dobres, 1999; Sillar & Tite, 2000). Moreover, I also expect to contribute to a wider understanding of gold and silver metalwork both in SPA and in the wider South Central Andes region, during the MP.

1.1 Aims

This research focuses on the study of gold and silver grave goods deposited in various cemeteries in SPA, and dated to the MP. While this research is conceived as a holistic approach to precious metals, gold will inevitably take centre stage as the metal most frequently documented and preserved; however, silver data will be included as far as possible. This study constitutes the first systematic approach to this materiality, a significant step in a long-term research agenda oriented to promote the understanding to the groups and individuals involved in the production, distribution and consumption of these items.

This thesis seeks to address the questions posed in the previous section, while contributing to establishing and substantiating broader research agendas. For this purpose, the following aims were set out:

1- To characterise the gold and silver technology manifest in SPA, by reconstructing the *chaîne opératoire* and life-histories of the grave goods as a starting point to identify different technological traditions and use patterns, and to explore the degree of variability of the assemblage. Although goldwork is described as a "sheet-metal technology" (González, 2003), its production is a flexible process with plenty of scope for variation; i.e., there are several ways of producing sheets, as well as different techniques to shape objects of different shapes and sizes. Aspects investigated in this thesis include the identification of raw materials and alloy practices; the characterisation of trace elements in a subset of the overall population, to explore, as far as possible, potential gold (and silver) sources and circulation; and the reconstruction of the manufacturing techniques employed, considering the quality of the work and re-use evidence.

2- To compare SPA results to morphological, chemical and manufacturing data from Argentina, Bolivia and Chile, to recognise potential technological traditions. For this purpose, published data was gathered, and additional chemical and technological analyses were carried out on a set of Chilean, Argentinean and Bolivian objects accessible in different museums. The collection, systematising and publication of these data represents a significant step forward in the regional study of gold technology in the South Central Andes.

3- To investigate the ritual and symbolic consumption of noble metals artefacts in SPA, by considering the context of deposition and technological aspects of the objects to understand:
    a. Who is buried with metals: by establishing consumption patterns based on geographical and chronological distribution of gold and silver within SPA, and the characteristics of noble metal consumers (e.g., sex, age, etc.).
    b. How noble metals were used: by considering how objects were placed in the burials, evidence of re-use, wear-marks and typology.

4- To discuss the role of noble metals and their social significance in SPA, considering their production and consumption characteristics, and their relation with other areas of the South Central Andes.

5- From a methodological perspective, it is hoped that this study will make a contribution to establishing protocols for the technological and compositional study of archaeological gold and silver, with due consideration to issues such as corrosion or other surface phenomena and their impact on the results of different analytical techniques. Furthermore, it will demonstrate that even seemingly small and unimpressive artefacts can be fruitfully interrogated from archaeological perspectives if the appropriate techniques and theoretical frameworks are employed.

1.2 Structure of the thesis

This thesis in divided in five parts. Part I includes this introductory **Chapter 1**, and **Chapter 2** which provides the necessary background including a 2.1.) geopolitical and chrono-cultural framework, to situate SPA, Tiwanaku and other polities within the Central Andes; 2.2) a brief overview of gold and silver technology in the Andes, considering symbolic and geological aspects. And 2.3) the archaeological background of SPA, including its development during the Late Formative Period, the changes during the Middle Period, the characteristics of gold and silver objects and a description of the cemeteries studied here.

Part II comprises **Chapter 3**, which provides an overview of the theoretical framework used in this thesis; and **Chapter 4**, which presents the methodological framework, including materials, sampling strategy, and analytical methods.

Part III focuses on results regarding the production of the objects. In **Chapter 5**, raw materials and alloy practices are identified based on the compositional data. This chapter describes the sample in general, explores potential raw materials and alloys practices, and presents the distribution of compositions by sites. **Chapter 6** focuses on characterising the manufacturing techniques employed to make the objects. It includes microscopic and macroscopic evidence of manufacture, the latter organised in forming, decoration, finishing and modification techniques. It also considers the distribution of manufacturing techniques by sites. **Chapter 7** provides the comparative information from other regions, including composition and manufacturing techniques, to identify different technological traditions within SPA assemblage. In **Chapter 8**, results from chapters 5-7 are discussed.

Part IV focuses on results regarding the consumption of these items. **Chapter 9** explores the distribution of gold and silver within SPA, the characteristics of the individuals bearing precious metals and how objects were used. In **Chapter 10** results of chapter 9 are discussed.

Part V includes **Chapter 11**, with the main conclusions and suggestions for future work.

Chapter 2. Background

This thesis will focus on gold production in San Pedro de Atacama (“SPA”), northern Chile, during the Middle Period (“MP”, AD 400-1000). The information given in this chapter aims to provide 1) a geopolitical and chrono-cultural framework, 2) a brief overview of current knowledge of goldwork traditions in the Central Andes, and 3) relevant information about SPA culture and its development during the MP.

2.1 Geopolitical and chrono-cultural framework

The focus of this thesis is SPA, which is part of the *Circumpuna*, a subarea of the *South Central Andes*, the southern section of the *Central Andes* (Figure 1-2). This section contextualises the areas geopolitically, considering their main cultural developments.

The Central Andes (“CA”) covers the territory from the border between Ecuador and Colombia, to the border among Peru, Chile and Bolivia. Geographically, the CA includes different ecological zones, generating multiple microenvironments that were the basis of Murra’s classic “archipelago model of vertical control” (Murra, 2002). Chiefly, it includes the high mountains or *cordillera*, intermontane valleys, the green eastern slopes where the cordillera connects with the Amazon jungle, and the arid western slopes - interrupted by irrigable valleys - connecting with the Pacific coast (Sandweiss & Richardson, 2008). In the CA, a series of cultures developed in ancient times (Figure 1). In north Peru, the cultures of Moche, Sican, Chimu and Chavin stand out; whereas in south Peru, the Paracas, Nasca, Siguas, Ica and Wari polities developed. Their chronology is outlined in Figure 3.

The South Central Andes (“SCA”) comprises the south border of Peru, including northern Chile, southwest Bolivia and northwest Argentina (“NWA”; Figure 1). Compared to the CA, the SCA is more arid and colder, resulting in a low primary productivity. The core of the SCA is a vast high intermontane plateu (above 3,500 masl), called *altiplano* in Bolivia and *puna* in Argentina and Chile (Figure 2). This area offered ideal conditions for *llama* herding, a reason why communities in this area had a strong emphasis on pastoralism (Nielsen, 2013). Archaeologically speaking this area has been divided into two subareas: the “*central Altiplano of Bolivia*” and the “*Circumpuna”*, which saw characteristic cultural developments (Castro et al., 2016).

The subarea of the central *Altiplano* comprises the area between Lake Titicaca and Lake Poopo (Figure 2). Culturally speaking, this area was the centre of early state development. Since *ca*. 500 BC, societies appear hierarchically organised, showing internal political and economic differences, as well as external differences between communities (Stanish, 2001). From around AD 100 *Tiwanaku* stands out, becoming towards AD 400 a powerful state that would dominate the central *Altiplano* and the entire SCA until *ca.* AD 1000 (Janusek, 1999, 2004; Stanish, 2001). Although the nature of Tiwanaku is extensively discussed elsewhere (for a good review see Janusek, 2004, Chapter 3), current approaches suggest that this Andean State was organised in hierarchical settlement networks, among urban centres, rural communities and monumental ritual complexes (Janusek, 2004). Janusek's research on urban centres - Tiwanaku (with a population between 10,000 and 20,000 people) and Lukurmata (with a population of ~4,000 people) - indicates that residential life involved the production, distribution and use of valuable goods made in Tiwanaku style (Janusek, 1999, 2003, 2004). In these centres, elites were closely related to religious practices, whereas commoners organised in semiautonomous microcommunities, administered by local leaders. These local administrators would have been in charge, for instance, of local craft production (Janusek, 1999). Tiwanaku sites and cities also served as centres for pilgrimage and ceremonial convergence (Janusek, 2004; Korpisaari, 2006; Korpisaari et al., 2011, 2012).

Between AD 400-1000 (Figure 3), the Tiwanaku cultural influence expanded throughout the SCA. In some cases, the influence was direct, establishing colonies or Tiwanaku administrators, such as in Moquegua; or indirectly, by the circulation and consumption of artefacts with Tiwanaku religious iconography, as proposed for San Pedro de Atacama (Castro et al., 2016; Janusek, 2004). Still, Tiwanaku expansion was uneven, leaving some areas with little or no evidence of influence, such as some sectors of NWA (Albeck, 2001; Janusek, 2004).

The subarea of the Circumpuna corresponds to the meridional section of the SCA. This area comprises the Bolivian southern *Altiplano* (or Lipez), the Argentinean *puna* and northern Chile. It includes the Uyuni Salt Flat in the north (Bolivia) and the Arizaro Salt Flat (Argentina) in the south; the Pacific coast in the west and the fertile valleys and ravines of NWA in the east (Martínez, 1998). For the sake of simplification, unless is otherwise specified, NWA refers in this thesis only to the sub-area of *Circumpuna*. The geographic and climatic conditions of the *Circumpuna* are harsh and niches suitable for human settlement - i.e., fertile oases - are small, supporting relatively small populations, which are separated by vast uninhabited deserts, salt pans and high mountains (Llagostera, 2006b; Nielsen, 2013). The oases of this subarea were key for human development and they include **San Pedro de Atacama**, Chiu Chiu, Lasana and Calama in Chile; Humahuaca and Purmamarca ravines in Argentina and Rio Grande de San Juan and Potosi valleys in Bolivia (Figure 2; see Appendix Nº2: 2; Martínez, 1998; Nielsen, 2013).

Archaeologists have identified evidence of regular interactions between the different groups living in the *Circumpuna* since early times (*ca*. 8000 BC; Castro et al., 2016; Núñez, 1987; Nuñez & Dillehay, 1995; Stovel, 2008; Tarragó, 1977), these relationships survived until post-colonial times, according to ethnographic studies (Martínez, 1998). These interactions were facilitated by natural corridors - such as small valleys and river basins that concentrated pastures and water -, which linked in relatively short distances areas as different as the eastern mountain rainforest (or *yungas*), the dry *puna* and the *circumpuna* oases (Llagostera, 2006b; Nielsen, 2006a, 2013; Tarragó, 1984). The fluid mobility facilitated a common cultural background, different from the cultural developments identified in neighbouring areas such as the central *Altiplano* (Castro et al., 2016; Llagostera, 2006b; Martínez, 1998; Tarragó, 1984). During the MP, the main archaeological entities - defined by their ceramic styles - were SPA in Atacama, Yavi in the *puna*, La Isla in Humahuaca, and Lipez/Potosi and Huruquilla/Yura in the southern *Altiplano* (Albeck, 2001; Goretti, 2012, p. 54; Stovel, 2002, 2008; Tarragó, 1989).

Politically speaking, if we take state-level institutions, urbanism, monumental architecture, and large-scale productive infrastructure as indicators of social complexity, then it can be argued that communities in the *Circumpuna* were never complex, compared to the communities in the central *Altiplano* (Nielsen, 2013). The communities from the *Circumpuna* - including SPA - are described as *corporative* and *heterarchical*, with a decentralised economic and political organisation (Castro et al., 2016; Nielsen, 2006b). During the MP, these communities were organised both in semi-conglomerate and dispersed seasonal settlements, located in fertile lands where agriculture was practiced (oases). Local craft production was independently organised at household levels (Albeck, 2001; Castro et al., 2016; Goretti, 2012, p. 54). The architectural uniformity of the settlements and burial patterns, the visibility and importance of ancestor worship and the development of decentralised production systems would be evidence of their heterarchical organisation (Nielsen, 2007).

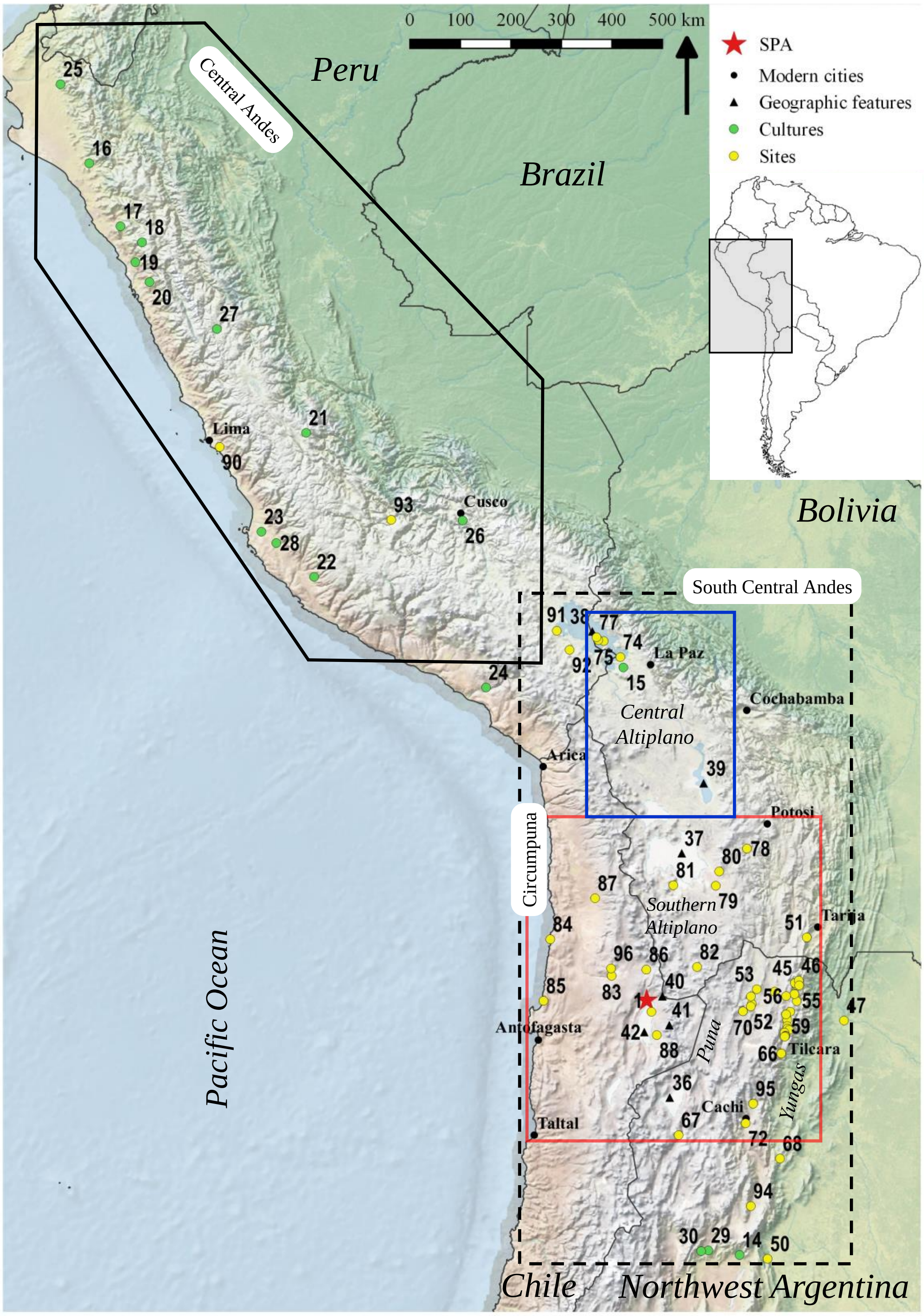


Figure 1: Map of the Central Andes, South Central Andes, Central Altiplano and Circumpuna. Legends are given below. "Cultures" are represented here by the location of their key sites.

1 SPA	30 Condorhuasi	48 Co Morado	65 Pucara de Tilcara	82 Sud Lipez
14 Aguada	31 Humahuaca	49 Casabindo	66 Pucara de Volcan	83 Chorrillos cemetery
15 Tiwanaku	32 Purmamarca	50 Yaminas-1	67 Tebenquiche	84 Urco cove
16 Sican	33 Rio Grande de Sn Juan	51 Tolomosa	68 Pampa Grande	85 Hornitos-1
17 Chimu	34 Chiu Chiu	52 PV de Tucute	69 Los Amarillos	86 Caspana
18 Moche	35 Lasana	53 Queta	70 Cienaga Grande	87 Guatacondo
19 Viru	36 Arizaro Salt Flat	54 Titiconte	71 Aconcagua Shrine	88 Tulan-54
20 Cupisnique	37 Uyuni Salt Flat	55 Huayra Huasi	72 La Paya	89 Yona-2
21 Wari	38 Lake Titicaca	56 PV de la Cueva	73 Doncellas	90 Mina Perdida
22 Nasca	39 Lake Poopo	57 PV de Coctaca	74 Pariti island	91 Puno
23 Paracas	40 Licancabur	58 Muyuna	75 Moon Island	92 Jiskairumoko
24 Sihuas	41 Lascar	59 San Jose	76 Sun Island	93 Waywaka
25 Frias	42 Atacama Salt Flat	60 Huacalera	77 Khoa Island	94 Rincon Chico
26 Inca	44 Rodeo Colorado	61 La Huerta	78 Yura	95 Potrero de Payogasta
27 Chavin	45 Molino Viejo	62 Juella	79 Cobrizos	96 Chuquicamata
28 Ica	46 Cuesta Azul	63 La Isla de Tilcara	80 Pulac-50	97 Tabladitas
29 Cienaga	47 Manuel Elordi-1	64 Malka	81 Colcha K	

Table 1: Legend of sites

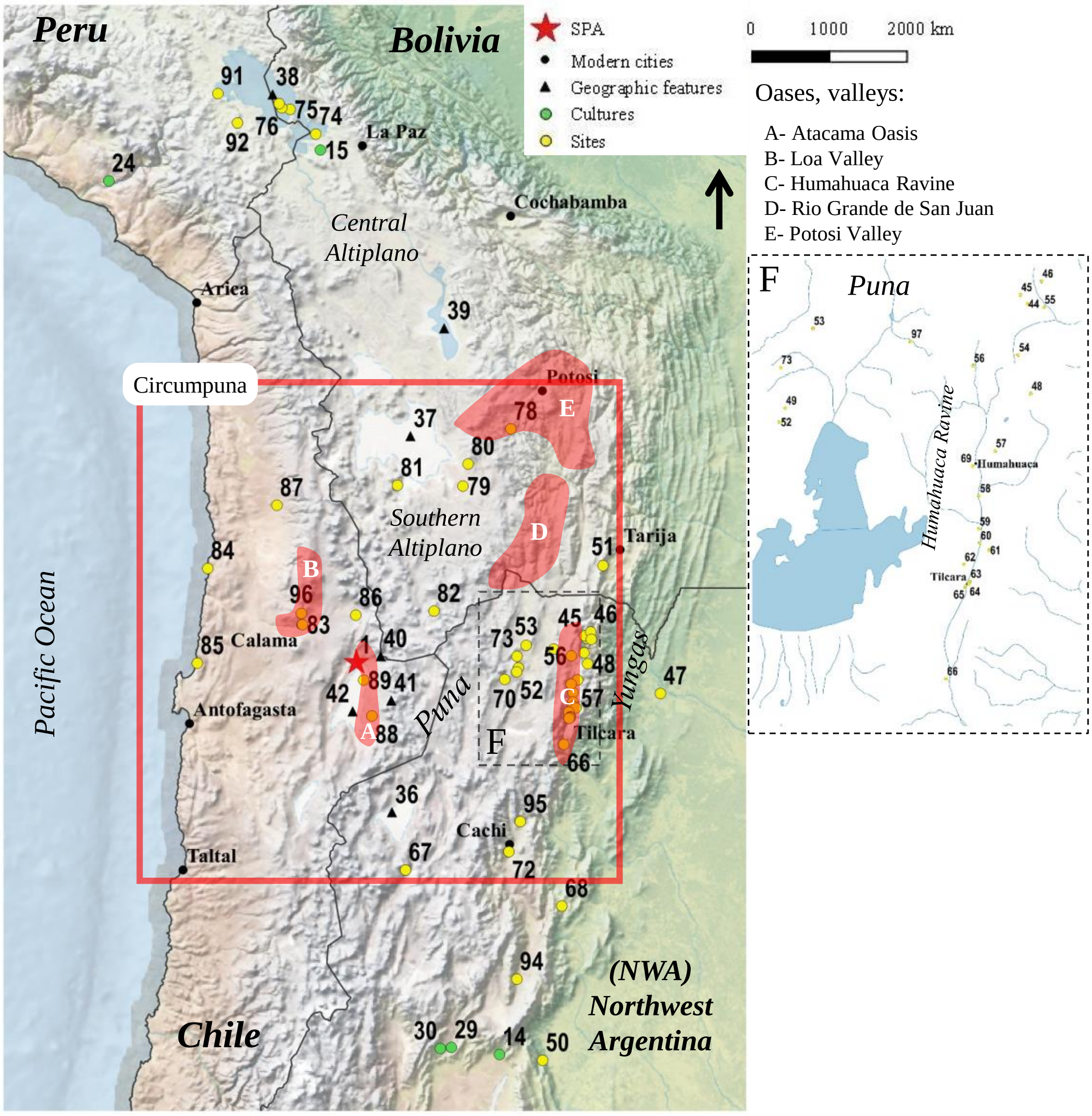


Figure 2: Map of the South Central Andes and Circumpuna.
Sites are given in Table 1. "Cultures" are represented here by the location of their key sites.

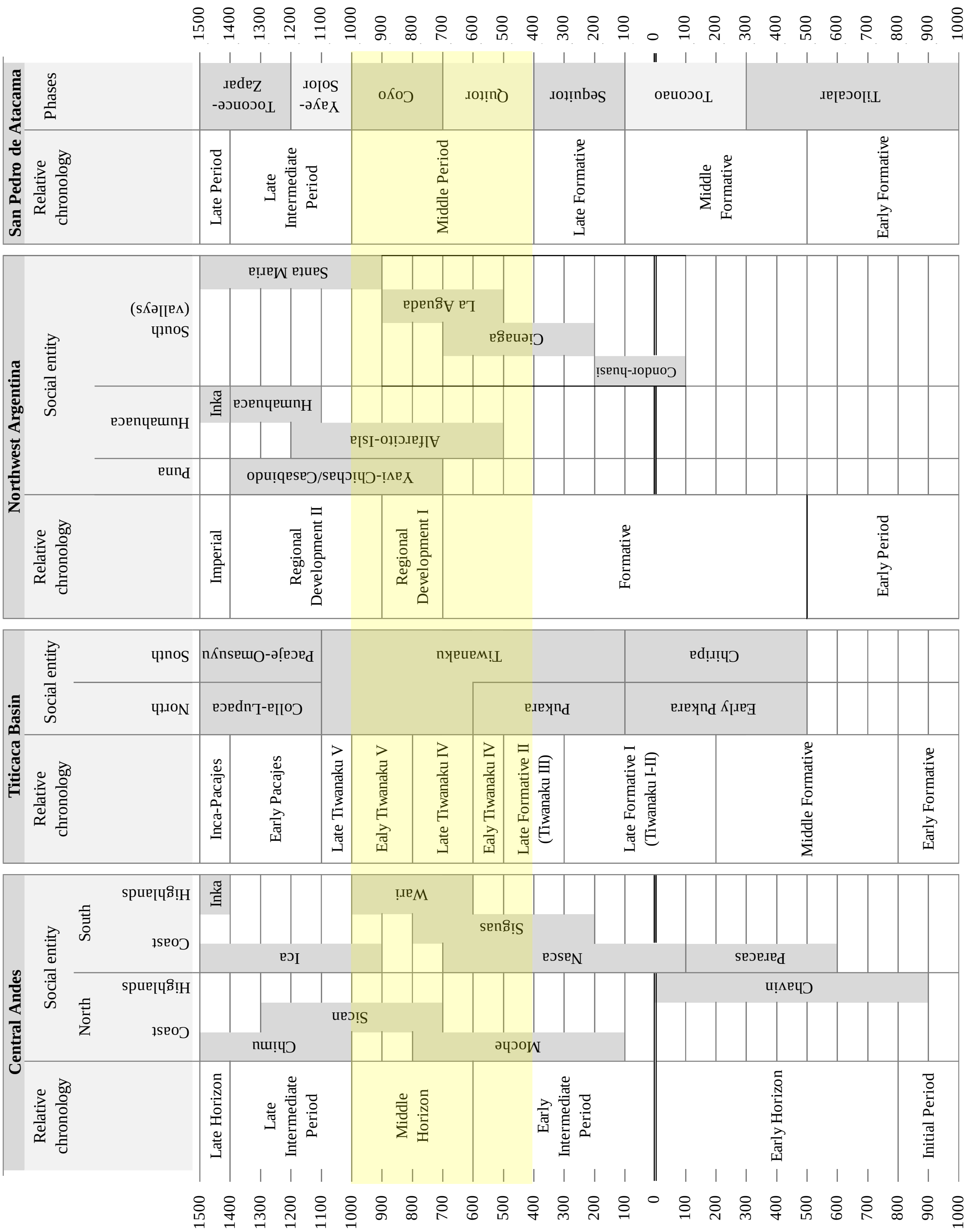


Figure 3: Chronology of the Central and South Central Andes.
(After Falabella, 2016, p. 22; Lechtman, 2014, fig. 15.4; McEwan, 2000, p. 14; Nielsen, 2007; Sinclair, 2006, p. 21; Tarragó, 1984, fig. 2).

2.2 Gold and silver technology in the Andes, a brief overview

In the Andean zone of South America, metallurgy developed as an independent technology, dominated by copper alloyed with gold, silver, tin or arsenic (González, 2004a; Lechtman, 2014). Gold in this context was the first metal to be worked, and overall it developed a different technological trajectory compared to copper (Lechtman, 2014). Even though tools were made, the majority of the metallic production in the Andes was oriented to symbolic objects (e.g. personal ornaments, ritual cups, masks ; Figure 4) used to communicate and express ideological and political power (González, 2004a; González & Vargas, 1999; Lechtman, 1991a, 1993; Shimada et al., 2000). The expertise and engineering of Andean metallurgists is revealed in the sophisticated and complex casting or gilding techniques to produce a vast range of colours and sounds (González, 2004a, 2004b, 2010; Lechtman, 1973, 1984, 1993, 2014; Merkel et al., 1994; Shimada, 1996; Shimada & Merkel, 1991).

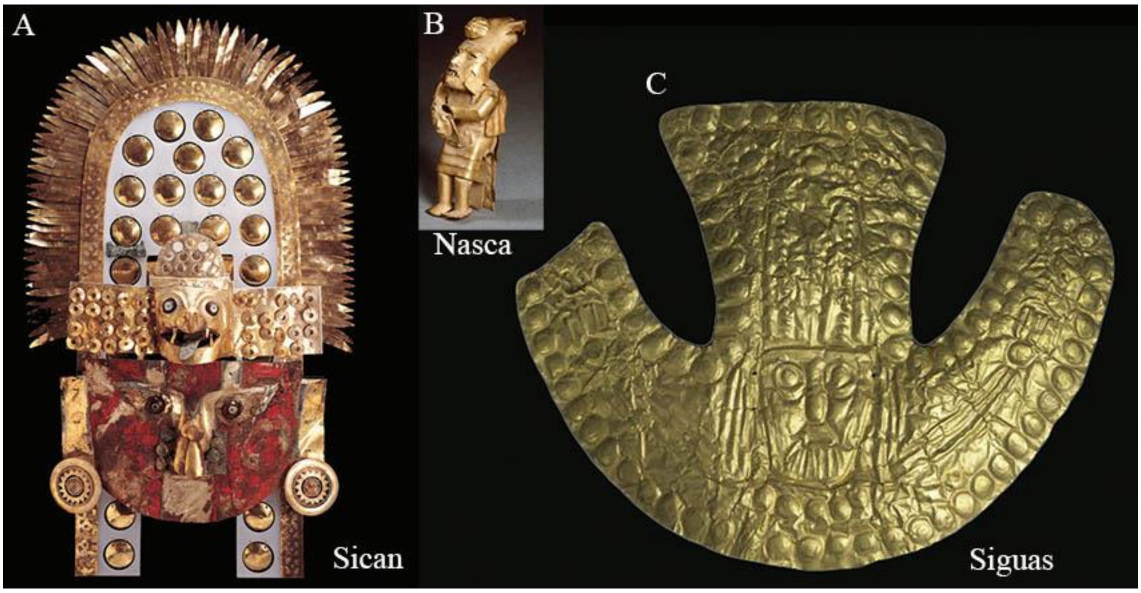


Figure 4: Gold objects from (A) north Peru, and (B-C) south Peru.
(After McEwan & Haeberli, 2000, fig. 1.2; Schlosser et al., 2009, fig. 24.1; Shimada & Griffin, 2005, p. 81)

The earliest evidence of goldwork is reported in Peru, as small hammered sheets deposited in ritual contexts (see Appendix Nº2: 1). The oldest object is a necklace of nine tubular beads, associated to a hunter-gatherer's burial in site Jiskairumoko (2155-1936 BC), at the Lake Titicaca basin (Figure 1:92; Aldenderfer et al., 2008). Other early evidence are gold foils and a metalworker's kit containing stone hammers and an anvil, also in a burial, at Waywaka (1680-1410 BC, Figure 1:93), in south-central Peru (Grossman, 1972, 2013); and Mina Perdida (1410-1090 BC), a large ceremonial centre in central Peru (Lurín Valley, Figure 1:90), where a series of gold and native copper foils were given as offerings (Burger & Gordon, 1998; Sáenz Samper & Martinón-Torres, 2012).

It is during the Early Horizon (900 BC-0, Figure 3) with the expansion of Chavin religious imagery towards the north and south coast of Peru, that goldwork expands in the Central Andes (Lechtman, 2014). Although no production evidence has been recovered so far, Chavin objects reveal remarkable skill and technological knowledge. Artisans worked native gold by hammering, annealing, embossing, chasing and engraving; they experimented with the first artificial alloys by mixing metallic silver and gold, sometimes adding copper; and they introduced different soldering techniques (Lechtman, 2014; Schlosser et al., 2009). Chavin metallurgists developed a gold-centred metallurgy, where silver objects were rare. According to Lechtman, Chavin metallurgy is relevant in the first place, because it uses gold as a vehicle to deliberately express and expand an ideology; and in the second place, because it sets the technological stage to work gold by making objects in thin sheets (2014).

After Chavin, gold metalwork expands showing regional differences that can be broadly grouped in two traditions. A first tradition is found in the north coast of Peru, with the complex metallurgical systems developed by the Moche (AD 100-800), Sican (AD 750-1300) and Chimu (AD 1000-1470; Bezúr, 2003; Lechtman, 2014; O'Day, 2000; Shimada et al., 2000). Although casting was practised, artisans in north Peru produced primarily thin sheets by hammering, creating golden and silver artefacts by gilding or silvering copper alloys containing gold, silver or both (Lechtman, 1973). They shaped complex and intricate three-dimensional forms by joining various sheets, bangles and wires; joining methods included metallurgical (e.g. soldering) and mechanical techniques (e.g. stapling, sockets). Masks, goblets and earrings were inlayed with stones, shells, and amber; or were painted red with cinnabar (Figure 4:A). They covered textiles, leather and even walls with gold, silver and copper sheets (Shimada et al., 2000). The societies of the north coast of Peru were highly stratified, and the use of gold reflected social differences, as suggested by Shimada's research on La Leche Valley, where four social strata were proposed based on the access of metals (Shimada et al., 2000). It is noteworthy that Lechtman observes that among the Moche, metals in general were used to cover the bodies and burials of the elite and she proposes that metals *"had a protective or empowering role or quality"* (2014, p. 375). Even low-rank individuals tried to cover their burials with copper sheets, or were buried with folded sheets in their mouths (Lechtman, 2014).

In the south, the panorama is different. The second goldwork tradition includes south Peru (Paracas, Nasca, Ica, Siguas), Bolivia, northern Chile and NWA, which is more similar to Chavin technology. Gold was mainly used in its native state or was alloyed with silver, but the production of copper-gold or copper-silver alloys was unusual compared to north Peru. In this area, specifically the Puno Bay in Lake Titicaca, researchers have recovered the earliest evidence of silver production *ca.* AD 60-120, already using complex smelting processes (Schultze, 2013; Schultze et al., 2009, 2016). Gold was hammered and annealed, objects were relatively simple in that most of them were two-dimensional ornaments decorated by embossing, chasing and cut-out (Figure 4:C); some examples have inlays of semi-precious stones (McEwan & Haeberli, 2000; Money, 1991; Root, 1949; Schlosser et al., 2009). The complexity of these items is seen in the great size of some of them, and in obtaining three-dimensional shapes by deforming single sheets (e.g. raising, see later sections) or by soldering, although the latter was less common (Lechtman, 1991a; Schlosser et al., 2009). Towards the Middle Period, gold and silver are used in most of the SCA, including areas under Wari and Tiwanaku influence, northern Chile and NWA (Chávez, 1985; González, 2003; Goretti, 2012; Le Paige, 1961; Téllez & Murphy, 2007). However, in NWA, specifically in the Catamarca Province, the period with more gold and silver ornaments reported is the Formative Period (1000 BC-AD 500), associated to Condorhuasi and Cienaga contexts; their frequency decreases towards the MP with Aguada, and noble metals are virtually absent during later periods (González, 2003). During the Inka rule, both traditions from north Peru and SCA were combined and complemented.

Within this wider panorama, the goldwork found in SPA is broadly inserted within the second tradition. The description above though, is very general and conceals social and technological particularities of each area that will be analysed in more detail in subsequent chapters.

2.2.1 Noble metals from a symbolic perspective in the Americas

To investigate the role of gold and silver in SPA - or any other area of America -, it is important to understand their meaning and symbolism in the Andean context, which is substantially different from the meaning acquired in the Old World in general, and inherited by us, which predominantly considers these metals as wealth or having a commercial value (Saunders, 1998).

An interesting overarching concept is presented by Saunders, who considers that metals - together with other shiny objects and phenomena -, were inserted in a pan-Andean attitude towards materiality that he defines as an "aesthetic of brilliance". Although the exact meaning can vary between cultures, this aesthetic would be an essential part of the indigenous worldview rooted in the conception of the spiritual and creative power of light (Saunders, 1998, 1999, 2003, 2004, 2011). The light, associated to immanent natural forces such as the sun, moon, fire or water, is associated to fertility, creation and vital forces that regulate the universe. Light is full of scared, mythical, moral and social positive values (Falchetti et al., 2003; Hosler, 1994b, 1994a, 1995; Saunders, 2003). The symbolism and power of light can be materialised in objects that stand out because of their brilliance and colour. In such context woods, stones, pearls, multicolour textiles, feathered work, burnished pottery and especially metals, would become carriers of the energy and power of light (Saunders, 1999, 2003).

It is also noted that the cultural process of transforming natural materials into shiny objects - i.e., technology - increased the value of these items and the technological process itself (Bray, 2005; Saunders, 2003, 2004). This is illustrated by Helms, who points out that the value of gold in Panama was closely related to its transformation into "something", as noted in the account of the son of a native chief who *"perplexed by the conquistadors' melting of artistic pieces into ingots, is said to have pointed out that* ***rough gold had no more value than a lump of clay before it was transformed into a useful or pleasing*** *container"* (my emphasis; Helms, 1979, p. 79). The metallurgical process is seen as a moment whereby natural forces (e.g. fire) need to be managed correctly by the artisan, to produce a successful transformation of the raw material into a finished object, which is then infused with life. Metallurgy then is embedded in the field of the supernatural, with religious and ideological significance (Budd & Taylor, 1995; Eliade, 2016 [1974]; Valencia, 1978). Given this symbolic complexity, Saunders argues that American metallurgy had more esoteric than practical advantages. Thus, the value of the metals and their alloys was probably rooted in ideas related to the brilliance *"of which metallic artefacts were their most technologically sophisticated repositories, producing an incomparable reflection"* (my translation; Saunders, 2004, p. 133).

Against this background, it is possible to understand metals as sensory stimulants that visually expressed the links between the users and immanent energies of the sun and the moon, main sources of light (Falchetti et al., 2003; Saunders, 2003). This is probably the reason why leaders and shamans wore elaborate clothing, headdresses and jewellery as visual signs of their control over natural forces, religious and political power (Lechtman, 1993; Saunders, 2004; Shimada et al., 2000). Still, metals were also offered and used by common people to ask for protection or to ensure fertility, as seen in Colombian communities (Falchetti et al., 2003), or in the Andes, where pieces of gold sheets were offered by caravans in mountain-pass shrines (Nielsen, 2013; see also Lau, 2018).

The golden colour had a deep meaning in the Andes, associated with the sun, immortality, ancestry and the masculine. Complementarily, the silver colour was related to the moon, rebirth and the feminine (Falchetti et al., 2003; Saunders, 2004). It is proposed that these meanings were profoundly rooted in Andean ideology, since the ideological use of gold by Chavin, until their adoption as symbols of political power by the Inkas. They also determined the invention of different techniques to produce golden and silver surfaces (González, 2004c, 2004b; González & Vargas, 1999; Lechtman, 1971, 1973, 1978, 1984, 1991a). However, according to Lechtman, in the latter case the aim was not to simply obtain a golden or silver surface, but to reflect externally, the inner essence of the artefact (1977).

Still, the predominance of gold or silver as the most important metal (or colour) has to be carefully considered. For instance, Shimada and colleagues (2000) outline the risks of transposing the Inka worldview focused on the predominance of sun, and therefore gold, to pre-Inka cultures, using the example of north Peru where the moon was considered the main deity and the sun was rather inferior. They also claim that the division between gold-silver and the relationship gold=sun and silver=moon, may be too simplistic. The authors emphasise that both celestial bodies change their colour depending on atmospheric conditions and cycles (see also Falchetti et al., 2003, fig. 4). In Sican murals, the sun was depicted in reds and oranges, instead of yellows or golden colours (Shimada et al., 2000). Considering the wide range of colours produced by Sican metallurgists, it is possible that these associations were indeed more complex and culturally different, as evidenced by recent research in Nahuange metallurgy, where the pink colour was preferred over golden surfaces (Sáenz-Samper & Martinón-Torres, 2017).

This brief summary thus evokes the symbolic and aesthetic significance of metals and metallurgy in the Andean worldview, while at the same time emphasising the myriad of ways in which these may materialised in different regions and periods.

2.2.2 Noble metals in the South Central Andes from a geological perspective

To understand the production and use of gold and silver in the SCA, it is necessary to know the availability of gold and silver sources in the area. In this section, a brief overview of the types of gold and silver deposits will be presented, followed by mapping their presence and distribution near SPA and within the SCA in general.

The Central and South Central Andes are very rich in mineral deposits. This region contains the principal deposits of Cu, Sn, Ag, Sb, Li in the world, as well as important deposits of Pb, Zn, common salt, borates and rare-earth elements (REEs; Zappettini et al., 2001). The metalliferous deposits in this area are distributed in longitudinal belts (oriented N-S), organised in large metallogenic provinces, each one with their own compositional characteristics (Figure 5). From east to west these provinces are a) the Eastern Polymetallic Province, b) the Eastern *Cordillera* Tin Province, c) the Altiplano Polymetallic Province, d) the *Precordilleran* Copper Province, and e) the Coastal Cordillera Copper Belt (Boric et al., 1990; Ulriksen, 1990; Zappettini et al., 2001). Each province contains a range of gold and silver deposits.

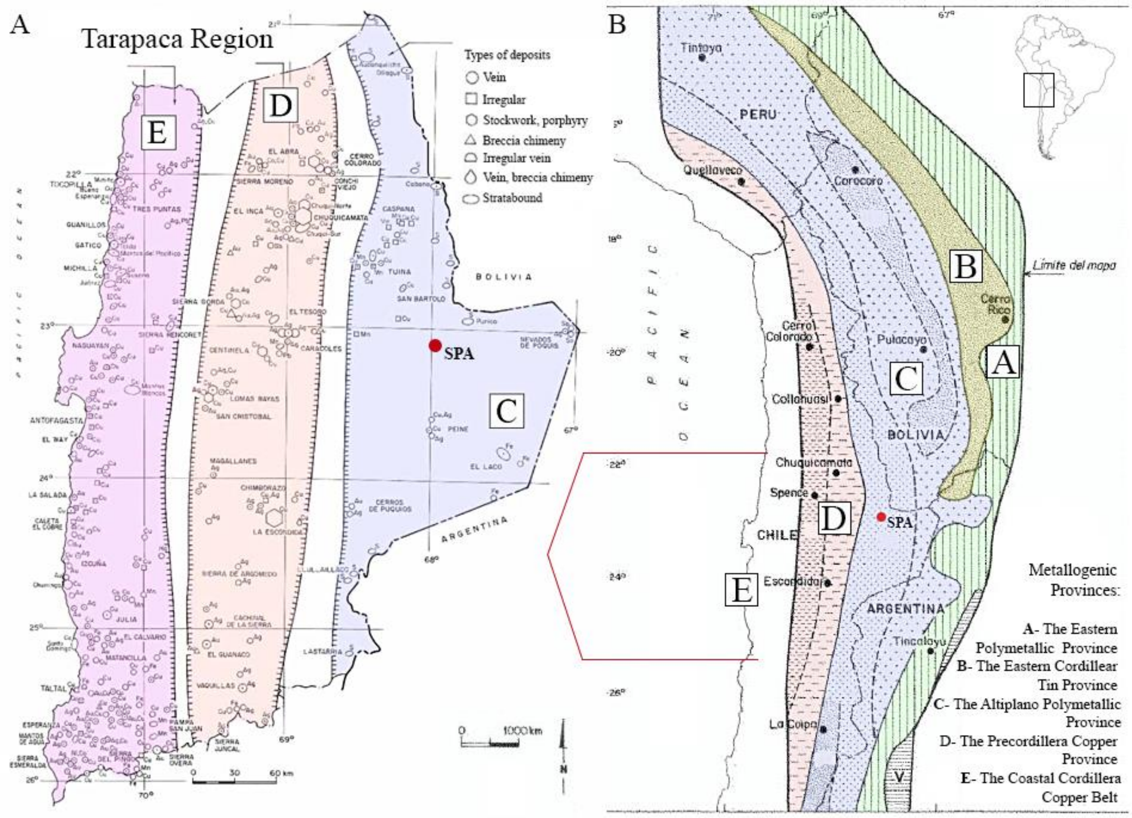


Figure 5: Map of the metallogenic provinces in the South Central Andes.
From right to left A- The Eastern Polymetallic Province (green), B- the Eastern Cordillera Tin Province (yellow), C- the Altiplano Polymetallic Province (blue), D- the Precordilleran Copper Province (red), and E- the Coastal Cordillera Copper Belt (pink; modified after Boric et al., 1990, fig. 11; Zappettini et al., 2001, fig. 6).

a) The Eastern Polymetallic Province starts in Cusco and finishes in the south of the Salta Province (Argentina). It is characterised by its polymetallic deposits of Pb-Zn-Ag, gold and antimony (e.g. Yani district). In this belt are located the rich deposits of antimony and gold-antimony of Bolivia and Argentina; and it also rich in placers and paleoplacers such as those from Bolivia (e.g. District of Tipuani, Cordillera Real) and NWA (e.g. *puna*).

b) In the Eastern *Cordillera* Tin Province, tin is the principal mineral, making this one of the most tin-rich areas in the world. It extends from southeastern Peru to NWA, but is best developed in Bolivia. Together with tin deposits, it also contains important silver, bismuth, tungsten, gold and base metal deposits. Tin appears in placers and veins, the latter associated to tungsten (Sn-W), or as polymetallic vein deposits of Sn-Ag-Zn-Pb-Bi-W. Associated to these ores, there are epithermal veins of Ag-Zn-Pb-Au, as well as tungsten and gold placers (Zappettini et al., 2001).

c) The Altiplano Polymetallic Province covers the occidental cordillera and the *altiplano-puna* region. It is characterised by multiple deposits of Pb-Zn-Ag, copper, gold, Au-Ag, U-Cu and iron. The western section of the belt comprises Pb-Zn-Ag and copper polymetallic veins, Au-Ag epithermal and gold porphyry deposits embedded in volcanic rocks. To the south, there is the Maricunga belt, an important auriferous district that contains Au and Ag deposits in veins, disseminations, mantles, and auriferous porphyries (e.g. San Pedro de Cachiyuyo, Cerro Casale). The eastern section of the belt is relatively poor in gold and silver deposits (Zappettini et al., 2001).

d) The Precordilleran Copper Province covers south Peru and the desert central valleys of Chile. The main deposits are mega-porphyry systems of Cu-Mo, with gold and silver as subproduct. Associated to these ores, in the Peruvian mountains, there are vein deposits of copper and gold (e.g. Nazca-Ocoña belt), while in the Chilean part of this belt, there are important gold, gold-copper and silver epithermal vein deposits. In addition, but of less importance, there are breccia pipes of copper and gold ores, and auriferous breccia bodies (Zappettini et al., 2001).

e) The Coastal Cordillera Copper Belt, located next to the Pacific coast, comprises a large number of metallic deposits, mainly copper ores, and in smaller scale copper and gold veins and a few silver deposits (Boric et al., 1990).

2.2.2.1 Gold sources

Gold (Au) as an element is relatively rare in the Earth's mantle, with a concentration of ~1.3 ppb and it goes up to a ~1 and 100 ppm in modern mineable deposits, or higher in bonanza deposits (Hough et al., 2009; Walshe & Cleverley, 2009). Given its resistance to corrosion, it is present in nature mostly as polycrystalline particles, grains or nuggets of native gold (Spiridonov & Yanakieva, 2009).

Gold as a metal is inert, soft, it has a high melting point of 1,064°C, and a density of 19.3 g/cm^3. It is highly malleable and ductile; and a good conductor (Hough et al., 2009; Morteani, 1995; Raub, 1995; Spiridonov & Yanakieva, 2009). Gold hardness is 2.5 in Mohs scale, and it reaches its hardest levels when alloyed: 65%Au-35%Ag or 75%Au-25%Cu (Petersen, 1970). Its occurence as native metal and its physical and mechanical properties, makes gold relatively easy to process and work, i.e. grains can be shaped directly by hammering or it can be melted to produce an ingot, but there is no need of smelting.

Gold deposits are formed by two main processes, producing a) primary or b) secondary gold. a) Primary or hypogene gold has been deposited as a result of the boiling and cooling of high-hydrothermal fluids, deep in the Earth's crust or by meteoric waters heated at shallow levels (Hough et al., 2009; Morteani, 1995). They form the most commonly mined deposits: ore bodies, called veins or primary deposits, and accumulations derived from the weathering of these ores, called placers or secondary deposits. b) Secondary or supergene gold is gold re-deposited in the surface or weathering environment from a solution. This type of gold is nearly pure (<1% of impurities) and very fine grained, being invisible at naked eye; however, depending on the geology, environment and climate, they can form mineable ores (e.g. Australia; Guerra & Rehren, 2009; Hough et al., 2009).

The gold present in the SCA is mainly primary gold (type "a" above), and depending on the environment and depth of deposition, deposits can be subdivided in three (Figure 6): deep-seated deposits, shallow or epithermal deposits, and placers or paleoplacers (Marsden & House, 2006; Oyarzún, 1992).

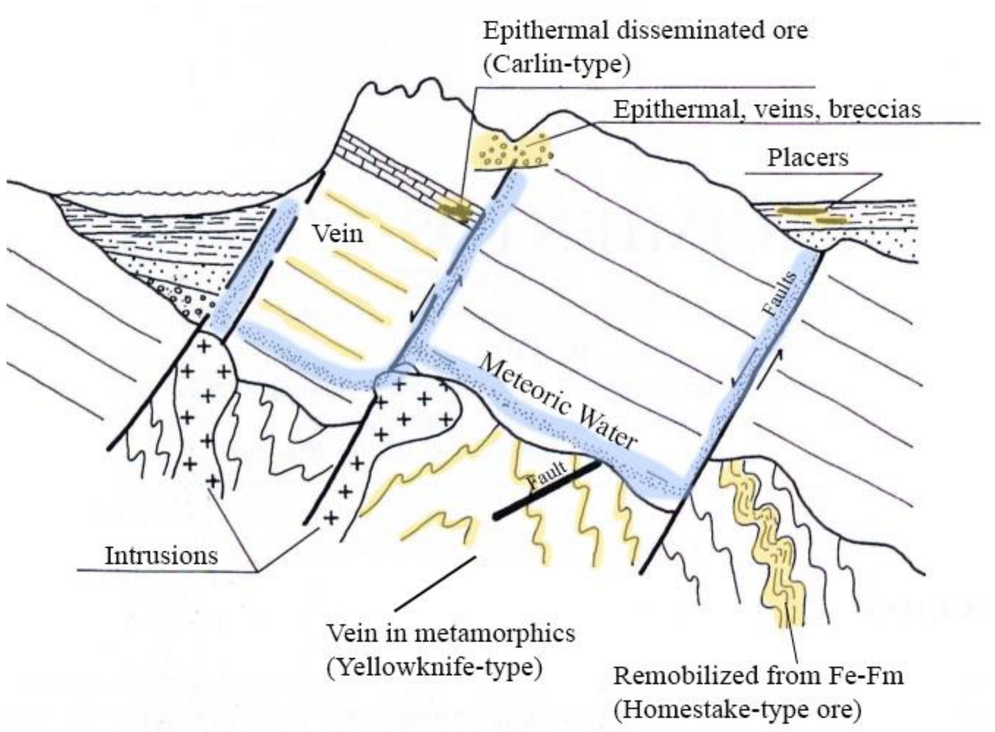


Figure 6: Diagram showing the geological setting for different types of gold deposits (modified from Oyarzún, 1992, fig. 1)

Deep-seated deposits are located beyond 1km from the surface, in form of auriferous veins and stratabound, related to metamorphic and hydrothermal phenomena (Marsden & House, 2006; Oyarzún, 1992; Sillitoe, 1973). They are associated to minerals such as quartz, carbonates, and iron (pyrite, arsenopyrite, pyrrhotite), zinc (spharelite) and antimony (antimonite) sulphides. In some cases, they form porphyry deposits where gold is a subproduct (main ores are Cu and Cu-Mo) which is mixed with the minerals in minute inclusions (Marsden & House, 2006; Oyarzún, 1992; Robert et al., 1997). According to Morteani (1995:107), this type of deposits are bulk open-cast deposits, which are mineable only using heavy mining equipment and advanced mineral preparation techniques. It is likely then, that these deposits were not used in the past.

Shallow or epithermal deposits include a series of mineralisations located between the surface and 1km depth. They are composed of gold, silver or a transition between both and base metals (such as Cu, As, Sb, Hg, Pb, Zn). They form veins, stockworks, disseminations and replacements. These deposits are formed by filling cracks, gaps and openings in the bedrocks (Figure 7; Oyarzún, 1992). Exposed deposits of this type, called primary deposits, were potentially accessible and mined in the past (Eerkens et al., 2008; Stöllner, 2009; Stöllner et al., 2013).

Placers and paleoplacers (or secondary deposits) are the gold deposits of most importance in the past, being the easiest to exploit (Hough et al., 2009; Tylecote, 1987).

They form by the mechanical concentration of weathered gold from primary deposits. The specific type of placer is named depending on the weathering agent, i.e. if it was caused by water, wind, gravity, etc. The most common are alluvial placers, where gold is transported by water in rivers or small ravines, from where it is panned (Oyarzún, 1992).

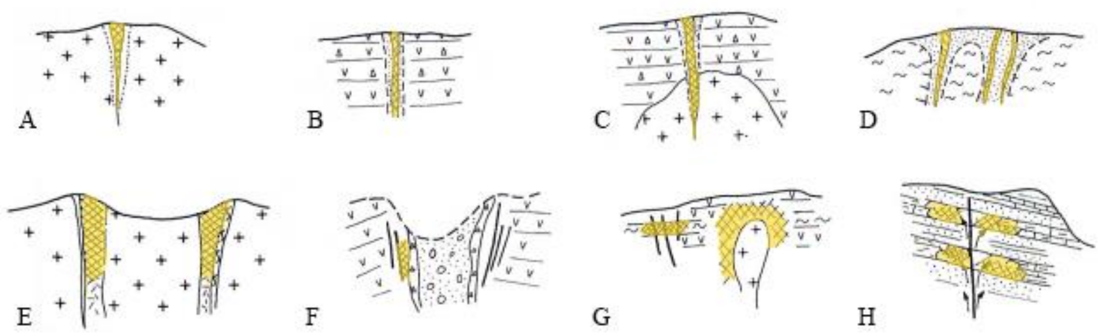


Figure 7: Examples of (A-F) veins and epithermal, (G) porphyry and (H) sedimentary deposits identified in Chile. Gold is shown in yellow (modified from Oyarzún, 1992, fig. 5).

In terms of composition, primary gold can contain a range of different impurities, depending on the fluid chemistry, temperature, depth of deposition and geology of the area. Most commonly gold is alloyed with silver (<40%), minor amounts of copper (<1%) and iron (<5%; Guerra & Calligaro, 2004). It may also be associated to platinoids, Hg, Pb, Sn, Sb, Bi and As depending on the local geology (Hough et al., 2009; Spiridonov & Yanakieva, 2009; Townley et al., 2003).

A map of the different gold deposits in the SCA is given in Figure 8. Note that the deposits are organised in belts from N-S, being part of different metallogenic provinces. Most placers and paleoplacers, together with their primary deposits (Figure 9:B) are in the eastern section of the Andes, corresponding to Eastern Polymetallic Province (a) and the Eastern *Cordillera* Tin Province (b). Gold from these areas can be associated to Sb, Sn, Zn and in lesser degree to Bi and Ni ores, especially those deposits located in b. Interestingly, placer deposits grouped in two areas: at the north of the SCA, i.e., east of the Titicaca basin (Peru and Bolivia) and the Cordillera Real of Bolivia; and at the south, i.e., Argentinean *puna* and southern Altiplano (Bolivia).

Towards the west, conditions change. Gold deposits appear less abundant in the Altiplano Polymetallic Province (c), reappearing in greater numbers in the Precordillera (d) and Coastal Cordillera (e) Copper provinces (Figure 9:C). In this area, gold and silver are present in primary deposits that were exposed to oxidation and erosion by uplifting and faulting events, producing important secondary enrichments on the surface. In this context, many gold deposits formed by the migration of gold towards the surface, caused by chemical and physical leaching of sulphides and gangue, enriching the ores near the surface. The extreme aridity of the region and its low weathering processes (therefore, no placers were formed) were key to preserve these oxidised zones (Boric et al., 1990). Gold deposits in belts (d-e) are closely associated to copper minerals, which contrasts with primary deposits in the eastern provinces (a-b).

According to the metallogenic maps, there are not gold deposits in SPA proximities. The nearest primary deposits are about 120km to the west and 140km to the south (Cerro de Puquios); whereas placer deposits are found at 240km to the east. However, these are modern maps identifying existent economically viable deposits, therefore it cannot be ruled out the possibility that smaller or exhausted old deposits existed in the past.

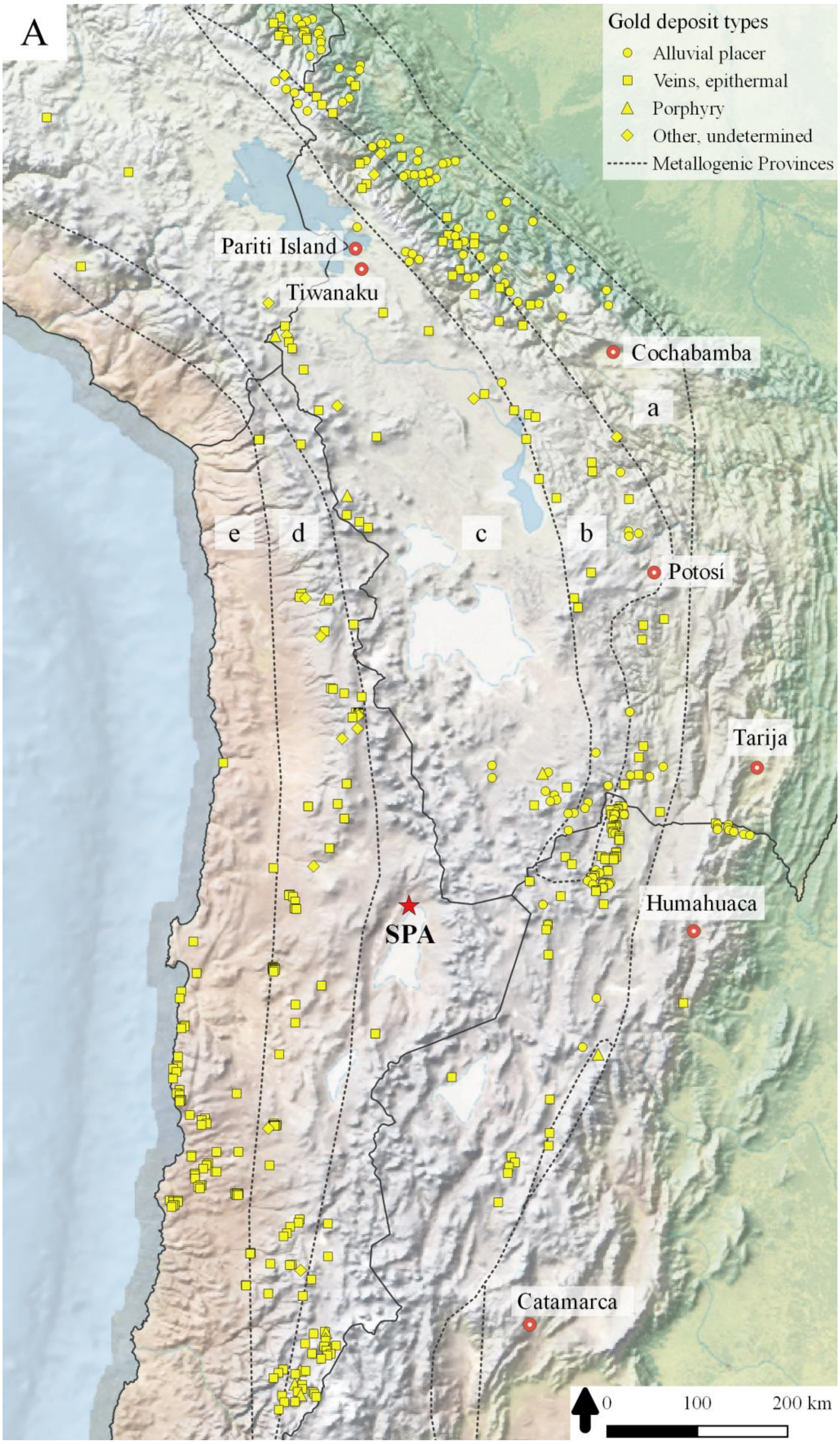


Figure 8: Gold deposits form the Central Andes. Metallogenic provinces (a-e) are specified in Figure 5. (After Boric et al., 1990; González, 2004d; Rubiolo, 2003; Zappettini et al., 2001).

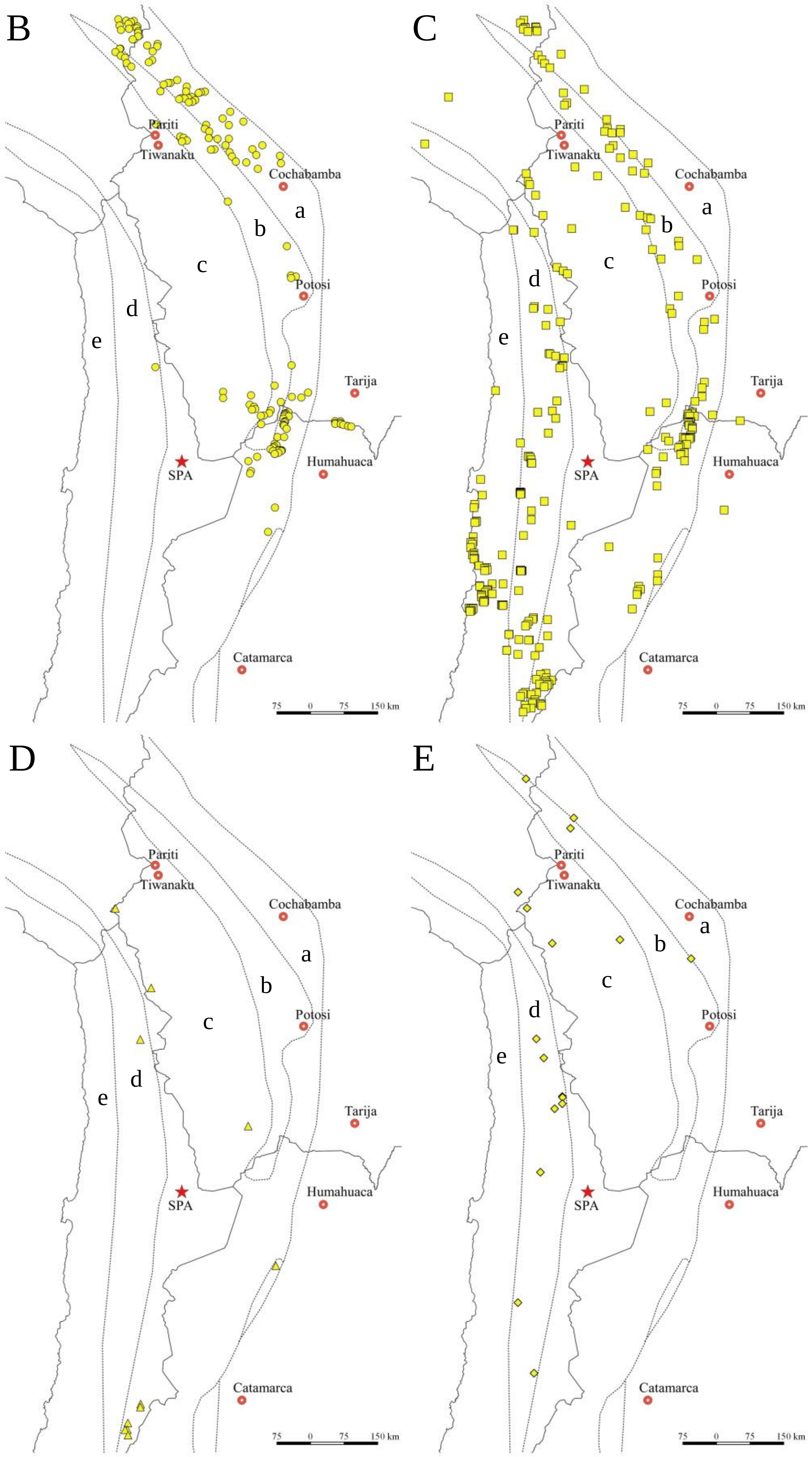


Figure 9: Distribution of gold type deposits (detail of Figure 8): B- Placer deposits, C- Veins and epithermal deposits, D- Porphyry deposits and E- Undetermined or other type of deposits.

2.2.2.2 Native silver and silver mineral sources

Silver (Ag) as an element is present in the Earth's mantle in 0.1ppm, being comparatively more abundant than gold, but still rare. In nature, silver appears as native silver, numerous silver minerals and as a relatively minor component of several complex minerals (Boyle, 1968).

As a metal, silver is soft, malleable, white and shiny; its melting point is 961.78ºC with a density of 10.49 g/cm^3. It exhibits the highest electrical and thermal conductivity of all metals. In the metallic state it is unaffected by water or oxygen, but it reacts with ozone gas or sulphur, forming a black layer of AgO or Ag_2S, respectively (Boyle, 1968). Still, corrosive solutions with salts or sulphurs can attack the metal resulting in its corrosion (La Niece & Meeks, 2000; Lechtman, 1973).

Compared to gold, native silver deposits are rare and more difficult to find, therefore most silver is obtained by reducing silver minerals or complex silver-bearing minerals (Boyle, 1968; Martínez-Frías, 1992; Tylecote, 1987, 1992). The extraction of silver in antiquity and today depends directly on the type of ores exploited and its components, as discussed below (Patterson, 1971; Tylecote, 1987). Silver minerals usually form in complex ores associated to other metals, where the most important are Pb, Cu and Zn; followed by Au, Co, U, Sb, and Bi. Based on their reduction process, silver minerals can be grouped in three: 1) *native metals*, 2) "*dry ores*" or *secondary minerals* such as halides and basic sulphide minerals, and 3) *complex or primary minerals* such as sulphides, sulfosalts, selenides, tellurides, antimonides, amongst others (Boyle, 1968; Martínez-Frías, 1992; Meyers, 2003). In general, all these ores can form in the same mineral deposits by hydrothermal processes, but they occur at different depths (Patterson, 1971; Zappettini et al., 2001). Table 2 summarises the main silver minerals.

Native metals include a) native silver and b) gold-silver alloys (e.g. electrum). Native silver is found in relation to many types of deposits. It usually forms in the oxidise zone section of the mantle (Figure 10:c), just above the phreatic zone as result of the oxidation and chemical leaching of silver sulphides or sulfosalts from supergene deposits (Boyle, 1968; Murillo-Barroso, 2013; Patterson, 1971). In the enriched zone (Figure 10:d) silver can be enriched with elements such as S, As, Hg or Sb, producing different varieties of silver (e.g. arquelite (Ag-Hg) or rubi silver (Ag-As); Murillo-Barroso, 2013). Native silver, therefore, is formed in relatively deep areas of the ground, which is why it is more difficult to find, and less accessible than gold. However, there are different processes, such as faults or *per ascensum* processes, which can expose silver-bearing veins or native silver outcrops (Murillo-Barroso, 2013; Patterson, 1971; Rehren, 2011).

Group	Type	Mineral	Formula
Native metals		Native silver	Ag
		Electrum (gold-silver alloys)	(Au,Ag)
		Arquelite (amalgam)	(Ag,Hg)
Dry minerals	Halides	Chlorargyrite/cerargyrite	AgCl
		Embolite/bromian chlorargyrite	Ag(Cl,Br)
		Bromirite	AgBr
		Iodargyrite	AgI
	Sulphides	Acanthite	Ag_2S
		Argentite	Ag_2S
Complex minerals	Carbonates	*Cerussite*	*(Pb,Ag)CO_3*
	Pb ores	*Argentiferous galena*	*AgPbS*
		Diaphorite	$Ag_3Pb_2Sb_8S_8$
		Fizelyite	$Ag_2Pb_5Sb_8S_{18}$
		Freieslebenite	$AgPbSbS_3$
	Sulphides, sulfoslats, selenides, tellurides, argentiferous copper	*Andorite*	$AgPbSb_3S_6$
		Miargyrite	$AgSbS_2$
		Pyrargyrite	Ag_3SbS_3
		Stephanite	Ag_5SbS_4
		Polybasite	$(Ag,Cu)_{16}Sb_2S_{11}$
		Proustite or ruby silver	Ag_3AsS_3
		Pearceite	$(Ag,Cu)_{16}As_2S_{11}$
		Naumannite	Ag_2Se
		Sylvanite	$(Au,Ag)_2Te_4$
		Hessite	Ag_2Te
		Petzite	Ag_3AuTe_2
		Matildite	$AgBiS_2$
		Stromeyerite	AgCuS
		Freibergite (Argentifeous copper/ argentian thetrahedrite)	$(Cu,Fe,Ag)_{12}(As,Sb)_4S_{13}$
		Argentojarosite	$AgFe_3(SO_4)_2(OH)_6$

Table 2: Silver minerals.
(After Boric et al., 1990; Boyle, 1968; Martínez-Frías, 1992; Murillo-Barroso, 2013; Ulriksen, 1990; Zappettini et al., 2001).

Native silver crystallises as cubes or octahedral specimens, wiry or arborescent forms, irregular masses, scales or spangles (Boyle, 1968). Technically speaking, native silver is easy to process; it only needs to be collected, melted and cast, leaving little archaeological evidence of its production (Rehren, 2011). In terms of composition, native silver is relatively pure (99%Ag), but it can contain traces of other elements such as As, Sb, Cu, Hg, Bi, Fe, Zn, Pb, Co, Ni, Te, Au, Pt and Ir (Boyle, 1968; Patterson, 1971; Pernicka, 1987). Furthermore, during its collection inclusions of other silver minerals found in the same deposits (e.g. dry minerals, see below) can be collected as well, entering the alloy as impurities (Patterson, 1971).

Another common silver source is native gold. Because silver and gold share the same atomic radius, both metals are completely soluble in each other producing a continuum of gold→ argentian gold (electrum, at 20%Ag)→ aurian silver→ silver (Boyle, 1968). Any of these combinations can be potentially found in nature, although not all are common.

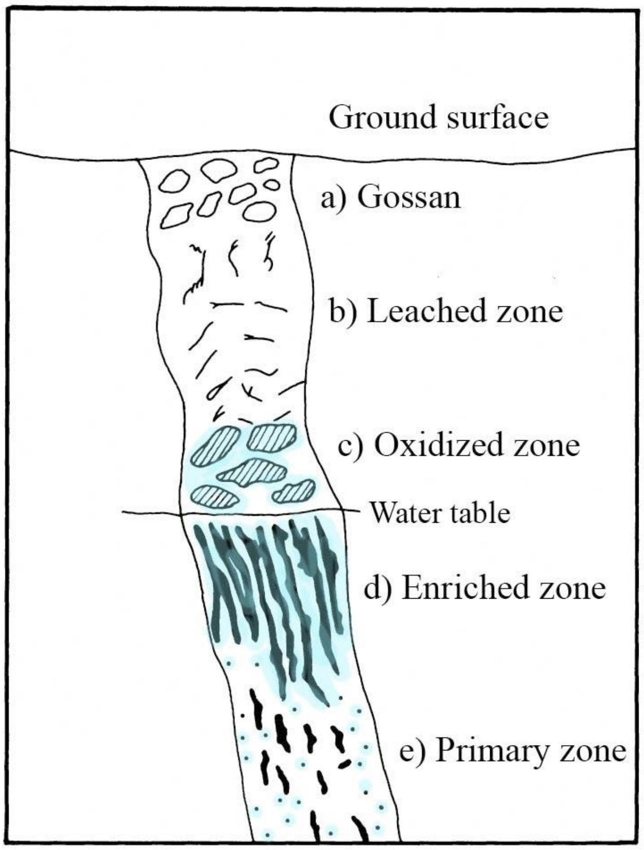


Figure 10: Idealised cross section of an ore vein.
The upper section is weathered (Modified after Patterson, 1971, fig. 2). Silver is shown in light-blue.

Dry ores, as defined by Meyers (2003), are secondary silver minerals that can be directly smelted, also leaving limited evidence of production (Meyers, 2003; Tylecote, 1987). They include a) halides such as chlorargyrite (AgCl), bromargyrite (AgBr) and iodargyrite (AgI); and b) simple sulphides as argentite or acanthite (Ag_2S). a) Halides are monovalent compounds, usually found as minerals in arid environments. The most common is chlorargyrite. They are photosensitive, insoluble in water, but soluble in complex reagents. b) Argentite or acanthite are very common silver sulphides; especially acanthite, which is an important mineral frequently found in silver deposits. Both a) and b) occur as supergene minerals in the leached and oxidised zone (Figure 10:c) together with native silver (Boyle, 1968).

Complex minerals are a range of different silver and silver-bearing minerals including silver sulphides, sulfosalts, selenides, arsenides, atinomides, tellurides and argentiferous copper (Boyle, 1968; Martínez-Frías, 1992; Murillo-Barroso, 2013). These are primary minerals formed deep in the crust, in the primary zone of the deposits (Figure 10:e), many associated to lead or copper minerals.

Lead and silver, as silver and gold, are soluble in each other, even in their mineral form resulting in that many silver ores are intergrown with lead minerals (Boyle, 1968), such as the argentiferous galena (Ag)PbS. Still, in complex minerals, silver occurs as small amounts dispersed throughout the ore, making it difficult to extract (Rehren, 2011). Given silver affinity with lead, lead is employed to collect the silver from the ores by cupellation; a sophisticated method to extract and refine silver that follows a series of steps including roasting-oxidising-reducing-oxidising the ores (Meyers, 2003; Murillo-Barroso, 2013; Murillo-Barroso et al., 2014; Patterson, 1971; Rehren, 2011; Tylecote, 1987, 1992). This process uses the lead naturally contained in the ores; however, if ores are lead-poor or do not contain lead - such as argentiferous copper - lead has to be added (Rehren, 2011).

According to the metallogenic maps, silver deposits are very common in the Central and South Central Andes. Figure 11 shows their abundance and indicates in light-blue those deposits containing native silver and relatively easy to smelt "dry ores". A few deposits are relatively near SPA at 90km and 130km to the west, 90km (Picados de Peine) to 160km to the south and 130km to the east. As previously mentioned, these are modern deposits and it is still possible that smaller or exhausted deposits (especially of native silver and dry ores) were mined in the past, but are not represented in the map.

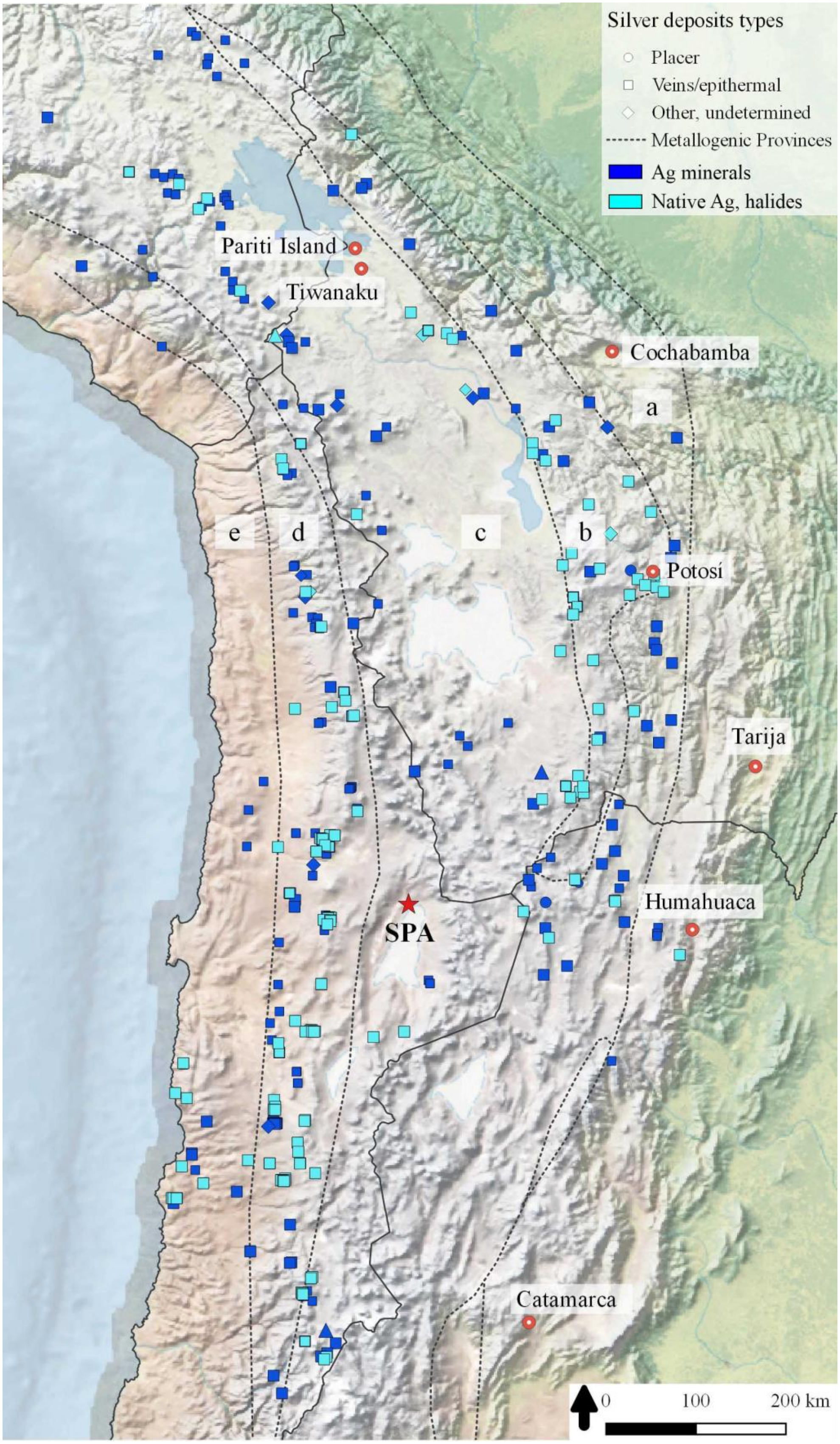


Figure 11: Silver deposits of the Central Andes. Metallogenic provinces (a-e) are specified in Figure 5. Deposits containing native silver and silver "dry ores" (halides and simple sulphides) are highlighted in light-blue (After Boric et al., 1990; González, 2004d; Rubiolo, 2003; Zappettini et al., 2001).

2.3 San Pedro de Atacama archaeological background

Regarding SPA archaeology, it is important to be aware that SPA prehistory is built, primarily, on funerary evidence; whereas only a few domestic settlements have been studied (Agüero, 2005; Llagostera & Costa-Junqueira, 1999; Stovel & Echenique, 2015). Therefore, the vast majority of objects recovered since 1950 are bodies, grave goods and offerings associated to mortuary contexts, which provide valuable information about the individuals buried (e.g. demography, health or diet), technology and chronology (Berenguer, 1994), but alone, cannot provide full insight on the domestic life of SPA society (Shimada et al., 2000). This information gap is widely acknowledged by the researchers working in the area (Castro et al., 2016; Salazar et al., 2014; Stovel & Echenique, 2015 and more).

It is also acknowledged here that funerary contexts and mortuary rituals can be intentionally used and manipulated to express ideology and ritualised aspects of culture (Berenguer, 1994; Parker Pearson, 2000; Renfrew, 1986, p. 144). This reality generates a risk then, inherent to much archaeology, in drawing inferences about the living from materials associated to the dead, because they may reflect discourses especially produced for those contexts. In this case, to examine whether artefacts were used in life or were especially made for the burial, would be of great help in identifying relevant aspects of these rituals and their significance.

2.3.1 Location and geography

Within the *Circumpuna*, the oasis of San Pedro de Atacama is located in the Atacama Salt Flat basin at the eastern limit of the Atacama Desert, in northern Chile (Figure 2:1). The modern town is 2,500 masl, between the confluence of the saltwater rivers San Pedro and Vilama (Figure 12). In a piedmont ecosystem, vegetation has little variability, occurring mainly as grasslands (where water is available) and local trees such as *algarrobo* and *chañar*, which were used for their pods and nuts, and as fuel (Appendix Nº2: 2). In nearby ravines, the areas protected from the harsh weather conditions were favourable for planting tubers and maize (Martínez, 1998).

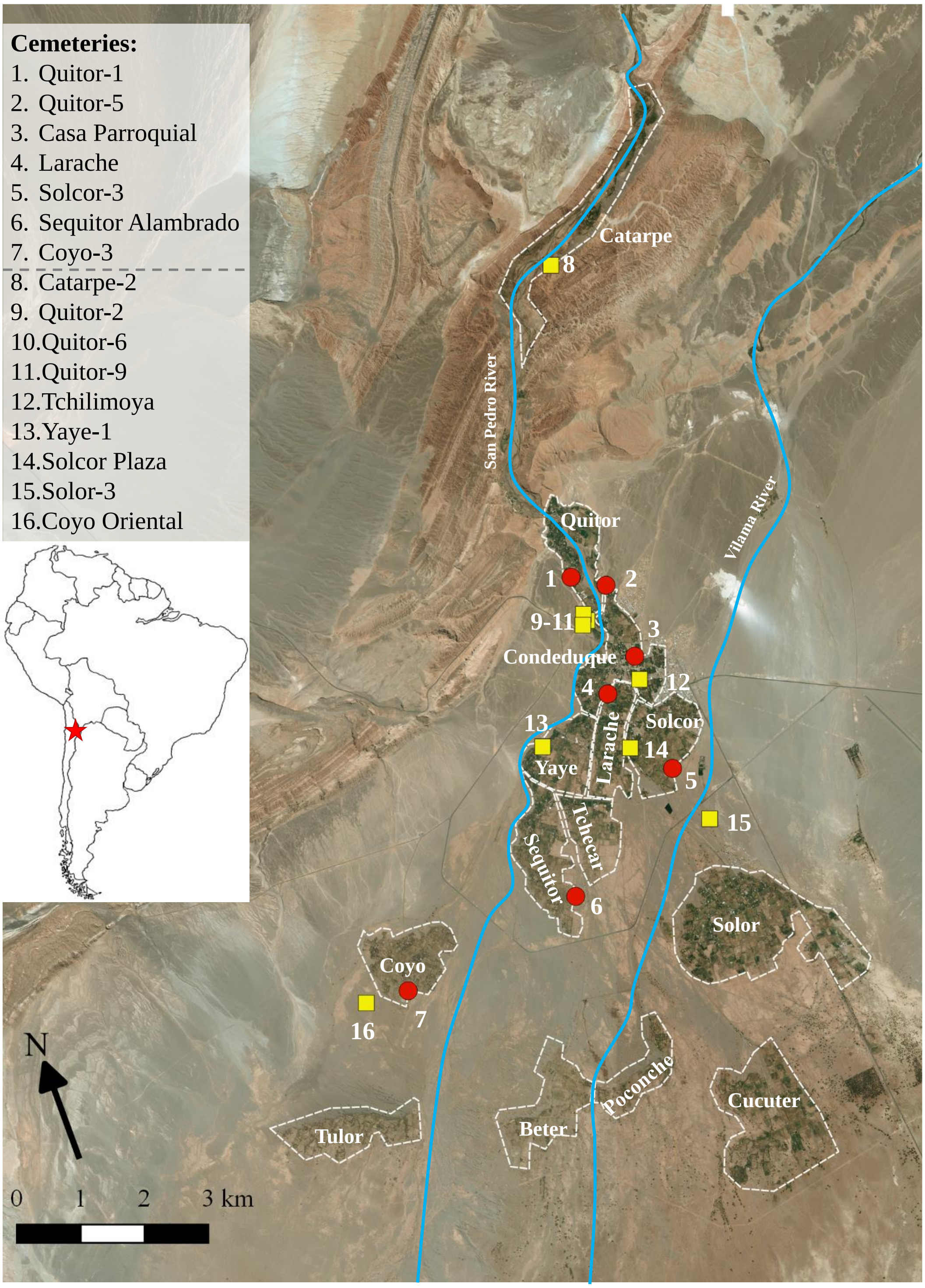


Figure 12: Map of San Pedro, the ayllus and cemeteries where noble metals are reported. Red circles indicate the cemeteries analysed in this thesis.

The Atacama Salt Flat basin borders at the northeast with the Salt Mountains or *"Cordillera de la Sal"*; to the west, with the Cordillera of Domeyko, which runs N-S for 600km; and to the east with the Andes mountain range, including two nearby active volcanoes: Licancabur (5,916 masl) and Lascar (5,592 masl.; Martínez, 1998; Pimentel, 1976). Ravines and other paths allowed people to cross through the mountains and volcanoes, facilitating communication and connection between SPA, and the northern valleys and ravines of NWA (Tarragó, 1984).

In terms of the economic geology of the area, around the Atacama Salt Flat there are metallic and non-metallic deposits of interest. Copper deposits are found in the San Bartolo mine, at 25km north from San Pedro, alongside the San Pedro River. In front of the Sequitor *ayllu* there is a secondary deposit of atacamite and malachite. In Picados de Peine and Cerro de Puquios (south of the basin) there are small veins of copper, gold and silver (Boric et al., 1990; Cifuentes, 2014; Pimentel, 1976). Deposits of common salt are found in the Salt Mountains, while sulphur is detected in the Andes Cordillera. Pumice and obsidian are abundant around the volcanoes (Pimentel, 1976).

2.3.2 The Late Formative Period (AD 100-400)

To understand the changes that occurred in San Pedro de Atacama during the Middle Period (AD 400-1000), it is necessary to characterise the SPA society, also called "San Pedro culture" at the end of the Late Formative Period ("LFP"; AD 100-400). During the LFP, SPA society consolidates a series of key economic, social and political changes occurred over a span of nearly 2,000 years (Castro et al., 2016).

The *San Pedrinos*[2] were a sedentary society, based on a village lifestyle. (Llagostera, 2004; Muñoz, 1989). The settlement pattern has been characterised as consisting of 14 distinct sectors, which are interpreted as being occupied by extended kinship units or *ayllus*[3] (Figure 12). These *ayllus* shared political, economic and ideological aspects; maintaining, however, some individual particularities (Llagostera, 2004; Salazar et al., 2014; Stovel, 2002). During the LFP, human occupation was concentrated in the southern *ayllus*, primarily Tulor and Coyo (Llagostera & Costa-Junqueira, 1999).

The San Pedrinos were agriculturalists, gatherers, *llama* and *alpaca* herdsmen and caravaners (Dillehay & Nuñez, 1988). They produced and used characteristic pottery, textiles, basketry, wooden, copper-based and stone artefacts (Llagostera, 2004). In particular, potters are known for their distinctive monochrome mortuary ceramic style that includes four types of wares: *Negro Pulido* (burnished black, see Appendix Nº2: 3),

[2] I will refer to the prehispanic culture from SPA as "San Pedro Culture" and its people as *"San Pedrinos*". They are also called *Atacameños*, but this concept mainly refers to colonial and modern population. Here I will use the archaeological term to avoid confusions.
[3] See full definition of this concept in the glossary, appendix Nº1.

Rojo Pulido (burnished red), *Gris Grueso Pulido* (burnished grey) and *Negro* and *Rojo Inciso* (incised black or red; Stovel, 2005; Tarragó, 1989).

Material evidence also indicates that mining and the use of metals were well established. Mining evidence dates back to the Early (1500-500 BC) and Middle Formative periods (500 BC-AD 100), appearing as raw mineral and beads in different burials and sites around the oasis (Castro et al., 2016; Núñez, 2006). Copper-based ornaments and tools are also common in this period. However, the absence of local metallurgical evidence points towards the Tarapaca region (e.g. Guatacondo site, Figure 2:87) or NWA as potential sources of these metals (Castro et al., 2016). Still, the tools found in SPA - chisels, awls, and small axes - coincide with finely-made wooden items, suggesting that copper tools were used in wood crafting (Castro et al., 2016).

Of particular interest is the use of gold ornaments during the Early Formative Period (1500-500 BC). These are not found in SPA itself, but in nearby areas such as Tulan or Calama. The most remarkable examples are the gold pendants found in the ceremonial site of Tulan-54 (Núñez et al., 2017) and Guatacondo (Horta, 2004; Núñez, 2006), both showing elaborate designs and high skill levels. Other examples are small pendants registered in Chorrillos cemetery, Calama (González & Westfall, 2010) and gold beads in Yona-2, a site between SPA and Tulan (Figure 2:9,88,89; see chapter 7, Figure 145).

People in SPA consumed tobacco and psycotropic substances using ceramic pipes that were locally made (Appendix Nº2: 4), although there was an increasing trend to replace pipes for wooden tubes and trays (Echeverría & Niemeyer, 2013; Gili et al., 2017). As an ethnic marker, from this period and onwards, San Pedrinos deformed their heads to give them an erect shape (Costa-Junqueira & Llagostera, 2014; Llagostera et al., 1988). Individuals were buried in graves dug directly into the soil, forming independent cemeteries within each *ayllu*. The bodies were flexed, deposited in sitting position, and were wrapped with textiles (Appendix Nº2: 5; Costa-Junqueira & Llagostera, 1994; Llagostera, 2004). Offerings included ceramic vessels, ornaments, textiles, baskets, weapons, tools and food. Some individuals were buried with copper minerals in their mouth (Llagostera, 2004).

In terms of social organisation, it is proposed that during this period, internal social differences start to appear (Costa-Junqueira & Llagostera, 2014; Llagostera et al., 1988; Llagostera, 2004, 2006b). Llagostera (2004) suggests that the figure of local male chiefs emerged, based on the richness of their graves in terms of variety and quantity of grave goods. However, because the difference between the “rich” and “poor” tombs is not pronounced, Llagostera argues that leaders earned their status based on their merits, experience and age; rather than by inheriting wealth and power (Costa-Junqueira & Llagostera, 2014; Llagostera et al., 1988; Llagostera, 2004, 2006b). Pipes and snuffing tablets, massive stone axes and maces would become the main leadership emblems of these male figures (Llagostera, 2006b).

During the Formative Period, long-distance traffic and mobility routes were developed in the *Circumpuna*, connecting SPA with areas such as the pacific coast, NWA and the Loa valleys (Figure 13; Dillehay & Nuñez, 1988; Korpisaari, 2006; Núñez, 1987, 2006). The presence of SPA pottery in those areas, as well as foreign objects and raw materials in SPA such as shells from the pacific, pottery from NWA, and minerals from Loa, indicates that these routes were used to complement the local resources, as well as to gain access to non-local items (Llagostera, 2004, 2006b; Muñoz, 1989; Núñez, 2006). However, towards the end of the Formative Period the presence of pottery and snuffing trays with early Tiwanaku iconography in SPA cemeteries suggests that these routes were expanding, reaching now the central *Altiplano* (Castro et al., 2016; Llagostera, 2004, 2006a).

2.3.3 The Middle Period (AD 400-1000)

The transition to the Middle Period is characterised by the appearance in most of the SCA of a variety of artefacts bearing an art style associated with Tiwanaku, thought to represent a shared religious iconography that developed in the circumtiticaca area (Berenguer, 1998; Korpisaari, 2006). Tiwanaku influence was also present in SPA where a series of changes are observed.

During the MP, SPA reaches it maximum development and expansion in terms of traffic and mobility networks. This period is subdivided into two phases: Quitor (AD 400-700) and Coyo (AD 700-1000). During the Quitor Phase, there is a demographic increment that is reflected also in changes to the settlement pattern, as people moved to the centre of the oasis occupying Larache, Quitor, Solcor and Solor *ayllus*. During the Coyo Phase, the 14 *ayllus* were fully occupied (Castro et al., 2016; Llagostera & Costa-Junqueira, 1999).

Research on local craft indicates a continuity and increment in production, suggesting the presence of local specialists (Núñez, 1991). The *Negro Pulido* pottery achieves its highest technical and aesthetic expression, whereas beads, snuffing implements, textiles and baskets developed particular local styles (Appendix Nº2: 6-11; Agüero, 2003; Carrión, 2015; Castro et al., 2016; Núñez, 1991; Salazar et al., 2014; Stovel, 2005). There is evidence of copper metallurgy (prills, ingots, slag), specifically working unalloyed copper to produce axes, maces, chisels and burins (Appendix Nº2: 12), but there is no evidence of noble metal working (Cifuentes et al., 2018). People continued to modify their heads with a tabular erect shape (Appendix Nº2: 13). In this period, pipes completely disappear, and snuffing tubes and trays proliferate (Castro et al., 2016; Horta, 2014).

Technological studies on local crafts suggests that production was probably decentralised and not controlled, since various sequences and techniques were used to manufacture beads, pottery and wooden trays; still, they followed explicit stylistic patterns achieving specific shapes and sizes in beads (Appendix Nº2:6; Carrión, 2015) and pottery (Appendix Nº2:3; Uribe et al., 2016), or iconographic patterns in wooden trays (Appendix Nº2:7; Horta, 2014). The studies above have not considered noble metals, having no information about the production of these items so far. It is noteworthy that individuals were buried with several toolkits, e.g. to weave, to make beads or wooden objects (assumed for the presence of copper tools used to carve them). Assuming that toolkits were deposited with their owners, it is likely that people were participating in more than one craft activity. Based on the above, authors propose that local crafts were used to define social identities at individual and community levels (Salazar et al., 2014).

Mining is consolidated and optimised in this period. According to Núñez, groups of miners exploited distant deposits within the region, possibly controlling some of them (Núñez, 2006; Núñez et al., 2003). Chuquicamata-2 is a mining site with these characteristics, where groups of San Pedrinos travelled 120km to extract atacamite, chrysocolla and azurite (Núñez et al., 2003). Further evidence is the "copper man", the mummy of a miner that died while extracting minerals in Chuquicamata (Calama), dated around AD 500. The male individual carried a complete mining set and the textiles he was using were of SPA style (Appendix Nº2: 14; Bird, 1978, 1979). Interestingly, individuals from cemetery Coyo-3 of SPA are the only ones that present pathologies related to mining activities (osteophytosis of the cervical vertebras) and were buried with mining hammerstones (Salazar et al., 2014).

Another major change in this period is an increase in the number of finished objects, raw materials and people from the Central *Altiplano* and other areas of the *Circumpuna*, evidencing the intense traffic and the extent that trade and mobility networks reached (Figure 13). The interaction with NWA[4], the Pacific coast, and southern *Altiplano* shows a continuity from the Formative Period; whereas the interaction with the central *Altiplano* - rarely seen in the LFP - and east valleys of Cochabamba flourishes, especially during the Coyo Phase when most Tiwanaku objects arrived to SPA (Appendix Nº2: 15-16; Castro et al., 2016; Llagostera, 2006b).

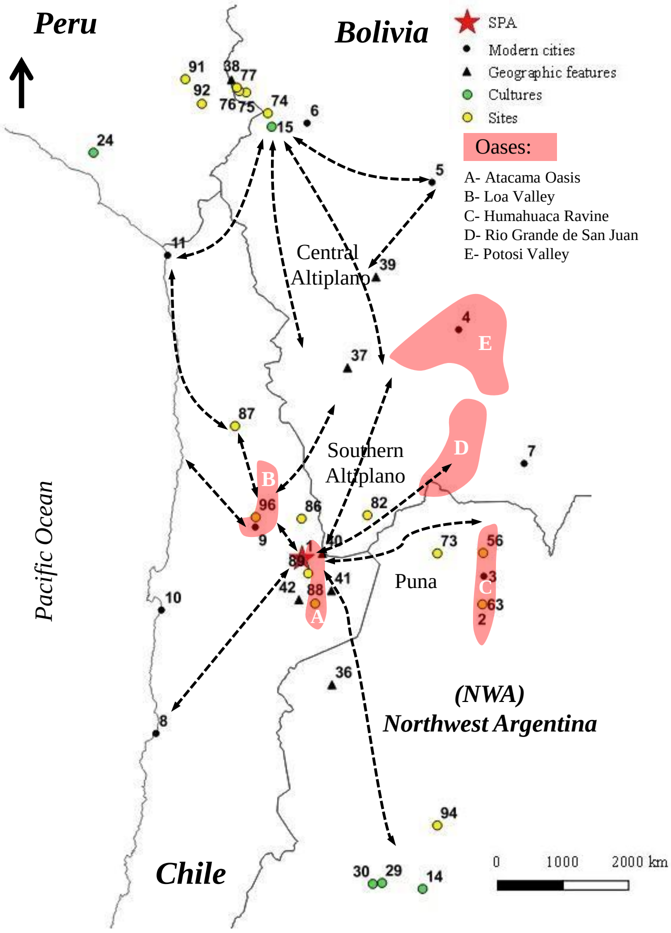


Figure 13: Map of the SCA showing proposed traffic and mobility routes (Modified after Nielsen, 2013; Lechtman et al., 2010, Llagostera, 1995). Legends are given in Table 1.

Non-local raw materials include turquoise, red and blue dyes, wood, cane, psychoactive substances, freshwater snails, tropical bird feathers, obsidian, *parina* eggs, and fish and shells from the Pacific. Finished objects comprised fine pottery, textiles, baskets, metallic, wooden and bone objects, many of them characterised as prestige items (Castro et al., 2016; Echeverría & Niemeyer, 2013; Llagostera, 2004; Niemeyer et al., 2013; Niemeyer & Agüero, 2015; Salazar et al., 2014).

Furthermore, bioarchaeological and biochemical data have identified individuals that were born and grew up their first years of life in NWA, the central *Altiplano* (Titicaca

[4] During the Middle Period, there are two pottery styles in the NWA that have been used to define communities living the area: Yavi style in the *puna* and La Isla style in Humahuaca, both styes are found in SPA.

and Poopo basins) and other unidentified foreign regions, but died in SPA. These people, however, are not the majority; of 173 individuals analysed, only 13% (n=22) showed non-local biochemical signatures (Cocilovo et al., 2011; Costa-Junqueira et al., 2009; Costa-Junqueira & Llagostera, 2014; Knudson, 2007; Knudson & Torres-Rouff, 2014; Torres-Rouff et al., 2013; 2015; Torres-Rouff & Knudson, 2007 and more). People and goods moved in varied ways: by specialised *llama* caravans, traders travelling by foot, or social visits including matrimony or political alliances, amongst others (Llagostera, 2006b; Martínez, 1998; Nielsen, 2006a, 2013).

The situation of this period shows a dynamic and complex social context with high levels of interaction with foreign polities, which was not exempt of tension and conflicts, as violence evidence shows (Torres-Rouff, 2011; Uribe et al., 2016). In this scenario, social differences and local leaders emerged, primarily seen in the quality and uneven distribution of non-local items, snuffing implements and leadership emblems such as axes and maces (Llagostera, 2004, 2006b). In particular, Salazar and colleagues propose that the influence of Tiwanaku was crucial in promoting the local elites, who were explicitly demonstrating their affiliation to Tiwanaku polity through the use of metals (2014; see also Tamblay, 2004). However, these claims are based mostly on copper-based objects and on stylistic observations that are inevitably skewed towards the more spectacular and stylistically recognisable Tiwanaku objects.

2.3.3.1 San Pedro de Atacama and Tiwanaku

The relationship between SPA and Tiwanaku has been extensively discussed (see Llagostera, 2006b; Salazar et al., 2014 and references within). Based on the presence of gold artefacts, pottery, snuffing trays and textiles with Tiwanaku iconography, some archaeologists have proposed that changes seen in SPA during the MP were caused by a direct contact between the Tiwanaku State and the San Pedro culture, including people from Lake Titicaca setting up colonies in SPA (Barón, 2004; Benavente et al., 1986; Tamblay, 2004; Thomas et al., 1985). Today, the accepted theory is that the relationship with Tiwanaku was indirect, i.e. rather than colonies or administrators coming from Tiwanaku, SPA remained independent and autonomous, and their contact was articulated by the dynamic trade routes mediated by communities from the southern Altiplano or other Tiwanaku centres such as Cochabamba (Berenguer et al., 1980; Castro et al., 2016; Dillehay & Nuñez, 1988; Llagostera, 2004, 2006b; Núñez, 2006; Salazar et al., 2014; Torres-Rouff et al., 2015; Uribe & Agüero, 2001 and more).

Thus, Tiwanaku objects appear in various *ayllus*, but their distribution and quantity indicates that most Tiwanaku objects appear as "intrusive" elements within local burial patterns (Llagostera, 2006b; Stovel, 2001; Uribe & Agüero, 2001). The study of other non-local pottery styles shows similar patterns: they appear as unique items in burials of local characteristics. Based on this, Stovel proposes that foreign materials were indeed a relevant part of the local burial ritual, but that they did not necessarily represent foreign people (2001, p. 389). Llagostera and others also note that neither Tiwanaku nor other non-local styles influenced local pottery (or any other craft) production in SPA, i.e., there was never a hybrid SPA-Tiwanaku pottery style, evidencing the relative autonomy of SPA community (Llagostera, 2006b; Stovel, 2008, 2005; Tarragó, 1989; Uribe et al., 2016).

Still, Salazar and colleagues (2014) claim that the influence of Tiwanaku polity cannot be underestimated. Firstly, because it is during its period of influence that SPA flourished; and secondly, because the metals buried with the local elites - which in the Andes are highly symbolic elements - are mostly arriving from the central *Altiplano*. Elemental and lead isotopes analyses on nearly 50 copper-based artefacts have identified in 45% of them a ternary alloy copper-arsenic-nickel characteristic of Tiwanaku, whereas a 30% was tin-bronze, either from Tiwanaku or NWA (Lechtman, 1991b, 1996, 1998; Lechtman & Macfarlane, 2005, 2006; Macfarlane & Lechtman, 2016; Maldonado et al., 2010, 2013; Salazar et al., 2014); only 25% was made of unalloyed copper, representing local production (Cifuentes et al., 2018).

Therefore, about 75% of copper-based items used by high ranked individuals are non-local, possibly from the central *Altiplano*. The same is assumed for gold and silver items, which are thought to be imported from Tiwanaku (Salazar et al., 2014). However, Stovel warns that relating noble metals to Tiwanaku is premature, especially considering that a) some items are stylistically different from their Tiwanaku counterparts and b) noble metals were also produced in other areas of the *Circumpuna*, such as NWA and the southern *Altiplano*, which have maintained long-lasting relationships with SPA (Stovel, 2001; Torres-Rouff et al., 2015). Consequently, it is necessary to study noble metal objects systematically in order to clarify these connections – a major aim of this thesis.

2.3.3.2 Elites in San Pedro de Atacama

It has been proposed that SPA social organisation was divided in four main levels, based on the access to metal objects (Salazar et al., 2014, p. 146): 1) elite burials associated to gold and silver artefacts, 2) lower ranked leaders, accessing to a few gold and silver objects, and copper items, 3) people accessing to copper only, and the 4) the rest of the population with no access to metals. The role of the leaders would include ritual and political functions, based on the association of these individuals with snuffing implements (for ritual uses), maces and axes (as leadership emblems; Llagostera, 2006b; Salazar et al., 2014).

Nonetheless, the mechanism by which SPA people gained access to power and prestige objects - including gold and silver - remains unclear. Traditional theses suggest that social differences were possible thanks to the control certain individuals had over long-distance traffic routes and the objects that were being traded (Berenguer et al., 1980; Llagostera, 1996, 2006b; Núñez, 2006). However, studies on the Andean traffic and mobility systems indicate that is virtually impossible to control traffic. Firstly, because people moved freely. Secondly, SPA and other communities of the *Circumpuna* were primarily herders, therefore there were *llamas* everywhere, promoting seasonal movements between areas of the *puna* to feed the animals, and also provided the necessary pack animals to travel. Thirdly, paths and crossing routes were ubiquitous; and fourthly, there is no archaeological evidence that routes were controlled in any way during this period; on the contrary, material evidence shows that routes were used by different communities simultaneously (Nielsen, 2006a, 2007, 2013).

All in all, it seems that controlling the movement of goods was improbable, and thus more research is required to provide more convincing mechanisms whereby local individuals or groups gained access to prestige items. Still, Llagostera (1996) and Nielsen (2007) recognise that certain items moved in more restricted spheres, including gold and silver items, snuffing paraphernalia, axes, maces or fine textiles. Nielsen argues that given the difficulty of controlling the circulation of goods, the reason of the differential access to these items should be sought within the social sphere, which is probably dictating the cultural parameters of who, how and when it was appropriate to use these items (2007). Characterising the individuals buried with noble metals in SPA, and exploring the life-histories of the objects themselves to learn about the ways in which these materials were used, is another major aim of this thesis that will offer a contribution to this discussion.

2.3.4 Gold and silver during the Middle Period

Compared to the Formative Period, the amount of metals reported during the MP is much higher, and amongst them, the number of gold and silver artefacts stands out not only within SPA, but at regional level. As an indication, out of nearly 900 metallic objects[5] stored in the Museo R.P. Gustavo Le Paige, ~700 (78%) were found in cemeteries dated to the MP (Cifuentes et al., 2018).

Of those ~700, 48% (n=335) are gold (177, 26%) and silver (158, 23%) items. Gold and silver objects include ritual cups (e.g. *keros* and portrait-vessels), axes, headbands, bracelets, pectorals, beads, bells, pendants and rings, distributed in 16 cemeteries of SPA (Figure 12). In particular, Larache (Figure 14:A-E) and Casa Parroquial concentrate most of precious metals objects. Since their discovery, gold objects have been associated with Tiwanaku, mostly because of the *keros* and portrait-vessels of Tiwanaku style (Figure 14:A; Barón, 2004; Benavente et al., 1986; Le Paige, 1964; Salazar et al., 2014; Tamblay, 2004; Thomas et al., 1985). However, most of the assemblage consists of small and plain pendants, headbands and sheets, where the Tiwanaku attribution is not so straightforward

Despite their wide publicity, gold ornaments are actually rare during the MP. Even at the site of Tiwanaku gold artefacts are uncommon. At the site of Tiwanaku itself, the burials with the greatest amount of gold ornaments were found at the Kalasasaya temple (Figure 15), with three individuals sharing six tripartite diadems and nine pectoral-discs. The rest of the findings are usually isolated small gold sheets (Korpisaari, 2006, pp. 78, 87). In Lake Titicaca, another important gold assemblage is from Pariti Island, with 23 gold vessels (including some miniature vessels) and diadems in a single grave (Bennett, 1936), and ~30 decorated pendants recently recovered from the islands of the Sun, the Moon and Khoa (Christophe Delaere, *pers. comm.* 2016). From Cochabamba, the San Sebastian treasure stands out (Figure 2 and Figure 15), made of nearly 650 gold objects (590 are small pendants, stitched to clothes), all associated to one individual (Korpisaari, 2006; Money, 1991). In NWA, Tarragó and colleagues (2010) describe two discoveries in the Humahuaca ravine: burial N°11 with approximately 25 gold ornaments in La Isla de Tilcara (Figure 15); and nine gold objects from Pueblo Viejo de la Cueva. Whereas in the *puna*, Rolandi reports two *keros* and other silver and copper-based ornaments in Doncellas River (however, the chronology of this find is uncertain; 1974).

[5] Including copper-based, gold, silver and "undefined" metals, see chapter 9 for details.

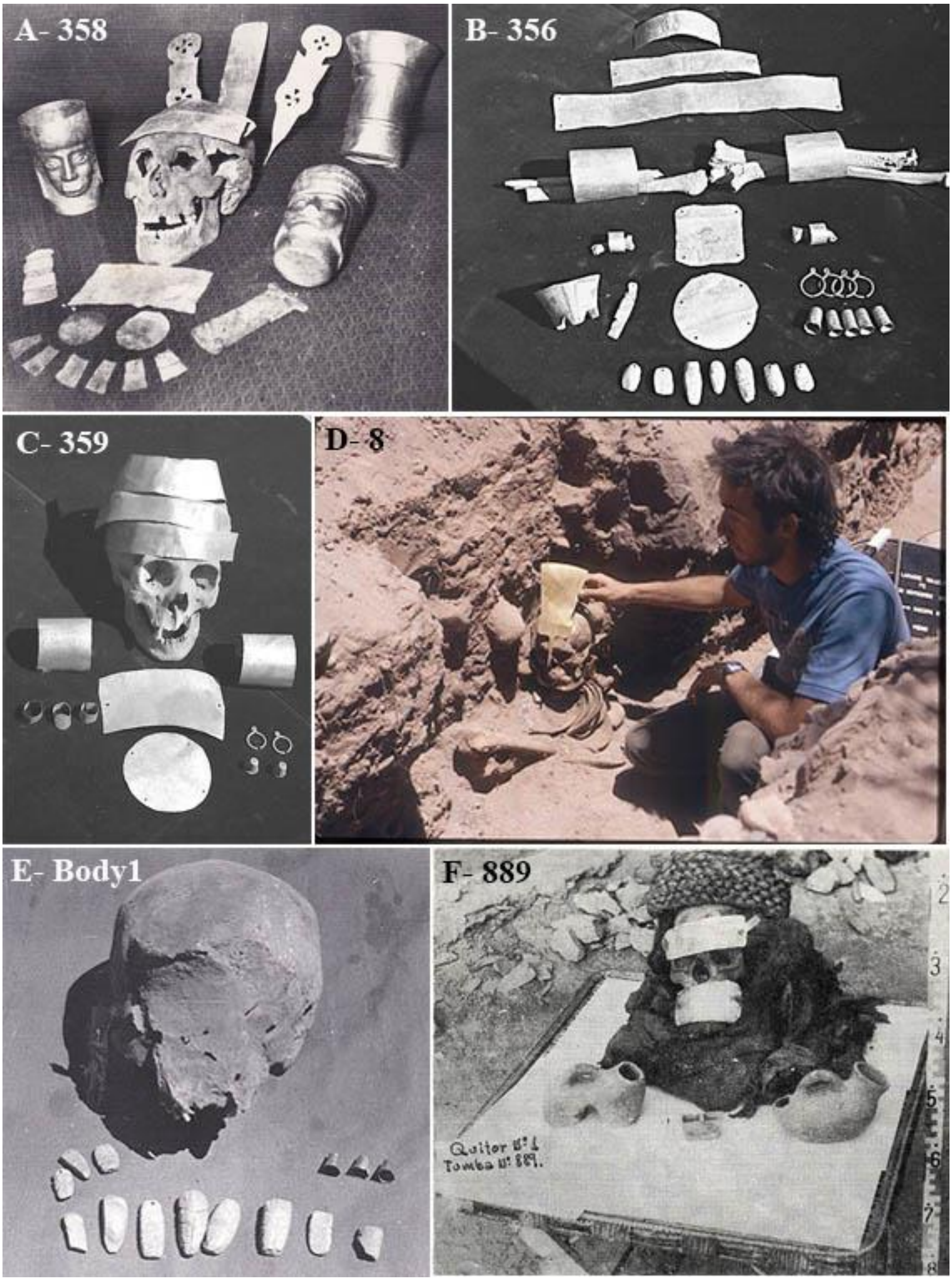


Figure 14: Gold and silver grave goods from SPA.
A-C,E- Larache Callejón, D- Larache rescate, F- Quitor-1. Note keros and portrait-vessels in A. Images: A-C after Le Paige, 1961, fig.7,15-16; E- Le Paige, 1964, fig.1; D- image courtesy of Ana María Barón, 2016; F- image courtesy of IIAM.

In general, gold finds are exceptional in the Bolivian *Altiplano* and NWA, and they usually are significant concentrations of artefacts in specific burials or offerings. Therefore, the presence of various cemeteries in SPA with several individuals bearing gold objects is very special and different from contemporary contexts in other areas of the SCA. However, a factor to consider in this panorama - especially in the case of gold - is the frequent looting of burials and theft of these valuable items, initiated in colonial times and which continues these days. Thus, it is likely that the amount of gold objects was originally much larger, both in SPA and at a regional level.

Figure 15: Gold ornaments from Central Altiplano (top) and NWA (bottom). After Money, 1991, plate 24-25; Tarragó et al. 2010, fig.5-8.

As Stovel already noted (2001), gold artefacts from SPA look different than Tiwanaku items (compare Figure 14-15). In general, ornaments found in the Tiwanaku area are fewer in number, but big and much more elaborate. They are embossed or engraved with Tiwanaku designs, known for their intricate images (Korpisaari, 2006, figs. 5.29-5.31). A similar decoration pattern is observed in the San Sebastian treasure (Money, 1991, figs. 24–25).

The gold ornaments from SPA, on the contrary, are small and simpler in design and most are undecorated, except for the portrait-vessels and the *keros* (Figure 14). The artefacts from SPA have stronger stylistic similarities to those reported by Tarragó and colleagues (2010) in La Isla de Tilacara (Figure 2:63 and Figure 15). Both assemblages, and particularly the diadems and pendants, have comparable shapes, are undecorated and used similar cutting patterns. The main difference is the presence of *keros* and portrait-vessels in SPA. Therefore, a connection with the *puna* may be responsible, at least in part, for the higher number of gold artefacts in SPA. Additionally, the *puna* is very rich in metal deposits: gold, silver, tin and copper (Angiorama, 2001), making possible that gold (either as raw material or finished objects) may have been circulating in this area. These preliminary observations challenge suggestions that claim that precious metals - as most bronze artefacts - were distributed and introduced into SPA by contact with Tiwanaku (Salazar et al., 2014, pp. 146–147), and also highlight the little knowledge we have about the assemblage of gold and silver objects deposited in SPA.

Figure 16: Examples of Aguada Culture bronze cast work, disc and axes. After Goretti, 2012, p.191,206-207.

Finally, in terms of technology, whereas gold and silver artefacts in the SCA and SPA are made of hammered sheets, copper industry was in a fast growing stage during the MP, both in the central *Altiplano* and NWA (Angiorama et al., 1999; González, 2004a, 2010; Lechtman, 2003a). Artisans were involved in the exploitation and processing of ore minerals not previously mined or smelted (see examples in Appendix Nº3: 1); and produced massive cast objects such as axes, discs, chisels, maces, knifes or cramps; as well as ornaments made of hammered sheets (Lechtman, 2003b, 2003a). The cast axes and disc attributed to Aguada Culture at Catamarca, central-NWA (Figure 16) are evidence of the sophisticated cast copper technology developed during the MP, which sets the stage for copper metallurgy in NWA and the SCA for the next centuries (González, 2004a).

2.3.5 The cemeteries

Although 16 cemeteries at SPA have reported gold or silver objects, the objects specifically studied in this thesis belong to seven cemeteries: Larache, Casa Parroquial, Quitor-1, Quitor-5, Sequitor Alambrado, Coyo-3, and Solcor-3 (Figure 12). Here, I provide a brief description and chronology (Figure 17) of these seven cemeteries, while in chapter 9 information will integrate all the precious metals reported from SPA. Overall, cemeteries vary in size, conservation conditions and periods of occupation. Images of the artefacts analysed in this thesis are given in Appendix Nº5.

The cemetery of **Larache,** also called *Larache Callejón* or *Callejón Real* (royal alley) is located in the *ayllu* of the same name, in a centric location within SPA (Figure 12:4). It was excavated by Le Paige in several occasions (1958, 1960, 1965, 1972; Le Paige ms), however it was in 1960, during the construction of an irrigation canal, that seven individuals with various gold grave goods were discovered, see Figure 14:A-C,E (Le Paige, 1961, 1964). Between 1960 and 1972, a total of 84 bodies have been reported in this site (Le Paige ms). In 1989 works related to the irrigation canal revealed 24 new bodies, which were recovered by Barón and Tablay in a excavation called *Larache Rescate* (Figure 14:D). On that occasion five individuals were associated to gold and silver ornaments (Barón, 2004; Tamblay, 2004). Between Larache Callejón and Larache Rescate, referred in this thesis together as "**Larache"**, 12 individuals were found, having ~120 gold and silver items in total. For this thesis I studied 62 items, associated to six individuals.

The only radiocarbon date of this cemetery is 2σ 250-534 Cal AD, obtained from *Larache Callejón*, individual 5056 recovered in 1972 (Hubbe et al., 2011). The date situates the cemetery between the LFP (AD 100-400) and Quitor phase (AD 400-700). Still, this date is provisional, given that is the only date of this site and is not directly related to individuals with gold or metals (Figure 17).

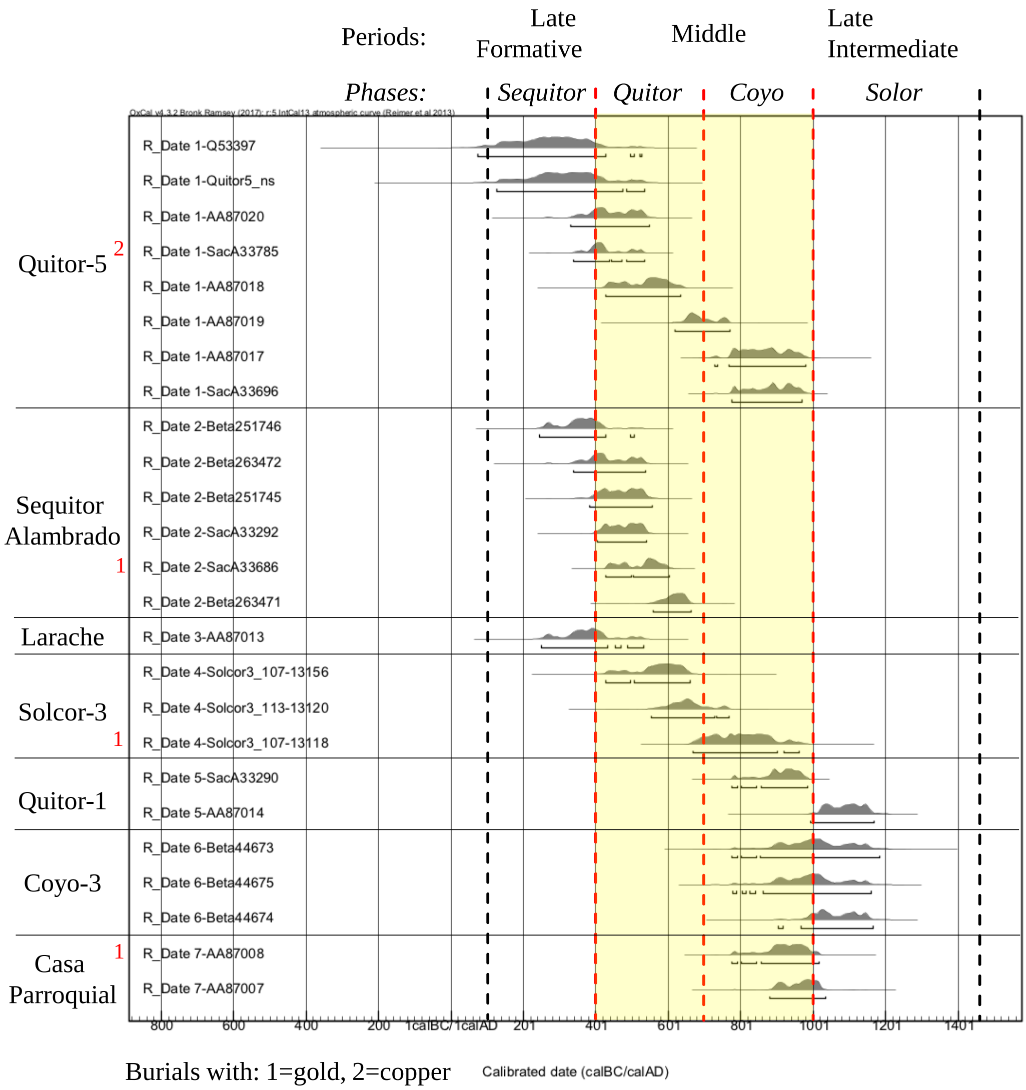


Figure 17: Re-calibrated radiocarbon dates using the programme OxCal version 4.3, date: 08/2018 (after Costa-Junqueira & Llagostera, 1994; Hubbe et al., 2011; Richardin et al., 2015; Stovel, 2013; Torres-Rouff, 2002). Numbers indicate burials with metals; full dates in Appendix Nº3: 12.

The cemetery of **Casa Parroquial** is located in the Condeduque *ayllu* (Figure 12:3), another central location within SPA. This cemetery was discovered in 1994, during construction works in the Parish House. The excavation, led by Téllez and Murphy (2007), involved a very small area of 2x3m, which revealed a section of a probably larger cemetery where 22 individuals were identified. Of these, 14 (64%) individuals contained a total of 49 noble metals grave goods. Silver was reported in 10 burials, however only one fragment out of 14 items was preserved, and the rest did not survive the excavation. Another 35 gold items were found in 10 burials, of which 34 will be analysed in this research. Calibrated radiocarbon dates (2σ) were obtained from burial 18, 777-1017 Cal AD, a male adult deposited with gold (two *keros*, an axe and three ornaments); and burial 6, 880-1035 Cal AD, placing the site and the use of gold within the Coyo Phase (AD 700-1000; Hubbe et al., 2011). Both Larache and Casa Parroquial are located in the core of the oasis where farming activities have been intense since prehistory, resulting in a very humid and disturbed terrain, and consequently a poor conservation of the organic material (e.g. textiles, wood).

From the Quitor *ayllu*, objects of two cemeteries will be analysed here: **Quitor-1** and **Quitor-5,** both having a few gold and silver items. Quitor-1 is located on a dry plateau at the west side of the San Pedro River bank, whereas Quitor-5 is located in the opposite side. Both cemeteries were located in dry and relatively peripheral areas, resulting in a fantastic preservation of the burials and their organic material. Of nearly 94 burials found in Quitor-1, only six have noble metals: 14 silver and 2 gold items are reported, 10 of them will be analysed here (Figure 14:F). Two radiocarbon dates of 777-986 and 995-1169 Cal AD situate the site at the end of the MP, in the Coyo and Solor (AD 1000-1430) phases; dated burials did not contain metals (Figure 17).

In Quitor-5, of 218 burials, only four graves contained gold items: 2 small plates and 3 wooden tablets with gold inlays (Le Paige, 1964); the two sheets are analysed here. Quitor-5 has eight calibrated radiocarbon dates ranging between AD 76-971, indicating a period of prolonged use; including the LFP (AD100-400) and the MP (AD 400-1000; Berenguer et al., 1986; Hubbe et al., 2011; Richardin et al., 2015). A wooden tablet in burial 2077-2089 associated with a copper mace and two bracelets, is the only date directly related to metals (340-535 Cal AD); neither of the four burials with gold are dated (Figure 17).

The cemetery **Sequitor Alambrado**, from the Sequitor *ayllu*, is divided in three areas: *Acequia* (canal), *Occidental* and *Oriental*; the three objects analysed here belong to Acequia sector. The cemetery has six radiocarbon dates (2σ) 245-663 Cal AD, situating the three sectors within the Quitor phase. Burial 1702, dated 428-604 Cal AD contained a gold sheet. From **Solcor-3**, there is only one gold item and it will be analysed here: a wooden tube wrapped in gold sheets. This cemetery is located in the border of Solcor *ayllu*, and was excavated in 1983 by Bravo and Llagostera (1986; Llagostera et al., 1988), who recovered 94 bodies. Solcor-3 has 17 dates: six TL, and 11 radiocarbon dates, only three calibrated. All dates situate the cemetery within the MP, including both Quitor and Coyo phases. The individual with the tube was dated 669-961 Cal AD, within the Coyo phase. The last cemetery is **Coyo-3**, located adjacent to Coyo *ayllu*. Of 51 burials excavated; five of them contained gold and silver items, all of them analysed in this thesis. Three calibrated dates, none associated to metals directly, place Coyo-3 at the end of the MP, between AD 777-1184 (Figure 17).

PART II

Theoretical framework and Methods

Chapter 3. Theoretical and conceptual framework

In this chapter, I will outline the different approaches and concepts used in this thesis to characterise ancient metallurgical technology and its consumption from the study of finished objects. I have divided them in two sections. In section 3.1 I introduce the *chaîne opératorie,* life-histories and deliberate fragmentation approaches to material culture, with particular reference to the study of archaeological metal artefacts. Section 3.2 explores in more detail a number of useful avenues used to identify individual artisans in archaeological contexts, and their potential to explore aspects such as the organisation of goldwork production. Although I am aware that there are more authors to be cite about these subjects, the aim of this section is to explain the key concepts employed in this thesis, thus an exhaustive review of the different theoretical approaches is not included.

3.1 *Chaîne opératoire* and life-histories

This research shares the perspectives that understand technology as *social phenomenon*, positing that when people make and use things, they are, at the same time, building and expressing their identities, as well as reproducing their culture (Dobres, 1999; Gosselain, 2000; Lechtman, 1977; Lemonnier, 1992; Martinón-Torres, 2002; Miller, 2007; Sillar & Tite, 2000 and others). Such approach consider technology as an *active system of interconnections,* or integrated webs (Dobres, 1999), *between the processes and practices related to the production, use and discard of the objects* (Miller, 2007, pp. 4–5). In other words, technologies – obviously including metallurgy – appear and develop in close relationship to their specific social and environmental contexts (Lechtman, 1977, 1978).

Importantly, there are several ways to make metallic artefacts, and the key to identify specific technological traditions is to analyse the *technological choices* used in each case, which are inevitably interlinked to the natural environment, technological knowledge, economic and cultural systems (Sillar & Tite, 2000). As argued by Lechtman, technological activities are not random, they conform a “package” of technical modes of operation, attitude towards materials, rituals and a specific organisation of labour that are culturally determined (Lechtman, 1977, p. 6).

3.1.1 The *chaîne opératoire*

Against this background, the framework of the "*chaîne opératoire*" seems particularly useful to study ancient metallurgy (Figure 18:A). This approach focuses on the reconstruction of full technological sequences, directly engaging raw materials, tools, energy, techniques, sequences, ideas and gestures (Dobres, 1999; Sillar & Tite, 2000). The research interest encompasses from the first steps of production (e.g. the acquisition of the raw material), to the life-history and the deposition or discard of the object (Martinón-Torres, 2002). Focusing on the *chaîne opératoire* implies an interest in the artisans themselves, their skill and technical knowledge, their agency and potential of innovation; but also a consideration of their social and political organisation, culture and beliefs (Martinón-Torres, 2002). To identify the technological choices within a sequence, material science appears extremely relevant, because it allows us to improve the resolution of the characterisation, and to identify and understand the properties of the raw materials, tools and energy sources used (Sillar & Tite, 2000). In this research, as series of laboratory-based techniques were complemented with careful observations of the artefacts to reconstruct their sequences (see later sections).

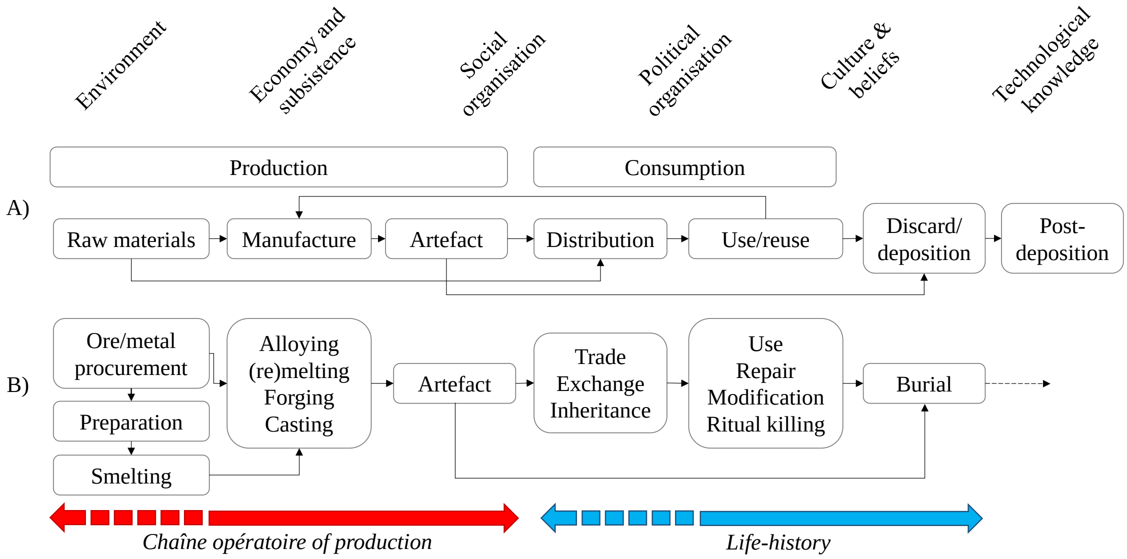


Figure 18: A- Diagram with the representation of the chaîne opératoire and its sections (modified after Martinón-Torres 2002, fig.1; Sillar and Tite 2000, fig.1). B- Metallurgical chaîne opératoire *and some of its steps (modified after Hauptmann 2015, fig.5.1; Miller 2007, fig.7.1). Red and blue arrows shows the span of the concepts as used in this thesis.*

In particular, the metallurgical *chaîne opératoire* involves a series of steps that have been defined in detail elsewhere (e.g. Bezúr, 2003, fig. 5.2; Hauptmann, 2015, fig. 5.1; Merkel et al., 1994, fig. 2; Miller, 2007, fig. 7.1; Ottaway, 2001, fig. 1; and more). A general example is given in Figure 18:B, comprising 1) raw material procurement and preparation, which is different in gold and silverwork (see chapter 2:2.2.2), 2) primary production (e.g. smelting silver), 3) secondary production (melting, alloying, forging, casting) and 4) the consumption of the objects produced (Hauptmann, 2015; Miller, 2007). Each step of the chain involves multiples technological choices, which in many cases were performed by different people (e.g. miners, metallurgist, etc). In this research, I will work from finished objects, which inevitably means it will be possible to reconstruct some of the steps outlined here, e.g. identification of raw materials, alloys practices, manufacturing techniques, while the characterisation of (e.g. mining techniques or distribution systems) will be more tentative, and completed by using additional archaeological, ethnohistorical and ethnographic records.

Even though the *chaîne opératoire* as an approach includes several stages (Figure 18), for operative purposes of this thesis I will separate some sections. I will mainly focus on the "*production*" stage of the *chaîne opératoire*, defined by Miller as "*process of fabrication or creation, including both material objects involved and the techniques or gestures used*" (2007, p. 5); whereas I will use the term "*life-histories*" to describe how objects are transformed during their lives of use, until their deposition or discard. Regardless of the specific terms employed, the idea to be emphasised is that the technical reconstruction is seen as a first step only, to approach broader dimensions of human behaviour and culture.

3.1.2 The life-history

As a complement, I will draw ideas from the life-history approach to material culture, which sustains that objects, as people, have a "life" that continues once they were made. Assessing what happens to the objects during their lives yields significant insight into the lives of their owners and others engaged in their biographies, not to mention the changes of meaning and value over time and space (Gosden & Marshall, 1999; Gosselain, 2000; Kopytoff, 1986; Shanks, 1998). In this context, the material changes suffered during the life of gold and silver objects take relevance, as observed in the evidence left on the artefacts themselves, such as wear-marks, repairs or modifications (Chapman & Gaydarska, 2009; Gosden & Marshall, 1999; Shanks, 1998). Registering and interpreting these traits can offer important information about use, re-use and meaning of these objects in SPA society (Joyce & Gillespie, 2015; Kopytoff, 1986; Sáenz-Samper & Martinón-Torres, 2017). Fortunately, most of the objects in SPA are contextualised; this makes it possible to reveal interesting situations where long and complex life-histories linking two people have been identified (see chapter 9). In this thesis, life-histories are considered until objects are deposited, i.e., a short life-history compared to other approaches that consider long life-histories, including the artefact's trajectory up to the present (e.g. Holtorf, 2002; Joyce & Gillespie, 2015).

As a part of the life-histories of some of the objects', I have identified items that were intentionally fragmented. To interpret this *"deliberate fragmentation"* I will follow Chapman and colleagues, who have extensively study this phenomena in ancient societies (Blanco-González & Chapman, 2014; Brück, 2006; Chapman, 2010, 2015; Chapman & Gaydarska, 2007, 2009, 2015). Their approach is based on the premise that in antiquity objects were regularly fragmented and these fragments had a practical use (Chapman & Gaydarska, 2007). They consider that a fragment does not represent *a part of* an object, the fragment *is* the object, and acts as an extension of the original artefact maintaining its qualities and properties. This is important in two ways; first, it means that fragments are far from being scraps or secondary items; they have (and accumulate) value by themselves. And second, when exchanged, fragments have the capability to connect people and to materialise relationships despite separation by time and space, and therefore becoming an active element of people's social identity in showing the extension of a person's social relationships (Brück, 2006; Chapman, 2015; Chapman & Gaydarska, 2007, 2009).

3.1.3 Manufacture, batches and production groups

Lastly and related specifically to production, it is appropriate to introduce some additional concepts that will be used in this study. For instance, *"manufacture"* will specifically refer to the process of making and shaping the metallic objects, in contrast to other authors that use "manufacture" as synonymous of "production", (see Miller, 2007, p. 5).

I will also use *"the batch"* as an analytical category, developed by Freestone and colleagues (2009). This concept is a useful tool to look at archaeological craft production at higher-resolution, primarily based on *elemental analyses*. It allows us to recognise individual production events, to have a closer look of the acts of acquisition and the behaviour of the consumer, as well as to look in more detail how workshops operate. The aim is to match chemical data and other attributes such as manufacture techniques, form, colours or styles to identify *batches of objects produced in a single production event*. In archaeometallurgy this concept has been used to identify the work of workshops and individual craftsmen producing sets of artefacts (Bezúr, 2003; Blackman et al., 1993;

Freestone et al., 2009; Martinón-Torres et al., 2011, 2014; Martinón-Torres & Uribe, 2015; Uribe & Martinón-Torres, 2012).

In this thesis, I will refer to a "*batch*" to describe a *group of objects* sharing the same style, manufacturing techniques and composition (within analytical error). It is assumed in that case, that objects were made together, and the chemical similarity reflects the product of individual melting or casting events, i.e., objects made from a single metal stock which is shaped afterwards (Bezúr, 2003; Martinón-Torres et al., 2011; Martinón-Torres & Uribe, 2015). However, a batch of objects may also represent the work of a day or several campaigns comprising multiple melting events, but made by individual workshops or artisans in the production of specific sets or commissions, such as the poly-alloy offerings identified in Muisca metalwork (Uribe & Martinón-Torres, 2012).

Although the concept *"metal batch"* is used in metallurgy to identify the metal stock of a particular melting or casting event (Uribe & Martinón-Torres, 2012); I will not use this term here to avoid possible confusion between *metal batches* and *objects batches*. I will use batches only when talking about a set of objects, and "metal load" or "melting event" when referring to the metal specifically used in their production.

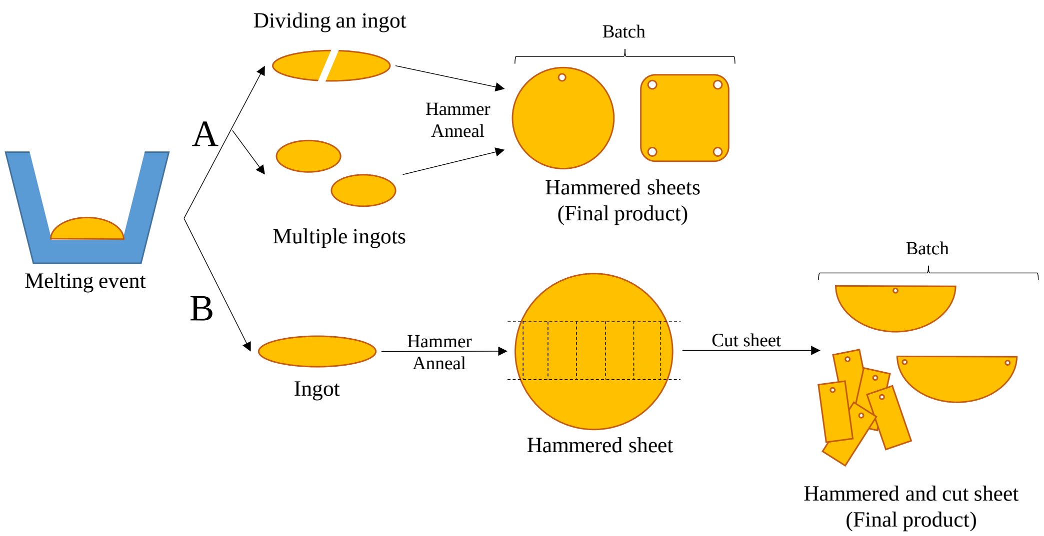


Figure 19: Batches. Examples of different pathways to generate batches of sheet metal artefacts that may be recognised analytically.

In a sheet-metal technology, such as that typical of SPA, batches of objects can be generated in at least two different moments of the *chaîne opératoire*: a) when preparing the raw material, i.e. a single melting event produces an ingot that is divided, or several ingots that are subsequently hammered to shape (Figure 19:A). In this case, object compositions are expected to be very similar, however there is scope for slight differences, given that each object is hammered and annealed separately. The other option is b) after hammering (Figure 19:B), i.e. a hammered sheet is divided into multiple parts (e.g. Bezúr, 2003, p. 278). In this case, compositions are expected to be almost identical, as they derive from the same sheet. Still, in both cases, the similarities can be obscured by post-deposition events and corrosion processes. Additionally, we should note that the division of a metal sheet as described in option b can take place in different moments of the artefact's life: during manufacture or afterwards, as a modification of a finished (and used) artefact. To distinguish between both is crucial for interpretation, and to understand the trajectories and life-histories of the objects (Gosden & Marshall, 1999; Joyce & Gillespie, 2015; Kopytoff, 1986; Sáenz-Samper & Martinón-Torres, 2017; Shanks, 1998).

To gather several batches or several single objects made in individual production events by the same artisans or workshops, the concept of *"production group"* will be used. It was defined by Costin (1991, p. 33) to identify groups of *finished objects* that are internally coherent, implying the work of a number of producers sharing a technology. In this research, *batches* and *production groups* will be used to explore in some extent the organisation of production, identify objects made by single artisans, as well as sets possibly produced in workshops (see next section). They also shed light on the acts of acquisition involved and the distribution of gold and silver objects within the communities. In particular, the concept of batch will refer to objects with the *same chemical composition and manufacturing techniques,* whereas production groups will refer *to a group of objects sharing manufacturing techniques, designs, forms and quality of the work (e.g. skill, dexterity), that may include one or several batches.*

3.2 The artisanal practice: the social context of production

Despite the small assemblage, a careful analysis of the *chaîne opératoire* allows us to explore to some extent how the artisanal practice was organised by identifying 1) the work of individual artisans or groups or artisans and 2) comparing the quality of the metalwork and the type of objects produced.

3.2.1 The individual in archaeology

Although the pursuit of the individual in archaeology is not new (Blackman et al., 1993; Costin & Hagstrum, 1995; Gosselain, 2000; Hill & Gunn, 1977; Marcus, 2015; Thomas et al., 2009; Whittaker, 1987), recent studies have highlighted the potential of using archaeological science methods to explore material culture at a higher resolution and ascribe some of the artefacts to individual artisans (Martinón-Torres & Uribe, 2015). As Martinón-Torres and Uribe have pointed out this so-called "science-based archaeological connoisseurship" allows *"detailed insight into the organisation of workshops, knowledge transmission, skill and the tension between individual and social agency"* (2015, pp. 136–138).

To identify the artisan, it becomes relevant to differentiate between conscious and unconscious technical attributes during manufacture, in order to identify individual traits. "*Attributes of form"*, following Whittaker's terminology (1987), will consider those aspects thought to be consciously learned and controlled by the artisan and relatively easy to copy. They include stylistic elements such as size, shapes, decoration or design elements (Gosselain, 2000; Martinón-Torres & Uribe, 2015; Whittaker, 1987). These attributes are culturally-mediated (Thomas et al., 2009), and were most likely used to intentionally express group identity, or other functional, economic or political needs (Costin & Hagstrum, 1995; Whittaker, 1987). *"Attributes of execution"* will consider unconscious motor habits, hardly controlled by the artisan and difficult to copy. They are ruled by the skill, capabilities and the experience of the craftsman, or the way in which tools are handled, which would leave idiosyncratic patterns on the objects, as result of specific working habits (Costin, 1991; Costin & Hagstrum, 1995; Martinón-Torres & Uribe, 2015; Thomas et al., 2009; Whittaker, 1987). The identification of specific attributes of execution in particular groups of objects would reveal the work of single artisans or groups or craftsmen working together.

3.2.2 Metalwork quality

In the analysed assemblage, metalwork of different qualities and skill levels are identified. To assess "*skill"* in ancient metallurgy, Maikel Kuijpers (2015, 2017, 2018) has looked in more detail at the concept of the "specialist", defined as an individual that "*produces more of some goods than he or she personally uses"* (Costin, 2005, p. 1036). Kuijpers identifies at least four levels of skill, based on the production details and quality of finished objects (bronze axes in his case; 2017, pp. 12–14): "*amateurs*", whose products demonstrate a basic knowledge of the craft, but showing little or no refinement; results are poor, but overall acceptable. "*Common craftspeople"*, individuals that have learnt the craft and they produce well-made objects, but do not stand out of the rest. They represent the traditional production, where innovation occur slowly. Objects are good quality, but with some mistakes. "*Master crafters*" are individuals who know well the material they work, therefore they are willing to take risks, being more innovative and developing new techniques. They show high level of perfection, being admired and recognised by peers. Their products are very well made and stand out in terms of care, symmetry, surface finish and decoration. And finally, there is the "*virtuoso*", an exceptionally skilled craftsperson. They know the material so well (limitations, potential and qualities) that they explore their limits creating original and unique objects, using unconventional techniques. They generate admiration, probably leading to a special social status.

Although my aim here is not identify each one of these specialists, these categories are relevant to assess and interpret the variability of the assemblage. Other useful concepts to describe the quality of my materials are taken from Costin and Hagstrum (1995) who use the relative degree of *"standardisation"* and *"labour investment"* to determine the relative quality of finished objects (Costin, 1991, 2005; Costin & Hagstrum, 1995).

Briefly, as defined by Kuijpers, *skill* will be understood as the "*ability to recognise and respond to the qualities of the material*" (2017, p. 5), it refers to the level of proficiency, knowledge, talent and effort of the artisan, which can change over time (Martinón-Torres & Uribe, 2015). *Standardisation* considers the "*relative amount of uniformity in materials, forms or decoration"* in a given assemblage (Costin, 2005, p. 1064). It assumes that more standardisation is result of a routinized and frequent practice, as well as the use of a particular technological sequence, and therefore a product of a greater skilled specialist, compared to less standardised items. In this research, standardisation will be used to compare objects of the same type, such as conic-bells, wire-rings or goblets (Costin, 1991, 2005; Costin & Hagstrum, 1995). *Labour investment* relates to the length of the *chaîne opératoire* and effort required to make the object. In this particular case, it will consider the application or not of decoration, finishing treatments (e.g. polishing the edges or surfaces), treatment of the perforations, etc.

Combining quality and the identification of groups or individual artisans as proposed in the previous section, will give us some indications of the organisation of production of goldwork in SPA and the SCA, e.g. possible evidence of workshops, or artisans with different specialisation levels (Costin, 1991, 2005; Costin & Hagstrum, 1995).

Chapter 4. Material, sampling, contexts and methods

4.1 Materials

Based on excavation reports and museum archives, the number of gold and silver objects reported in SPA, and ascribed to the cemeteries of the Middle Period, is *ca.* 335 artefacts. However, due to poor conservation conditions during excavation and subsequent losses only 170 were physically found at the "Instituto de Investigaciones Arqueológicas y Museo R.P. Gustavo Le Paige" or "IIAM" in San Pedro de Atacama. From those 170 items, 142 (84%) were accessible for this research.

Most of the gold and silver objects from SPA are small and thin sheets (~2.5gr), that were hammered, cut and perforated to produce 2D and 3D objects. Overall, they can be classified in two categories: ornaments and ritual objects (Table 3). The ornaments are very variable in shape and size, making their classification difficult. After many attempts, the most useful organisation for this research was based on their function (it is recognised here that this classification is arbitrary and it may be of limited -if any- relevance to the past), proposing the following types: attachments, pendants, headbands, headdresses, bracelets, beads, rings and bands. The ritual objects include parts of inhalation tubes, bells, *keros,* portrait-vessels, a miniature jug and axes. A full description of each type and reference images are given in Appendix N°6.

Types of objects	Accesible	Not accesible	Total
Ornaments			
Attachments	32	6	**38**
Pendants	20	1	**21**
Tubular beads	0	15	**15**
Bands	5	0	**5**
Rings	13	0	**13**
Headbands	14	2	**16**
Headdresses	7	1	**8**
Bracelets	4	0	**4**
Fragments of sheets	13	1	**14**
Total	***108***	***26***	***134***
Ritual objects			
Bells	22	0	**22**
Goblets (*keros* and portrait-vessels)	6	0	**6**
Axes	1	1	**2**
[1]Inhalation tubes	4	1	**5**
Miniature jug	1	0	**1**
Total	***34***	***2***	***36***
TOTAL	**142**	**28**	**170**

Table 3: 170 ornaments and ritual objects stored at the Museo Arqueológico R.P. Gustavo Le Paige, San Pedro de Atacama (IIAM).
The inhalation tubes counted by parts include a complete tube (2 tips and body) and two loose tips.

Overall, objects are in good conditions, only a few (n=5) were very thin being more delicate and showing broken edges. Regarding their surfaces, 52% of the objects present a clean surface, 28% has a red tarnish, 10% a black tarnish, 1% a grey surface, and 9% were heavily corroded with a mineralised surface (Figure 20). The latter group comprises all the silver objects. In the rest of the objects, analyses were performed in the cleanest areas of the surface.

Surface	A- Clean	B- Red tarnish	C- Black tarnish	D- Grey tarnish	E-Mineralised	Total
Nº	76	40	14	2	13	145
%	52	28	10	1	9	100

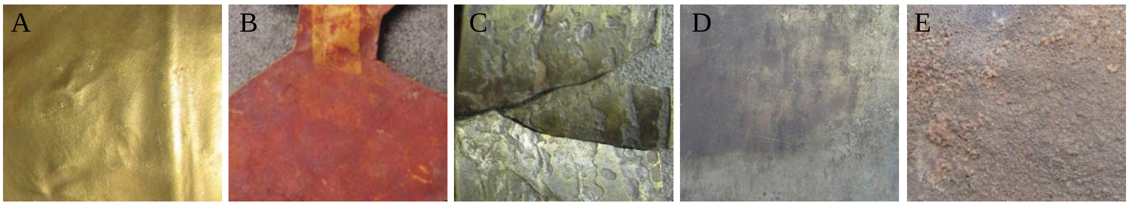


Figure 20: Surface condition of 142 objects (145 parts are reported, because three items had two parts) from SPA.

XRD analysis directly applied on the surface of two samples with the red tarnish (popm1, popm47), detected minerals rich in silver, gold, sulphur, chlorine and in smaller amounts copper: AuAgS (petrovskaite), AgCl (chlorargyrite), $Ag(ClO_4)$ (silver perchlorate), Ag_2S (silver sulphide) and $Cu_6(OH)_{10}(SO_4)\text{-}H_2O$ (redgillite). The same elements (except copper) were identified by SEM-EDS analyses on cross sections and surfaces of other samples with red tarnish, indicating that the red layer is probably the product of silver corrosion. The black tarnish was also analysed under the SEM, revealing the presence of sulphur, silver, gold and sometimes chlorine. Given the composition and black colour, this layer would correspond to silver sulphide corrosion (full results in Appendix Nº7).

4.2 Sampling strategy

The selection of the artefacts analysed here was opportunistic, based on their accessibility and trying to obtain the largest coverage possible. For instance, in Larache nearly 80 precious metals artefacts have been recovered in different excavations: 1960-61 and 1989. I had access to the materials of the first excavations and only three objects of the last excavations in 1989 (n=62). From Casa Parroquial, 34 gold and silver objects were recovered and all -except a gold axe- were available for study. The rest of the assemblage comprises 47 gold and silver artefacts found in other cemeteries of SPA, which were accessible at the museum.

All 142 objects were studied macroscopically, with a digital microscope and analysed *in situ* using a portable x-ray fluorescence instrument (henceforth “pXRF”, Table 7); of these, 40 (28%) were sampled invasively to apply further analyses at UCL. Samples of about $2mm^2$ were cut from the free ends of the artefacts, avoiding as much as possible altering their original shape. Small and already broken objects were selected and sampled using a jeweller’s saw.

The studied objects and samples were named with a new code and number: “popm000”, where “popm” stands for “***P**royecto **O**ro, **P**eriodo **M**edio”* (Gold Project, Middle Period). A correspondence table with the new and museum's codes is given with the pXRF results (Table 19).

4.3 The contexts

At the beginning of this research 75 objects (53%) of the total analysed had unclear contexts, due to the loss of their registration numbers. However, during different field seasons it was possible to re-contextualise most of the assemblage cross-checking information from the museum's records, descriptions from the excavation diaries, photographs and drawings of the materials. For most artefacts it was possible to establish the cemetery and burial number; in others cases only the cemetery was identified.

The number of objects without registration number was reduced to 15 cases (11%), where it was impossible to assign them a specific site, although reports and records suggest that they belonged to MP cemeteries from SPA. In eight cases (6%) there are indications of one or more than one potential cemeteries, but their allocation is not completely sure. The 119 remaining objects (84%) belong to seven cemeteries: Larache, Casa Parroquial, Quitor-1, Quitor-5, Sequitor Alambrado, Coyo-3 and Solcor-3 (Figure 12). For some of these objects however, the burial number was not always identified. Table 4 summarises the objects, cemeteries and their chronology (see also chapter 2: 2.3).

Cemetery	Site Certain	Site Uncertain	Total	Dates (AD)	Method	Reference
Sequitor Alambrado	3	1	4	245-663	^{14}C	(Hubbe et al 2011, Richardin et al. 2015)
Larache	58	4	62	250-534	^{14}C	(Hubbe et al 2011)
Quitor-5	2	1	3	76-971	^{14}C, TL	(Berenguer et al. 1986, Hubbe et al 2011, Richardin et al. 2015)
Solcor-3	1	0	1	400-1041	^{14}C, TL	(Berenguer et al. 1986; Llagostera et al. 1988)
Casa Parroquial	33	0	33	777-1135	^{14}C	(Téllez & Murphy 2007, Stovel 2013)
Quitor-1	10	0	10	777-1169	^{14}C	(Hubbe et al 2011, Richardin et al. 2015)
Coyo-3	12	0	12	590-1000	^{14}C	(Costa & Llagostera 1994)
Quitor-5 or Solor-3[1]	0	1	1	83-602[1]	^{14}C	(Hubbe et al 2011)
Quitor(?) or Solor-3	0	1	1	-	-	-
Unknown	0	15	15	-	-	-
TOTAL	**119** **84%**	**23** **16%**	**142**			

Table 4: Objects from the different cemeteries from SPA from the Middle Period (AD 400-900). Note that some cemeteries have longer occupations, being used since the Late Formative (0-AD 400) and Late Intermediate Period (AD 1000-1400). Twenty three objects of the total assemblage do not have clear contexts. (1)The dates here represent only Solor-3 cemetery.

4.4 Methods

A range of analytical techniques was applied to determine different aspects of the technology and raw materials employed in the production of these objects (Table 5). Manufacturing techniques were identified studying macroscopically the surface of the 142 objects using a digital microscope; and it was combined with metallography of the cross sections of 41 samples.

Analytical techniques	Objects analysed	Samples analysed	Information obtained
Macroscopic analysis	142	-	Manufacture techniques
pXRF	142	145	Bulk chemical composition
OM and SEM-EDS (surface)	45	45	Microstructure and composition
SEM-EDS (section)	41	41	Microstructure and composition
PIXE	40	42	Major and trace elements
Metallography	43	43	Manufacture techniques
XRD	2	2	Mineralogy of red patina

Table 5: List of techniques, objects and samples analysed for this project.

The bulk chemical composition was obtained by the pXRF. To investigate whether any intentional or post-depositional surface enrichment was present, inclusions and internal phases, 45 samples were observed directly under the optical microscope ("OM") and scanning-electron microscopy ("SEM"), and their surfaces were analysed using SEM with energy-dispersive spectrometry ("SEM-EDS"). Of these, 41 samples were mounted as cross-sections in resin blocks to be analysed using SEM-EDS. Proton-induced X-ray emission ("PIXE") was used to analyse for major, minor and trace elements in 42 samples.

All the techniques used for chemical analyses complemented each other. pXRF is a portable non-destructive technique that allowed the analysis *in situ* of all the assemblage, key factor considering that most objects cannot be taken out of the museum; but it is a superficial analysis. With the microscopic analysis using OM and SEM-EDS, it was possible to observe in more detail elemental changes of the surface and in cross section that would not be detectable with the pXRF. Similarly, the limits of detection of the PIXE are lower than the SEM-EDS, being able to identify trace elements that were under the limits of detection of the SEM-EDS. The combination of the data of these different techniques is possible due to their instrument compatibility, expressed in the good agreement of the results obtained from the analysis of gold and silver alloy certified reference materials, showing a good precision in spite of a slight underestimation of Cu by pXRF2015 (Table 6; precision and accuracy for each instrument is presented below. Full data quality results are given in appendix Nº9).

Standards	Technique	Cu%	Ag%	Au%	N°
MAC 1	**Given value**	**1.0**	**4.6**	**94.4**	-
	PIXE	1.0	4.5	94.5	1
	pXRF2015	1.0	4.3	94.7	17
	pXRF2016	1.1	4.4	94.6	21
	SEM-EDS	1.1	4.2	94.7	5
MAC 2	**Given value**	**5.2**	**19.4**	**75.5**	-
	PIXE	5.3	19.1	75.6	3
	pXRF2015	4.9	18.8	76.3	17
	pXRF2016	5.4	19.0	75.7	21
	SEM-EDS	5.3	19.0	75.8	5
MAC 3	**Given value**	**9.3**	**30.3**	**60.4**	-
	PIXE	9.9	30.4	59.7	1
	pXRF2015	8.9	30.5	60.6	17
	pXRF2016	9.6	30.5	59.9	21
	SEM-EDS	9.5	30.3	60.2	5
AGA 1	**Given value**	**20.2**	**78.3**	**1.5**	-
	PIXE	20.4	78.1	1.5	2
	pXRF2015	18.8	79.6	1.6	17
	pXRF2016	19.6	78.9	1.5	21
	SEM-EDS	20.9	77.4	1.7	5
AGA 2	**Given value**	**10.3**	**89.2**	**0.5**	-
	PIXE	11.3	88.2	0.5	2
	pXRF2015	10.0	89.5	0.6	17
	pXRF2016	9.9	89.6	0.5	21
	SEM-EDS	10.9	88.6	0.5	5

Table 6: Summary of the elemental composition in wt% of the gold and silver alloy standards by PIXE, pXRF and SEM-EDS to assess compatibility across techniques. All values are normalised to 100wt%.

Technique acronym	Name
SEM	Scanning electron microscopy
SEM-EDS	Scanning electron microscope with energy-dispersive spectroscopy.
PIXE	Particle-induced X-ray emission.
XRD	X-ray powder diffraction.
pXRF	Handheld portable X-ray fluorescence.
OM	Optical microscopy.

Table 7: Name of the techniques mentioned in this document.

The techniques I am using combine non-destructive surface analysis (pXRF, PIXE, SEM-EDS) and invasive analysis that explore the cross section of the objects (SEM-EDS). In the case of gold objects some issues need to be considered, such as potential surface enrichment phenomena, which may affect the result of surface analysis. Gold enrichment of the surface may occur, when copper and/or silver are depleted from the surface, generating a thin gold layer of usually <10μm. The depletion may be intentional, when a surface treatment is applied to obtain a golden surface; or unintentional, produced by annealing of the metal in oxidising conditions during manufacture or due to corrosion processes during deposition. Conservation and cleaning the objects in museums can also develop a surface enrichment (Blakelock, 2016; Blakelock et al., 2016; La Niece & Meeks, 2000; Lechtman, 1973; Troalen et al., 2014).

The analysis of 41 cross-sections by SEM-EDS showed that in certain samples, copper and silver levels were slightly higher in the core of the sheet, decreasing towards the surfaces and producing a slight surface enrichment. However, considering a) the characteristics of the samples - e.g. microstructure of the surface and the relative thinness of the depleted layers (La Niece & Meeks, 2000; Lechtman, 1973, p. 73; Meeks, 1998, 2000; Troalen et al., 2014) -, b) the absence of a colour change between the surface and the core metal, and c) the fact that SPA soils are rich in elements that would corrode copper and silver, such as salts (e.g. nitrates, perchlorates, iodates) and sulphates (Casanova et al., 2013, p. 27); it is proposed that the enrichment detected would be unintentional, as the inevitable result of the oxidation of copper during hammering, plus a corrosive environment of deposition[6].

Therefore, due to the presence of a potential surface enrichment, corrosion and to assess the nature of the information obtained from each instrument, the penetration depth or the thickness of the layer analysed by different techniques was assessed. The values were obtained by calculating the density (g/cm^3) and mass attenuation coefficients

[6] Gold corrosion is a relevant and trending topic in this moment, however, due to space and time constraints, it was not possible to expand more on this subject in this thesis. Still, it is expected to use the data obtained to produce a future publication discussing the effect on silver and copper during deposition in gold archaeological objects.

(cm^2/g) of five certified reference materials (gold and silver alloys; Kaiser & Shugar, 2012; Nicholas, 2015, 2016; Potts et al., 1997; Troalen et al., 2014); figures in Table 8 are a summary of selected elements (full results in appendix N°8) and represent the thickness in μm from which 95% of the x-rays detected for gold, silver and copper are produced[7].

Results show that penetration depths vary depending on the matrix of the material (gold-rich or silver-rich) and the technique used. In the case of the pXRF, the penetration depths are relatively deep. On a gold-matrix, the depth analysed is between 16-19μm for gold, 22-34μm for silver and 7-9μm for copper; whereas on a silver-matrix the depth is higher: between 25-26μm for gold, 84-85μm for silver and 13-14μm for copper. PIXE, on the other hand, penetrates less when reading gold and copper, but when detecting silver the depth is the same or higher, compared to the pXRF. Thus, the depth analysed is 10-16μm for gold, 6-13μm for copper and 22-140μm for silver. Because of its operation at substantially lower accelerating voltages, surface analyses by SEM-EDS showed the lowest penetration depths. On gold alloys, the depth analysed is around 1μm for gold and silver and 4-5μm for copper; on silver alloys the values are ~1μm for gold, ~3μm for silver and 8-9μm for copper (Table 8).

These results indicate that in the case of my assemblage, composed mainly by thin gold and silver sheets, pXRF and PIXE are less affected by surface enrichments; conversely, surface SEM-EDS results will not be representative of the metal composition, but they will provide a useful reference to compare to the deeper analyses provided by the other techniques.

Alloy (wt%)		**Density (g cm^{-3})**	**Effective penetration depth (μm) 95%**								
			pXRF			**PIXE**			**SEM-EDS**		
Au/ Ag/ Cu			Au Lβ	Ag Kα	Cu Kα	Au Lα	Ag Kα	Cu Kα	Au Mα	Ag Lα	Cu Kα
MAC1	93.8/4.6/1	18.2	15.7	21.7	7.1	9.6	21.8	6.2	0.9	0.5	3.8
MAC2	74.7/19.2/5.1	15.6	17.4	28.4	8.3	10.5	29.6	7.2	0.9	0.6	4.6
MAC3	59.2/29.7/9.1	13.9	18.7	35.3	9.3	11.2	38.2	8.1	1.0	0.8	5.3
AGA1	1.5/77.5/20	10.2	24.6	85.4	14.1	14.7	131.0	12.5	1.3	2.8	8.7
AGA2	0.5/87.1/10	10.3	25.6	84.3	12.8	15.7	139.3	11.3	1.3	2.9	8.0

Table 8: Summary of the calculated density and effective penetration depth values for different gold (MAC) and silver (AGA) alloys (Au/Ag/Cu).
The penetration values represent the thickness in μm from which 95% of the x-rays detected were produced by each technique. Full results in appendix N°8.

[7] I especially thank Matthew Nicholas, who provided me the formula and the procedure to understand and obtain these calculations.

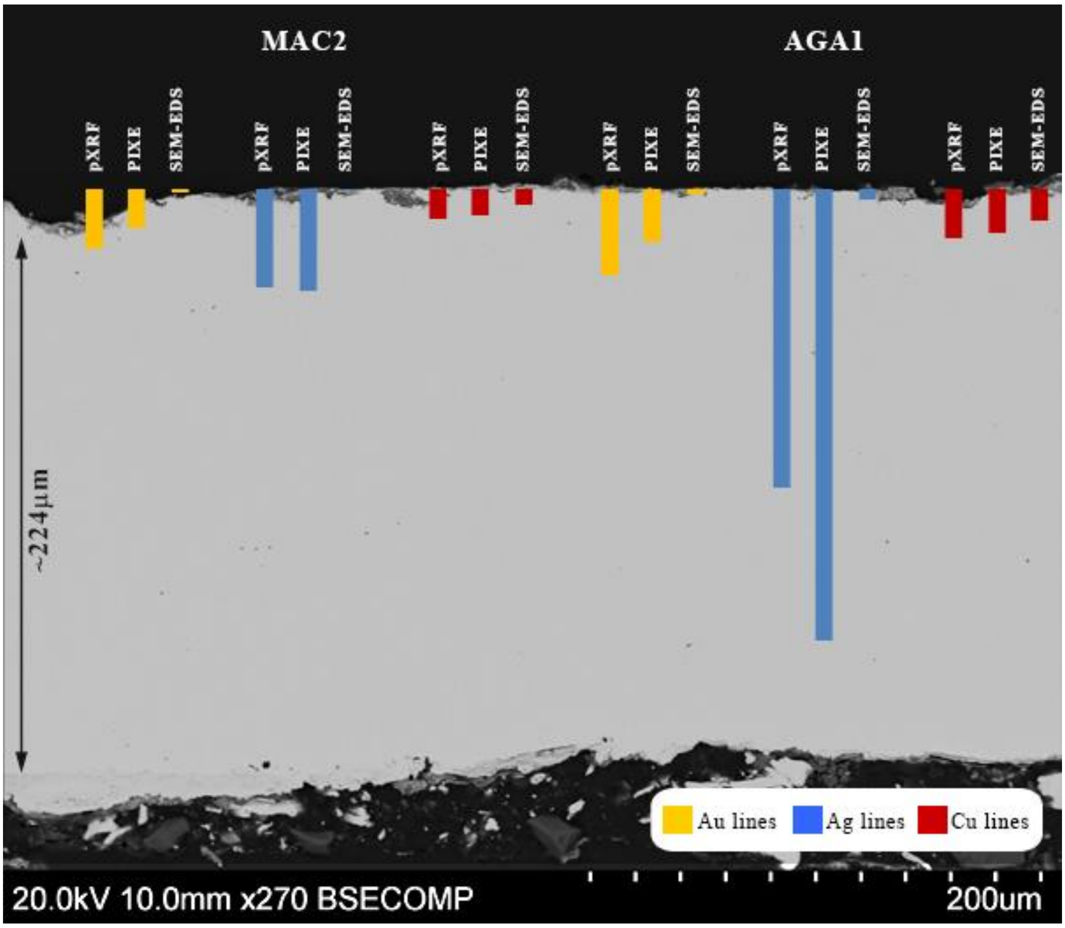


Figure 21: Backscattered ("BSE") image of a cross section of a 224 µm thick sample (headband popm17). It shows the penetration depth using the values of MAC2 (density=15.6gcm^{-3}) and AGA1 (density=10.2 gcm^{-3}) as examples (see Table 8).

An additional complication is caused by samples that are thinner than the calculated penetration depth, as these do not meet the infinite thickness requirement for optimum analyses (Nicholas, 2015, 2016; Troalen et al., 2014). In these cases the signal received by the detector is lower, with the risk of underestimating the real values or altering elemental ratios in the quantification. Moreover, in some cases the x-rays may cross through the sample, analysing everything that is behind it. Considering that the samples studied here can be as thin as 13µm, to avoid any possible interference all PIXE and pXRF analysis were made in air, with nothing behind the objects. However, to estimate potential measurement errors in thin samples (<100µm), pXRF and SEM-EDS (core) values were compared, calculating the absolute and relative difference between seven objects that represent the compositional variability in the assemblage (Table 9).

Overall, the absolute differences between pXRF and SEM-EDS are small, with maximum variations of ±7.7%; and in relative terms, silver and copper appear more variable. Silver varies especially in samples popm3 and 11, the thinnest sheets of the assemblage. One could expect lower silver values in the pXRF compared to the SEM-

EDS, considering that the critical penetration depth would exceed the thickness of the sample and the instrument would calculate the composition assuming an infinitely thick sample. However, pXRF values are higher. A possible explanation is that, because the samples are so thin, most of the interaction volume derives from the surface opposite to the analytical spot. In these cases, both samples have a thin layer of corrosion rich in silver sulphides. The analysis of the corrosion in addition to the bulk metal, may explain the higher values of silver detected by the pXRF.

In the case of copper, the divergence between instruments does not appear to be related to penetration depth. As seen in Table 8, copper lines in a silver-rich matrix go as deep as ~14µm and up to ~10µm in a gold-rich matrix; and the samples analysed here are thicker than those. Therefore, the variation in this case is better explained by the copper distribution within the matrix of the sheets. In cross section, copper content decreases towards the surfaces, due to depletion during working of the metal and corrosion processes (see above). The pXRF will give us a bulk composition including this variation within the sample (note as well that analysis with pXRF2015 slightly underestimates Cu contributing to this divergence, see Table 6); whereas the SEM-EDS is based on analyses of the centre of the core, where copper is usually at its highest levels.

Still, considering the multiple causes, analytical uncertainties of ±7.7% in all major elements between samples are deemed acceptable, and differences below this threshold will not be used to establish differences between samples.

N° Id Lab	Thickness (µm)	pXRF (%)			SEM-EDS (%)			δ absolute			δ relative (%)			
		Cu	Ag	Au	Cu	Ag	Au	Cu	Ag	Au	Cu	Ag	Au	
popm027	93	48.7	4.9	46.4	55.3	4.8	39.9	6.7	0.2	6.5	12.1	3.2	14.0	MAC
popm016	79	1.5	8.9	89.6	2.6	9.7	87.7	1.1	0.8	1.9	43.5	7.9	2.1	MAC
popm003	13	1.4	**24.9**	73.7	1.6	**19.1**	79.4	0.2	5.8	5.6	13.0	**23.5**	7.1	MAC
popm011	18	2.5	**27.9**	69.5	2.3	**20.4**	77.2	0.2	7.5	**7.7**	8.2	**26.8**	10.0	MAC
popm032	75	1.1	65.6	33.3	1.5	66.3	32.2	0.4	0.7	1.1	24.8	1.1	3.3	AGA
popm006[1]	54	1.2	69.4	29.4	1.6	70.8	27.5	0.4	1.4	1.8	24.3	2.0	6.2	AGA
popm007	42	1.1	73.1	25.8	1.5	70.2	28.3	0.3	2.9	2.5	23.2	3.9	9.0	AGA

Table 9: The absolute and relative difference is calculated in seven samples, comparing pXRF and SEM-EDS (core) analyses, to estimate potential error readings in thin samples (<100µm).
The first four samples are similar to MAC standards composition, whereas the latter three are closer to AGA standards. (1) Sample analysed with pXRF2016, for the remaining samples pXRF2015 was used. In bold are figures mentioned in the text.

4.4.1 Analytical protocols

4.4.1.1 Handheld XRF

The 142 metallic objects were analysed using two Delta Premium Innov-X handheld XRF (pXRF) analysers. The pXRFs are equipped with a Si drift detector (SDD) providing a typical resolution of 143-157eV FWHM for x-rays of 5.9keV (on a steel standard). Readings were taken using the mode "Alloy Plus", setup especially for the analysis of archaeological non-ferrous metals. The single beam mode (Beam1) was chosen, set up at a live-time of 20 seconds at 40kV with a 2mil Al filter in the X-ray path that quantifies heavy elements only, but it gives an indicative reading for light elements with a high confidence limit of 30%, i.e. an overall figure for light elements is reported when they are detected above 30% (Table 10). This set up would avoid detecting corrosion or soil elements such as Si, S or Cl. For quantification, the fundamental parameters method, supplemented by in-house empirical standardisation was used. All the readings were applied on unprepared surfaces and each sample was analysed three times; values given are an average of the three readings, in percentage by weight.

Beam	N°1 - 40kV
Filter	Al - 2mm
Elements measured	Ti, V, Ce, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ir, Ta, W, Os, As, Pt, Au, Hg, Pb, Bi, Zr, Nb, Mo, Rh, Pd, Ag, Cd, Sn, Sb

Table 10: Elements detected by the pXRF using the mode Alloy Plus setup for the analysis of archaeological non-ferrous metals.

Although the manufacturer and set up are the same, two different instruments were used in this research owing to variable availability (pXRF2015 and pXRF2016, after the year of analysis). The difference between both instruments is that the analyses with the pXRF2015 were performed using a collimator with a beam of 5mm diameter and higher beam current; while the pXRF2016 was uncollimated with a beam of 10mm diameter and lower beam current. The technical specifications of both instruments are summarised in Table 11.

Instrument	Manufacturer /Model	Model n°	Tube	Resolution	Mode	Voltage	Current	Collimator	Spot diameter
pXRF2015	Olympus Innov-X /Delta Premium	6000CC	Rh	143eV	Alloy Plus	40kV	100µA	Yes	5mm
pXRF2016		4000	Au	157eV			15µA	No	10mm

Table 11: Technical specifications of both pXRF used for this research.

Five standards were analysed by pXRF to determine precision, accuracy and comparability within and between instruments: three gold (MAC1-3, Micro-Analysis Consultants Ltd) and two silver alloys (AGA1-2, MBH Analytical LTD). Precision and accuracy are high in all cases and for both instruments, with coefficients of variation and relative errors below 10% when elements were present above 0.5%. For elements present in amounts below 0.5% precision and accuracy decrease and vary considerably, suggesting that at low amounts, elements are more difficult to measure under the current setup. In a silver-matrix, elements ≤0.5% are in general more difficult to measure and are less consistent in their readings with the pXRF. Tin in particular presents high detection limits of 0.5% with both instruments, showing that detected values under 0.5% are not reliable: with pXRF2016, figures <0.5% need to be checked on the spectra to avoid false-positives, while with pXRF2015 it was unsystematically detected. The problem with tin resides in the overlap between silver Kβ (24.9keV) and tin Kα (25.0keV) spectral lines. In a gold-matrix, when the elements are present above 1%, precision and accuracy were high with both instruments (coefficients of variations and relative errors <7%).The detection of tin in this matrix was not problematic. In general, results indicate that pXRF2016 shows slightly better values for precision and accuracy than pXRF2015 (full accuracy and precision results in appendix N°9, supplementary information on pXRFs in appendix Nº10).

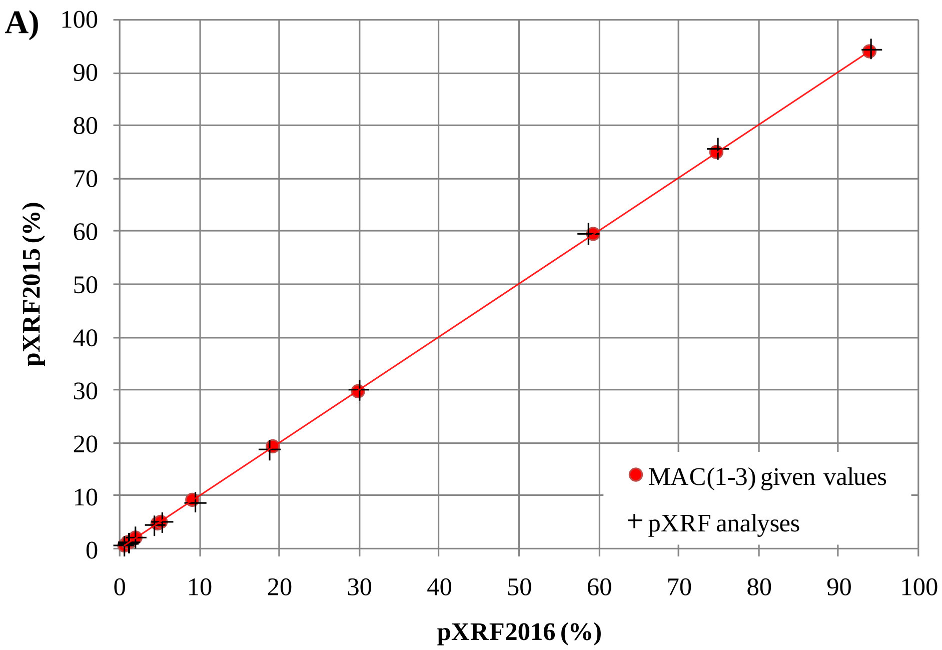
	MAC 1				**MAC 2**				**MAC 3**			
(wt%)	**Cu**	**Au**	**Ag**	**Sn**	**Cu**	**Au**	**Ag**	**Sn**	**Cu**	**Au**	**Ag**	**Sn**
Given values	**1.0**	**93.8**	**4.6**	**0.5**	**5.1**	**74.7**	**19.2**	**1.0**	**9.1**	**59.2**	**29.7**	**2.0**
pXRF 2015	1.0	94.3	4.3	0.5	4.9	75.4	18.6	1.1	8.7	59.4	29.9	2.0
pXRF 2016	1.1	94.1	4.3	0.5	5.3	74.8	18.8	1.1	9.4	58.7	29.9	2.0
δ relative (%)	**9**	**0.2**	**1**	**4**	**8**	**1**	**1**	**3**	**8**	**1**	**0.1**	**2**

	AGA 1									**AGA 2**								
(wt%)	**Cu**	**Pb**	**Au**	**Zn**	**Sn**	**Sb**	**Bi**	**Fe**	**Ag**	**Cu**	**Pb**	**Au**	**Zn**	**Sn**	**Sb**	**Bi**	**Fe**	**Ag**
Given values	**20.0**	**0.2**	**1.5**	**0.2**	**0.3**	**0.1**	**0.2**	**0.04**	**77.5**	**10.0**	**1.0**	**0.5**	**0.5**	**0.5**	**0.2**	**0.1**	**0.03**	**87.1**
pXRF 2015	18.6	0.2	1.6	0.2	<dl	<dl	0.2	<dl	78.7	9.7	1.3	0.6	0.5	0.6	0.2	0.1	<dl	87.1
pXRF 2016	19.4	0.2	1.5	0.3	<dl	<dl	0.2	<dl	78.0	9.7	1.1	0.5	0.5	0.4	0.1	0.1	<dl	87.5
δ relative (%)	**4**	**10**	**7**	**44**	-	-	**5**	-	**1**	**0.1**	**14**	**10**	**11**	**27**	**11**	**11**	-	**0.4**

Table 12: Given values and analytical results of five standards analysed by pXRF2015 and pXRF2016. The relative difference (δ relative%) is calculated between pXRF2015 and pXRF2016. Note that despite small differences, values are very close between both instruments allowing pooling both dataset together. Full results in appendix N°9 and Nº10.

A comparison of both pXRFs is given in Table 12. In general, the relative difference between machines is lower on the gold standards than on the silver standards. In a gold matrix, the relative differences between instruments is very low for gold and silver, with a δ relative ≤1%; copper, however, is overestimated on pXRF2016 by 8-9% relative. In the silver matrix the relative difference for silver and copper is low (δ relative ≤4%); whereas the difference between machines for minor elements such as lead, zinc, tin, antimony and bismuth increases with δ relative between 10-44%. No systematic differences are found in the dataset, making it difficult to apply correction factors to improve comparability. Even though copper is systematically overestimated in the gold standards with pXRF2016, in the silver standards the error is much less and a correction of this element would affect the quantification on silver-rich objects. Overall, in spite of these small differences, data shows a good degree of correspondence between both instruments (Figure 22-23), and it was decided that it would be appropriate to pool both dataset together without any correction, but remaining mindful of these differences (see appendix N°10).

The presence of corrosion, tarnish or dirt on the surfaces, as well as the sometimes imperfect surface geometry, increase the sampling uncertainty of these analyses and it may lead to spectral peaks that may be artefacts of the analyses or, if truly present, cannot be taken as indicative of the bulk alloy composition. Considering these issues as well as the precision and accuracy reported above, it was decided to establish confidence limits at a conservative level of 0.5%, even though the instrument can report values lower than 0.1%. Elements often identified in these lower ranges included Fe, Zn, Ni, Ti, Bi, Sn and Sb, but trace elements from PIXE or concentrated particular phases identified by SEM-EDS were deemed more reliable. All spectra were checked to confirm the presence of the elements reported here (Martinón-Torres & Uribe, 2015; Mass & Matsen, 2012).



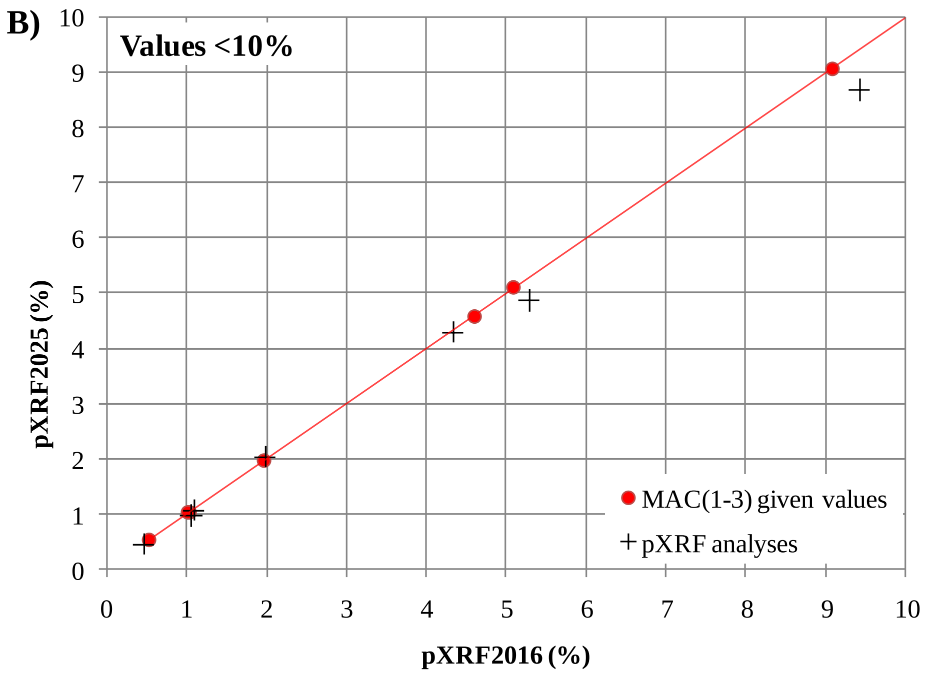


Figure 22: A) Scatter plot comparing the results of pXRF2016 against pXRF2015, given values of the gold standards are plotted in red dots.
B) Detail of scatter plot A showing values below 10%. The plot includes all the elements from MAC1-3: Au, Ag, Cu and Sn. The pXRF results are an average of 17 measures. Note the good agreement between both datasets.

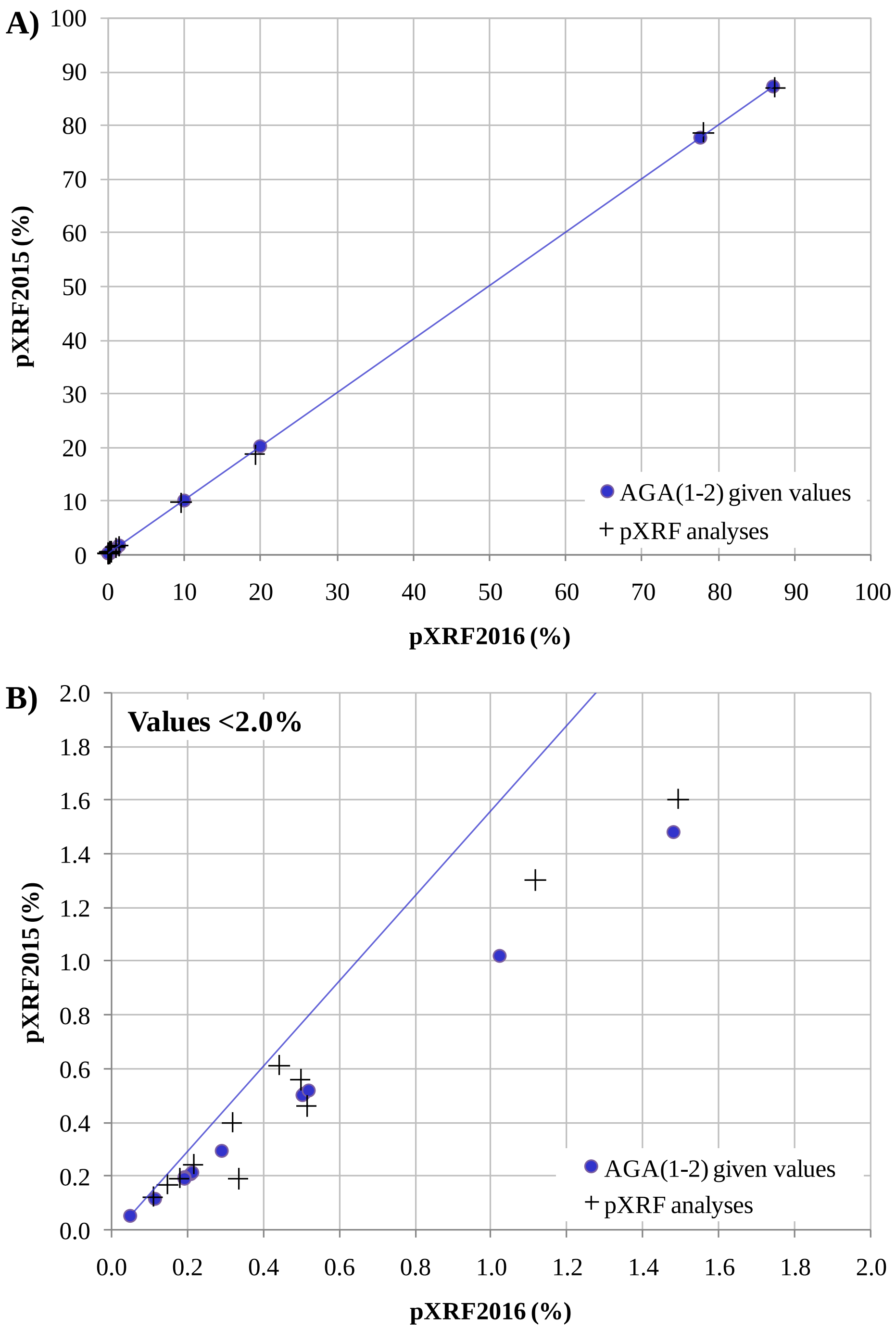


Figure 23: A) Scatter plot comparing the results of pXRF2016 against pXRF2015, given values of the silver standards are plotted in blue dots.
B) Detail of scatter plot A showing values below 2.0%. The plot includes all the elements from AGA1-2: Au, Ag, Cu, Sn, Pb, Zn, Sb, Bi and Fe. The pXRF results are an average of 21 measures. Note that at lower concentrations, values are less accurate.

4.4.1.2 PIXE

To explore the presence of trace elements in the gold samples, PIXE was used on 42 samples, as this instrument has lower detection limits than the pXRF. Thirty-eight objects from SPA (two were sampled twice) and two from an early period (Yona-2 site) were studied. The setup of the AGLAE accelerator used a 3MeV external proton beam of 30-50μm in diameter, 3-6nA current and four Peltier-cooled SDD detectors to collect the x-ray emitted by the sample. The first detector (LE0) has no filter to detect the light elements at the low energy range of the spectrum (Table 13). The second detector (HE1) has a 200μm aluminium filter used mainly to detect major elements, the third detector (HE3) has a 75μm copper filter, to absorb the gold lines; and the fourth detector (HE4) has a 50μm zinc filter also to absorb gold lines and better isolate the platinum line. The surfaces of the samples were mechanically cleaned to remove a surface layer and analysed using beam scanning areas of 500x500μm. Counts doses of ions particles were selected between 15,000,000 and 600,000. Due to time constraints, samples were only analysed once and the count doses were shortened later in the day.

As internal standards, two silica standards (SiO_2 and SiO_2 + Au coating of 1.5μm) and one gold standard (LA6917) were used. To check precision, reproducibility and compatibility of the compositional data with pXRF; three gold (MAC1-3, Micro-Analysis Consultants Ltd) and two silver standards (AGA1-2, MBH Analytical LTD) mounted in polished blocks were used. Data normalisation from different detectors was carried out using silver composition, with the program GUPIX combined with the homemade software TRAUPIXE. The analysis were carried out at the AGLAE laboratory of the C2RMF (Centre de Recherche et de Restauration des Musées de France) in Paris.

Detector-Filter	Elements detected
LE0 - no filter	Si, P, S, Cl, K, Ca, Ti, Cr, Ni
HE1 - Al filter	**Au, Cu,** Mn, Fe, Co, Ga, As, Se, Te, Os, Ir, Hg, Pb, Bi
HE3 - Cu filter	**Ag,** Zn, Mo, Ru, Rh, Pd, Cd, In, Sn, Sb, W
HE4 - Zn filter	Pt

Table 13: Table showing the four different SDD filters used with the PIXE and the elements detected with each of them. Main elements of the alloys are indicated in bold.

In general, precision and accuracy are high for all the elements analysed in MAC2 (Table 14:A), with all elements present in concentrations above 1%. Tin in amounts of 0.3% and 0.5% was not detected in the silver-rich alloys, while it was perfectly identified in the gold-rich alloys (0.5%, 1% and 2%), although overestimated by ~0.2% (absolute error). In silver alloys only three trace elements were detected As, Co and Ni in AGA1; and Ni in AGA2 (Table 14:B). Several trace elements present in the standards in ranges

13-406ppm were not detected (Table 14:C). Detection limits are estimated in 14-120ppm for elements with atomic number 20-40 and 50-1000ppm for atomic numbers >45. Full results are given in appendix N°9.

A-		MAC 2					
		(wt%)	**Cu**	**Au**	**Ag**	**Sn**	**Total**
	Given values		**5.1**	**74.7**	**19.2**	**1.0**	**100.0**
	PIXE (n=3)		5.2	74.7	18.9	1.2	100.0
Precision	Standard deviation	±	0.05	0.1	0.1	0.1	
	Coeficient of variation (%RSD)		0.9	0.1	0.3	4.3	
Accuracy	Absolute error		0.1	0.01	-0.2	0.2	
	Relative error (%)		1.7	0.01	1.3	15.0	

B-	(wt%)	Cu	Au	Ag	Sn	Pb	Zn	Sb	Bi	Fe	Ni (ppm)	As (ppm)	Co (ppm)	Total
AGA1	**Given values**	**20.0**	**1.5**	**77.5**	**0.3**	**0.2**	**0.2**	**0.1**	**0.2**	**0.04**	**118**	**255**	**407**	**100.0**
	PIXE	20.2	1.5	77.5	nd	0.2	0.3	nd	0.2	nd	100	250	625	100.0
AGA2	**Given values**	**10.0**	**0.5**	**87.1**	**0.5**	**1.0**	**0.5**	**0.2**	**0.1**	**0.03**	**264**	**144**	**163**	**100.0**
	PIXE	11.1	0.5	86.5	nd	1.0	0.6	0.2	0.1	nd	165	nd	nd	100.0
MAC1	**Given values**	**1.0**	**93.8**	**4.6**	**0.5**									**100.0**
	PIXE	1.0	93.9	4.5	0.6									100.0
MAC3	**Given values**	**9.1**	**59.2**	**29.7**	**2.0**									**100.0**
	PIXE	9.7	58.3	29.7	2.3									100.0

C-	Given values in ppm													
	Al	**Cd**	**Cr**	**Ge**	**In**	**Mg**	**Mn**	**Pd**	**Pt**	**Rh**	**Se**	**Si**	**Ti**	**Te**
AGA 1	96	165	20	107	37	45	61	54	67	16	169	91	79	271
AGA 2	19	113	76	47	65	17	115	76	114	13	78	43	69	98

Table 14: PIXE analytical results.
(A) Summary of the precision and accuracy results of the gold standard MAC2, analysed by PIXE (average of 3 analyses). (B) Given values and analytical results of standards MAC1, MAC3, AGA1, AGA2; which were analysed 1-2 times only because of time constraints. (C) Trace elements present in AGA1-AGA2 as ppm that were not detected by PIXE. Full results in appendix N°9.

To assess the sampling uncertainty and the potential variability in trace elements within artefacts, two samples each were analysed for two objects: A silver band with perforations from Quitor-1 (popm5-popm6) and disc fragments from the burial 6-6 in Larache (popm13-popm14; Table 15). In the Quitor-1 band both samples have Zn, but showing an internal variability of ~50ppm. However, popm5 contained Ti and Si, which were not detected in popm6. A possibility is that the difference relates to surface contamination. Both samples were mechanically cleaned, so it is possible that surface dirt remained in sample 5. The disparity might also derive from the fact that the analyses of both samples had different doses (popm5 dose 12,000,000; popm6 dose 600,000); however, the LOD in popm6 are <76ppm for Ti and <0.6% for Si, much lower than the amounts detected in popm5. Given the above, I believe the presence of Ti and Si in popm5 relates primarily to surface contamination, rather than being an artefact of the analysis or a reflection of internal heterogeneity.

In the Larache disc, the fragments agree in their bulk composition and both share similar amounts of zinc as a trace element (550-650ppm). Sample popm13 however, contains Fe (0.1%) and Ni (160ppm), elements not detected in popm14. The high value of Fe may suggest that surface contamination was measured during the analysis (both analyses used the same dose). But the Ni content illustrates the variability of this element in a same object, which may range from <25ppm (LOD in popm14) to the 160ppm detected in popm13. This difference of 135ppm is a warning that nickel may not be a good element to make groupings, at least at those levels, and I need more caution when interpreting nickel content in this dataset.

			Trace elements (ppm)									**Light elements (wt%)**				
Site	Id Lab	Counts	Ti	Mn	Fe	Ni	Zn	Ga	Hg	Pb	W	Si	S	Cl	K	Ca
Larache	popm14	12000000	< 40	< 1200	< 640	< 25	550	< 77	< 2900	< 150	< 1100	< 0.9	< 0.2	0.1	< 0.1	0.1
	popm13		< 23	< 960	1020	160	650	< 63	< 970	< 110	< 140	< 0.9	< 0.2	0.2	< 0.1	0.1
Quitor-1	popm5	12000000	430	< 1000	< 400	< 37	690	< 53	< 1500	< 100	< 370	1.6	1.7	< 0.1	< 0.1	0.2
	popm6	6000000	< 76	< 790	< 230	< 20	740	< 47	< 590	< 71	< 590	< 0.6	0.3	< 0.1	< 0.1	0.1

Table 15: Trace elements of 2 objects from SPA, by PIXE. Two samples of each object were analysed to assess sampling uncertainty and the internal variability in trace elements.

4.4.1.3 SEM-EDS

Chemical analysis: Chemical compositions were obtained using a Hitachi s-3400N scanning electron microscope with energy dispersive microscopy (SEM). The instrument was operated at 20kV with counting times of 100s, a working distance of 10mm and a process time of 5.

Five reference materials were used as standards (Table 16): three gold (MAC1-3, Micro-Analysis Consultants Ltd, N°10156) and two silver (133x AGA1-2, MBH Analytical LTD). In general, for silver-rich alloys precision and accuracy were good with <8%RSD (i.e. ±0.1-0.7%SD) and relative error <1.3%; except when concentrations were below 0.3% in AGA1 and below 1% in AGA2, where precision (13-24%RSD) and accuracy (relative error 15-24%) appear low and more variable. Lead, zinc, antimony, bismuth and iron when present ≤0.5% were not always detected. In the case of gold-rich alloys, all elements were detected (0.5% was the minimum), showing however less precision when concentrations were low: amounts >1% showed <8.2%RSD (i.e. ±0.1-0.4%SD), whereas values <1% have 14-23%RSD (i.e. ±0.1-0.2%SD). Still, in MAC standards accuracy was very high in all cases (relative error <7.8%; full results in appendix N°9).

Samples were analysed both semi-quantitatively, i.e. directly on the surface of the extracted sample (non-mounted); and quantitatively, mounted as cross sections in resin blocks, polished down to 0.03μm (using aqueous alumina suspension polisher) and carbon coated. This instrument was mainly used to analyse phases and inclusions within the samples. Nominal limits of detection are typically around 0.1%, but values below

0.5% should be taken as indicative given the increasing analytical uncertainty. Values below 0.1% are reported as below detection ("<dl").

		AGA 1									
	(wt%)	**Cu**	**Pb**	**Au**	**Zn**	**Sn**	**Sb**	**Bi**	**Fe**	**Ag**	**Total**
	Given values	**20.0**	**0.2**	**1.5**	**0.2**	**0.3**	**0.1**	**0.2**	**0.04**	**77.5**	**100.0**
	SEM-EDS (15-09-2015)	20.0	nd	1.5	nd	nd	nd	nd	nd	78.6	100.0
Precision	Standard deviation ±	0.6	-	0.1	-	-	-	-	-	0.7	
	Coefficient of variation (%RSD)	3.2	-	8.0	-	-	-	-	-	0.9	
Accuracy	Absolute error	-0.03	-	-0.005	-	-	-	-	-	1.0	
	Relative error (%)	0.1	-	0.3	-	-	-	-	-	1.3	

		AGA 2									
	(wt%)	**Cu**	**Pb**	**Au**	**Zn**	**Sn**	**Sb**	**Bi**	**Fe**	**Ag**	**Total**
	Given values	**10.0**	**1.0**	**0.5**	**0.5**	**0.5**	**0.2**	**0.1**	**0.0**	**87.1**	**100.0**
	SEM-EDS (15-09-2015)	10.1	1.1	0.6	0.4	nd	nd	nd	nd	87.8	100.0
Precision	Standard deviation ±	0.2	0.1	0.1	0.1	-	-	-	-	0.4	
	Coefficient of variation (%RSD)	2.4	13.3	23.9	16.1	-	-	-	-	0.5	
Accuracy	Absolute error	0.0	0.1	0.1	-0.1	-	-	-	-	0.7	
	Relative error (%)	0.5	5.7	23.6	15.8	-	-	-	-	0.8	

		MAC 1					MAC 2					MAC 3				
	(wt%)	**Cu**	**Au**	**Ag**	**Sn**	**Total**	**Cu**	**Au**	**Ag**	**Sn**	**Total**	**Cu**	**Au**	**Ag**	**Sn**	**Total**
	Given values	**1.0**	**93.8**	**4.6**	**0.5**	**100.0**	**5.1**	**74.7**	**19.2**	**1.0**	**100.0**	**9.1**	**59.2**	**29.7**	**2.0**	**100.0**
	SEM-EDS (15-09-2015)	1.1	94.1	4.3	0.6	100.0	5.4	74.9	18.8	0.9	100.0	9.2	59.1	29.7	2.0	100.0
Precision	Standard deviation ±	0.2	0.4	0.1	0.1		0.2	0.1	0.2	0.2		0.2	0.1	0.2	0.2	
	Coefficient of variation (%RSD)	14.5	0.4	2.9	22.6		2.9	0.1	0.9	17.6		2.6	0.2	0.8	8.2	
Accuracy	Absolute error	0.02	0.2	-0.3	0.02		0.3	0.2	-0.4	-0.1		0.1	-0.1	0.003	-0.01	
	Relative error (%)	1.5	0.3	6.0	3.7		5.7	0.2	2.1	7.8		1.6	0.2	0.01	0.4	

Table 16: Summary of the precision and accuracy results of five standards analysed by SEM-EDS. Full results in appendix N°9.

Mapping: X-ray compositional mapping was carried out at the same instrument. The process time was set up to 2 using the "run up to stop" mode for 15 minutes, producing 10-12 frames. The SEM was operated at 20kV with a working distance of 10mm.

Imaging: Imaging was undertaken at the same instrument; the whole artefacts and unprepared samples were placed directly in the SEM chamber under high vacuum and observed under the second electron detector (“SE”) and backscattered electron detector (“BSE”). The SEM was set to a 15 and 20kV, and variable working distances were used.

4.4.1.4 XRD

The mineral composition of the red patina on the surface of some gold objects was analysed using X-ray powder diffraction. In this case the samples were thin enough to be fixed in the instrument’s sample holder with double-sided tape; therefore the analysis was conducted directly on the surface of the objects. A Rigaku Miniflex600 diffractometer with Bragg-Brentano geometry was used, with a Cu anode ($K\alpha_1$= 1.5406), at 40kV and 15mA. Diffractograms were recorded in the scanning ranges of 2θ (theta) from 5.0° to 90.0° with a step size 0.02°, at a rate of 20 seconds/step.

4.4.1.5 X-ray radiography

Radiographies on a bead (popm45) and a pendant (popm47) were taken with a Todd Research X-Ray Inspection Cabinet, set at 3mA with exposure times between 60-90 seconds at 80-90kV, on an AGFA D7 X-ray film.

4.4.1.6 Metallography

Metallographic analyses were made after preparing the samples using different etchants following Scott's (1991) recipes (Table 17). The aim was to attack copper, silver or gold within the alloys, depending on their concentration. The high gold content in most samples, however, made the etching very difficult. It was possible to reveal the microstructure of 10 samples only; nine with silver contents between 7-66%, and one with copper content of 55%. The remaining samples were burnt or not attacked by the chemicals. Full table listing positive and negative etching attempts are given in appendix N°11.

		Positive results	
Etchant	**Components**	**Time**	**Results**
Aqueous Ferric Chloride	12ml Ionised water 3ml Chlorhydric acid 1gr Ferric chloride aqueous	65 seg	Popm27: revealed banding (Cu-high). Did not react with the other samples
Aqua regia concentrated	40 Nitric acid (65%) 60 Chlorhydric acid (37%)	5 seg	Popm30: partially revealed some grains and banding. The remaining samples with >30%Ag were burnt; samples with <30%Ag were not affected, only developed a minor pitting.
Hydrogen peroxide / iron (III) chloride (fresh)	3.2gr Ferric chloride aqueous 10ml Hydrogen peroxide 10ml Distilled water	5 seg	Popm10, 15, 24, 25, 32, 34, 35, 37: revealed grains and twin bands in some samples with silver ~30%Ag. The remaining samples were burnt (Ag-rich) or not attacked at all (Au-rich).

Table 17: List of etchants used to reveal the microstructure of SPA samples, after Scott (1991). Only 10 samples were positively attacked.

PART III

Results: Production

Chapter 5. Raw materials and alloy practices

This chapter focuses on the chemical composition of the assemblage, reporting data obtained by pXRF, PIXE and SEM-EDS. I will show here that the alloys of the SPA assemblage are varied, particularly in their silver content, showing no preference for a particular composition. This variety would represent primarily the use of unalloyed gold from different deposits, and to a lesser extent the use of artificial alloys adding extra silver or copper. The likely presence of both alloyed and unalloyed gold indicates that a range of different alloy practices were known by Andean metalsmiths. By site, composition show slightly different patterns, indicating that communities did not necessarily access the same type of gold. Several compositional clusters were detected as well, suggesting that some of these items were made in single production events. Lastly, given the distribution of gold and silver sources and the heterogeneity of the assemblage, it is proposed that the precious metals found in SPA were most likely introduced from different areas.

Section 5.1 introduces an overall view of the composition of the assemblage. Section 5.2 focuses on the raw materials used and the alloy practices identified. It starts with a description of the silver and copper levels, trace elements and inclusions identified in SPA materials (5.2.1); followed by more focused discussion about the variety and possible sources of the gold and silver (5.3.1) and the range of alloy practices identified in the assemblage (5.3.2). In section 5.4 compositions are explored on a site basis, identifying specific chemical clusters and detecting differences between sites. Finally, section 5.5 summarises the main findings of the chapter.

5.1 General characterisation of the alloys

The chemical composition of the assemblage was obtained using pXRF and PIXE. Considering that the complete assemblage was analysed by pXRF and only a small part by PIXE, pXRF results will be used by default when discussing bulk chemical composition, whereas PIXE results will be used when talking about minor and trace elements. Both techniques show a very good degree of correspondence - with a couple of exceptions - in the detection of major elements (Au, Ag, Cu), which allows me to interpret the data together, as well as to corroborate the main composition of the alloys (Figure 24).

However, the composition of the 13 silver objects should be considered with caution, because all objects presented a thick corrosion layer. In this case, pXRF results reveal 100%Ag, which represents the silver enrichment of the corrosion layer, even if some of this is likely present in the form of sulphides, chlorides or other corrosion products (light elements were not detected in the mode selected; more information about corrosion in appendix Nº7). Only three of these objects were sampled and analysed in section under the SEM-EDS where small areas of sound metal were identified (popm42, 44 and 46). Their compositions are summarised in Table 18, for these objects SEM-EDS data are used for the plot in Figure 25, to give a better indication of the original metal composition. pXRF results for the remaining 10 objects are still plotted in Figure 25, but their composition will not be used in further interpretations.

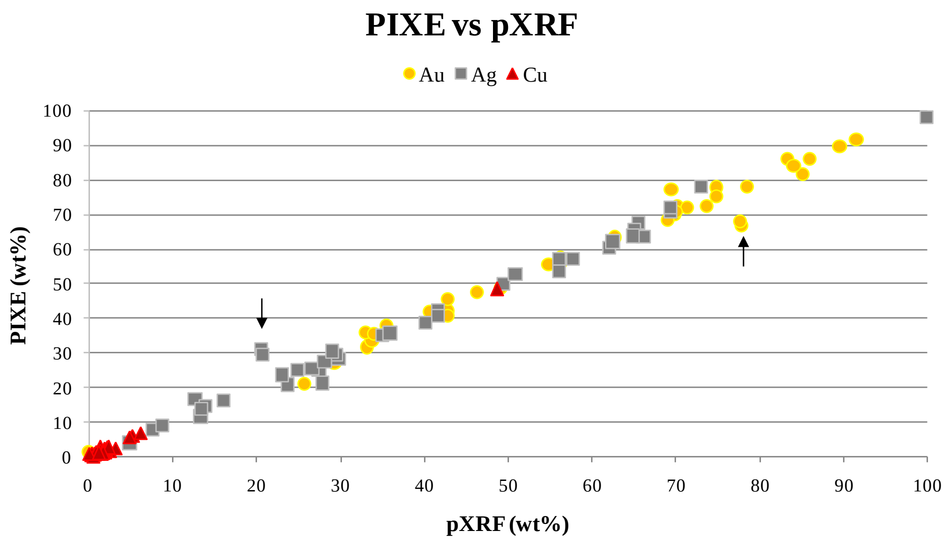


Figure 24: Scatter plot comparing pXRF and PIXE results of the same 42 samples from gold and silver objects from San Pedro de Atacama.
Note the good degree of correspondence between both datasets showing a linear relationship. Exceptions are popm2 and popm9 (arrows), where silver content was higher when detected by PIXE. Probably, the difference is caused by the thinness of the sheets (33 and 54 μm). Given that silver penetration depth is slightly deeper in PIXE than pXRF (see Table 8), it is possible that part of the silver-rich corrosion of the opposite side was included in the reading.

The bulk chemical composition of 145 samples (from 142 objects, since some are made from separate parts) are plotted in Figure 25, and full results given in Table 19. In general, alloy compositions show a widely scattered distribution where gold and silver concentrations vary largely. The diversity of alloys ranges from relatively pure gold, through silver-rich electrum and aurian-silver to silver objects. Another characteristic of the assemblage of SPA is the very low copper concentrations (median 1.3%Cu), except for four artefacts with copper contents above 10%. The compositional variability is materialised in a range of colours from gold to white, passing through yellow, greenish yellow and whitish; only the few copper-rich objects show reddish colours (Figure 26).

Excluding the objects made of pure silver (n=13), the gold alloys analysed have gold ranges between 25.8-96.5% (Figure 27), where 72% of the samples contain ≥60% of gold (Figure 28). Silver contents range between 3.3-73.1%, whereas copper concentrations are between below detection limits and 6.2% (Figure 27). Four objects exceptionally contain high-copper percentages between 11.9-48.7%. Overall, copper concentrations are relatively low in the assemblage of SPA. The estimated melting points of these alloys are relatively high, from 950ºC when silver is over 40%, to 1000º and 1050ºC when silver is below 40% (Figure 29). Given the variety of compositions and colours, from now onwards, I will refer to "silver" objects, when they are made of pure silver or silver-copper alloys with minor or no gold contents; whereas I will refer to "gold" for the rest of the artefacts, including all gold-silver(-copper) alloys.

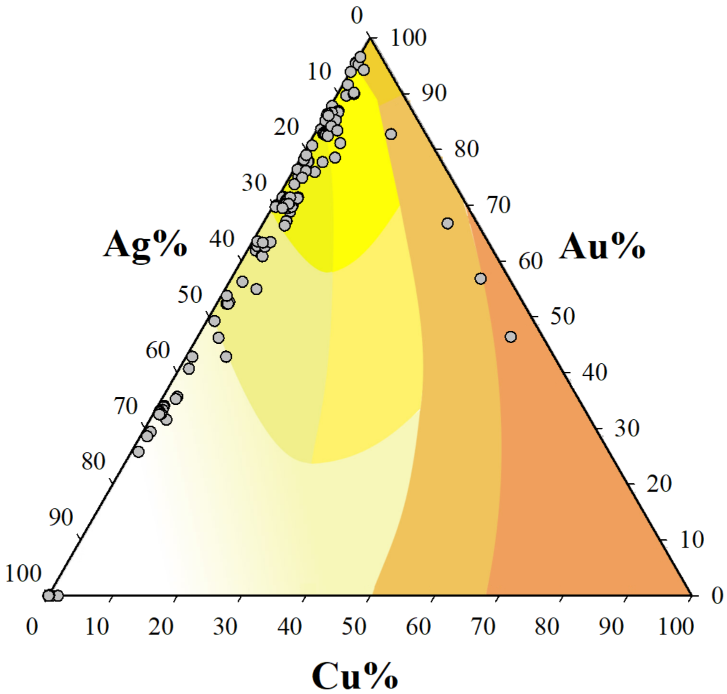


Figure 25: Au-Ag-Cu ternary diagram presenting the chemical composition of 142 metallic objects from SPA, by pXRF (except two samples obtained by SEM-EDS).
Four artefacts were composed of two parts that were analysed independently, so the total samples plotted in the graph are 145 points, which are an average of three readings per sample. Results are normalised to 100wt%.

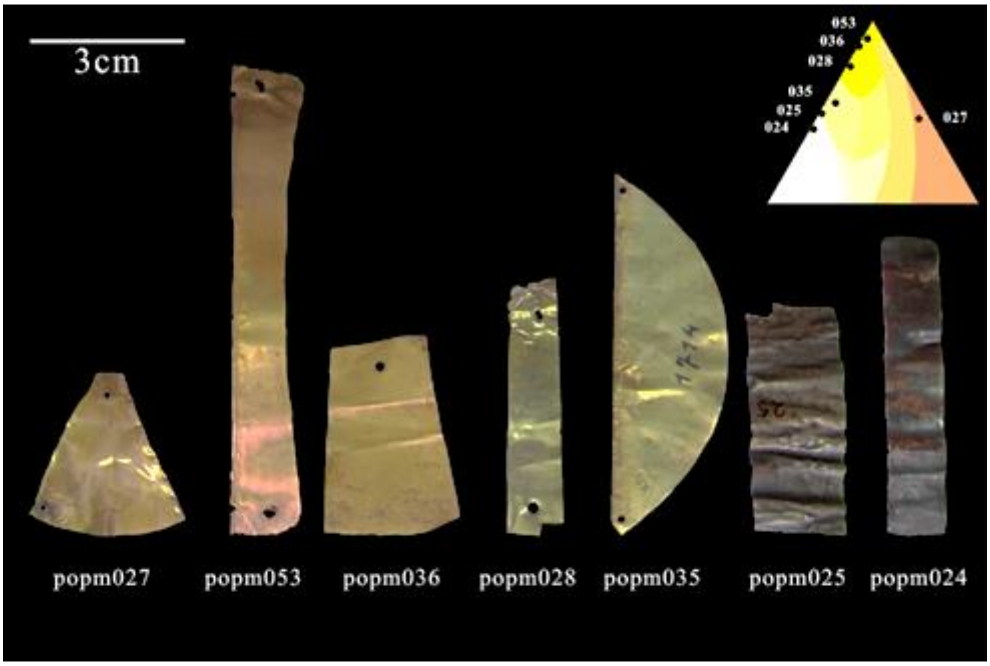


Figure 26: Example of artefacts showing the range of colours present in the precious metal assemblage of SPA.
The objects were photographed together, under the same light and conditions. The ternary diagram inset shows the objects with their reference numbers in the colour diagram.

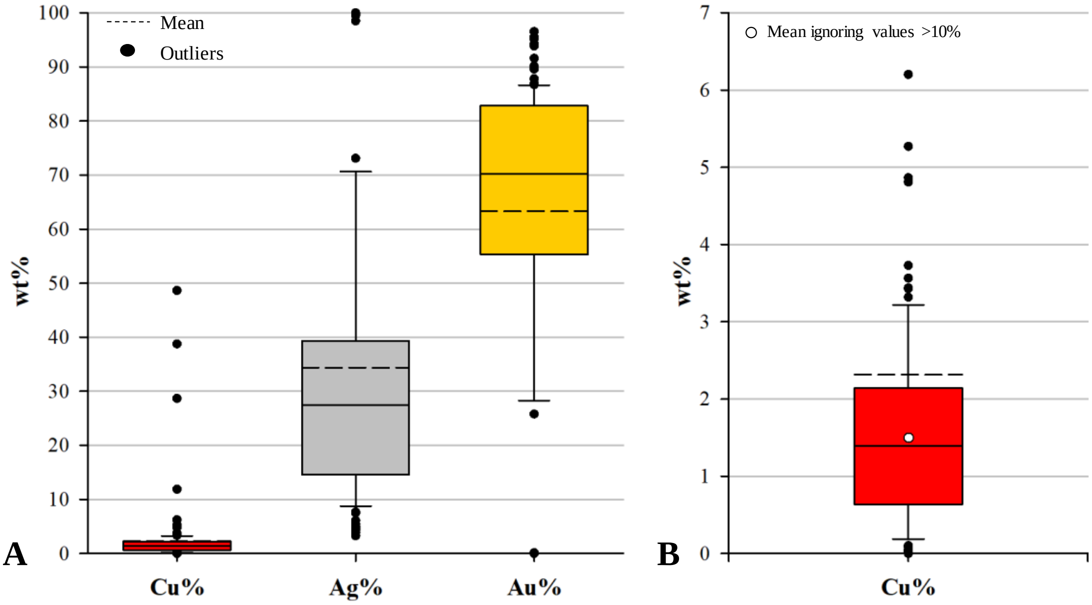


Figure 27: A) Box-and-whisker plot showing the visual summary of the distribution of copper (Cu%), silver (Ag%) and gold (Au%) percentages present in the alloys of SPA.
B) Detail of the copper composition distribution, ignoring objects with copper above 10%.

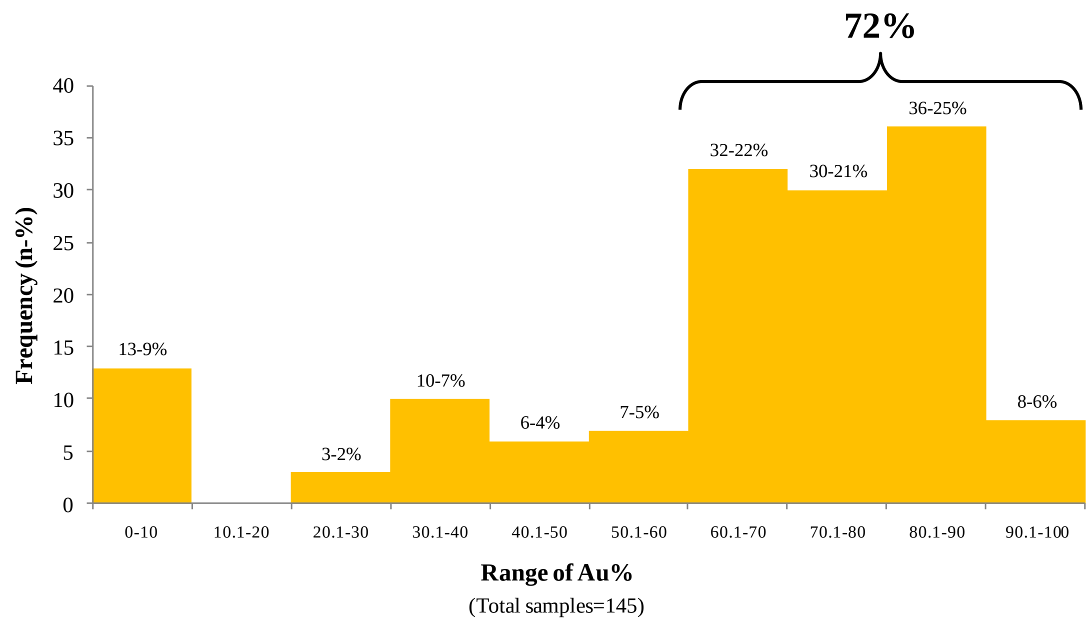


Figure 28: Frequency distribution histogram of Au% in 145 samples of SPA. Note that 72% of the samples have over 60%Au.

		SEM-EDS spot analysis (wt%)							
Sample	Nº readings	O	Na	Cl	Cu	Ag	Au	Total	Analytical total
popm042	5	nd	nd	nd	0.5	99.5	nd	100.0	98.4
popm044	3	nd	nd	nd	1.5	98.5	nd	100.0	92.6
popm046	3	2.3	0.8	18.9	nd	78.0	nd	100.0	97.0

Table 18: Chemical composition of uncorroded and corroded metal in three silver objects, by SEM-EDS. Note that gold is absent and copper is detected only in popm42 and 44. The presence of chlorine, oxygen and sodium in popm46 indicates some alteration in progress.

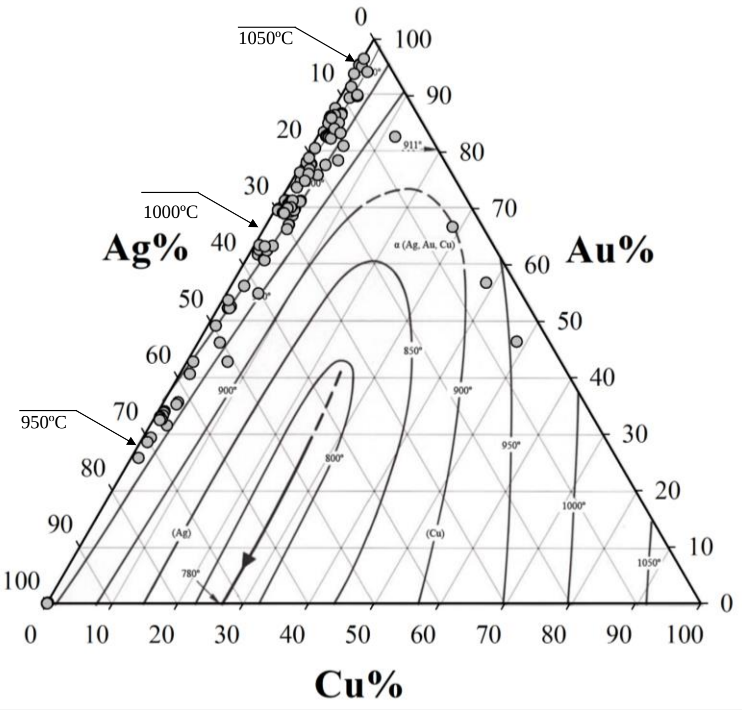


Figure 29: The Au-Cu-Ag liquidus ternary diagram showing the melting temperatures used for the artefacts in SPA (modified from Brepohl, 1968, fig. 30; Scott, 1991, fig. 210).

Table 19: Chemical composition of 142 objects from the Museum of San Pedro de Atacama, by pXRF. Values are an average of three readings. Results are organized by sites, burial and silver content. Three objects composed of more than one part were analysed twice; in total 145 analyses are presented here. Ti and Fe reported here possibly derive from surface contamination trapped in silver corrosion layers. "<dl": below detection limits.

Id Lab	Museum code	Type	Site	Burial	Ti	Fe	Cu	Ag	Au	%Ag/ (Ag+Au)	Year of analysis
popm141	18.087	Goblet	Casa Parr	1	<dl	<dl	0.2	12.0	87.8	12.0	2016
popm089	18.119	Ring	Casa Parr	3	<dl	<dl	3.2	28.0	68.8	28.9	2016
popm002	1086	Fragment	Casa Parr	7	<dl	<dl	1.5	20.6	77.9	20.9	2015
popm009	18.113	Fragment	Casa Parr	7	<dl	<dl	1.5	20.8	77.8	21.1	2015
popm008	18.115	Fragment	Casa Parr	7	<dl	<dl	1.3	23.7	74.9	24.1	2015
popm003	18.116	Fragment	Casa Parr	7	<dl	<dl	1.4	24.9	73.7	25.3	2015
popm011	18.114	Pendant	Casa Parr	7	<dl	<dl	2.5	27.9	69.5	28.7	2015
popm001	18.109	Attachment	Casa Parr	8	<dl	<dl	2.2	62.1	35.6	63.6	2016
popm010	18.110	Pendant	Casa Parr	8	<dl	<dl	2.2	62.6	35.3	63.9	2016
popm085	18.107	Headdress	Casa Parr	11	<dl	<dl	1.0	35.8	63.3	36.1	2016
popm087	18.108	Headdress	Casa Parr	13	<dl	<dl	0.4	14.0	85.5	14.1	2016
popm082	18.096	Headdress	Casa Parr	16	<dl	<dl	1.3	35.7	63.1	36.1	2016
popm083	18.102	Headdress	Casa Parr	16	<dl	<dl	1.3	35.7	63.1	36.1	2016
popm074	18.098	Pendant	Casa Parr	16	<dl	<dl	1.2	35.9	62.8	36.4	2016
popm075	18.100	Pendant	Casa Parr	16	<dl	<dl	1.2	35.9	62.9	36.4	2016
popm047	18.105	Pendant	Casa Parr	16	<dl	<dl	1.2	36.0	62.8	36.4	2016
popm077	18.097	Attachment	Casa Parr	16	<dl	<dl	1.2	36.1	62.6	36.6	2016
popm076	18.099	Pendant	Casa Parr	16	<dl	<dl	1.1	36.2	62.8	36.6	2016
popm079	18.094	Attachment	Casa Parr	16	<dl	<dl	1.3	36.2	62.5	36.7	2016
popm080	18.095	Attachment	Casa Parr	16	<dl	<dl	1.4	36.3	62.3	36.8	2016
popm078	18.103	Attachment	Casa Parr	16	<dl	<dl	1.2	36.4	62.5	36.8	2016
popm073	18.101	Pendant	Casa Parr	16	<dl	<dl	1.0	36.5	62.6	36.8	2016
popm051	18.104	Pendant	Casa Parr	16	<dl	<dl	1.2	36.5	62.3	36.9	2016
popm050	18.106	Pendant	Casa Parr	16	<dl	<dl	1.3	36.8	61.9	37.3	2016
popm007	C.P. 16	Fragment	Casa Parr	16	<dl	<dl	1.1	73.1	25.8	73.9	2015
popm140	18.088	Goblet	Casa Parr	18	<dl	<dl	0.4	13.8	85.8	13.9	2016
popm139	18.089	Goblet	Casa Parr	18	<dl	<dl	0.5	23.1	76.4	23.2	2016
popm018	18.092	Headband	Casa Parr	18	<dl	<dl	0.5	29.6	70.0	29.7	2015
popm017	18.091	Headband	Casa Parr	18	<dl	<dl	0.5	29.8	69.7	30.0	2015
popm081	18.093	Attachment	Casa Parr	18	<dl	<dl	1.1	36.2	62.7	36.6	2016
popm088	18.090	Ring	Casa Parr	21	<dl	<dl	0.6	15.9	83.6	16.0	2016
popm086	18.112	Headdress	Casa Parr	22	<dl	<dl	0.6	21.1	78.3	21.2	2016
popm084	18.111	Headdress	Casa Parr	22	<dl	<dl	0.6	21.2	78.1	21.4	2016
popm046	13.322	Attachment	Coyo 3	6	<dl	<dl	<dl	100.0	<dl	100.0	2015
popm042	13.265	Headband	Coyo 3	11	<dl	1.0	<dl	99.0	<dl	100.0	2015
popm144	13.732	Jug	Coyo 3	23	0.7	<dl	<dl	99.3	<dl	100.0	2015
popm143_5	13.818-A5	Attachment	Coyo 3	33	1.5	8.5	<dl	90.0	<dl	100.0	2015
popm143_3	13.818-A3	Attachment	Coyo 3	33	0.6	3.2	<dl	96.3	<dl	100.0	2015
popm143_6	13.818-A6	Attachment	Coyo 3	33	<dl	0.9	<dl	99.1	<dl	100.0	2015
popm044	13.818-B	Fragment	Coyo 3	33	<dl	0.8	<dl	99.2	<dl	100.0	2015
popm143_4	13.818-A4	Attachment	Coyo 3	33	<dl	0.8	<dl	99.2	<dl	100.0	2015
popm143_1	13.818-A1	Attachment	Coyo 3	33	<dl	0.6	<dl	99.4	<dl	100.0	2015
popm143_2	13.818-A2	Attachment	Coyo 3	33	<dl	<dl	<dl	100.0	<dl	100.0	2015
popm143_7	13.818-A7	Attachment	Coyo 3	33	<dl	<dl	<dl	100.0	<dl	100.0	2015
popm052	14.145	Attachment	Coyo 3	35	<dl	<dl	38.7	4.4	56.8	7.2	2015
popm058	18.136	Bell	Larache	356	<dl	<dl	1.6	11.5	86.9	11.7	2015
popm115	46	Bell	Larache	356	<dl	<dl	1.7	11.6	86.6	11.9	2016
popm116	47(7)	Bell	Larache	356	<dl	<dl	1.6	11.7	86.7	11.9	2016
popm057	18.137	Bell	Larache	356	<dl	<dl	0.8	12.7	86.6	12.8	2015
popm096	38	Ring	Larache	356	<dl	<dl	1.7	15.1	83.2	15.4	2016
popm093	2	Headband	Larache	356	<dl	<dl	1.5	15.4	83.1	15.7	2016
popm091	35	Attachment	Larache	356	<dl	<dl	1.7	15.6	82.7	15.8	2016
popm097	40	Ring	Larache	356	<dl	<dl	1.4	15.6	83.0	15.8	2016
popm090	34	Attachment	Larache	356	<dl	<dl	1.8	15.6	82.6	15.9	2016
popm095	11	Attachment	Larache	356	<dl	<dl	1.4	15.8	82.8	16.0	2016
popm094	10	Headband	Larache	356	<dl	<dl	1.3	15.9	82.8	16.1	2016
popm104	n/n (1)	Ring - wire	Larache	356	<dl	<dl	3.4	29.4	67.2	30.4	2016
popm105	n/n (2)	Ring - wire	Larache	356	<dl	<dl	3.4	29.5	67.1	30.5	2016
popm125	18	Headdress	Larache	358	<dl	<dl	0.6	4.2	95.2	4.3	2016
popm136	18.120	Goblet	Larache	358	<dl	<dl	0.01	4.4	95.5	4.5	2016
popm137	18.121	Goblet	Larache	358	<dl	<dl	0.1	4.5	95.4	4.5	2016
popm118	n/n	Pendant	Larache	358	<dl	<dl	0.2	13.4	86.4	13.5	2016
popm124	21	Pendant	Larache	358	<dl	<dl	0.6	13.5	85.9	13.6	2016
popm121	19	Pendant	Larache	358	<dl	<dl	0.6	13.5	85.8	13.6	2016
popm119	24	Pendant	Larache	358	<dl	<dl	0.6	13.5	85.8	13.6	2016
popm122	20	Pendant	Larache	358	<dl	<dl	0.6	13.7	85.7	13.8	2016
popm120	23	Pendant	Larache	358	<dl	<dl	0.6	13.7	85.7	13.8	2016
popm109	6	Bracelet	Larache	358	<dl	<dl	0.2	13.7	86.1	13.7	2016
popm123	22	Pendant	Larache	358	<dl	<dl	0.6	13.8	85.7	13.8	2016
popm142	5	Headband	Larache	358	<dl	<dl	0.5	14.1	85.4	14.2	2016

This table continues below…

Id Lab	Museum code	Type	Site	Burial	Ti	Fe	Cu	Ag	Au	%Ag/ (Ag+Au)	Year of analysis
popm110	8	Headband	Larache	358	<dl	<dl	0.5	14.4	85.1	14.5	2016
popm138	18.122	Goblet	Larache	358	<dl	<dl	0.7	18.7	80.7	18.8	2016
popm126_1	18.129	Axe (body)	Larache	358	<dl	<dl	3.4	20.6	75.9	21.4	2016
popm126_2	18.129	Axe (band)	Larache	358	<dl	<dl	0.1	99.8	0.1	99.9	2016
popm127	18.125	Attachment	Larache	358 (?)	<dl	<dl	0.2	3.3	96.5	3.3	2016
popm111	3	Headband	Larache	359	<dl	<dl	2.3	27.0	70.7	27.6	2016
popm132	18.124	Headband	Larache	359	<dl	<dl	1.6	27.0	71.4	27.5	2016
popm062	18.135	Bell	Larache	359	<dl	<dl	3.0	27.1	69.9	27.9	2015
popm108	7	Bracelet	Larache	359	<dl	<dl	1.9	27.3	70.8	27.8	2016
popm061	18.134	Bell	Larache	359	<dl	<dl	3.0	27.4	69.7	28.2	2015
popm106	12	Bracelet	Larache	359	<dl	<dl	0.8	27.7	71.5	27.9	2016
popm107	121	Attachment	Larache	359	<dl	<dl	1.5	27.8	70.7	28.2	2016
popm112	9	Headband	Larache	359	<dl	<dl	0.7	27.9	71.4	28.1	2016
popm103	n/n (3)	Ring - wire	Larache	359	<dl	<dl	3.6	30.1	66.3	31.2	2016
popm114	18.128	Ring (appliquéd)	Larache	359	<dl	<dl	2.9	36.3	60.8	37.4	2016
popm113	18.128	Ring (band)	Larache	359	<dl	<dl	2.7	36.3	61.0	37.3	2016
popm129	18.130	Ring	Larache (?)	359 (?)	<dl	<dl	11.9	5.4	82.7	6.1	2016
popm071	n/n	Ring	Larache (?)	359 (?)	<dl	<dl	0.7	35.8	63.5	36.0	2015
popm036	74 (22)	Pendant	Larache	1714	<dl	<dl	0.5	13.5	86.0	13.5	2015
popm035	1714 (75/21)	Attachment	Larache	1714	<dl	<dl	4.9	40.2	54.9	42.2	2015
popm063	18.142	Bell	Larache	1714 (?)	<dl	<dl	1.9	21.9	76.1	22.3	2015
popm065	63-64	Bell	Larache	1714 (?)	<dl	<dl	3.1	25.5	71.4	26.3	2015
popm064	18.143	Bell	Larache	1714 (?)	<dl	<dl	3.1	25.7	71.2	26.5	2015
popm066	62	Bell	Larache	-	<dl	<dl	2.2	15.4	82.4	15.7	2015
popm056	18.141	Bell	Larache	-	<dl	<dl	0.6	20.4	79.0	20.5	2015
popm013	91.1.8	Attachment	Larache	6/6	<dl	<dl	2.0	41.7	56.3	42.6	2015
popm019	91.1.13	Tip	Larache	7/8	<dl	<dl	2.1	12.7	85.2	13.0	2015
popm012	91.1.15	Fragment	Larache	7/8	<dl	<dl	5.3	16.2	78.5	17.1	2015
popm147	18.140	Bell	Larache	body1	<dl	<dl	1.8	45.5	52.6	46.4	2016
popm146	18.138	Bell	Larache	body1	<dl	<dl	1.8	45.9	52.3	46.7	2016
popm145	18.139	Bell	Larache	body1	<dl	<dl	1.5	46.2	52.3	46.9	2016
popm099	2	Bell	Larache	body2	<dl	<dl	2.3	26.7	71.0	27.3	2016
popm098	1	Bell	Larache	body2	<dl	<dl	1.9	26.8	71.3	27.4	2016
popm100	3	Bell	Larache	body2	<dl	<dl	2.3	27.1	70.6	27.8	2016
popm101	4	Bell	Larache	body2	<dl	<dl	1.8	27.2	71.0	27.7	2016
popm102	5	Bell	Larache	body2	<dl	<dl	2.2	27.4	70.4	28.0	2016
popm060	18.133	Bell	Larache	body2	<dl	<dl	1.7	27.6	70.7	28.1	2015
popm059	18.132	Bell	Larache	body2	<dl	<dl	1.8	27.9	70.3	28.4	2015
popm039	117-118-119	Attachment	Quitor 1	889	<dl	<dl	0.9	56.2	42.8	56.8	2015
popm037	76 (23)	Fragment	Quitor 1	889	<dl	<dl	1.0	65.0	34.0	65.6	2015
popm033	79 (19)	Ring	Quitor 1	889	<dl	<dl	1.0	65.2	33.8	65.8	2015
popm032	72 (18)	Pendant	Quitor 1	889	<dl	<dl	1.1	65.6	33.3	66.3	2015
popm151	19.331b	Headband	Quitor 1	889	<dl	<dl	1.2	66.2	32.6	67.0	2016
popm150	19.332	Attachment	Quitor 1	889	<dl	<dl	0.9	66.2	32.9	66.8	2016
popm034	78 (20)	Bell	Quitor 1	889	<dl	<dl	0.7	66.2	33.1	66.7	2015
popm152	19.331a	Headband	Quitor 1	889	<dl	<dl	1.0	66.5	32.5	67.2	2016
popm005	16514b	Attachment	Quitor 1	n/n	<dl	<dl	1.2	69.4	29.4	70.3	2016
popm048	16514a	Attachment	Quitor 1	n/n	<dl	<dl	1.1	70.4	28.6	71.1	2016
popm026	15 (30)	Bracelet	Quitor 5	2003	<dl	<dl	1.9	14.0	84.1	14.2	2015
popm030	31 (25)	Attachment	Quitor 5	-	<dl	<dl	2.4	35.1	62.6	35.9	2015
popm027	28 (31)-b	Attachment	Quitor 5?	-	<dl	<dl	48.7	4.9	46.4	9.6	2015
popm023	29 (33)	Fragment	Quitor5 or Solor3	-	<dl	<dl	3.2	13.4	83.4	13.9	2015
popm028	26 (37)	Attachment	Quitor5 or Solor3	-	<dl	<dl	2.0	23.1	74.9	23.6	2015
popm015	69 (16)	Pendant	Sequitor Al	767	<dl	<dl	0.7	7.7	91.6	7.7	2015
popm131	18.127	Attachment	Sequitor Al	710-757	<dl	<dl	28.7	4.6	66.7	6.5	2016
popm016	70 (17)	Attachment	Sequitor Al	no burial	<dl	<dl	1.5	8.9	89.6	9.0	2015
popm133	8431-b	Tip	Solcor3	107	<dl	<dl	2.5	7.5	90.0	7.7	2016
popm134	8431-c	Tip	Solcor3	107	<dl	<dl	2.5	7.6	89.9	7.8	2016
popm135	8431-a	Wrapping sheet	Solcor3	107	<dl	<dl	4.8	14.1	81.1	14.8	2016
popm092	18.123	Headband	Unknown	-	<dl	<dl	1.9	3.9	94.2	4.0	2016
popm130	18.131	Ring	Unknown	-	<dl	<dl	0.0	6.1	93.9	6.1	2016
popm053	13 (34)	Attachment	Unknown	-	<dl	<dl	2.4	7.5	90.1	7.6	2015
popm128	18.126	Pendant	Unknown	-	<dl	<dl	3.7	18.5	77.7	19.3	2016
popm022	114(15)b	Band	Unknown	-	<dl	<dl	1.9	26.7	71.4	27.2	2015
popm021	114(15)a	Band	Unknown	-	<dl	<dl	2.2	27.5	70.2	28.2	2015
popm029	113 (14), 115, 120	Band	Unknown	-	<dl	<dl	1.6	28.9	69.5	29.4	2015
popm067	32 (26)	Unknown	Unknown	-	<dl	<dl	2.8	33.8	63.4	34.8	2015
popm069	116	Fragment	Unknown	-	<dl	<dl	1.7	35.0	63.3	35.6	2015
popm055	27 (32)	Band	Unknown	-	<dl	<dl	0.9	45.4	53.8	45.8	2015
popm025	25 (35)	Fragment	Unknown	-	<dl	<dl	1.2	49.6	49.2	50.2	2015
popm054	4 (13)	Headband	Unknown	-	<dl	<dl	3.3	50.4	46.2	52.2	2015
popm041	38	Fragment	Unknown	-	<dl	<dl	6.2	51.0	42.8	54.3	2015
popm024	30 (36)	Band	Unknown	-	<dl	<dl	1.5	57.8	40.7	58.7	2015
popm117_2	n/n	Ring (appliquéd)	Unknown	-	<dl	<dl	2.6	65.9	31.5	67.6	2016
popm117_1	n/n	Ring (band)	Unknown	-	<dl	<dl	<dl	100.0	<dl	100.0	2016

5.2 Exploring raw materials and alloying practices

In this section, the compositions will be analysed in more detail to identify potential raw material sources and alloy practices, particularly looking at the a) silver, b) copper content, c) trace elements and d) inclusions within the metal.

5.2.1 Compositions of the SPA assemblage

5.2.1.1 Silver content

Silver levels up to 30% are consistent with silver contents naturally expected in mined and alluvial gold deposits (Chapman et al., 2002; Guerra & Rehren, 2009; Hough et al., 2009; Spiridonov & Yanakieva, 2009). Between 30-50% (Samusikov, 2002) or 30-70% silver (Spiridonov & Yanakieva, 2009) it is called electrum. Above 50% or 70% (depending the author) and up to 90% it is called kuestelite, which is a very rare mineral; and from 90% upwards it is considered a silver deposit (Hough et al., 2009; Spiridonov & Yanakieva, 2009). It must be considered that in nature all these alloys are possible, and that these divisions are arbitrary and may be totally irrelevant in the past.

The ratio of Ag/(Ag+Au) in artefacts has been used in archaeometallurgical studies to estimate the hypothetical amount of silver naturally present in the gold before it was alloyed, based on the fact that unalloyed gold has negligible amounts of copper (<1%), and assuming that all the silver in the gold was present as a natural impurity (Guerra & Calligaro, 2004; Hough et al., 2009; Martinón-Torres et al., 2007, 2012; Uribe & Martinón-Torres, 2012). The present case is different, however, in that copper values are typically very low anyway, and in that presence of pure silver objects suggests that this metal could have been available for artificial alloys with copper. Therefore, this ratio is used here with a slightly different purpose, as an exploratory tool to search for modes that might denote individual gold sources or possible alloying practices.

The frequency distribution histogram of %Ag/(Ag+Au) shows that the distribution is not normal, and rules out the use of a single source or gold deposits with similar silver levels (Figure 30), in which case they would have arranged in a normal distribution curve (see Uribe & Martinón-Torres, 2012, p. 6 for an example). The plot shows a much more variable distribution with a main mode in the 25-30% range, followed by subsidiary modes at 10-15%, 35-40% and 100% silver. Between 40-75% of silver, it shows a fluctuating tail with frequencies between 2-8 objects. In general, 59% of the assemblage contains silver levels below 30%.

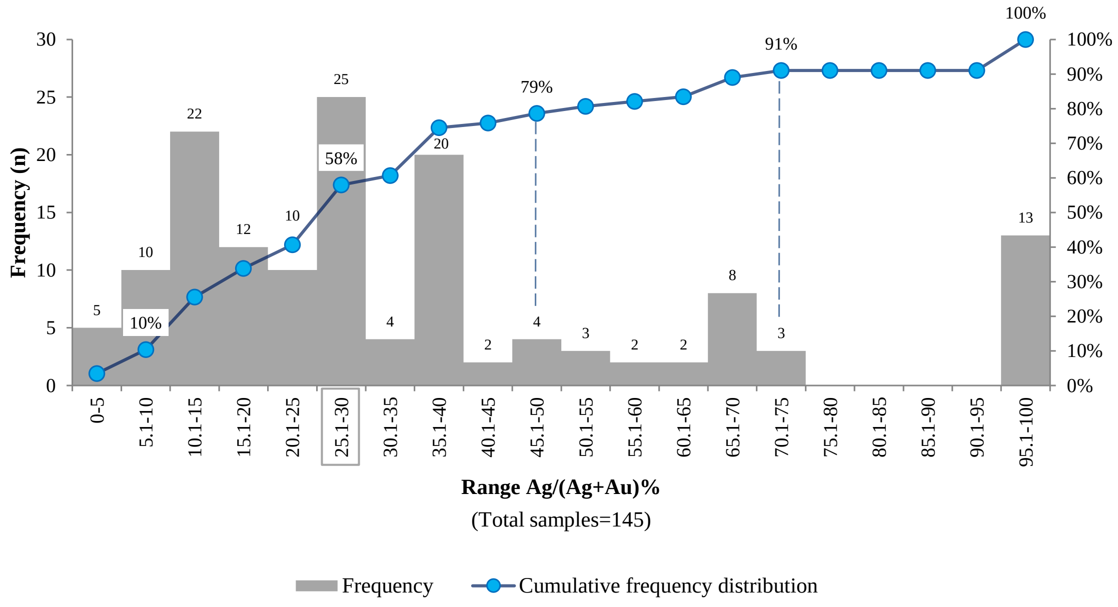


Figure 30: Frequency distribution histogram of %Ag/(Ag+Au) values in 145 samples of SPA. A cumulative frequency distribution line was plotted on top, summing up the percentage of samples at each compositional range. Note that 58% of the total assemblage contains up to 30% Ag, which is the range of silver content that may be typically expected in native gold, although this does not mean that all of these necessarily represent natural, unalloyed gold.

5.2.1.2 Copper Content

It is widely accepted that native gold usually contains levels of copper below 1%, commonly ranging between 0.1-0.8% (Guerra & Calligaro, 2004; Guerra & Rehren, 2009; Hough et al., 2009; Schlosser et al., 2009; Spiridonov & Yanakieva, 2009; Townley et al., 2003); however, other authors report copper levels up to 2% or even extraordinary cases of 6-8%Cu in alluvial gold (Ogden, 2000; Petersen, 1970). Native silver, on the other hand, may contain copper traces from 0.08% up to 3%Cu (Murillo-Barroso et al., 2014) or 18%Cu (Schlosser et al., 2009). Still, Murillo-Barroso and colleagues (2014, p. 263) suggest for Spanish silver objects that up to 20%Cu can derived from native silver. Silver minerals can contain from 0-45%Cu, depending their type such as argentiferous tetrahedrites (although some Cu is lost during the smelting process; Murillo-Barroso, 2013, pp. 139-150,155).

The frequency distribution histogram of copper levels in SPA samples shows a skewed distribution to the left, which means that most values are close to zero. It has an asymmetrical shape with dispersion up to 6.2%, and a few extreme values above 6.6% (Figure 31). 36% of the sample contain up to 1%, which correspond to natural copper levels expected in alluvial gold. However, the highest frequency is between 1-1.5% copper content. Overall, 56% of the assemblage contains up to 1.5%Cu and 88% contain up to 3%Cu (Figure 32). Values between 3-6.5%Cu represent 10% of the assemblage.

Four objects stand out in their high copper contents (>10%Cu): a ring probably from Larache with 11.9%Cu, a decorated plate from Sequitor Alambrado with 28.7%, a disc from Coyo-3 with 38.7% and a pendant probably from Quitor-5 with 48.7%Cu. Two of the three silver objects analysed by SEM-EDS contained copper in 0.5%Cu (popm42) and 1.5%Cu (popm44).

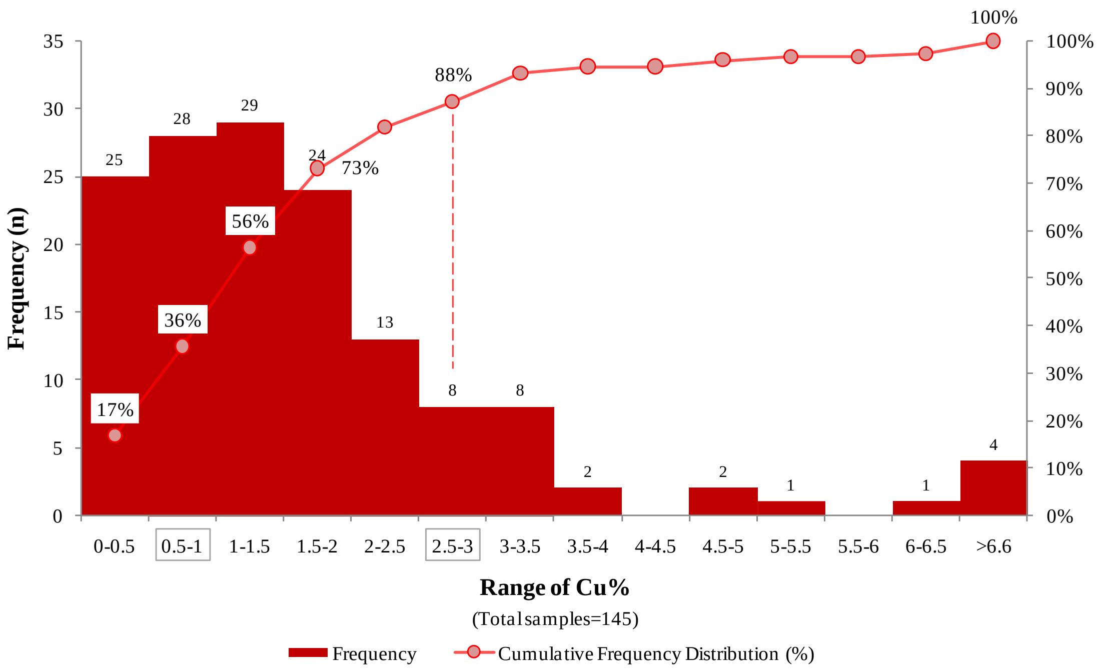


Figure 31: Frequency distribution histogram of Cu% of 145 samples from SPA.
A cumulative frequency distribution line was plotted on top, summing up the percentage of samples at each compositional range. Note that 36% of the samples have less than 1% copper, while 88% is accumulated below 3% Cu.

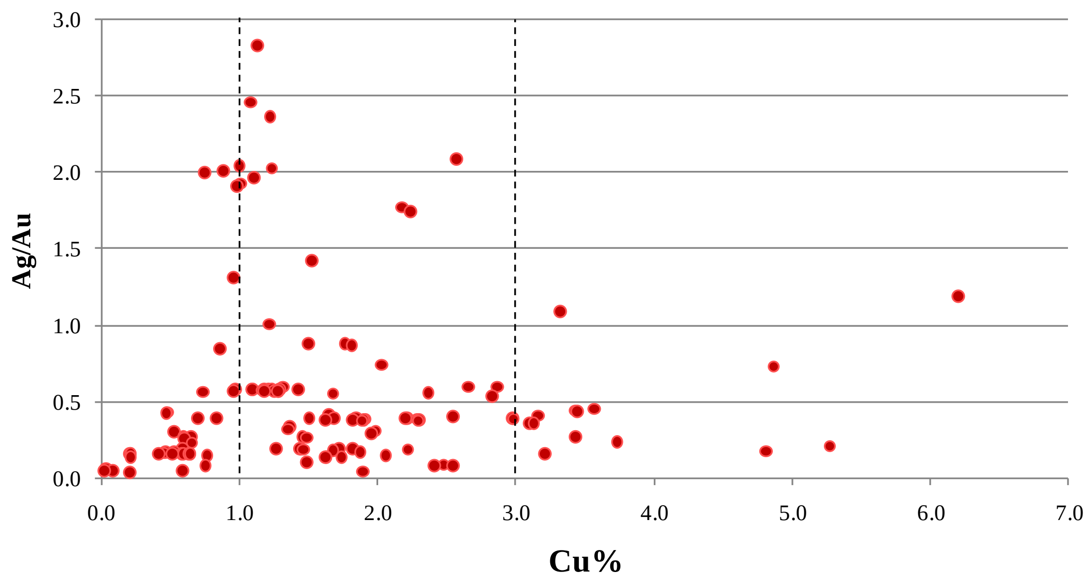


Figure 32: Scatter plot comparing copper content against Ag/Au ratio.
Most of the samples fall below 3%Cu. The four high-copper objects are not shown in this plot.

5.2.1.3 Trace elements

The combination of characteristic trace elements in metallic objects (<0.1%) is used in archaeology to obtain fingerprints from the ore deposits or artefacts to establish provenance, to identify different raw material sources within an assemblage, changes in the ore supply and circulation of metal, fake artefacts and the possibility of re-melting or reuse of metals (Gondonneau & Guerra, 2002; Guerra, 1998; Guerra et al., 1999; Guerra & Calligaro, 2004; Kovacs et al., 2009; Wilson & Pollard, 2001). In the case of native gold, the assumption is that "*a fingerprint of gold samples is representative of both gold from a specific mine and of gold from a specific mineralisation event, which is being mined*" (Watling et al., 1994, p. 218). For archaeological artefacts, two principles are assumed: first, that some trace elements are not altered during smelting and melting, so their presence and relative concentration in the objects reflect the original ore composition. And second, that artefacts sharing the same pattern of trace elements were made using metal of the same ore deposit (Gondonneau & Guerra, 2002).

Trace elements are used here to identify different raw materials and grouping. Forty-two samples from SPA were analysed by PIXE detecting nine elements at trace levels: Fe, Zn, Ti, Ni, Ga, Pb, Hg, Mn and W. Most of the samples shared similar elements -mainly Zn-Fe-Ti and the results do not show obvious groups (Table 20). Light elements were also detected: Si, K, Ca, S and Cl. Si is most likely associated to quartz inclusions in the metal or on the surface, whereas K and Ca would result from surface contamination (except in popm43 where Ca (~46%Ca) is part of the corrosion layer). The levels of S and Cl are relatively high in some objects, most likely resulting from corrosion processes (see appendix Nº7). Objects with high silver content tend to present high-S levels.

Considering the heavy elements, zinc is the most characteristic element detected in 71% of the samples (n=30) ranging 380-1700ppm, although this element is volatile, and its concentration would decrease during smelting. PIXE LODs ranged between 201-510ppm depending on the analyses, which suggests that the boundary between objects with “present” and “absent” zinc may be artificially created by the LODs. Zinc is present in both gold and silver-rich alloys, as well as in objects with various levels of copper (0-47%Cu). By SEM-EDS, eight samples[8] (of 41) showed minute inclusions containing Zn, Cu, Fe, Ti and S. Also PIXE detected these elements in the same samples: Ti (102-490ppm), Fe (780-2200 ppm), Zn (600-660ppm) and S (0.9-3.6%). Ni (84ppm) and Ga

[8] Samples: popm10, 12, 19, 24, 25, 33, 34 and 40

(140ppm) appear only in one case; Sn was not detected. In four cases (popm3, 27, 37, 47) PIXE detected minor levels of Zn (0.1-0.2%) that were not identified by SEM-EDS.

Iron was detected by PIXE in 60% of the samples (n=25) in ranges 780-6700ppm. Its LODs range between 160-780ppm. Iron is a natural impurity of gold (Guerra & Calligaro, 2004), but it also may be present as surface contamination from post-depositional process. However, under the SEM minute Fe-rich inclusions were found within the metallic core of 23 objects. The iron particles may derive from the original ores of the gold deposits. Primary gold deposits are usually associated to quartz veins and iron ore minerals such as pyrite (FeS_2); indeed, 13 samples contain Fe and S (based on PIXE); particles of these minerals can be present in alluvial gold grains as well (Boric et al., 1990).

Titanium is present in 45% of the samples (n=19) between 102-630ppm, only an object has a much higher 8100ppm (popm19). This element is related to higher Fe, Zn and, in one case, with Pb. Titanium may be present both on the surface as dirt from the soil or as a trace element within the metal. The analysis of five tiny alluvial gold grains detected a Ti-O inclusion (3x11μm) on one of them, indicating that Ti can be introduced to the alloy through the gold (see below section 5.3.1 and appendix Nº12).

Nickel was detected in 24% of the samples (n=10) in 81-300ppm, with LODs of 18-95ppm. It is associated to either Zn and Fe or Fe; and in two cases, Ti appears associated to Zn and high Ga (500 and 820ppm). Gallium is found in only 12% of the samples (n=5) between 60-820ppm, although LODs are 40-210ppm. It is associated to Zn and S (n=3), Ni and Pb (n=2) and Ti, Mn, Fe and Hg (n=1). Lead is detected in 7% of the samples (n=3), between 150-8000ppm. In two cases, it is associated to Zn, Ga and S. Only sample popm43 contains 600ppm of mercury and 0.3% of manganese; this is a corroded silver band from Coyo-3 that also has Zn, Pb, Ga and S. Tungsten is detected only in popm1, together with Zn. It is important to note, however, that W can be misidentified due to an overlap of its Mα (1.77KeV) spectral line with Si Kα (1.73KeV), which is quantified as 3% in this object.

In general, no evident groups are found by trace elements, but some patterns have helped in the identification of specific batches, supporting the information obtained by the pXRF and SEM-EDS, as discussed later sections. The presence of elements such as Zn could also help demarcate potential geological origins of the gold deposits, as discussed in the next section.

				Major elements (wt%)			Trace elements (ppm)									Light elements (wt%)*				
			Filter	HE1	HE3	HE1	BE0	HE1	HE1	BE0	HE3	HE1	HE1	HE1	HE3	BE0	BE0	BE0	BE0	BE0
Counts	Id Lab	Site	Burial	Cu	Ag	Au#Lα	Ti	Mn	Fe	Ni	Zn	Ga	Hg#Lα	Pb#Lα	W #Lα	Si	S	Cl	K	Ca
12000000	popm008	C. Parr.	7	1.4	20.6	77.0	< 150	< 1000	1300	300	960	< 210	< 3500	< 16	< 150	< 1.2	< 0.5	0.8	< 0.1	< 0.1
1000000	popm011	C. Parr.	7	1.8	21.0	76.2	< 38	< 1200	960	< 42	690	< 83	< 1500	< 160	< 640	< 0.2	0.5	0.1	< 0.1	0.1
15000000	popm003	C. Parr.	7	2.7	24.9	71.7	< 26	< 990	< 590	< 95	1190	< 210	< 2700	< 190	< 380	< 0.3	< 0.2	0.6	< 0.1	< 0.04
6000000	popm009	C. Parr.	7	2.8	28.9	66.9	< 50	< 580	< 640	81	750	500	< 3900	< 290	< 480	< 0.2	< 0.1	1.2	< 0.1	0.1
6000000	popm002	C. Parr.	7	2.1	28.7	61.5	< 60	< 1200	< 720	< 29	520	< 81	< 3300	< 160	< 180	< 0.5	2.5	4.9	< 0.1	0.1
6000000	popm001	C. Parr.	8	1.9	57.7	36.3	< 100	< 1000	< 780	< 38	610	< 66	< 1700	< 130	200	3.0	0.6	0.3	< 0.1	0.2
12000000	popm010	C. Parr.	8	2.3	58.6	33.5	190	< 870	1700	< 20	600	140	< 2100	< 110	< 540	2.9	0.9	1.4	< 0.1	0.3
6000000	popm047	C. Parr.	16	1.1	35.2	62.6	< 110	< 420	1700	< 62	1500	< 96	< 3500	< 180	< 1000	< 1.0	0.6	< 0.1	< 0.1	0.1
12000000	popm007	C. Parr.	16	0.9	78.0	21.1	< 3300	< 770	< 160	< 3100	730	140	< 1100	< 75	< 110	< 27.2	< 1.9	< 0.7	< 0.9	< 0.3
12000000	popm017	C. Parr.	18	0.4	27.1	68.5	390	< 660	1900	< 57	800	< 140	< 4000	< 140	< 1000	2.4	0.9	0.2	< 0.1	0.3
12000000	popm018	C. Parr.	18	0.7	28.0	66.7	230	< 1500	3000	< 48	800	< 190	< 4000	< 200	< 940	2.4	1.2	0.2	0.2	0.2
6000000	popm043	Coyo-3	11	0.4	49.4	0.6	< 220	3000	< 1400	< 82	380	60	600	150	< 440	< 2.4	0.6	1.7	< 0.2	46.9
15000000	popm036	Larache	1714	0.2	13.3	82.7	< 84	< 620	2700	170	800	< 180	< 3900	< 380	< 990	2.4	< 0.4	0.5	0.4	0.2
1000000	popm035	Larache	1714	5.6	38.3	55.0	400	< 870	1110	< 23	< 410	< 62	< 1000	< 86	< 110	< 0.6	0.5	0.3	< 0.02	0.2
12000000	popm014	Larache	6-6	2.1	40.5	57.2	< 40	< 1200	< 640	< 25	550	< 77	< 2900	< 150	< 1100	< 0.9	< 0.2	0.1	< 0.1	0.1
12000000	popm013	Larache	6-6	1.9	42.1	55.6	< 23	< 960	1020	160	650	< 63	< 970	< 110	< 140	< 0.9	< 0.2	0.2	< 0.1	0.1
6000000	popm012	Larache	7-8	6.0	16.0	77.4	< 51	< 900	1400	240	< 210	< 70	< 1200	< 63	< 640	< 0.7	< 0.2	0.2	0.2	0.1
12000000	popm019	Larache	7-8	1.8	15.6	77.0	8100	< 790	4400	< 83	< 780	< 180	< 4000	8100	< 820	2.4	< 0.1	1.0	< 0.1	0.2
15000000	popm040	Quitor-1	889	1.1	51.2	43.6	450	< 1200	1600	< 59	600	< 77	< 1800	< 150	< 720	< 1.1	2.7	0.6	< 0.04	0.6
15000000	popm039	Quitor-1	889	0.9	56.4	41.5	570	< 830	< 650	< 48	800	< 83	< 2000	< 150	< 710	< 0.5	0.4	0.5	< 0.1	0.1
12000000	popm034	Quitor-1	889	0.8	61.6	34.7	102	< 670	780	< 26	640	< 40	< 1400	< 78	< 690	1.1	1.2	0.3	< 0.1	0.2
15000000	popm037	Quitor-1	889	0.8	58.6	32.5	430	< 750	3400	< 38	1010	< 86	< 1600	< 32	< 830	2.8	3.8	0.4	< 0.1	0.6
12000000	popm033	Quitor-1	889	1.0	61.4	31.6	360	< 520	2200	< 18	620	< 50	< 1700	< 91	< 520	3.5	1.7	0.2	< 0.1	0.4
12000000	popm032	Quitor-1	889	1.0	64.9	30.4	630	< 560	< 510	< 22	660	< 51	< 1700	< 92	< 810	1.6	1.3	0.4	< 0.1	0.3
12000000	popm005	Quitor-1	-	1.1	68.3	27.1	430	< 1000	< 400	< 37	690	< 53	< 1500	< 100	< 370	1.6	1.7	< 0.1	< 0.1	0.2
6000000	popm006	Quitor-1	-	1.3	71.5	26.8	< 76	< 790	< 230	< 20	740	< 47	< 590	< 71	< 590	< 0.6	0.3	< 0.1	< 0.1	0.1
6000000	popm026	Quitor-5	2003	1.4	13.6	78.9	400	< 710	3200	< 42	< 390	< 65	< 4200	< 160	< 1500	2.9	1.1	0.7	0.3	0.8
1000000	popm030	Quitor-5	-	2.6	33.0	58.7	500	< 1300	940	< 56	< 360	< 160	< 3200	< 170	< 410	1.2	3.5	0.7	< 0.1	0.3
12000000	popm027	Quitor-5?	-	47.9	3.9	46.9	< 51	< 750	< 560	113	1700	820	< 960	740	< 2000	< 0.2	0.3	0.4	0.2	0.1
12000000	popm023	Q5 or S3	-	2.2	10.6	78.6	490	< 1200	5900	< 63	650	< 140	< 5000	< 190	< 500	5.3	< 0.2	1.5	0.7	0.3
1000000	popm028	Q5 or S3	-	1.2	23.5	74.8	< 130	< 1100	2100	170	< 510	< 70	< 3500	< 160	< 810	< 1.0	< 0.3	0.1	< 0.1	0.1
12000000	popm015	Seq. Al.	767	0.7	7.5	89.0	230	< 1300	2800	110	< 450	< 170	< 5300	< 190	< 920	2.2	< 0.5	0.2	0.2	0.2
1000000	popm016	Seq. Al.	no burial	1.4	8.3	83.9	250	< 640	6700	< 38	< 480	< 79	< 3600	< 82	< 1000	4.8	< 0.3	0.2	0.4	0.3
1000000	popm022	-	-	2.5	25.0	70.7	< 72	< 1100	< 770	< 24	< 480	< 80	< 2600	< 130	< 580	< 0.2	< 0.3	1.7	< 0.05	0.1
12000000	popm021	-	-	2.8	24.4	70.5	< 46	< 1000	< 770	< 32	< 390	< 74	< 1200	< 120	< 760	< 0.8	0.6	1.7	< 0.04	0.1
6000000	popm029	-	-	1.8	27.0	69.8	< 49	< 970	< 690	< 26	< 460	< 67	< 1100	< 110	< 940	< 0.3	< 0.1	1.4	< 0.04	0.1
15000000	popm038	-	-	1.1	29.4	66.2	< 130	< 790	1500	< 77	840	< 90	< 1400	< 140	< 1000	< 1.2	< 0.5	2.9	< 0.1	0.2
1000000	popm025	-	-	1.3	49.4	48.2	< 100	< 370	< 450	< 25	490	< 80	< 1100	< 150	< 400	< 0.2	0.8	0.2	< 0.1	0.1
12000000	popm024	-	-	0.9	54.5	40.0	310	< 690	1500	84	660	< 99	< 2500	< 120	< 450	< 1.3	3.6	0.4	< 0.1	0.4
6000000	popm041	-	-	6.4	48.0	37.0	< 68	< 1200	< 470	< 46	< 460	< 76	< 2300	< 130	< 810	< 0.9	0.9	7.1	< 0.1	0.2

Table 20: Trace elements of 40 objects from SPA, by PIXE. Results are organised by sites and burials.
Unknown cemeteries and burials are indicated with the symbol "-". Limit of detection for each reading are presented in grey, with the symbol "<". Three objects were sampled twice: popm005-006, popm013-014 and popm039-040.Major and light elements are presented in %, not ppm. (*) Light elements relate to surface dirt from the soil and/or corrosion.

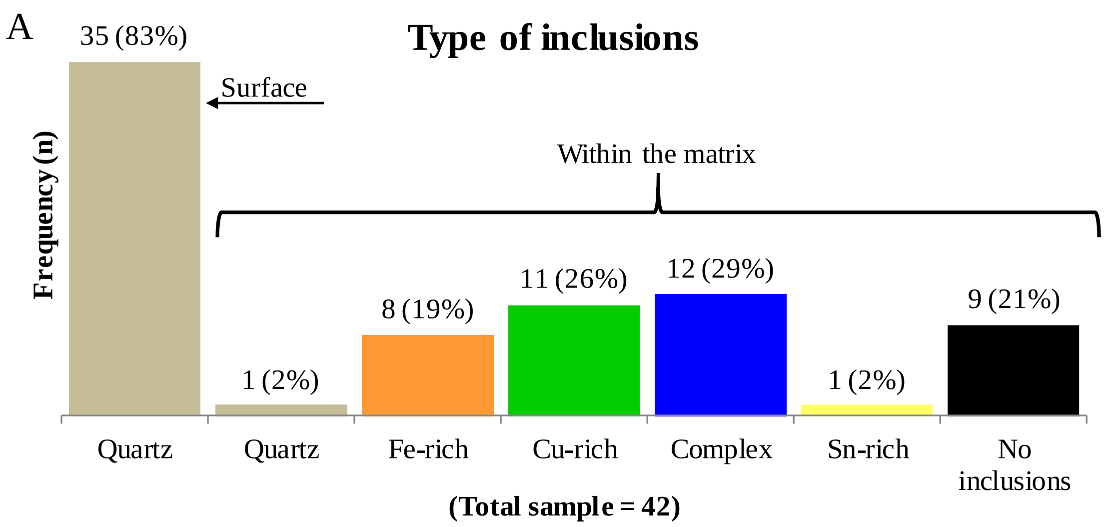
5.2.1.4 Inclusions and impurities

Both native gold and gold objects usually present inclusions that give indications of the type of gold used and the alloy practices employed, complementing the information given by the silver, copper and trace elements content. For instance, the presence of platinum group elements ("PGE": Ru, Rh, Pd, Os, Ir and Pt) or tin as cassiterite are a strong indication of the use of alluvial gold, because as primary deposits they are rarely found together with primary gold deposits. However, these metals and minerals are very hard and heavy, weathering into small fractions that are accumulated in alluvial deposits where they set down with gold. Because of their high melting points, these inclusions are transferred into artefacts during melting, where they can be detected and analysed (Dussubieux & van Zelst, 2004; Guerra et al., 1999; 2004; 2009; Hauptmann & Klein, 2009; Meeks & Tite, 1980; Standish et al., 2013).

Another indicator of the use of alluvial gold is micro-inclusions of quartz (SiO_2) or iron-bearing minerals. These are remnants of the original primary deposits in which gold is usually associated to quartz, limonite, hematite and pyrite as host minerals, which can be trapped in the gold grains (Boric et al., 1990; Chapman et al., 2002, 2006, 2011; Hauptmann et al., 1995; Hough et al., 2009; Maldonado et al., 2010; Spiridonov & Yanakieva, 2009; Tylecote, 1970; Walshe & Cleverley, 2009). These inclusions are not present in gold objects as metallic phases but as mineral inclusions; therefore, they would be lost during the melting of the gold as slag. Consequently, their presence would too suggest that gold in these objects was not completely melted, and that the objects were probably shaped from alluvial grains applying cycles of cold-work and annealing. This is particularly possible when gold nuggets are relatively large and were directly worked, as it was observed by Garcilaso de la Vega in 1560 (1609, bks. 8, chapter 24 [1560]) and Paloma Carcedo in ethnographic groups of the north coast of Peru (1998 and *pers. comm*. 2017; see also Martinón-Torres et al., 2012).

Conversely, elements of the inner microstructure such as remnants of dendrites, pores and oxides would suggest that some items were melted (Scott, 1991); whereas the presence of impurities may point towards minerals associated to the original gold or silver sources (Chapman et al., 2006; Hauptmann & Klein, 2009).

Forty-two samples were mounted in resin blocks and analysed by SEM-EDS. The bulk chemical composition of the cross sections obtained through area scans is given in Appendix Nº3: 2. In this section, the results of the analysis on inclusions and impurities within the metallic core of the samples are presented. To rule out the possibility that these inclusions were derived from contamination during sample preparation, some blocks were re-polished and re-analysed, and the same types of inclusions were identified. Overall, no PGE inclusions were detected in the assemblage and only one artefact (fragment popm41) was found to contain tin-rich inclusions. Still, samples contain other types of inclusions within the metallic core, which were grouped in three categories: eight samples with Fe-rich inclusions only; 11 samples with Cu-rich inclusions (three have additional Fe-rich inclusions); and 12 samples combining "complex", Cu-rich and Fe-rich inclusions. Minute quartz fragments were seen mostly on the surfaces. Remnants of dendrites and pores where also detected.



B	Inclusions:	Samples: popm_	Total	General total
Quartz	in surface	All except 3, 7, 32, 39, 42, 43, 44	35	35
	in the matrix	22	1	
Fe-rich		3, 8, 9, 17, 22, 23, 26, 36		8
Cu-rich		1, 5, 6, 14, 27, 30, 33, 39	8	11
	+ Fe-rich	13, 21, 38	3	
Sn-rich		41		1
Complex	+ Cu-rich	10, 12, 24, 32, 34, 35, 37, 40	8	12
	+ Fe-rich	18, 19, 25, 28, 34	5	
No inclusions		2, 7, 11, 15, 16, 29, 42, 43, 44, 46		10

Figure 33: A- Bar chart showing the frequency and % of samples with each type of inclusions. B- Inclusions present in each sample.

5.2.1.4.1 Quartz and Fe-rich inclusions

Minute quartz inclusions (composed of Si-O) were identified in almost every object sampled (83%, n=35; Figure 33). In all cases the inclusions were found embedded in the surface, and sometimes a couple of micrometre deeper (Figure 34); only one case (popm22, 2%) has quartz grains within the metal matrix (Figure 34:D). Grains are between ~1-15μm in size and are usually sub-rounded to round in shape, however some cases are sub-angular in shape, probably because of different erosion degrees (Figure 34:A-B).

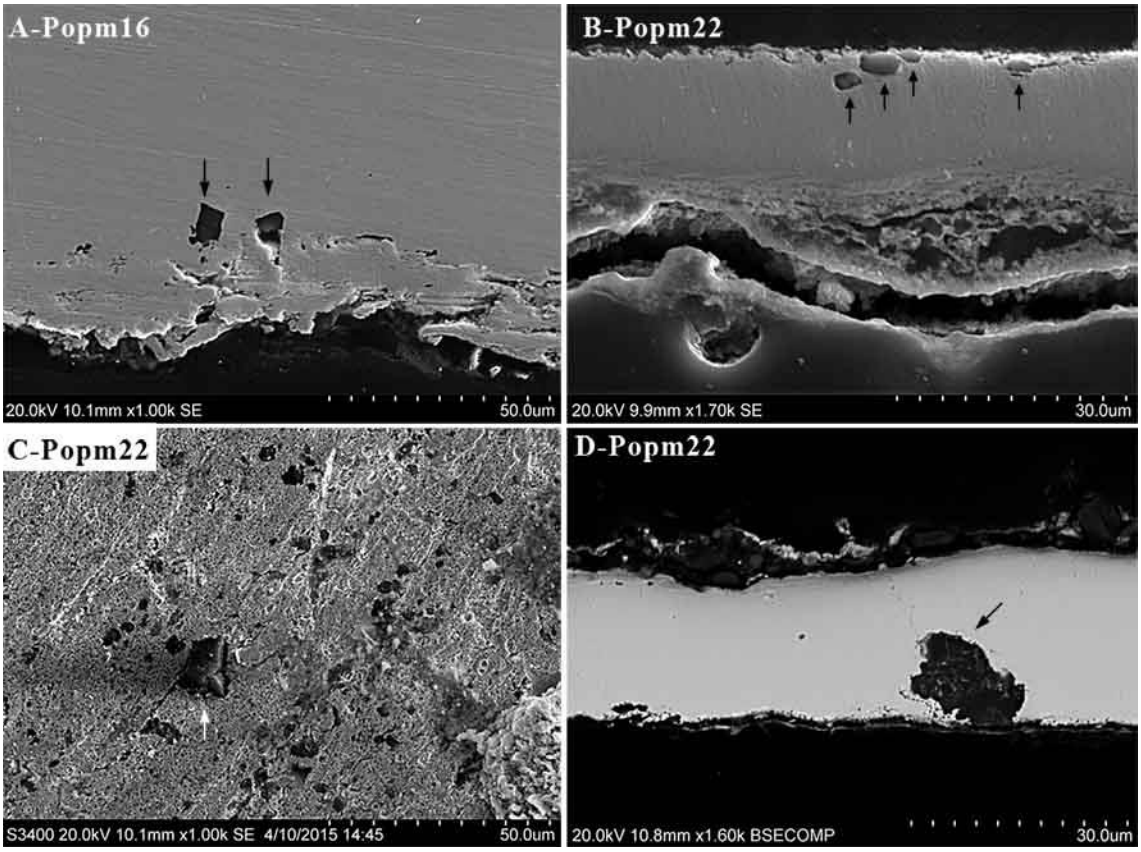
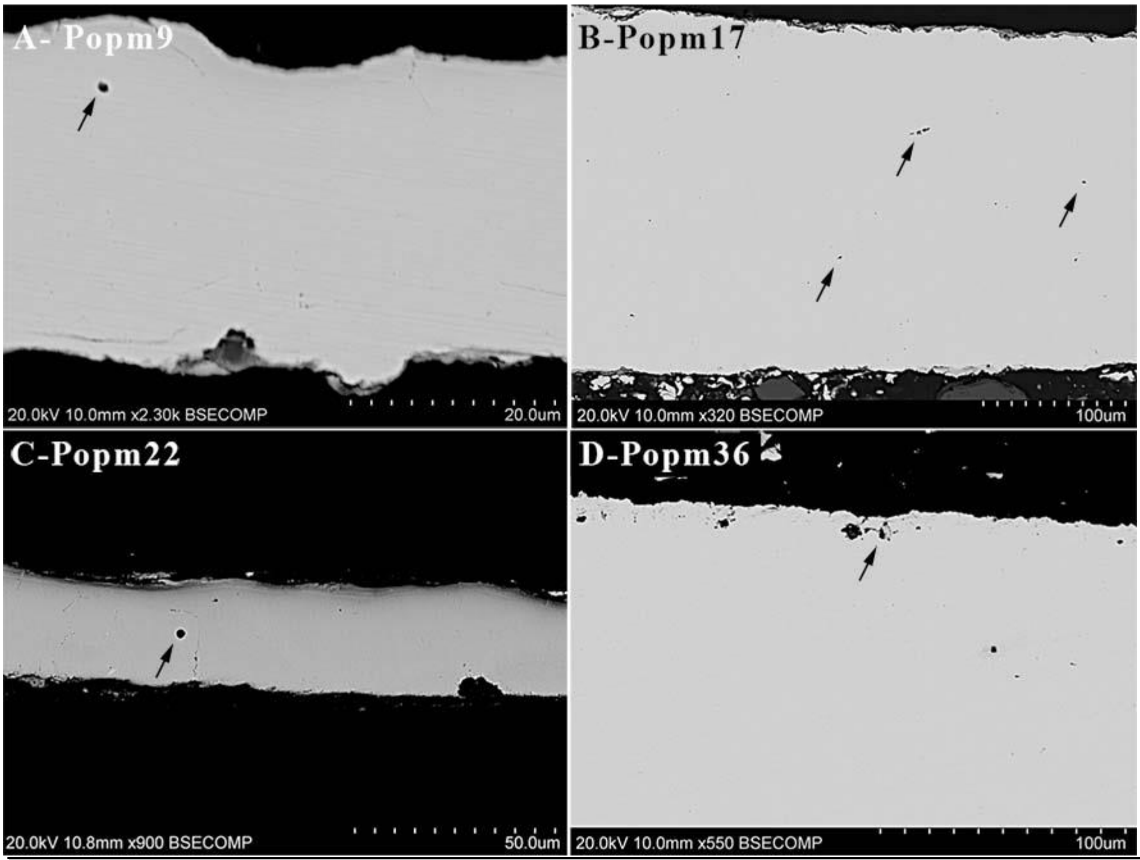


Figure 34: BSE images showing quartz inclusions (SiO_2), by SEM-EDS.
Note that some inclusions are rounded (B), whereas other are sub-angular (A). All images are cross sections, except C which shows the surface of the metallic sheet.

Eight samples (19%) contained only Fe-rich inclusions within the metallic core. Overall, the inclusions are up to ~9µm in size, with elongated-ellipsoid to round shapes (Figure 35). Their high iron content is usually associated to elevated levels of oxygen, together with copper, silver and gold (the latter three, probably derived from the electron beam interaction volume). Calcium, manganese and magnesium are detected in specific cases (Figure 35:E). The eight objects presenting only Fe-rich inclusions within the core, also contain less than 30%Ag. It is likely that these inclusions are tiny fragments of iron-minerals trapped in the metal.

As mentioned, quartz and iron mineral micro-inclusions within gold may indicate the use of alluvial gold that was hammered and annealed to shape (Boric et al., 1990; Hough et al., 2009; Martinón-Torres et al., 2012). However, considering that in the assemblage most quartz particles are at- or near the surface, it is possible that they were embedded into the objects during hammering (or during their use), and did not come with the gold. Only sample popm22 contains grains deep into the metal matrix (Figure 34:D) that could suggest that they come with the gold grains; but in the remaining objects, it is considered here that the presence of quartz is not conclusive to assume the use of un-melted alluvial gold.

The Fe-rich inclusions seen in eight objects, on the contrary, are found mainly within the core (Figure 35); therefore is possible in these cases that Fe-rich inclusions were trapped in the alluvial gold, indicating objects that were hammered and annealed directly from gold grains that were not completely melted. This is supported by their relatively low silver and copper levels, which are consistent with those of unalloyed gold.



E-

		Chemical composition (wt%)															
		Bulk (pXRF)			Fe-rich inclusions (SEM-EDS)												
Sample	N° of incl.	Cu	Ag	Au	O	Mg	Al	Cl	Ca	Ti	Mn	Fe	Cu	Rb	Ag	Au	Analytical total*
popm003	2	1.4	24.5	74.1	17.1	<dl	<dl	<dl	<dl	<dl	<dl	**16.5**	1.8	<dl	10.4	54.4	104.5
popm008	2	1.5	21.4	77.1	15.7	<dl	<dl	<dl	1.1	<dl	<dl	**14.2**	2.2	<dl	11.6	55.4	99.4
popm009	5	1.5	20.4	78.1	15.4	≤0.3	<dl	<dl	≤1.4	<dl	≤0.5	**14.4**	≤2.3	<dl	11.7	57.5	99.4
popm017	3	0.5	29.5	70.0	28.7	0.6	<dl	<dl	6.1	<dl	0.2	**32.0**	0.4	<dl	8.7	23.4	109.0
popm023	3	3.2	13.2	83.6	24.7	<dl	<dl	<dl	<dl	<dl	<0.4	**28.5**	2.6	<dl	3.5	40.6	110.6
popm026	1	1.9	13.7	84.4	16.4	<dl	<dl	<dl	0.6	<dl	<dl	**18.2**	4.7	<dl	7.9	52.2	94.9
popm036	1	0.5	13.2	86.3	19.4	0.8	1.4	0.2	1.6	2.0	<dl	**24.8**	0.9	1.0	7.2	40.7	84.4

Symbology: "<dl": below detection limits. "≤": indicates that results of that element were below limits of detection in one or more readings.
(*) Values are normalised to a 100wt%, however the analytical total is given as reference.

Figure 35: A-D- BSE images showing Fe-rich inclusions, by SEM-EDS.
E- Table summarising the composition of some Fe-rich inclusions analysed by SEM-EDS. Some readings represent one inclusion, while others are an average of several similar inclusions. Bulk results are normalised to a 100%.

5.2.1.4.2 Copper-rich and complex inclusions

Eleven samples contain copper-rich inclusions within their core (26%; Figure 36-37). Their analysis gave mainly copper and oxygen, suggesting that they are copper oxide inclusions (Table 21). The specific type of oxide is impossible to identify based on SEM-EDS analyses, because of their small size and the poor accuracy of this technique for detecting light elements like oxygen. However, according to Scott the most likely candidate is cuprite (Cu_2O) as this is the first copper oxide to develop in contact with air (Scott, 1983, 2002). Just to obtain a broad idea of the type of oxides present, the Cu/O ratio of some inclusions was calculated (Table 21), considering that stoichiometric cuprite (Cu_2O) contains 88.8%Cu and 11.2%O (Cu/O=7.9), and tenorite (CuO) 79.9%Cu and 20.1%O (Cu/O=4.0). In six samples ratios were ~3.8, and in two were ~7.4, suggesting the potential presence of both cuprite and tenorite as copper oxides, together with other solid solutions between both. The colour of the inclusions under OM are a better indicator of their nature as well: cuprite is red under cross polarised light, whereas tenorite is black. Red cuprite inclusions were only visible in sample popm27 (Figure 36:A), the inclusions in the remaining samples were too small for the OM. In three samples, Fe-rich inclusions were also detected.

These Cu-rich inclusions appear in eight objects with silver levels over 30%Ag, only two under 30%Ag (though silver levels were still high ~27-29%Ag); and one case was a high-copper alloy with 48.8%Cu (popm27).

		Chemical composition (wt%)																			
		Bulk (pXRF)			Cu-rich inclusions (SEM-EDS)																
Sample	N° of incl.	Cu	Ag	Au	O	Mg	Al	Si	S	Cl	K	Ca	Mn	Fe	Cu	Ag	Sn	Au	Pb	Analytical total*	Cu/O
A- Samples with Cu-rich inclusions																					
popm001	3	2.0	61.7	36.3	15.2	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	**49.2**	22.6	<dl	13.1	<dl	107.3	3.2
popm005	7	1.2	69.1	29.6	11.4	<dl	<dl	<dl	≤6.6	≤0.3	<dl	<dl	<dl	<dl	**37.8**	36.5	<dl	14.9	<dl	105.4	3.3
popm006	2	1.2	69.1	29.6	30.4	0.8	1.9	5.5	<dl	3.2	<dl	0.7	<dl	0.8	**15.2**	30.8	<dl	10.9	<dl	79.3	0.5
popm013	1	2.1	42.0	55.9	20.9	<dl	<dl	<dl	6.1	<dl	<dl	1.4	0.7	**28.5**	**20.8**	8.5	<dl	13.0	<dl	115.8	1.0
popm014	2	2.0	41.4	56.7	13.0	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	**55.8**	12.4	<dl	18.9	<dl	108.0	4.3
popm021	5	2.2	27.1	70.7	3.7	<dl	≤0.3	<dl	9.1	<dl	<dl	<dl	<dl	2.6	**27.3**	16.1	<dl	41.9	<dl	97.4	7.4
popm027	5	48.8	4.9	46.4	11.6	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	**84.9**	≤0.4	<dl	3.1	≤1.5	88.5	7.3
popm030	5	2.4	34.6	63.0	12.8	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	**71.2**	4.9	<dl	11.2	<dl	108.4	5.6
	1				18.9	<dl	1.5	<dl	<dl	<dl	<dl	<dl	<dl	8.8	**66.2**	2.6	**0.8**	1.3	<dl	100.6	3.5
popm033	21	1.0	64.9	34.1	13.0	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	**54.1**	21.5	<dl	11.9	<dl	104.5	4.2
	2				10.8	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	1.7	**20.8**	41.7	<dl	25.1	<dl	103.6	1.9
popm038	2	1.7	28.8	69.5	7.5	<dl	<dl	<dl	13.6	≤0.7	<dl	<dl	<dl	10.5	**37.8**	12.8	<dl	17.4	<dl	100.2	5.0
popm039	6	1.0	55.8	43.3	11.8	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	**50.8**	19.9	<dl	17.5	<dl	104.9	4.3
B- Samples with additional Fe-rich inclusions																					
popm013	2	2.1	42.0	55.9	27.6	<dl	<dl	<dl	<dl	<dl	<dl	0.5	0.9	**35.5**	4.5	13.9	<dl	17.2	<dl	110.7	
popm021	5	2.2	27.1	70.7	28.6	<dl	≤0.4	≤2.6	≤4.0	≤0.6	≤0.3	≤0.4	≤0.7	**36.8**	≤1.1	5.9	<dl	24.9	<dl	101.3	
	2				15.4	<dl	0.6	2.7	≤4.5	0.7	<dl	0.4	<dl	**5.1**	2.1	20.4	<dl	50.4	<dl	87.5	
popm038	1	1.7	28.8	69.5	25.5	<dl	<dl	<dl	4.6	<dl	<dl	0.2	0.7	**42.9**	12.7	3.1	<dl	10.4	<dl	106.5	

Symbology: "<dl": below detection limits. "≤": indicates that results of that element were below limits of detection in one or more readings. (*) Values are normalised to a 100wt%, however the analytical total is given as reference.

Table 21: Chemical composition obtained by SEM-EDS.
(A) Cu-rich inclusions and (B) Fe-rich inclusions in the same objects. Some readings represent one inclusion, while others are an average of several similar inclusions. When Cu content varied largely within a sample, more than one result is given.

Regarding their microstructure, three structures are noted: elongated inclusions, rounded globules distributed across the core and globules aligned near the surface (Table 22). All of them are produced when the metal is melted, however the latter may also result from annealing and hammering (Scott, 1991, 2002). In five samples, inclusions are elongated (≤60µm long). Their shape and composition (copper oxides) suggest they are remnants of dendrites or larger phases generated by the absorption of oxygen during melting, which were not totally removed by working and annealing the metal (Scott, 1991). The best example of dendrites is in sample popm27, whereas in the other samples the remnant dendritic structures are smaller and subtler (Figure 36). According to Scott (1991, p. 9), these structures are very difficult to remove even after several cycles of cold-work and annealing, appearing alongside recrystallised grains.

Microstructure	**Popm_**	**1**	**5**	**6**	**13**	**14**	**21**	**27**	**30**	**33**	**38**	**39**	**10**	**12**	**24**	**32**	**34**	**35**	**37**	**40**	**Total**
Dendritic structure		x					x	x	x	x			x	x		x					8
Globules aligned near edge		x		x									x						x		4
Globules in core			x		x	x					x	x			x		x	x		x	9
		A- Cu-rich inclusions											*B- Complex + Cu-rich inclusions*								

Table 22: Summary of different molten microstructures of the Cu-rich inclusions in objects presenting Cu-rich (A) and complex combined with Cu-rich (B) inclusions.

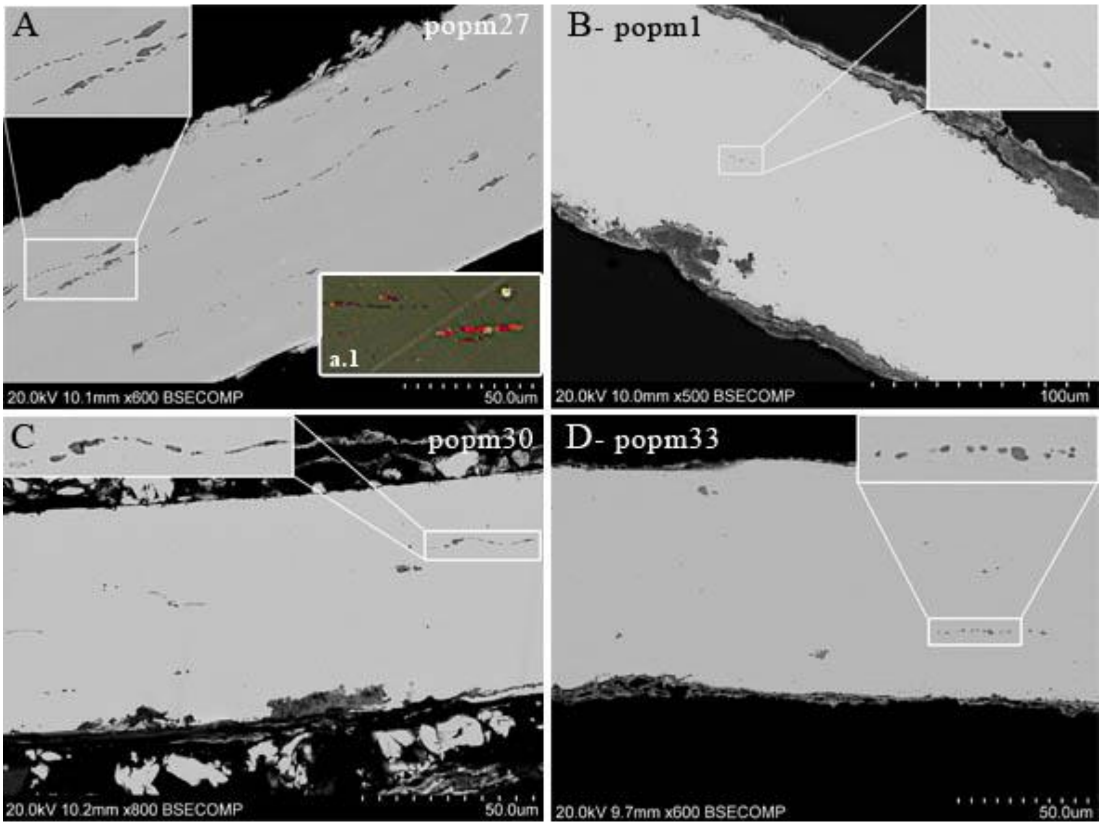


Figure 36: BSE images showing remnant of Cu-oxides dendritic structures, by SEM.
The elongated Cu-oxides are parallel to the surfaces, perpendicular to the working direction during hammering. Inset a.1: OM image showing an inclusion of cuprite in cross polarised light (magnification 50x).

In two samples, copper oxides appear as aligned globules (combined with pores) parallel to the surface (Figure 37). The location and arrangement of these inclusions - near the surface - would suggest that oxygen diffused into the alloy during annealing by heating in air (Scott, 1991, p. 7). In that case, Cu-rich inclusions so close to the surfaces could be produced by particles of copper oxide formed on the surface while the metal is heated on air -cuprite first and then tenorite (Scott, 2002)- and then embedded into the matrix by subsequent hammering. Alternatively they may form by the internal oxidation of copper within the alloy (Scott, 1991, p. 7).

In other four samples, minute globules (<10μm) of copper oxides of round and ellipsoid shape were evenly distributed across the metallic matrix. Porosity present as spherical voids is produced by gasses trapped in the melt that may react with the metal to form oxides (Scott, 1991, p. 6). Given their shapes, composition and distribution, it is likely that these inclusions represent copper oxides formed within minute voids during or after melting (Figure 38).

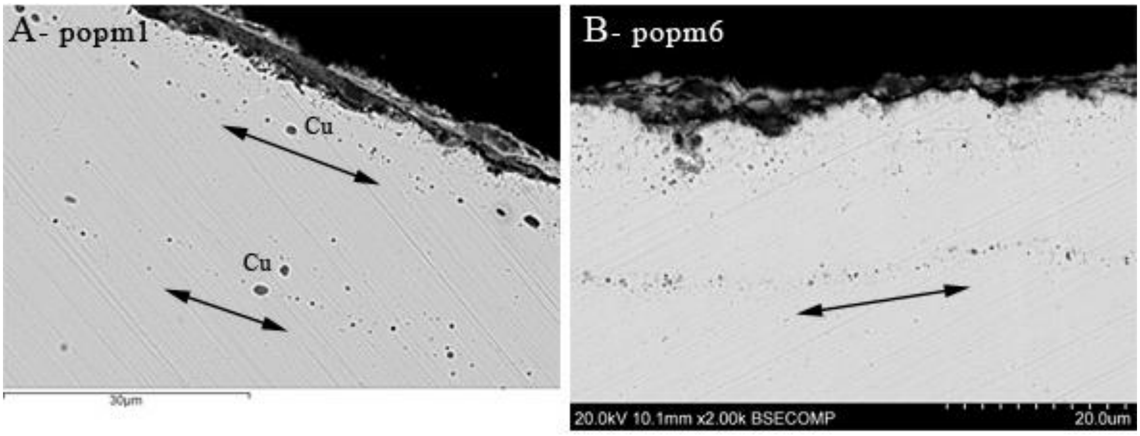


Figure 37: BSE images showing Cu-oxides inclusions and pores near the edges, by SEM. The alignment is showing the working direction during hammering.

Similar minute inclusions (<10μm) of round and ellipsoid shape, but composed of a mix of different elements were detected in 12 samples (29%); they have been arbitrarily named here "complex inclusions" (Figure 38). Randomly distributed within the core along with Cu-rich and Fe-rich inclusions, these complex inclusions are composed of elements such as nickel, zinc, tin, lead, bismuth, arsenic and mercury, in addition to gold, silver, copper and/or iron (Table 23). Elevated levels of oxygen (up to 31%), suggest they are oxides. The detection of gold and silver in most inclusions is likely due to the interaction volume of the beam.

These inclusions are impurities from the original ores, potentially from any of three major metals that were reduced during smelting or melting and incorporated into the alloy (Guerra & Rehren, 2009; Hauptmann & Klein, 2009). Alternatively, they may have been acquired as contamination during the melting process (Rademakers & Rehren, 2016). Interestingly, most samples with these kinds of impurities have silver levels over 30%, only four cases are below 30% (between ~12-29%Ag), suggesting an association between high-silver levels and the presence of impurities.

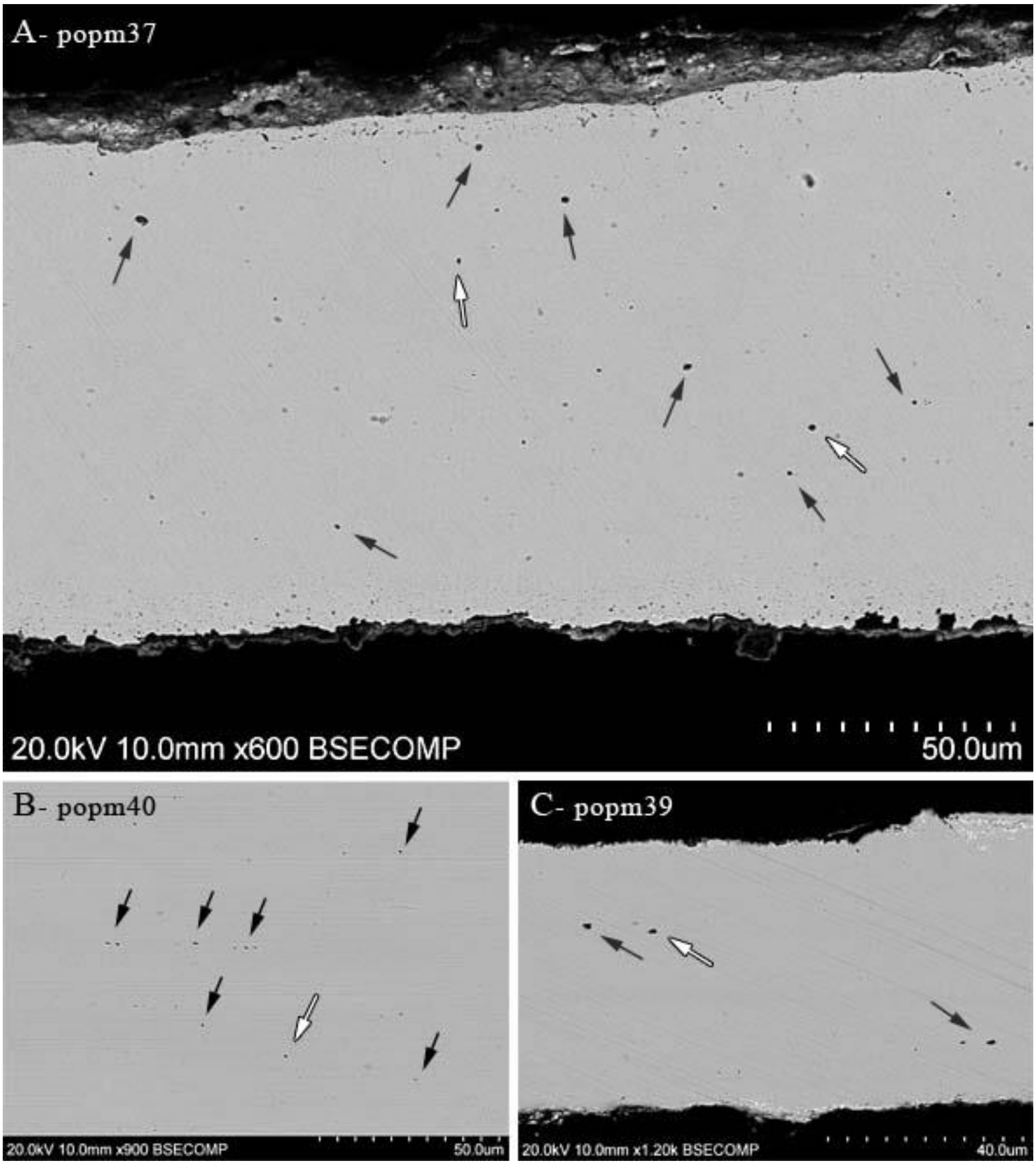


Figure 38: BSE images showing mixed Cu-rich (black arrows) and complex inclusions (white arrows) within the matrix, by SEM. Note their minute size and similar aspect.

The impurities included volatile elements, such as Zn, As, S, I and Hg, together with Fe, Ni, Sn, Pb and Bi (Table 24). Four silver-rich objects contained inclusions with Pb and S (popm25, 35, 37, 40). Sn is found in eight samples (popm10, 12, 18, 19, 24, 25, 34, 37), six associated with Zn and Fe; Zn in eight samples always with Fe (popm10, 12, 19, 24, 25, 28, 34, 40); and Bi appears in three samples (popm12, 25, 35): all associated with Pb, Fe and Cu, and twice with Sn and Zn. Ni was present in three samples, together with Fe, Zn, Sn and Cu (popm12, 24, 25).

Due to the small size of these complex particles, as well as the detection limit of the SEM-EDS around 0.1%, none of these elements were detected in the bulk composition obtained by area analyses, where their concentrations would have been diluted by major alloy constituents. PIXE however, detected some of these elements such as Ni, Zn, Pb, Hg, S; other elements such as Sn, Bi and As are only detected by SEM-EDS spot analyses of phases where they are concentrated, demonstrating the usefulness of phase analyses for the identification of potential chemical tracers that may fall below detection limits of conventional bulk analyses. Finally, some samples with complex inclusions also contained Fe-rich (n=5) and Cu-rich (n=8) inclusions. Three samples showed evidence of melting as Cu-rich inclusions present as remnants of dendrites (popm10, 12, 32), in two they appear as globules aligned near the surfaces (popm10, 37) and in four samples inclusions were randomly distributed across the matrix (popm24, 34, 35, 40; Table 22).

			Bulk (pXRF)			Chemical composition (wt%) — Complex inclusions (SEM-EDS)																						
	Sample	N° of incl.	Cu	Ag	Au	O	Na	Mg	Al	Si	S	Cl	Ca	Mn	Fe	Ni	Cr	Cu	Zn	As	Ag	Sn	Cd	Au	Pb	Bi	Hg	Analytical total*
A- Samples with complex inclusions																												
1	popm010	2	2.5	60.5	37.0	15.5	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	**7.4**	<dl	<dl	**10.1**	**1.4**	<dl	41.5	<dl	<dl	24.1	<dl	<dl	<dl	110.5
		1				14.1	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	**5.4**	<dl	<dl	**10.3**	**0.9**	<dl	42.0	**3.1**	<dl	24.2	<dl	<dl	<dl	104.8
2	popm012	2	5.3	16.2	78.5	14.3	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	**4.0**	**1.0**	<dl	7.2	**2.8**	<dl	7.0	**7.9**	<dl	35.6	**9.2**	**11.3**	<dl	106.3
3	popm018	1	0.5	29.3	70.2	19.0	<dl	<dl	<dl	<dl	<dl	0.3	6.4	<dl	**4.6**	<dl	<dl	0.7	<dl	**1.7**	17.7	**2.6**	<dl	47.0	<dl	<dl	<dl	97.9
4	popm019	1	2.1	12.7	85.2	18.5	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	**8.8**	<dl	<dl	2.3	**1.0**	<dl	6.8	**6.2**	<dl	56.4	<dl	<dl	<dl	117.6
5	popm024	2	1.5	57.6	40.8	12.7	<dl	<dl	<dl	<dl	<dl	<dl	≤1.0	<dl	**7.0**	**0.7**	<dl	2.3	**4.9**	<dl	41.9	<dl	<dl	30.0	<dl	<dl	<dl	105.8
		1				13.3	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	**3.9**	<dl	<dl	2.0	**2.2**	<dl	46.0	<dl	<dl	32.5	<dl	<dl	<dl	111.2
		1				18.4	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	**1.7**	**0.6**	<dl	0.9	**1.8**	<dl	32.0	**20.9**	<dl	23.6	<dl	<dl	<dl	115.2
		1				14.5	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	**1.0**	<dl	<dl	**22.1**	**1.4**	<dl	29.9	**8.7**	<dl	22.3	<dl	<dl	<dl	108.0
		1				21.7	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	1.5	<dl	<dl	24.4	**33.9**	<dl	18.5	<dl	<dl	<dl	109.3
		1				20.0	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	**9.1**	<dl	<dl	5.5	<dl	<dl	31.6	**9.5**	<dl	24.3	<dl	<dl	<dl	112.8
5	popm025	1	1.2	49.6	49.2	16.1	<dl	<dl	0.8	<dl	<dl	<dl	<dl	<dl	**9.9**	**1.0**	<dl	1.2	**13.7**	**0.1**	16.6	**10.7**	<dl	18.3	**4.0**	**7.5**	<dl	88.1
		2				22.6	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	**7.9**	**0.7**	<dl	1.3	**10.4**	<dl	26.3	**4.3**	<dl	26.5	<dl	<dl	<dl	112.6
		2				16.1	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	**3.0**	<dl	<dl	1.3	**5.6**	<dl	31.9	**6.3**	<dl	34.0	**1.8**	<dl	<dl	90.2
		1				14.6	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	**3.4**	<dl	<dl	1.4	**4.9**	<dl	37.4	<dl	<dl	38.4	<dl	<dl	<dl	97.5
		1				11.3	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	**1.3**	<dl	<dl	1.4	**2.2**	<dl	41.1	<dl	<dl	39.5	**3.1**	<dl	<dl	109.3
		2				7.7	<dl	<dl	≤0.8	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	1.3	<dl	<dl	41.8	<dl	<dl	38.2	**10.6**	<dl	<dl	90.0
		4				16.7	<dl	<dl	<dl	<dl	**5.5**	<dl	<dl	<dl	<dl	<dl	<dl	≤0.7	<dl	<dl	21.2	<dl	<dl	21.7	**34.5**	<dl	<dl	97.0
7	popm028	2	2.0	22.7	75.3	30.7	<dl	≤1.2	<dl	<dl	<dl	<dl	1.5	0.7	**23.3**	<dl	<dl	5.5	**4.8**	<dl	6.1	<dl	<dl	26.4	<dl	<dl	**≤1.2**	101.3
8	popm034	6	0.7	66.2	33.1	27.5	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	**18.4**	<dl	<dl	1.3	**5.6**	<dl	31.4	<dl	<dl	15.8	<dl	<dl	<dl	124.5
		7				19.4	<dl	<dl	≤0.4	<dl	<dl	<dl	<dl	<dl	**9.7**	<dl	<dl	4.0	**2.6**	<dl	42.9	<dl	<dl	21.3	<dl	<dl	<dl	113.1
		1				24.0	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	**3.8**	<dl	<dl	1.1	**1.2**	<dl	36.3	**15.3**	<dl	18.3	<dl	<dl	<dl	131.1
9	popm035	4	4.9	39.7	55.4	10.1	<dl	<dl	≤0.6	<dl	**≤4.2**	≤2.7	<dl	<dl	**≤0.7**	<dl	<dl	3.6	<dl	<dl	17.0	<dl	<dl	25.3	**30.5**	**13.6**	<dl	89.6
10	popm037	1	1.0	64.7	34.3	27.1	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	**11.3**	<dl	<dl	18.8	<dl	<dl	25.5	**3.0**	<dl	12.1	**2.1**	<dl	<dl	121.0
11	popm040	1	0.9	56.4	42.7	11.6	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	**0.8**	<dl	<dl	**72.6**	**1.5**	<dl	6.6	<dl	<dl	6.9	<dl	<dl	<dl	97.8
		1				14.6	<dl	<dl	<dl	<dl	**1.3**	<dl	<dl	<dl	<dl	<dl	<dl	**35.4**	<dl	<dl	22.9	<dl	<dl	19.6	**6.1**	<dl	<dl	94.9
B- Samples with additional Cu-rich inclusions																												
1	popm010	7	2.5	60.5	37.0	10.9	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	**61.3**	<dl	<dl	16.3	<dl	<dl	11.6	<dl	<dl	<dl	102.8
		4				8.5	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	**24.4**	<dl	<dl	41.8	<dl	<dl	25.3	<dl	<dl	<dl	106.4
		6				≤2.1	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	**5.8**	<dl	<dl	59.6	<dl	<dl	33.9	<dl	<dl	<dl	100.3
2	popm012	3	5.3	16.2	78.5	9.0	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	**35.1**	<dl	<dl	9.4	<dl	<dl	46.6	<dl	<dl	<dl	107.2
3	popm024	1	1.5	57.6	40.8	15.3	<dl	<dl	0.3	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	**55.3**	<dl	<dl	16.9	<dl	<dl	12.2	<dl	<dl	<dl	109.5
		15				9.1	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	≤0.6	<dl	<dl	**22.9**	<dl	<dl	40.0	<dl	<dl	28.5	<dl	<dl	<dl	106.5
		1				8.8	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	**9.5**	<dl	<dl	48.4	<dl	<dl	33.3	<dl	<dl	<dl	107.2
4	popm032	8	1.1	65.2	33.7	14.4	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	**42.4**	<dl	<dl	29.0	<dl	<dl	14.2	<dl	<dl	<dl	115.4
5	popm034	5	0.7	66.2	33.1	10.6	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	**33.2**	<dl	<dl	36.6	<dl	<dl	19.7	<dl	<dl	<dl	108.4
6	popm035	6	4.9	39.7	55.4	11.5	<dl	<dl	≤1.7	≤1.0	<dl	<dl	<dl	<dl	<dl	<dl	<dl	**46.3**	<dl	<dl	16.2	<dl	<dl	26.4	≤2.8	<dl	<dl	91.6
7	popm037	6	1.0	64.7	34.3	9.4	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	≤6.0	<dl	<dl	**39.1**	<dl	<dl	33.3	<dl	<dl	17.2	<dl	<dl	<dl	100.9
8	popm040	9	0.9	56.4	42.7	10.9	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	**43.2**	<dl	<dl	25.0	<dl	<dl	20.8	<dl	<dl	<dl	107.4
C- Samples with additional Fe-rich inclusions																												
1	popm018	4	0.5	29.3	70.2	22.9	≤2.5	≤1.9	<dl	<dl	<dl	<dl	3.0	≤1.1	**24.8**	<dl	<dl	0.7	<dl	<dl	13.8	<dl	<dl	32.9	<dl	<dl	<dl	108.1
2	popm019	10	2.1	12.7	85.2	13.7	<dl	≤0.5	≤0.6	<dl	<dl	<dl	<dl	<dl	**15.2**	<dl	<dl	2.0	<dl	<dl	7.7	<dl	<dl	61.0	<dl	<dl	<dl	100.2
3	popm028	1	2.0	22.7	75.3	30.2	<dl	0.4	<dl	<dl	<dl	<dl	0.6	1.1	**33.7**	<dl	<dl	1.9	<dl	<dl	7.0	<dl	<dl	25.0	<dl	<dl	<dl	113.7
4	popm034	1	0.7	66.2	33.1	<dl	<dl	<dl	<dl	0.4	<dl	<dl	<dl	0.5	**90.4**	<dl	8.6	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	96.4
		1				22.5	<dl	<dl	0.6	<dl	<dl	<dl	3.0	<dl	**7.4**	<dl	<dl	1.7	<dl	<dl	44.7	<dl	1.8	18.3	<dl	<dl	<dl	75.1

Symbology: "<dl": below detection limits. "≤": indicates that results of that element were below limits of detection in one or more readings. (*) Values are normalised to a 100wt%, however the analytical total is given as reference.

Table 23: Chemical composition of complex inclusions (A), Cu-rich inclusions (B) and Fe-rich inclusions (C) within the metallic core, by SEM-EDS.
Some readings represent one inclusion, while others are an average of several inclusions with the same characteristics.

		Bulk (pXRF, wt%)			Inclusions under SEM-EDS			Elements present in complex inclusions										
Sample	Site	Cu	Ag	Au	Fe-rich	Cu-rich	Complex	I	S	Fe	Ni	Zn	As	Sn	Au	Pb	Bi	Hg
popm034	Quitor-1	0.7	66.2	33.1	•	•	•			•		•		•				
popm032	Quitor-1	1.1	65.6	33.3		•	•	•	•									
popm037	Quitor-1	1.0	64.7	34.3		•	•			•				•		•		
popm010	C. Parr.	2.5	60.5	37.0		•	•			•		•		•				
popm024	-	1.5	57.6	40.8		•	•		•	•	•	•		•				
popm040	Quitor-1	0.9	56.4	42.7		•	•		•	•		•			•	•		
popm025	-	1.2	49.6	49.2	•		•		•	•	•	•	•	•		•	•	
popm035	Larache	4.9	39.7	55.4		•	•		•						•	•	•	
popm018	C. Parr.	0.5	29.3	70.2	•		•			•			•	•				
popm028	Quitor-5 or Solor-3	2.0	22.7	75.3	•		•			•		•						•
popm012	Larache	5.3	16.2	78.5		•	•			•	•	•		•		•	•	
popm019	Larache	2.1	12.7	85.2	•		•			•		•		•				

Table 24: Summary of the elements present/absent in complex inclusions, organised by silver levels. Volatile elements with low boiling temperatures (<905ºC) include Zn, As, S, Hg and I.

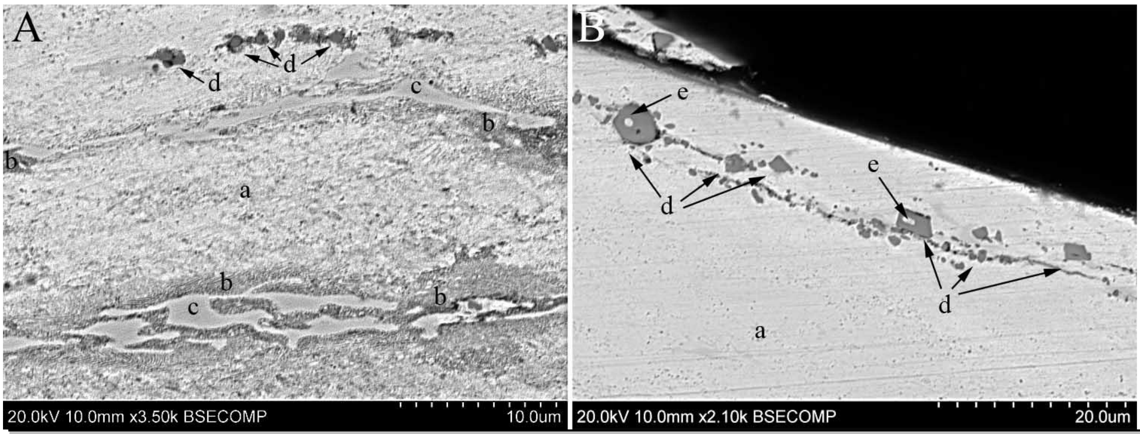
5.2.1.4.3 Tin-rich inclusions

A particular case is fragment popm41, the only sample with tin oxide inclusions (Sn-O; Figure 39:C). The fragment (probably part of a ring) is composed of an artificial silver-rich alloy with 12.1%Cu, 58.6%Ag and 29.2%Au. The matrix is heterogeneous (Figure 39) presenting copper-rich and silver-rich phases, as well as tin inclusions. Interestingly, PIXE and SEM-EDS analysis did not detect tin in the main alloy, except one reading with 3.8%Sn given by SEM-EDS (of 66 area and spot analyses). Tin oxides are well defined euhedral crystals of quadrangular or pentagonal shape and are distributed unevenly across the sample, they are seen both in the core and in the edges (Figure 39:B). They are ~1µm in size, being bigger near the surface (up to ~4.7µm); some of the large crystals have a core filled with matrix material and tin (46.1%Sn, 16.9%Ag and 3.4%Cu, see Figure 39:C).

These types of crystals are often formed in bronze (or bronze metallurgical remains) heated at elevated temperatures as result of the oxidation of tin, which easily reacts with oxygen forming euhedral shapes, some of them with a core filled with matrix material. Their presence indicates that the metal reached a liquid state in oxidising conditions, promoting the oxidation of tin (Dungworth, 2000; Ellingham, 1944; Klein & Hauptmann, 1999; Rademakers & Rehren, 2016; Rademakers & Farci, 2018; Rovira, 2007). Alternatively, similar crystals can form when objects are heated on air, as is the case of cremated bronze artefacts (Dungworth, 2000).

In the case of popm41, small crystals appear across the sheet, whereas larger crystals with core are seen near the surface. Their presence across the section would suggest that tin (as metal or mineral) was present in the alloy, and melting conditions were oxidising enough to oxidise all tin; the core in some crystals would indicate that metal reached a liquid state; whereas the larger crystals near the surface would suggest that further annealing work was applied producing extra oxidising conditions resulting in larger crystals.

Unfortunately, these tin oxides are not good indicators of the nature of tin used, i.e. whether oxides derived from fresh metal or re-crystallised cassiterite (Dungworth, 2000; Rademakers & Rehren, 2016). In the case of popm41 and considering tin availability and geological associations in the region, tin may have been introduced with any of the major elements: a) with silver in metallic state; b) with copper, probably as bronze (recycling perhaps?) or as ore impurity; or c) in the form of cassiterite (SnO_2) impurities in alluvial gold (see map in Appendix Nº4: 1).



C- (%)	O	Al	Cl	Cu	Ag	Sn	Au	Total	Analytical total
a) Metal matrix - mean (8)	nd	nd	nd	12.1	58.6	nd	29.2	100	100.9
Min				8.6	54.7		27.9	100	100.1
Max				15.1	63.5		30.3	100	101.8
b) Dark grey phase - mean (12)	7.6	≤0.9	2.5	18.2	**32.3**	nd	41.0	100	97.9
Min	3.4	nd	0.3	6.3	11.1		32.1	100	94.5
Max	10.5	0.9	4.2	26.5	60.6		51.5	100	101.9
c) Mid grey phase - mean (8)	nd	nd	≤0.6	**35.7**	23.1	nd	41.1	100	99.5
Min			nd	5.5	16.5		40.1	100	98.1
Max			0.6	41.4	52.1		42.4	100	101.3
d) Tin inclusions - mean (8)	**28.9**	≤0.3		≤2.7	≤9.8	**62.1**	≤6.9	100	111.5
Min	25.3	nd		nd	nd	54.9	nd	100	105.1
Max	30.6	0.3		2.7	9.8	68.2	6.9	100	127.2
e) Tin inclusions core - mean (2)	**20.0**	nd	nd	3.4	16.9	**46.1**	13.6	100	119.1
Min	14.3			0.9	13.2	29.9	8.8	100	111.3
Max	25.4			6.9	28.0	55.1	18.1	100	128.4

Figure 39: A-B: BSE image of popm41, by SEM.
Detail of the matrix with different phases in the centre of core (A), and near the edges (B).C-Table summarising the chemical composition of the different phases and inclusions within the metallic matrix, by SEM-EDS. The symbol "≤" indicates that results of that element were below limits of detection in one or more readings.

5.3 Discussion chapter 5

5.3.1 Raw materials: a variety of sources and deposits

It is not in the scope of this thesis to establish the provenance of the precious metals used in SPA. In the case of the SCA, that would require an extensive study, given the limited geological information available, the lack of analyses of archaeological materials, and the need of a systematic identification and location of ancient and small gold and silver deposits in the region. Additionally, provenance studies typically need more precise and accurate analysis, using techniques such as ICP-MS (with or without laser ablation), unless strong diagnostic signatures can be identified.

However, I would like to explore here the variety of metals sources used, as well as their nature. The evidence presented suggests that the gold used in SPA comes from different deposits, probably from different areas. As expected, most gold was obtained from alluvial placers, but I consider that the potential exploitation of primary gold deposits cannot be ruled out in this area. Regarding silver, it is believed that both native and refined silver were used in SPA artefacts, however the evidence is not conclusive and further research is needed in that matter.

As mentioned in chapter 2:2.2.2, native gold can be obtained from primary or secondary deposits. The primary gold is deposited in its original host rock, usually associated to quartz veins, pyrite or other minerals that need to be mined. The weathering of the primary ores and their accumulation, create secondary deposits called placers or alluvial deposits, where gold can be collected or panned as sand, grains or large nuggets (Boric et al., 1990; Chapman et al., 2006; Guerra & Calligaro, 2004; Hough et al., 2009; Morteani, 1995; Petersen, 1970; Standish et al., 2013).

Some compositional differences are reported between the gold from both types of deposits. For instance, placer gold is usually purer than primary gold. Because of transportation, some elements such as silver and copper are leached out, whereas minerals from the bedrock are removed generating a rim of higher fineness (Chapman et al., 2006; Hérail et al., 1990; Hough et al., 2009; 1999; Knight, Morison, et al., 1994; Townley et al., 2003). However, in the same transportation and deposition process gold can acquire other heavy elements such as PGE or cassiterite. They can also retain in their core micro-inclusions of quartz or iron associated to the primary ores (Boric et al., 1990; Chapman et al., 2002, 2006; Garcia-Guinea et al., 2005; Guerra & Calligaro, 2004; Hough et al., 2009; Morteani, 1995; Petersen, 1970; Standish et al., 2013). Instead, primary gold usually retains particles of the original ores that can be dragged into the alloy, contributing to higher levels of impurities in the metal (Chapman et al., 2006).

Silver and copper contents are more variable in alluvial gold than in primary gold, for two main reasons: a) transportation produces a differential purification process for each grain, and b) alluvial deposits can collect gold from several primary deposits of different composition (Chapman et al., 2002, 2006, 2011; Leake et al., 1995; Styles, 1995). However, in primary gold, its Ag and Cu levels, can vary along the same vein or deposit (Chapman et al., 2006).

5.3.1.1 Silver in gold

Based on modern metallogenic maps, there are a few gold deposits near SPA and unfortunately, they have not been chemically characterised (Appendix Nº4: 2). This does not exclude the possibility that smaller deposits existed in the past, which are not currently viable, and therefore do not appear in these maps. The chemical analysis on native gold found so far - and presented here -, are from primary and secondary deposits from the Central and South Central Andes region. Overall, the analyses show gold deposits with different silver levels, but consistently below 30%Ag (Figure 40, full values in Appendix Nº3: 3-5).

Most alluvial deposits analysed to date (12 placers) have very pure gold with silver content up to 5-7%, such as those in southern Altiplano (Sud Lipez), NWA (Eureka, Colquimayo), south Peru (Sandia and Carabaya region) and north Peru (deposit Ninamahua, Ancash). Meanwhile, silver contents up to 15% are registered in a few placers (n=5): Vilander (Sud Lipez), Rinconada (NWA), Pallasca (north Peru), and Sandia and Vetasmayo (south Peru). Only one placer in the Peru-Ecuador border presents 26%Ag (Zaruma region, Tumbes river; Angiorama, 2004; Fornari & Hérail, 1993; Petersen, 1970; Ramos & Fornari, 1994).

Additionally, five minuscule alluvial gold grains (85-266μm) from a placer in Rinconada (NWA)[9] were analysed in this research using SEM-EDS (Appendix Nº12). Interestingly, silver values at their surfaces were different in each grain, ranging from 2.1-27.2%Ag. These figures are not representative of the whole grain composition, because

[9] I am grateful to María Ester Albeck and Juan Ignacio Robles who gave me the alluvial gold samples to include them in this research.

the analysis is from the surface which is purer than the core; however, they exemplify the potential variability of alluvial gold. The average of the five grains is 11.9%Ag, similar to values previously reported for placers of the same area (Angiorama, 2004). Copper in this case was not detected.

Studies on primary gold in Bolivia detected silver values up to 6% in the Yani region, Oriental Cordillera and Korikollo deposit in La Joya district (10 deposits); whereas three other deposits in La Joya present silver values between 20-30%. In northern Chile, levels up to 10%Ag (San Pedro de Cachiyuyo) and between 3-21%Ag (Cerro Casale) are also reported (Appendix Nº3: 3-5 and Appendix Nº4: 2; Alarcón & Fornari, 1994; Hérail et al., 1999; Palacios et al., 2001).

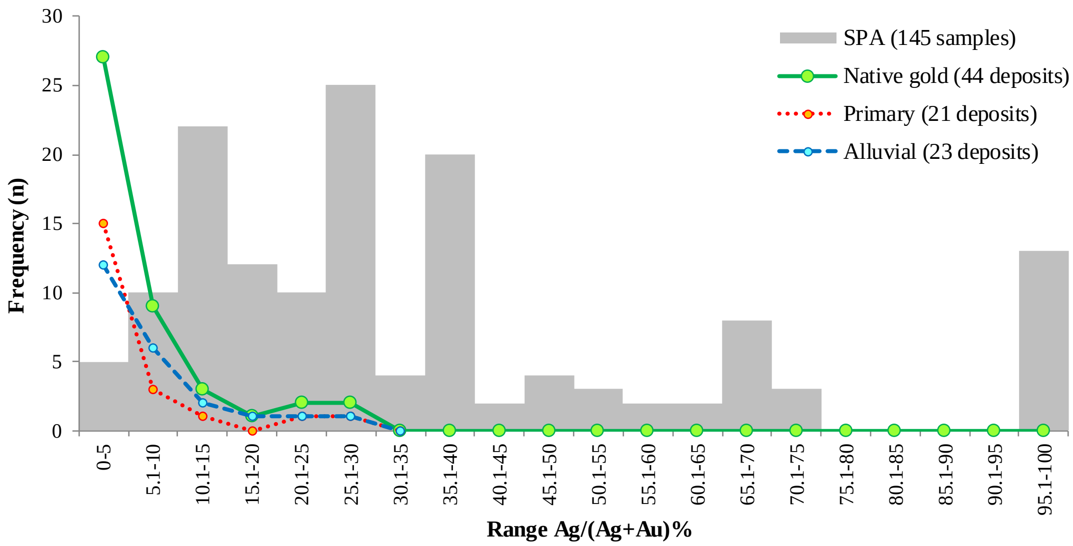


Figure 40: Frequency distribution histogram comparing Ag/(Ag+Au)% in SPA objects and Ag% in gold of 21 primary (red) and 23 alluvial (blue) deposits from the SCA.
The sum of both, primary and alluvial deposits (n=44), is presented in green. Locations are specified in Appendix Nº4: 2.

Looking at the assemblage of SPA, it is conceivable that the distribution in Figure 30 replotted in Figure 40 (grey bars), represents gold deposits with at least two different silver ranges, and one (or more) silver deposit: i.e. gold with medium-silver content (~10-15%), gold with high-silver content (~20-30%Ag); and silver deposits expressed by the high frequency at 100%Ag. For samples above 30%Ag, however, their concentrations are more difficult to interpret. They could be formally designated as electrum (~30-70%Ag) or kuestelite (~70-90%Ag); nevertheless, the geological data collected does not record gold deposits in the region with such high-silver concentrations (over 30% and up to 75%Ag). As such, they may represent artificial alloys, where metallic silver was added or mixed with native gold, as is proposed for other objects of the SCA of similar compositions (Angiorama, 2004; Lechtman, 1978; Root, 1949; Rovira, 1994; Schlosser et al., 2009). Mechanically and physically speaking, a gold alloy up to 50-60% silver retains the malleability and ductility of gold, but it changes its colour, microstructure, hardness, work-hardening (during deformation) and melting point (Hough et al., 2009). Surely, many of these properties were recognised by ancient metallurgists.

Therefore, based on the silver content, it is possible to propose that 58% of the SPA assemblage was potentially made of native unalloyed gold from more than one gold deposit (~15% and ~20-30%Ag), 9% were made of silver and 33% of the objects were made of artificial alloys where silver was added.

However, it is interesting to note that most of the natural gold deposits analysed in the SCA heretofore have from trace levels to 5% silver contents (Figure 40, green line). Silver contents ~15% are reported in a few placer deposits in sud Lipez (Bolivia, ~200km from SPA as the crow flies), the *puna* (~220km) and south Peru (~950km); and primary deposits from northern Chile (Copiapo, ~460km), although the latter are porphyry deposits mineable using modern techniques and unlikely exploited in the past (Morteani, 1995, p. 107). Also less common are high-silver gold deposits (20-30%Ag), being represented by primary deposits in Bolivia at the La Joya mining district, and only one placer deposit in the border of Peru and Ecuador (Tumbes river). Despite the fact that not many analyses of native gold from the region were found in the literature, other potential sources of gold with medium to high-silver levels are primary epithermal deposits, which generate gold with silver levels over 15% (Leake et al., 1995).

Considering the substantial number of unstudied deposits in the area (Appendix Nº4: 2), it is likely that the frequency of the natural deposits seen in Figure 40 will change if more deposits are analysed. Still, peaks at ~15%Ag and ~25-30%Ag in SPA objects, may represent the use of a few specific deposits, unstudied deposits, or even exhausted ones. With the information currently available, possible sources of medium-silver gold are most likely alluvial deposits; whereas high-silver gold is potentially from primary deposits, though the exploitation of placer deposits derived from high-silver deposits cannot be ruled out. Nonetheless, these propositions can only be taken as preliminary and should be tested against future geochemical studies on the many placer and primary deposits from the region, ideally including trace elements.

Although the use of primary gold deposits is rare in antiquity (Tylecote, 1992), it has been proposed that primary sources were indeed mined by indigenous communities, such as those in the south coast of Peru where river streams are very dynamic, preventing the formation of placers (Eerkens et al., 2008; Stöllner, 2009; Stöllner et al., 2013).

Something similar happens in SPA: the aridity of the desert and the lack of weathering in the west slope of the Andes prevented the formation of placer deposits in that region (the *Precordillera* and Coastal *Cordillera* Copper provinces, see section 2.2.2), but preserved numerous primary gold deposits that were potentially available and accessible in the past (Boric et al., 1990).

Considering that artificial Au-Ag alloys are identified (see below), it cannot be ruled out the possibility that silver levels between ~15%Ag and 20-30% may be artificial as well, resulting from adding silver to low-silver gold with ~5%Ag or ~15%Ag. Other processes that may alter the silver content in the objects, compared to native gold, is the mixing gold from different deposits: e.g. mixing gold with ~5% and 20-30%Ag. All of these options are possible, but difficult to identify conclusively.

5.3.1.1.1 Artificial alloys

Silver levels over 30% would result from the mixing of gold and silver. Silver may have been added as fresh metal or by recycling finished objects or scrap. Interestingly, when the occurrence of Cu-rich and complex inclusions within the gold matrix were plotted against silver levels (Figure 41), most of the samples with Cu-rich and complex inclusions fall in ranges over 30%Ag (n=13); whereas a smaller group was under 30%Ag (n=7). Samples with Fe-rich inclusions only, on the other hand, appear in objects under 30%Ag. It is plausible therefore, that the presence of complex inclusions, understood as impurities, were introduced when silver was added. If that was the case, are these natural impurities of silver or represent artificial contamination from the alloying process?

Previous research on silver objects has suggested that impurities in silver may derive from recycling silver-copper objects, but this would result in high levels of copper, which is not the case (Patterson, 1971; Rehren et al., 1996); or from re-melting silver artefacts with vestiges of intergranular corrosion, which would increase Zn, Fe and Ca levels according to Patterson (1971, fig. 306). Other contamination sources may be the use of dirty crucibles or other tools. Evidence of the re-use of crucibles with gold traces is registered in NWA (González, 1997, 2003, 2004b, 2004a); while tin bronze objects with minor amounts of Ag, Pb, Fe, Zn and Ni are reported specifically in Jujuy (Angiorama, 2001). In those cases, traces of such bronzes could contribute as impurities. In Jujuy, a prill found in Los Amarillos contained copper as a major element with minor amounts of Au and Ag and traces of Zn and Al (Angiorama, 2001).

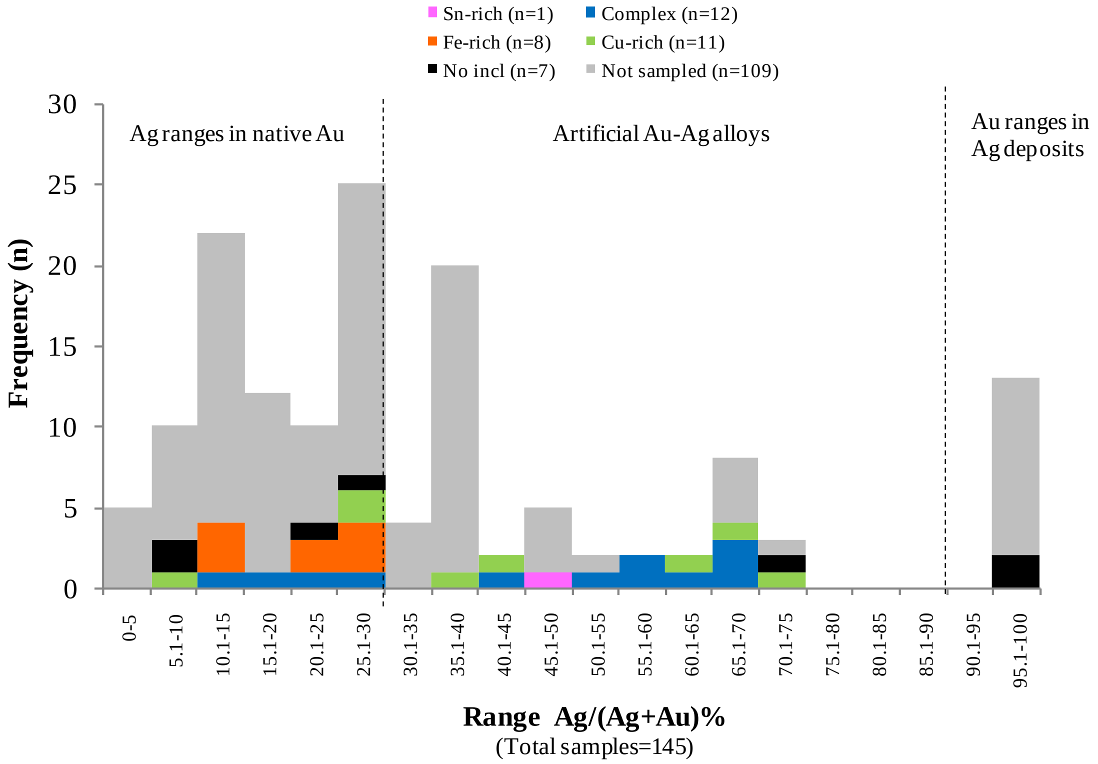


Figure 41: Frequency distribution histogram of %Ag/(Ag+Au) values showing the presence of inclusions in 145 samples of SPA.

Alternatively, the impurities may suggest the addition of native silver or silver minerals (e.g. halides). As explained in chapter 2 (2.2.2) there are three main ways to obtain silver: by melting native silver, smelting silver "dry ores" or smelting silver-bearing complex minerals, using lead as collector and subsequently refining the silver in a process called cupellation (Meyers, 2003; Murillo-Barroso, 2013; Rehren, 2011). The absence of Pb and the presence of volatile elements such as Zn, As, S and Hg within the impurities, which would evaporate during cupellation, and probably after several re-melting episodes, may point to the use of native silver or silver chlorides instead (Meyers, 2003; Murillo-Barroso et al., 2014; Patterson, 1971; Pernicka, 1987). Native silver sources can also present other impurities such as Pb, Cu, Bi and Ni, usually derived from the nearby ore bodies (Meyers, 2003; Murillo-Barroso et al., 2014; Patterson, 1971; Pernicka, 1987; Tylecote, 1987). Even the presence of Sn is not strange, considering that many of the silver deposits from the SCA combined native silver and silver chlorides with other silver sulphides and tin minerals (Appendix Nº4: 1; Zappettini et al., 2001). Native silver, associated to minerals containing bismuth and nickel is reported in Bolivia (Appendix Nº4: 3), also related to Pb-Zn-Ag ores.

However, the use of native silver is not conclusive and it is likely that silver produced in different ways was utilised. For instance, the impurities in sample popm25 (see Table 23) contain lead, which may indicate the use of cupellation. Further, the three silver objects sampled from SPA and observed under the SEM[10], had no inclusions or impurities of any type (although they were highly corroded, with small areas of sound metal).

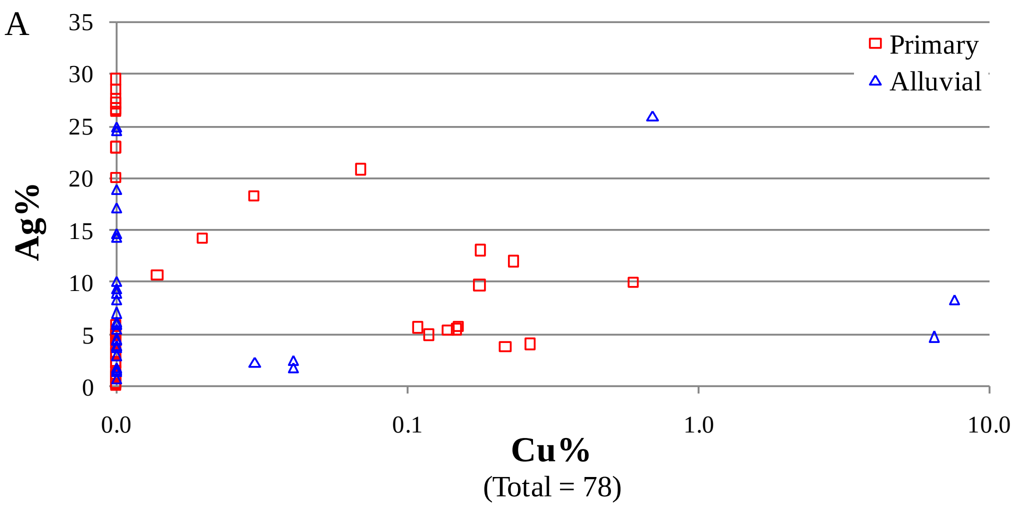
Silver deposits containing native silver, silver minerals and silver-bearing complex minerals are abundant in the Central Andes, as shown in Figure 11. Early evidence of silver production is found in Puno Bay (Lake Titicaca), where remains of cupellation, ore reduction and melting native silver are dated from pre-Tiwanaku (*ca*. AD 60-120) and Tiwanaku periods (AD 400-1000; Schultze, 2013; Schultze et al., 2009, 2016). Indirect evidence based on measuring metal pollution in lake sediments near Lake Titicaca (e.g. Ag, Pb, Bi, Sn, Sb), also indicates an increment in the smelting activity of complex silver-bearing ores between AD 400-1000, associated to Tiwanaku development (Cooke et al., 2008). Towards the south, metal pollution in Lobato Lagoon, next to Cerro Rico in Potosi (southern *Altiplano*), shows that the concentration of heavy elements is low during Tiwanaku Period, and that smelting activities of complex silver ores start *ca*. AD 1000 (Abbott & Wolfe, 2003). In the case of Cerro Rico, it is possible that the low levels of pollution represent the local use of native silver or silver minerals of easy reduction that leave few or no archaeological traces, at the same time that complex silver-ores were exploited around Lake Titicaca.

Summing up, given the presence and absence of impurities in some gold and silver objects, it is possible that native silver or silver halides were used to make SPA ornaments and to alloy with gold, although silver produced by cupellation cannot be completely ruled out. Still, it is possible that impurities reflect the use of recycled and/or dirty crucibles. In these cases, it would be interesting to verify the extent to which impurities of volatile elements would survive cycles of melting/re-melting, e.g., to determine at what levels Zn volatilisation is unlikely to proceed.

[10] The pXRF analysis of these samples only detected silver, light elements were not measured, see chapter 3 for pXRF parameters used; PIXE was not performed in these samples.

5.3.1.2 Copper in gold

Chemical analysis of samples from gold deposits in the Central and South Central Andes usually show copper levels as traces, i.e. <0.1% (Appendix Nº3: 3-5; Alarcón & Fornari, 1994; Ramos & Fornari, 1994); similarly, copper was not detected in any surface of the five alluvial grains analysed from Rinconada (Appendix N°12). Higher copper contents of ≤0.7% (Figure 42:A) are reported in primary deposits from Chile (San Pedro de Cachiyuyo and Cerro Casale) and placer deposits in Zaruma, in the boundary between Peru and Ecuador (Hérail et al., 1990; Palacios et al., 2001; Petersen, 1970). The placers in Pallasca and Ninamahua region, north coast of Peru, contain copper levels up to 6-8%, a very unusual composition (Petersen, 1970). Copper levels in native silver can contain from traces up to 0.08%, 3%, 18% and even 20%Cu; whereas in silver minerals, copper can range from 0-45% (Murillo-Barroso, 2013; 2014; Schlosser et al., 2009).



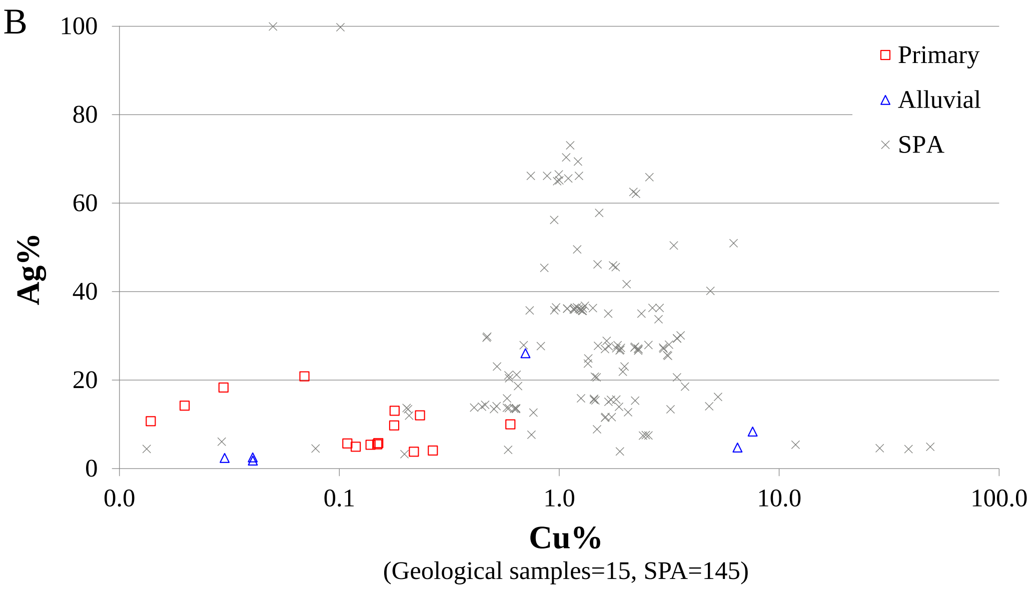


Figure 42: A- Scatter plot comparing Cu% against Ag% in primary and alluvial gold deposits from the SCA. Copper values are in logarithmic scale. B- The same plot with SPA samples.

In SPA, 36% of the artefacts contain <1%Cu, as expected in native gold (Figure 42:B); whereas 58% contain 1-4%Cu, 2% have 4-6%Cu (n=3) and 2.7% over 10%Cu (n=4). Ranges between 1-6%Cu are relatively high compared to most native gold reported in the literature, thus researchers have proposed that copper over 1% was artificially added, whether or not this was intentional (Rehren & Temme, 1994; Schlosser et al., 2009). Values over 10%Cu, on the other hand, are usually considered intentional *tumbaga* alloys of Au-Cu and Au-Ag-Cu (Martinón-Torres & Uribe, 2015; Uribe & Martinón-Torres, 2012).

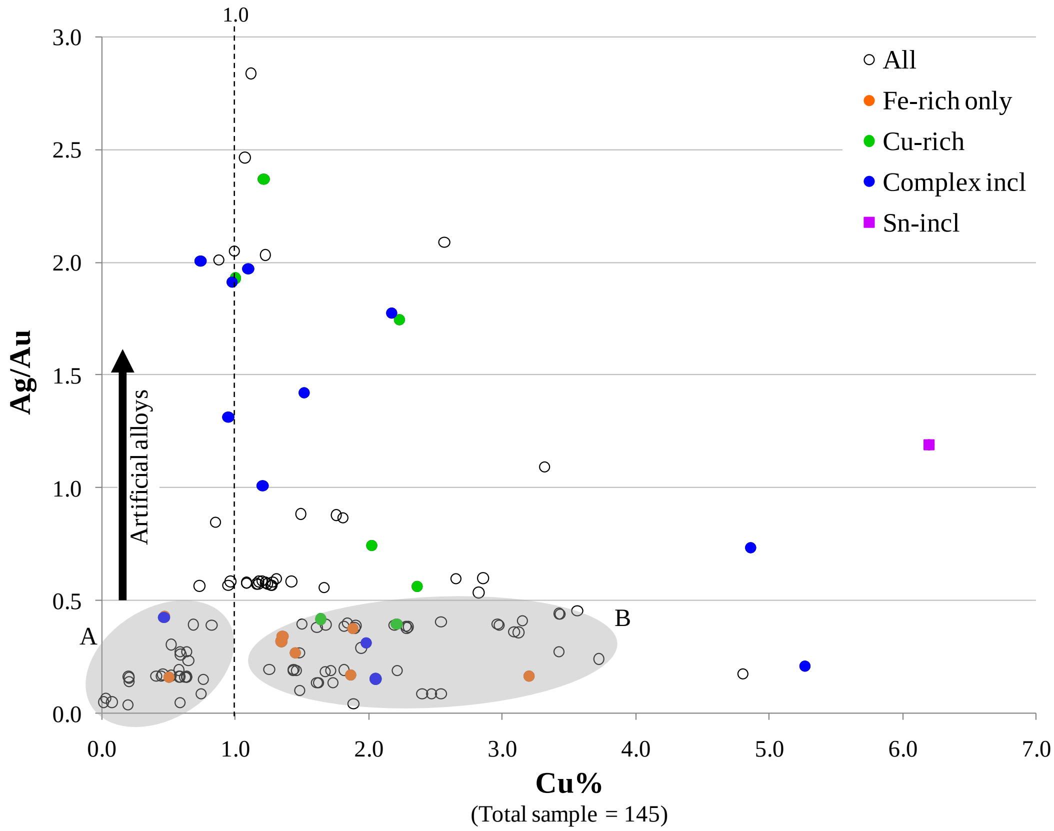


Figure 43: Scatter plot comparing Cu% against Ag/Au ratio, and indicating those samples with inclusions within the metallic core. Group A would represent native gold sources, ratio 0.5 represent ~30%Ag.

Comparing the Cu% and Ag/Au ratio (Figure 32, replotted in Figure 43) some grouping is observed. Group A comprises a series of objects containing silver levels below 30% and copper between traces-0.8%; these values correspond to gold reported in different areas of the SCA, and most likely represent natural sources of unalloyed gold with varied silver and copper levels. However, there are objects under 30%Ag with copper levels 1-5%, which are still low to assume an intentional addition of copper (Figure 43, group B), especially if some deposits may contain up to 2%Cu (Ogden, 2000) or 6-8%Cu, as the case of the placer deposits from the north coast of Peru (Petersen, 1970). Consequently, these relatively high levels of copper (>1%) may indicate one or more of the following options:

a) Copper was introduced with the silver, if goldsmiths are alloying gold and silver.
b) The use of gold deposits with naturally high copper levels
c) Copper was acquired as contamination during melting by 1) reusing dirty crucibles, 2) recycling previously alloyed metal or 3) copper minerals introduced during the collection of gold.

For option a), it would be expected that objects with high-silver content, would also have high-copper levels; however, this is not the case for all artefacts. Figure 43 shows that most artificial gold-silver alloys (over Ag/Au ratio 0.5, which corresponds to ~30%Ag) have ~1%Cu, and a few have over 3%Cu; these values are slightly higher than those seen in group A. In SPA, of three silver objects sampled, only two contained copper: popm42 with 0.5%Cu and popm44 with 1.5%Cu. Assuming that silver with similar copper contents was used for the alloys, it is possible that copper values around 1-3% in samples over ratio 0.5 (or >30%Ag) are the result of mixing silver of 0.5-1.5%Cu, with low-copper gold (<0.8%Cu) such as group A, producing a slight increase in the copper content; or alternatively, silver with 0-1.5%Cu and gold with high-copper (1.3-3.7%) such as group B, where copper content would be diluted and totals would be lower. Therefore, values ~1-3%Cu in artificial alloys could be explained by adding silver with some copper to gold; but there is still group B with relatively high-copper levels which appear independent of the silver content.

Option b) is an alternative that must remain open until the chemical composition of more gold deposits from the region and around SPA are produced. Consequently, it is possible that group B indicates the use of naturally high-copper gold deposits, such those reported in the north coast of Peru (Petersen, 1970). The presence of Fe-rich inclusions in some of these objects (Figure 43, orange dots) - proposed as potential evidence of unalloyed and not melted gold - would support this idea, at least for some of the items. Though high-copper gold is unlikely, but not impossible, probable sources may be primary deposits where copper can be potentially higher than in alluvial deposits or alternatively, alluvial deposits directly related to these primary ores (Chapman et al., 2002, 2006, 2011; Hough et al., 2009; 1999; Knight, Morison, et al., 1994; Palacios et al., 2001; Townley et al., 2003).

The last option c), would suggest that copper was acquired as contamination during melting process. Here, higher copper levels would be expected in potentially melted or alloyed objects. Samples with copper and complex inclusions, identified in Figure 43, would indicate that the metal of those objects was melted before being shaped. Most of the samples with these inclusions fall within the artificial gold-silver alloys (ratio >0.5), but some also appear in group B, in samples around 2%Cu. Therefore, it is possible that some objects were contaminated during the melting process.

Potential contamination sources would be the reuse of dirty crucibles or recycling of objects (as mentioned in the previous section). Evidence of re-used crucibles with gold traces has been found in NWA (González, 1997, 2003, 2004b, 2004a); still, future experiments would be useful to clarify the relative amount of copper introduced during such process. Alternatively, it has been shown that both alluvial (Hauptmann & Klein, 2009, p. 79) and mined gold (Guerra & Rehren, 2009, p. 156) from other regions (e.g. Georgia, Cyprus) can be enriched with copper as result of an incomplete separation in their deposits, i.e., during collection, elements such as copper are not completely removed, being incorporated during melting as an impurity and elevating copper levels to up to 5-8% in finished objects (Chapman et al., 2006; Guerra & Rehren, 2009; Hauptmann & Klein, 2009). An increment up to 5-8%Cu as proposed is consistent with SPA assemblage which concentrates 96% of the objects under 6%Cu. This option would appear to be the best explanation for the relatively high-copper contents seen in group B. If considered, group B may represent the use of gold deposits more closely associated to copper ores, instead of natural gold alloys with high-copper content (option b) which is less likely in theory. It should be noted that gold deposits associated with copper minerals are common in the western slopes of the Andes (see map Appendix Nº4: 4).

Four objects show copper levels over 10% that are clearly artificial, producing a gold-copper-silver alloy named *tumbaga* (Figure 44): 11.9% (popm129), 28.7% (popm131), 38.7% (popm52) and 48.7% (popm27). Such high levels clearly indicate the use of a technology of high-temperature alloying where copper was intentionally added (Martinón-Torres & Uribe, 2015; Uribe & Martinón-Torres, 2012). Supporting this, the trace elements detected in sample popm27 showed a specific combination of nickel and elevated levels of zinc, gallium and lead not found in other objects, and probably related to copper. The gold used for these ornaments, however, contained 6-10%Ag, the same type of gold used for many other objects of the assemblage. A particular case is band popm41, which contains 6.2%Cu, 51.0%Ag and 42.8%Au, an artificial gold-silver alloy. In this case, copper may have been introduced with silver or added separately.

Given the rarity of these alloys within SPA, the addition of copper may represent a different technology compared to the rest of the assemblage, probably imported from neighbouring areas. Further, the few items with high copper levels supports the unintentionality of the small copper amounts detected in the rest of the assemblage, i.e., if metallurgists were deliberately adding copper, then one would expect to find more copper-rich alloys, rather than those relatively small, unnoticeable additions.

			pXRF (%)			
Lab id	Object	Site	Cu	Ag	Au	%Ag/(Ag+Au)
popm129	Band ring	Larache (?)	11.9	5.4	82.7	6.1
popm131	Decorated attachment	Sequitor Alambrado	28.7	4.6	66.7	6.5
popm052	Large disc	Coyo-3	38.7	4.4	56.8	7.2
popm027	Triangular attachment	Quitor-5 (?)	48.7	4.9	46.4	9.6
popm041	Band fragment	Unknown	6.2	51.0	42.8	54.3

Figure 44: Objects with artificial copper contents.

Summing up, copper contents in SPA are low, but small patterns in its variability may reflect different situations. For instance, samples with values <30%Ag and 0-0.8%Cu would represent native gold with different silver and copper contents (group A); whereas the slight increment of ~1-3%Cu in alloys >30%Ag, would result when silver with low amounts of copper is added to gold. Values >1%Cu and <30%Ag (group B) are more complicated to interpret. Potentially, they are the result of contamination during melting, most likely caused by Cu-bearing minerals incompletely removed during collection, though contamination by reusing dirty crucibles or recycling metal is also possible. Still, the existence of relatively high-copper sources cannot be completely ruled out yet. Finally, copper levels over 10% are clearly intentional, representing a different technology which appears to be rare in SPA.

The low copper levels would suggest that artisans are not producing (or preferring) alloys with high copper content (e.g. *tumbaga*), even if copper was available and used in SPA (Cifuentes, 2014) and the SCA. Contents up to 5%Cu (including 96% of SPA assemblage) in gold alloys will not affect the colour or melting temperatures (Schlosser et al., 2009, p. 416), thus the production of low-Cu alloys may respond to aesthetic preferences (e.g. specific golden/yellow colours), or may relate to the meaning of the metals (see later discussion). Another option is due to technical constraints: considering that most objects are made of sheets, the addition of copper will produce a harder metal that would be more difficult to hammer (Corti, 1999; Lechtman, 2014, p. 379; McDonald & Sistare, 1978), and would probably need different skills and manufacture techniques.

5.3.1.3 Impurities and trace elements in gold

The trace elements detected by PIXE in the assemblage of SPA are Zn, Fe, Ti, S, Ni, Ga, Pb, Hg and Mn (Table 20). In addition, the same elements plus As, Sn and Bi were identified in microscopic inclusions by SEM-EDS (Table 24). Unfortunately, conclusions related to trace element concentrations in the objects are not firm, owing to several reasons. First, there is very little comparative material, i.e. only a few gold and silver objects from the Central Andes have been analysed for trace elements. Second, the few analyses from gold sources did not show clear similarities to the trace elements seen in SPA, except from the deposits in Sandia (south Peru) containing zinc. Third, due to time constraints, the count doses for PIXE analyses were shortened later in the day available for analysis, which may have affected detection limits and the overall internal coherence of the dataset.

As mentioned, published data of trace elements found in gold or silver objects from the Central and South Central Andes for comparative use is extremely limited. Schlosser and colleagues (2009) analysed Nasca, Paracas and Chavin gold objects by LA-ICP-MS. They identify traces of platinum group elements (PGE) in concentrations ~1000ppm in gold objects from the central and north coast of Peru (e.g. Chavin), while in the south coast (Paracas, Nasca) objects have low PGE traces (<100ppm). Chavin ornaments (central highlands) contained high Pt, Pd, Rh and Ir concentrations comparable to those in objects from the north coast. They identified two objects with "uncommon" trace elements for the south coast: a Paracas object high in Ni (which is usually <10ppm), and a Nasca artefact high in As and Sn (Schlosser et al., 2009). Traces of Fe, Sn and Sb were detected in Inca gold objects (unknown context) by Rovira (1994), who also found Fe, Sn, Sb and Pb in Inca silver objects (1994). In Argentina, gold ornaments from La Isla de Tilcara and Pueblo Viejo de la Cueva (Humahuaca) have traces of Fe (by SEM-EDS; Tarragó et al., 2010). From the same region, Angiorama (2001) describes a silver object with 0.6%Fe and 2.4%Zn. While in Salta, Gonzalez (González, 2004b, p. 333) reports a gold and copper diadem with important amounts of Fe, Zn and Ni (≤5.3%), but with no detectable silver. The Fe-Zn-Ni combination is also found in tin-bronze objects from the *puna* (Angiorama, 2001).

Regarding gold sources, Alarcón and Fornari (1994) report traces (<0.1%) in specific deposits from Bolivia (Appendix Nº3: 3-5). In general, traces are of Cu, As and Sb; and specific deposits may contain Bi, Fe, Ti, Te, Sn and Hg as well. However, there is no mention of Ni or Zn, the latter a common element in the SPA assemblage. Petersen (1970) published data from placer deposits in Sandia Province, south Peru. He reports a placer with Sn concentration between 0.1-1% (Chinihuaya); while two have <100ppm of Sn: Vetasmayo and Sandia. Interestingly, the Sandia placer contained As (100-1000ppm), and Ni, Zn, Ti, Pb, Bi and Cr in concentrations <100ppm. The latter elements are similar to the traces and the composition of the complex phases detected in some objects from SPA, such as popm12, 15, 20, 24 and 25.

With the data available it is not easy to compare the assemblage of SPA with other areas. Based on the limited comparative data presented above, it appears that the presence of Zn, Sn and Ni, and no PGEs are more characteristic of sources from the SCA, in contrast to objects from north and central Andes where PGEs are present, and elements such as Sn and Ni are rare. Traces detected in some objects from SPA are similar in composition to the diadem of Salta with Zn-Ni. Regarding gold deposits, the Sandia placer contains similar traces as well, presenting Zn, Ni, Bi and Sn; although it includes high levels of As and Hg not detected in SPA samples, these elements may evaporate and decrease if the metal is heated (as Zn).

In SPA, the presence of zinc in both gold-rich (<30%Ag) and silver-rich (>30%Ag) objects (Figure 45) would suggest that zinc is probably associated to gold sources. Robert and colleagues (1997) indicate that gold with Cu-Pb-Zn as trace elements regularly appear in gold deposits of volcanic origins; whereas traces of As-Sb-Hg and Bi-Te-W are related to sedimentary and intrusive environments, respectively (Robert, et al., 1997, pp.218). Gold and silver deposits related to zinc minerals, and zinc ores are mapped in Appendix Nº4: 5. In contrasts to the abundant silver deposits related to zinc minerals in the area, only nine gold deposits (veins or porphyry deposits) appear associated with zinc minerals, five of which are located between ~170-250km[11] towards the north and east, in south Bolivia and NWA. It would be interesting to study these deposits further and determine whether they were used as sources for the SPA artefacts.

In the case of the elements present in the complex inclusions within samples, it was proposed in the previous section that they are most likely related to the addition of native silver or silver minerals. Silver deposits containing native silver and silver minerals

[11] Distances are only a general reference, they were calculated by a straight lines in QGIS.

relatively easy to process (i.e. no lead is needed to extract sliver), are relatively abundant in the area (see Figure 11). However, ores associated with Sn, Bi and Zn, are mainly found in Bolivia (Appendix Nº4: 6), and NWA; whereas native silver and silver minerals associated to gold deposits are seen on both sides of SPA, mostly as veins or epithermal deposits in the Precordillera Copper Province (Appendix Nº4: 7).

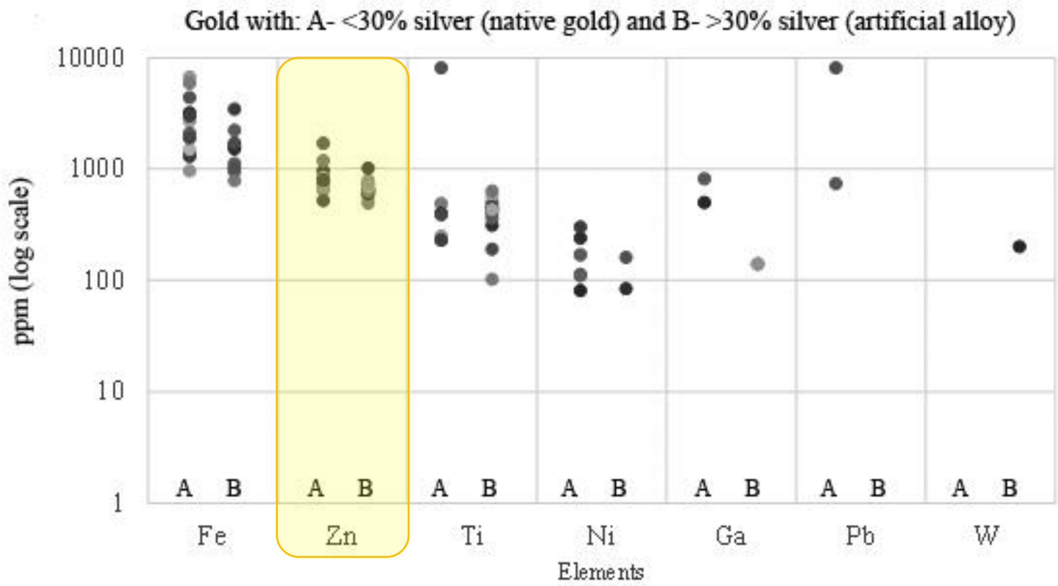


Figure 45: Graph showing the trace elements detected by PIXE in objects with silver contents (A) under 30% and (B) over 30%.
Values in ppm, presented on logarithmic scale. Note the similarity in both groups, although Zn appears slightly higher in some items with lower silver contents (A) that could be consistent with naturally argentiferous gold.

5.3.1.4 *Summary*

The silver and copper contents of the assemblage indicate that the raw materials used in SPA are varied, identifying both natural and artificial alloys. Even the presence and absence of zinc as trace element, would indicate a diversity of sources, potentially including gold deposits of volcanic, sedimentary or intrusive origins.

Overall, most objects in SPA were made of gold within the natural compositional ranges of the region (58%), whereas one third (33%) was made from artificial alloys where silver and/or, occasionally, copper, were added. No particular preference in terms of alloys is observed, pointing to a random and probably opportunistic supply of metal. Considering that there are not known gold or silver deposits in the immediate vicinity of SPA, gold and silver had to be introduced by exchange, either as metallic gold or as finished objects.

Regarding native gold, compositions suggest the use of placers and primary deposits. Placers and paleoplacers are concentrated in a) the *Cordillera Real*, east of Lake

Titicaca and Tiwanaku, and b) in the south, at the border between Bolivia and Argentina (Figure 9:B). Traditionally, it has been considered that placers are the easiest deposits to access, and therefore the only type used in antiquity (Tylecote, 1987). In SPA, this would imply that most gold would certainly be coming from the east: the central *Altiplano,* or southern *Altiplano* and NWA. However, in the Central Andes evidence of mining primary deposits is proposed for south Peru, specifically in the Nasca region (Eerkens et al., 2008; Schlosser et al., 2009; Stöllner, 2009; Stöllner et al., 2013). Given the large availability of primary gold deposits on the west slope of the Andes (Figure 9:C) - most of them associated to copper and silver ores - their use and exploitation in the past has to be considered as a possibility. This possibility is reinforced by our knowledge of an established mining tradition as recognised during the Middle Period by the presence of exploited copper mines in the area since the Formative period (Figueroa-Larre et al., 2007) and remains of the actual miners, such as "the copper man" in Chuquicamata (Bird, 1978, 1979). In fact, the relatively high concentration of copper in some objects, may derive from primary gold deposits closely associated to copper minerals, expanding the potential gold sources towards the west of SPA.

Whatever the case, the presence of trace elements in the SPA assemblage such as tin, bismuth and nickel, which correspond with mineral deposits found in Bolivia and NWA, appear to point towards the east as well. Also compelling are the traces of zinc and nickel associated to metal objects from NWA. It is possible then, that the gold found in SPA is mainly coming from the east, but we should not rule out the possibility that primary gold form the west slope of the Andes was also introduced. Yet, these ideas are based on modern metallurgical maps that identify current economic viable deposits; therefore, they may change with a closer analysis and mapping of the geological deposits.

Regarding artificial alloys, in most cases artisans added silver, whereas copper appears in a few examples only (n=4). However, both situations imply that different raw materials were needed, whether as metal, ingots or finished artefacts. For silver, the complex inclusions seen in some gold-silver alloys containing volatile elements (Zn, As, S, Hg) may suggest that the silver used was obtained from melting native silver or smelting "simple" silver minerals such as halides (e.g. chlorides). However, the absence of inclusions in pure silver objects and other gold-silver items, may suggest that refined silver was also produced. Still, the identification in SPA of native or refined silver obtained by cupellation needs further study, because the objects analysed were small in number and heavily corroded.

5.3.2 Alloy practices: melting, alloying and hammering

There are different pathways to obtain the gold alloys recorded at SPA, which would reflect different artisanal practices. First, artisans can use native gold that is directly hammered to shape. This is especially plausible when the objects are small, and considering that relatively large grains were available in the past (Barba, 1640; Carcedo, 1998; de la Vega, 1609). This approach can be taken as consistent with the evidence when silver and copper contents are within natural ranges; and if we document the presence of quartz, iron and/or clay inclusions in the gold, remnants of the primary ore that get trapped during alluvial transport (Boric et al., 1990; Chapman et al., 2006; Hough et al., 2009; Tylecote, 1970). Another option is to collect native gold, melt it to homogenise it and then hammer it to shape (2013; Armbruster et al., 2004; Perea, 2010). In this case, high-temperature microstructures such as rounded pores or molten textures may be expected; inclusions would be lost as dross or slag, while the composition should remain within natural ranges. Finally, the last option is to alloy the gold with other metals, such as silver or copper (or others). The main indication of this are silver and copper levels outside the natural ranges, combined with high-temperature microstructures (Tylecote, 1970).

Given the evidence, the three techniques were identified in SPA, indicating that artisans worked unalloyed and alloyed gold that was hammered and melted. However, the first option (direct hammering of gold grains) is not proven conclusively, as discussed below.

The use of alloys is revealed by the elevated amounts of silver or copper in 33% of the assemblage, showing compositions not expected in natural gold. In general, these objects represent a specific knowledge, where artisans would control at least some of the properties of different metals, their reactions and melting temperatures (Carcedo, 1998); as well as the access to the necessary raw materials (different metals). In particular, the addition of silver or copper yields different results in terms of mechanical properties of the metal, that would require different working techniques and probably different skills to shape them (Hough et al., 2009). For instance, hardening increases more and faster when copper is added (even in small amounts), as opposed to adding silver, which produces little hardening (Hough et al., 2009). In that case, hammering a gold-copper alloy would need more (and more frequent) cycles of annealing, compared to gold-silver alloys. Alloying also modifies the colour: pale greenish yellow to white, when silver is added and reddish to red when copper is added (Hough et al., 2009). Considering that most artificial alloys contain extra silver, a valid questions is whether users were looking for specific pale-golden colours, instead of more reddish hues which are rare within the assemblage.

The rest of the assemblage (53%) indicates the use of unalloyed gold (silver below 30%), that was most likely homogenised and melted leaving pores or copper oxides as evidence of the melting process. This technique is especially appropriate when fine alluvial gold is used, or small amounts of different sources are collected and melted. The mixing of gold of different sources would increase silver levels in low-silver gold, explaining for example the low frequency of artefacts with silver ranges ~5%, compared to the large number of deposits with the same composition (Figure 40).

The use of melting and alloying implies the use of crucibles (also moulds) and a hearth, and adequate management of the heat to reach temperatures around 1000ºC, as is shown in Figure 29. Still, the presence of complex impurities predominantly in objects with artificially high silver levels and in other objects where the concentration of silver is less notable raises the possibility that even more gold-silver alloys were produced than detectable by chemical analyses alone.

Finally, the presence of samples showing only Fe-rich inclusions and silver levels that are consistent with naturally argentiferous alloys, and with no visible high-temperatures microstructures, tentatively suggest that at least eight objects (5.5%) may have been worked directly from gold grains (Boric et al., 1990; Chapman et al., 2006; Hough et al., 2009; Tylecote, 1970). This technique is not very common, and researchers such as Perea (2010) and Armbruster (2013; 2004) maintain that gold has to be melted and homogenised before it is worked. However, direct hammering of gold grains has been proposed in the Americas by Grossman (1978, 1972), Martinón-Torres and colleagues (2012) and Carcerdo (1998). In fact, Carcedo observed the use of this technique in use during her ethnographic study of traditional metalworkers in north Peru (1998 and *pers. comm.* 2017).

The use of this technique is usually proposed for small objects, but it should be borne in mind that, given the high density and malleability of gold, relatively small volumes of metal are needed to produce sizeable objects. To illustrate this point, in Figure 46 the approximate volume of the gold required to make different objects is represented. Five of the eight objects in this case are relatively small, using between 0.003-0.3 cm^3 of gold (the same as cubes of 1-4mm side), but they are fragments and there is no register of the original shape; whereas two complete ornaments are pendant popm36 and headband popm26, which used 0.3 and 0.4cm^3 of gold, respectively, the same volume as cubes of 6 and 7mm side or relatively large gold grains.

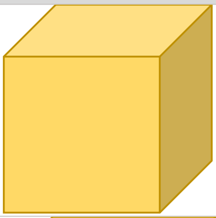
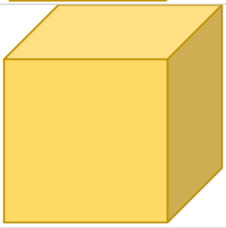
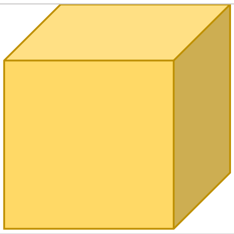
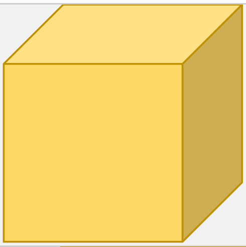
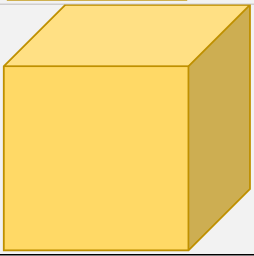
In any case, it should be remembered here that the detection of Fe-rich inclusions in cross-section should not be the only evidence used to support identification of directly hammered gold grains, because the samples taken are very small, and from a specific section of the object. As such, it is still possible that microscopic evidence of melting is present in other parts of the artefact. As a case in point I can mention sample popm17, a part of a large two-part headband (popm17-18). In this case, high-temperature microstructures are seen in popm18, but not in popm17. However, given their identical composition and manufacturing techniques, it is most likely that both parts were made using the same process. Moreover, these objects did not contain PGEs or Sn inclusions that are more conclusive proxies for the use of alluvial gold. Therefore, the use of direct hammering of gold grains is possible, but not definite in the SPA assemblage.

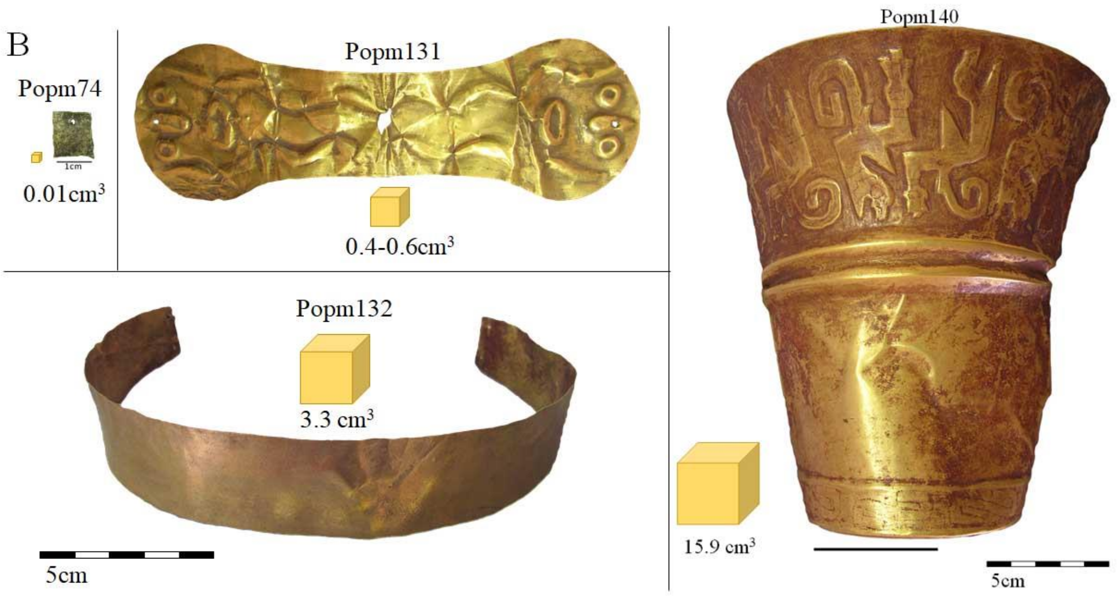
Summing up, the study of the assemblage in SPA provides evidence of a range of alloy practices that mainly include a) the use of artificial alloys, primarily adding silver and in a few cases copper; b) homogenising and melting native gold; and possibly, c) direct hammering to gold grains, identifying the use of different technical solutions to produce this items. Overall, there is no evident compositional pattern that would suggest that artisans were preferring a particular alloy, in fact, the distribution seen in Figure 25 appears random, and its concentration in compositions with silver levels found in natural unalloyed gold, would suggest that artisans were using what was available. Whether the artisans selected a specific colour or mechanical properties is not entirely clear.

Figure 46: Representation in cubes (cm^3) of the volume of gold used to make the items from SPA. Imagine these cubes as gold grains. Note that most of the assemblage was made with cubes of 3 to 8mm side, using 0.01-0.6cm3 of gold. The volume was calculated based on the weight and chemical composition of the objects. In red: objects discussed in the text above. B- Three examples with their objects.

Volume of metal (cm3)	**Cube side in cm**	**Example**	**Objects**	**Id: popm_**
0.003	0.1		Fragment	3
0.01	0.2		Fragments, pendants	2, 8, 69, 74
0.02-0.04	0.3		Fragments, pendants, attachments, bands	9, 11, 16, 21, 22, 30, 47, 50, 51, 67, 73, 75, 76
0.04-0.1	0.4		Fragments, attachments, pendants, bells, rings	5, 7, 10, 15, 23, 27, 28, 39, 48, 63, 66, 96, 114, 145, 146, 147
0.1-0.2	0.5		Pendants, bells, rings, attachments, bands, fragments	24, 25, 29, 32, 34, 37, 55, 57, 58, 61, 62, 64, 65, 77, 78, 89, 115, 116, 119, 120, 121, 123, 124, 127, 129
0.2-0.3	0.6		Attachments, rings, pendants, fragments, bells, headdresses	1, 33, 35, 36, 41, 53, 56, 59, 60, 71, 81, 83, 85, 98, 99, 100, 101, 102, 113, 122, 130
0.3-0.4	0.7		Pendants, rings, wire-rings, attachments, bracelet	26, 79, 82, 88, 95, 103, 104, 105, 117, 128
0.4-0.6	0.8		Headband, attachments, headdress, jug	80, 86, 91, 94, 131, 144
0.6-0.7	0.9		Headband, attachments, pendant	90, 92, 118, 150
0.8	1.0		Headband , headdress	54, 84
1.4-1.5	1.1		Headbands	93, 111
1.5-1.9	1.2		Headband, headdress, bracelet, attachment	87, 106, 107, 142
2.0-2.4	1.3		Headbands, headdresses	17, 18, 110, 112, 125
2.6-2.8	1.4		Bracelets	108, 109
3.3	1.5		Headband	132
4.5	1.6		Headband	42

This figure continues below…

Volume of metal (cm3)	Cube side in cm	Example	Objects	Id: popm_
11.3	2.2		Portrait vessels	137, 138
11.8	2.3		Portrait vessel	141
13.5	2.4		Kero	136
15.9	2.5		Kero	140
17.6	2.6		Kero	139



5.4 Distribution by sites: chemical clusters

The results so far have considered the assemblage as a whole, in order to illustrate and discuss overall trends. In this section, the compositions will be explored by considering separately the cemeteries where the objects were recovered (Figure 47). Overall, in both major cemeteries – Larache and Casa Parroquial – the assemblages combined the use of unalloyed gold (<30%Ag) and artificial alloys (>30%Ag); whereas in Quitor-1, ornaments are artificial alloys only. The remaining objects from known cemeteries (Figure 47:D) fall within natural unalloyed gold ranges, except for four items: three *tumbaga* alloys and one gold-silver alloy (Figure 47:D).

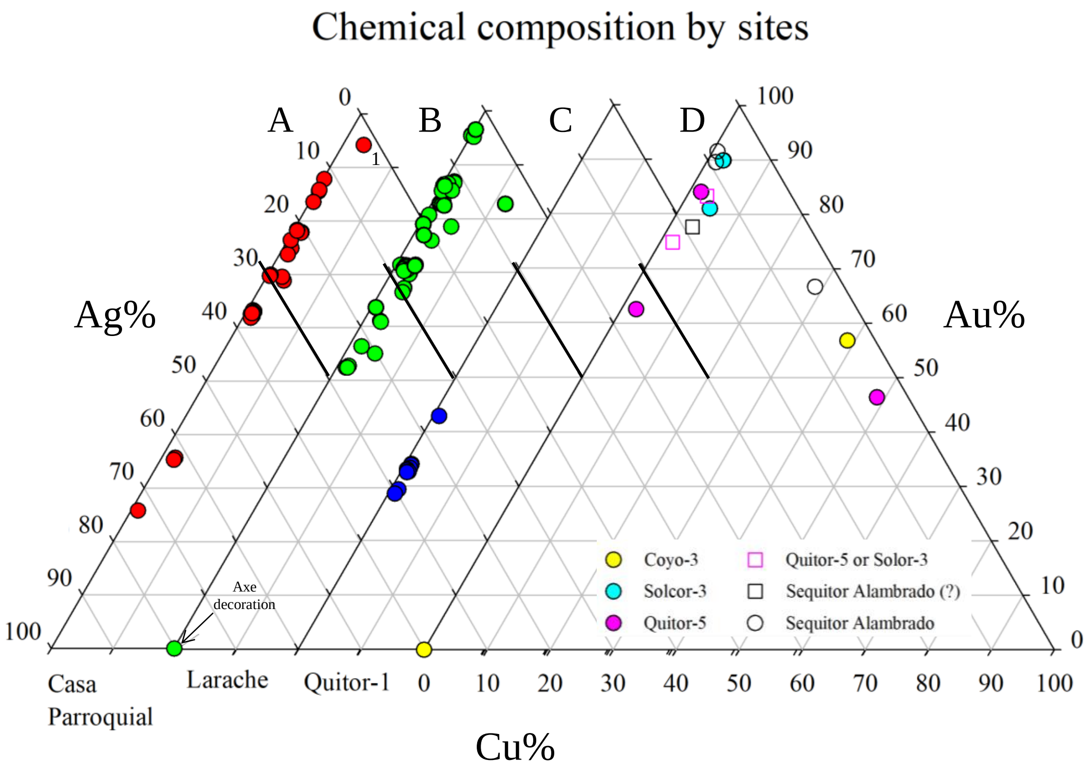


Figure 47: Au-Ag-Cu ternary diagram presenting the chemical composition of 130 analyses on objects from SPA by pXRF, and (1) one analysis by ICP-AES.
(1) axe popm49 with 94.2%Au, 2.4%Ag and 3.4%Cu (Salazar et al., 2011). Results are organised by cemeteries, excluding 15 items without a site. A bold line is marking the 30%Ag limit.

To better understand the distribution of the material and identify possible compositional groups, pXRF results were plotted by types of objects and burials. No patterns emerged when data was grouped by types; however when results were classified by burials, some clusters started to appear. Some of these clusters are relatively tight (within analytical certainty), showing a compositional coherence that most likely represents individual batches of artefacts that were potentially made together in single events (see chapter 3; Bezúr, 2003; Blackman et al., 1993; Freestone et al., 2009; LeClair, 1962; Martinón-Torres et al., 2011, 2014; Martinón-Torres & Uribe, 2015; Uribe & Martinón-Torres, 2012). To identify batches or single production events, groupings based on both composition and manufacturing techniques must be in agreement. Below, compositions will be presented, whereas manufacturing techniques are characterised and discussed in the next chapter, before a broader consideration of their significance.

The chemical clusters identified below were normally deemed such when the values for various items were identical within the analytical error, as proposed by Freestone and colleagues for glass studies (2009); however, a few exceptions were made where values were closely related even if not overlapping. In the latter case, to propose a batch, the chemical grouping will be supported by evidence of matching manufacturing traits (see next chapter 6). It has to be borne in mind that metals are more heterogeneous in nature than glass: they are subjected to corrosion processes, their geometry is not perfect, their inner structure is variable and their composition may change when annealed; therefore, expecting identical results in all cases may not be realistic.

The error bar used in the following graphs was calculated as the average standard deviation (SD) multiplied by 2 for the Cu% and Ag% levels of each artefact analysed (3-5 analyses per artefact). Even though specific precision errors were calculated by instrument (pXRF2105= ±0.3%Cu and ±0.6%Ag, pXRF2016 ±0.1%Cu and ±0.3%Ag), it was decided that using a SD was enough to identify and illustrate general patterns; especially considering that the data already has its own "noise" introduced by corrosion, heterogeneous matrices, uneven geometry, etc.

5.4.1 Casa Parroquial

This assemblage of 34 objects and 935gr[12] (Figure 48:A) is composed of both unalloyed gold (16 artefacts) and gold-silver artificial alloys (18 artefacts). The unalloyed gold has medium and high silver levels around 14%, 22% and 29%, except for the axe popm49 which contained 2.4%Ag and 3.4%Cu (object analysed by ICP-AES, Salazar et al., 2011), suggesting the use of more than one gold deposit. The artificial alloys also show different silver ranges around 36%, 62% and 75%. Overall, copper is low between 0.2-3.4%, corresponding to natural and unintentional ranges in most cases; whereas zinc was detected as trace element in all analysed samples (PIXE and ICP-AES). Other trace elements present are Fe, Ga, Ti, Ni and Sn.

[12] Excluding the axe (popm49).

In this site, six chemical clusters are identified (Figure 49). The largest cluster comprises 15 similar ornaments made of an artificial gold-silver alloy (~36%Ag), distributed in three different burials: B.11, B.16 and B.18 (Figure 49:4). Other clusters showing almost identical composition are headband popm17/18 in B.18 (Figure 49:1), headdresses popm84/86 in B.22 (Figure 49:5), fragments popm2/9 in B.7 (Figure 49:2), and headdress and *kero* popm140/87 in B.18 and B.13, respectively (Figure 49:6). Cluster 3 in Figure 49, although scattering more than the points in other clusters, is very consistent in shapes and manufacturing techniques, as discussed in the following chapter. The chemical similarity of major elements between popm17/18 is supported by their identical trace elements (Table 20).

Within the cemetery, of ten burials with precious metal objects, only B.18 (six items), and B.7 (five sheet fragments) included grave goods with a range of different compositions (Figure 48:B-C). The remaining eight burials - with one, two or 13 grave goods - showed a single compositional group each, except for B.16 that also had a silver-rich sheet (Figure 48:B-D).

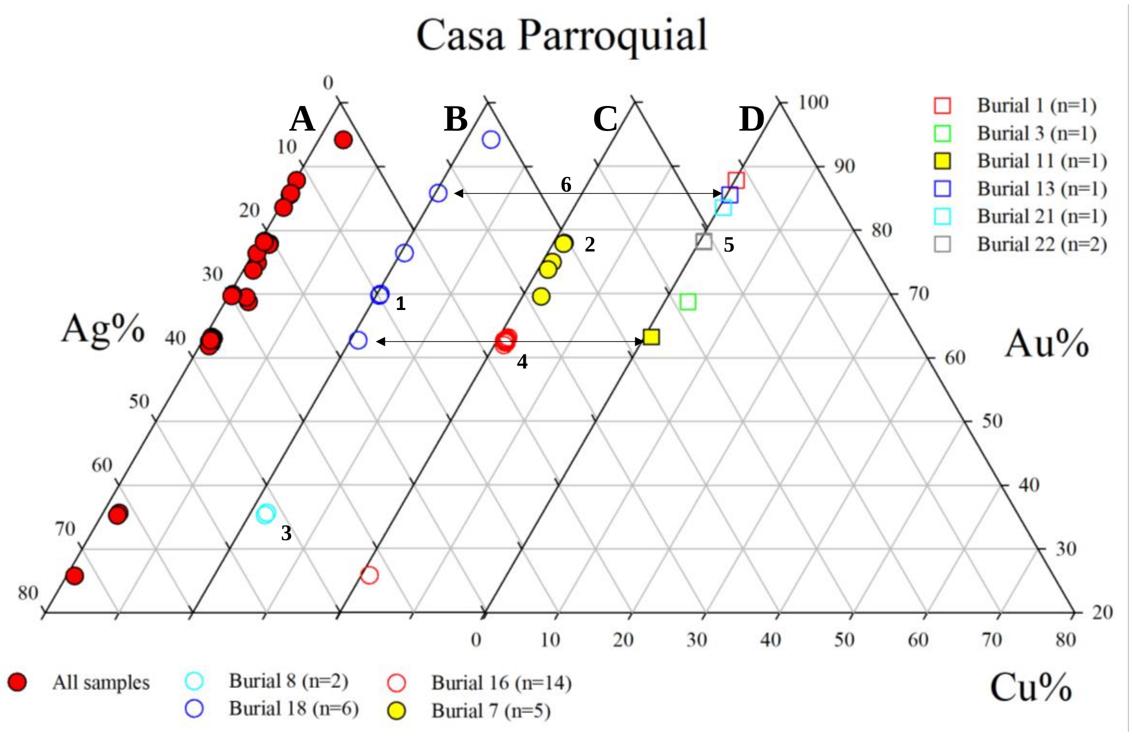


Figure 48: Casa Parroquial cemetery.
Au-Ag-Cu ternary diagram presenting the chemical composition of 33 objects by pXRF and one by ICP-AES (from Salazar et al., 2011). A- all samples, B-D- results organised by burials. Arrows and numbers 1-6 indicate objects with a composition apparently identical.

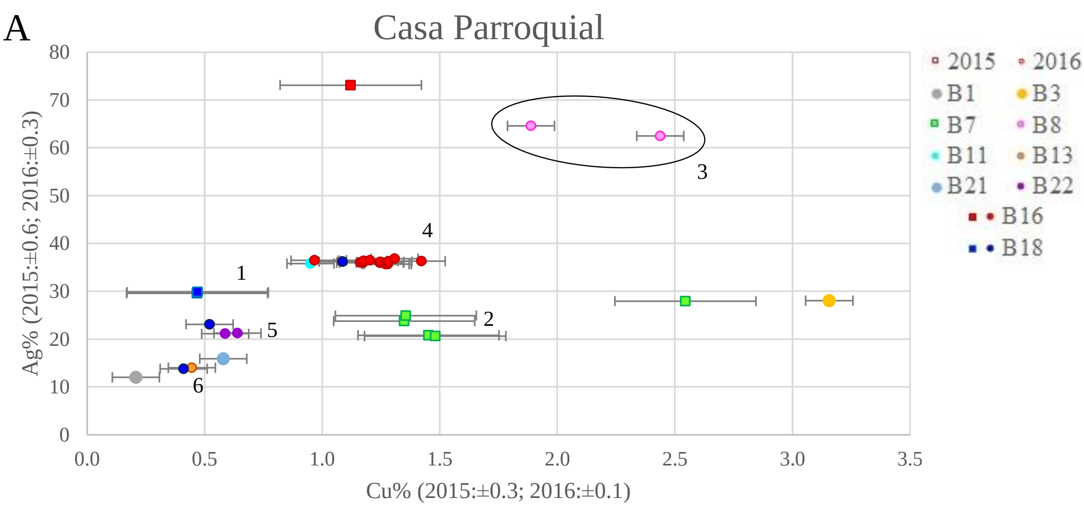


Figure 49: Scatter plot comparing copper against silver percentage of 33 gold grave goods from Casa Parroquial indicating six clusters discussed in the text (pXRF results only).
The standard deviation of the error bars were calculated independently by instrument, pXRF2015 (squares) and pXRF2016 (circles). Legend: "B" stands for "burial", colours represent specific burials.

5.4.2 Larache

In Larache, the 62 objects analysed (1,353grs) show a continuum of chemical compositions, with silver ranges between 4-50%Ag (Figure 50). Silver contents are predominantly below 30%, comprising 84% of the assemblage, including gold with low to high silver levels (*ca.* 4%, 14%, 20% and 27%Ag) potentially indicative of a large variety of gold deposits, or alternatively a number of alloying events. In fact, this is the site that contains the four objects with the purest gold of the assemblage: <0.6%Cu and <4.5%Ag (popm125/127/136/137). At least ten artefacts are made of artificial alloys (16%): nine of gold-silver alloys with ranges around 36%, 40% and 45%Ag; and one *tumbaga* with 11.9%Cu. The only silver-rich samples seen in the diagram are the decorative bands on axe popm126 (Figure 50:C). Copper levels (excluding the *tumbaga*) are low ranging from 0-3.6%Cu, with two slightly high values *ca.* 5%Cu. As proposed in previous sections, these values fall within natural and unintentional copper ranges. Trace elements did not show any visible pattern in the five items analysed, except for iron found in all samples; while zinc was detected in three of the six samples analysed.

Figure 51 shows 11 tight clusters within the site, showing almost identical or very closely related values. These include the bundles of bells clustering in 7, 10, 11, 14; rings from clusters 8 and 9; and different ornaments from clusters 13, 15, 16, and 17. Cluster 12 comprises a set of bells and a set of pendants and headbands. The distribution of the clusters is interesting. Heretofore, 10 burials have been found with gold grave goods in Larache, six of which were available for this research. Overall, burials in Larache contain more gold grave goods per individual than those from Casa Parroquial: B.356 and B.358 with 18 items each, B.356 with 13, B.1714 with five, B.Body-1 with three and B.Body-2 with seven. Only B.Body-1 and B.Body-2 are mono-component, i.e. all grave goods shared a single composition (bells). The other four burials contain a range of different alloys, some of them including several chemical clusters (Figure 50).

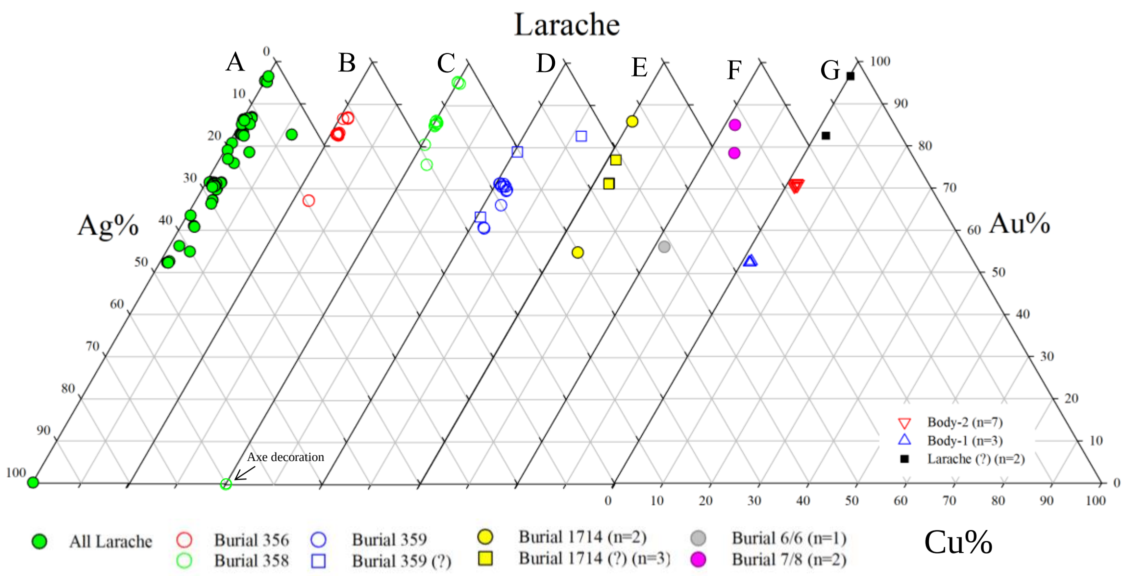


Figure 50: Larache cemetery.
Au-Ag-Cu ternary diagram presenting the chemical composition of 62 objects by pXRF. A- all samples, B-G- results organised by burials.

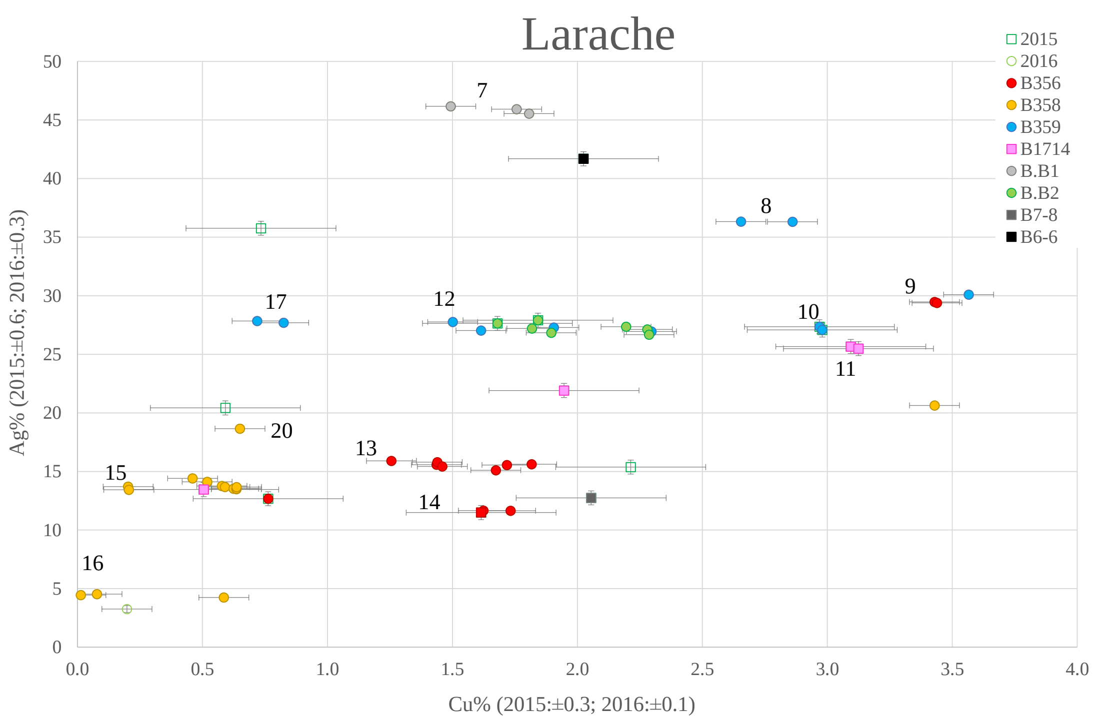


Figure 51: Scatter plot comparing copper against silver percentage of Larache grave goods.
7-17- Clusters discussed in the text. Legend: "B" stands for "burial". The standard deviation of the error bars were calculated independently by instrument, pXRF2015 (squares) and pXRF2016 (circles); colours represent specific burials.

5.4.3 Quitor-1 and other cemeteries

The objects in Quitor-1 are a relatively consistent group. The 10 artefacts studied (19gr) are silver-rich with levels between 55-71%Ag, indicating the use of artificial alloys in all cases (Figure 52:A). Copper levels are low, between 0.7-1.2%Cu. Trace elements detected in six samples analysed are Zn, Ti and Fe; five samples contain complex inclusions with Sn, Fe, Zn and Pb. The ten object compositions clustered in two groups, with a single outlier (Figure 52:C). In B889, cluster 18 includes seven ornaments and cluster 19 comprises two bands.

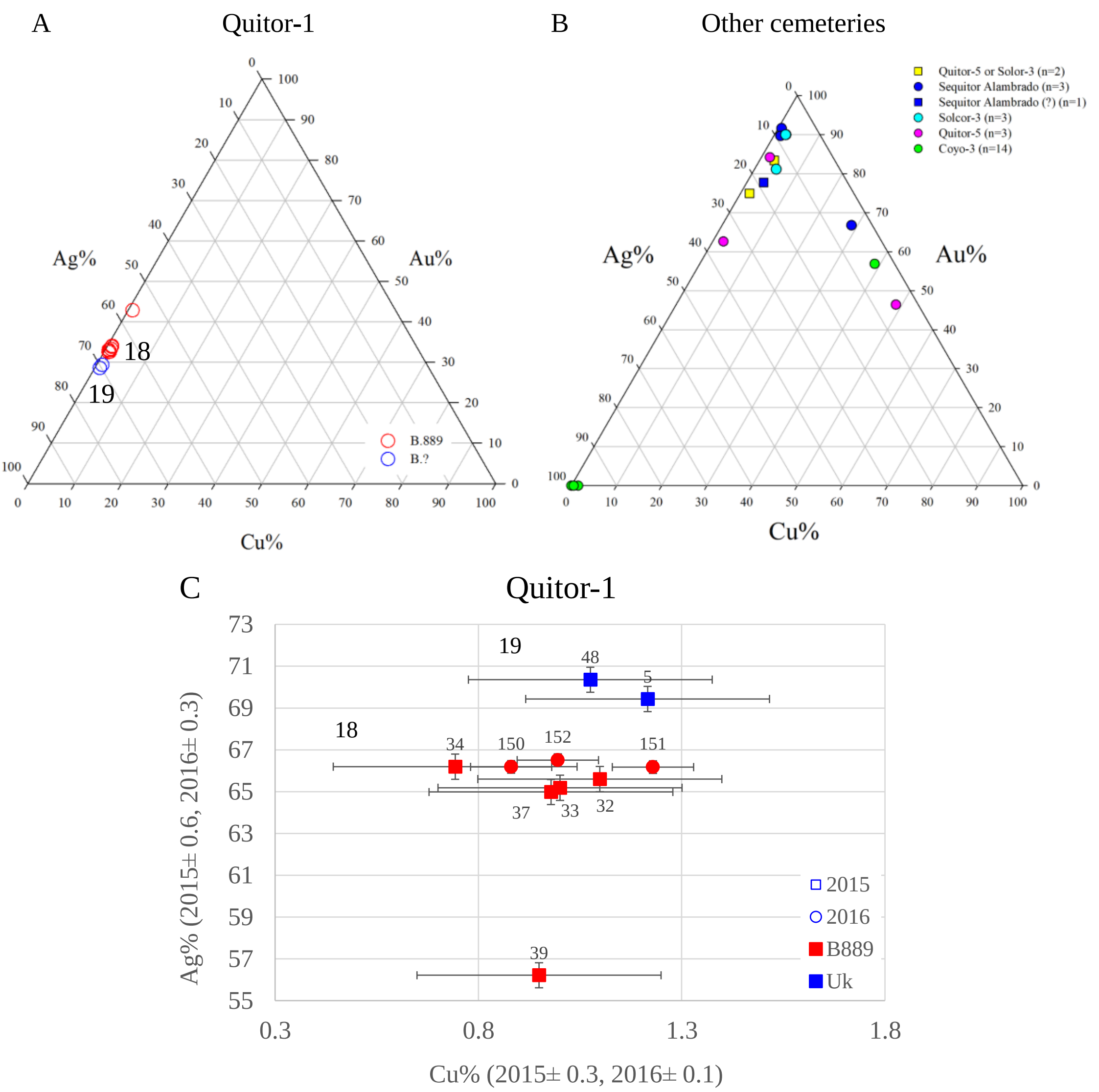


Figure 52: Au-Ag-Cu ternary diagram presenting the chemical composition of (A) 10 objects from Quitor-1 and (B) 26 objects from other cemeteries, by pXRF, organised by sites.
C- Scatter plot comparing copper against silver percentage in Quitor-1 grave goods. Leyend "Uk": unknown burial, "B": burial.

The other cemeteries included in this research (four, possibly five) have a few gold items each (13 in total, 75grs[13]) and do not allow a full exploration and identification of clusters. Still, it is noteworthy that clearly different compositions are represented, supporting the idea of several production events (Figure 52:B). Unalloyed gold was used in most of the artefacts, except one gold-silver alloy and three *tumbagas* (Au-Cu-Ag). Pure silver items (n=13) are found in Coyo-3, all heavily corroded.

5.4.4 Summary

In this section, chemical clusters have been identified as a first step to recognise the output of single production events and explore in more detail how these artefacts were made. Still, to propose the existence of archaeological batches, chemical composition needs to be supported by other lines of evidence such as techniques, forms, styles or trace element (see Freestone et al., 2009; Leusch et al., 2015; Martinón-Torres et al., 2011, 2014; Martinón-Torres & Uribe, 2015). In the next chapter, manufacturing techniques and forms will be analysed to complement these data.

However, it is worth noting that Casa Parroquial and Larache objects differ significantly in both, the variety of compositions in the sites and per burial. In Casa Parroquial, compositions in general are more varied and diverse, including unalloyed and artificial gold-silver alloys ranging from ~14-73%Ag. The gold objects in burials, on the other hand, are mostly mono-component (8 out of 10), i.e., they have the same composition; and only two burials gathered gold items with more than one composition. In Larache, compositions are less diverse, ranging between ~5-50%Ag and including the objects with the purest gold found at SPA. But within burials, they are more varied: of six burials, four were composed of a range of different alloys, while only two were mono-components. In Quitor-1, three different compositions were detected in two burials, all artificial gold-silver alloys between 55-70%Ag. The variability of the compositions and their distribution within the burials can provide information about the acquisition of these grave goods, indicating that objects were obtained on more than one occasion. These and other aspects are further discussed in the next chapter.

[13] The weight does not include all the objects, some were attached to other media and were not weighed.

5.5 Final summary

In this chapter the elemental composition of the assemblage has been presented and discussed. The main findings can be summarised as follows:

First and overall, results reveals a varied sample, not showing any particular patterns or standardised production, except for the low copper content. The different silver and copper levels, and the presence/absence of certain trace elements and impurities (e.g. Zn, Ni, Bi, Sn), indicate that raw materials come from different sources. The latter, together with the absence of gold or silver deposits near SPA, clearly points to an acquisition of metal from neighbouring areas.

Considering that all placer deposits are located to the east of SPA, in Bolivia and NWA, also associated to deposits containing Sn, Bi and Ni, the most likely sources are probably from those areas. However, based on the presence of gold with relatively high copper content, the abundance of primary gold deposits associated to copper ores, and the presence of miners and a mining culture associated to copper mining during the period; it is possible that primary deposits from the western slope of the Andes were also exploited. This certainly does not narrow down the possibilities to identify potential sources, but highlights the complexity of the area and the need of study in detail the provenance of the gold in the region. Yet, it has to be remembered that these proposals are based on modern metallogenic maps and a small number of studies on native gold from the area, therefore they may change in the future.

Second, most of the gold used in SPA is consistent with natural alloys, pointing to a selection of what appears to be available, without extra modification (although it is possible that gold batches of different type were melted together). Artificial alloys were also used but to a lesser extent, mainly mixing gold and silver; *tumbaga* alloys are present but in negligible frequency, pointing to a random and almost incidental occurrence. Alloy compositions are heterogeneous too, i.e. copper and silver were added in different amounts, showing no particular preference.

Third, the use of unalloyed gold and artificial alloys reflects the variety of alloy practices represented in SPA: melting unalloyed gold or alloying gold-silver or gold-copper. Alloying would have included artisans melting native silver, smelting complex silver minerals and copper ores; or acquiring these metals by different means. Direct hammering of gold grains is also possible in SPA, but the evidence is not conclusive.

Fourth, it was possible to identify several chemical clusters that may derive from single production events. These clusters will be compared in subsequent chapters with manufacturing techniques and forms to identify archaeological batches. In terms of access to gold, Larache shows a larger variability of unalloyed gold, from very pure gold with low silver and copper levels, to gold with high silver content, which would indicate the use of and access to a larger variety of sources and/or more batches of metals. Whereas in CP, silver levels are between medium to high, suggesting access to less or more specific sources. Finally, Quitor-1 accessed mainly artificial gold-silver alloys.

Chapter 6. Manufacturing techniques and life-histories

This chapter focuses on the manufacturing techniques identified in the SPA assemblage. I will show here that the techniques used to produce these gold and silver objects are varied, displaying different qualities based on relative skill levels, labour investment and standardisation (see chapter 3; *sensu* Costin & Hagstrum, 1995). In addition, the combination of manufacturing marks with different wear degrees has allowed to explore in more detail the life-history of certain items, recognising modified and repaired ornaments. Moreover, the combination of specific technological attributes, chemical composition and contextual data suggests that certain groups of items may be tentatively assigned to individual artisans, while others likely derive from several craftsmen working together. Overall, I argue that most metal objects arrived as finished items at SPA, however some of them were locally modified.

In total, 133 objects were studied under naked eye and using a digital microscope, and 44 cross sections were subjected to metallography to register manufacturing traits (see below). Overall, the objects were forged to shape, i.e. the solid metal was plastically deformed by hammering and annealing to produce plain sheets and wires that were used to create two- and three-dimensional items, except one axe that was made by casting (there are two gold axes in total, but only one was accessible for this work; Armbruster, 2013; Lechtman, 1981; Untracht, 1975). The two-dimensional (2D) objects (75%) were left flat and in some cases were bent to form rings and bracelets; whereas all the three-dimensional (3D) objects (24%) are hollow shapes made by thin sheets (except the axe).

Together, the objects analysed weighed 2,244gr (2.2kg), excluding nine items that are fixed to other supports. Most ornaments are small thin pendants, attachments, bells and rings (n=97, 72%), weighing between 0.1-8.0gr each; followed by 21 headdresses, headbands and bracelets weighing 10-50gr (16%). Both small and medium items add up to 832gr in total. The heaviest group comprises the six goblets (5%) weighing ~180-280gr, representing the 63% of the total weight with 1,412gr (1.4kg; details in Appendix Nº3: 6).

The manufacturing techniques identified in SPA are basically forging, cutting, perforating and raising. A few objects were folded, wrapped, chased, embossed and engraved. Joining techniques were identified in three objects only (2%). However, even within what looks like a very basic technical repertoire, it is possible to identify large variability in terms of specific ways of shaping, cutting, perforating and finishing treatments, as demonstrated here.

Section 6.1 starts with a brief contextualisation of the manufacturing sequence expected for gold and silver sheets objects; followed by a description of the microscopic (6.2) and macroscopic (6.3) evidence of manufacture. Section 6.3 is divided in six parts: forming (6.3.1) and decoration (6.3.2) techniques, motifs (6.3.3), finishing techniques (6.3.4), *chaîne opératoire* of the goblets (6.3.5); and modifications (6.3.6) and a final summary (6.4). The purpose is to illustrate the variety of techniques and tools used to do specific tasks (e.g. hammering or cutting), as well as to highlight the similarities between some set of objects. The chapter finishes with a discussion about the characteristics of the technology seen in SPA (6.5.1) and possible tools used (6.5.2). Section 6.6 focuses on the technological particularities found at each site (6.6.1-6.6.3), combining manufacture and the chemical information from the previous chapter, to explore artisanal practises based on the presence of batches and production groups in the assemblage (6.6.4). A final summary is given in section 6.7.

6.1 Manufacturing sequence of gold and silver objects

The manufacturing sequence of gold and silver sheet objects is generally divided in three main stages (Table 25) that include the 1) *formation*, 2) *decoration* and 3) *final treatment* of the objects (Armbruster, 2000, 2013; Carcedo, 1998; Maryon, 1971). In the first stage, the metal is transformed from an ingot or lump into a sheet or wire, by repeated cycles of hammering and annealing. In SPA, the forming techniques used are forging and raising. Cutting, perforating, joining and folding are also included in this stage, all helping to achieve the main form of the object. Once the main shape is obtained, the artefacts can be decorated by imprinting designs and motifs using techniques such as chasing, embossing, engraving and cutting. As a final stage, the surface and edges can be perfected and smoothened by grinding, polishing or compressing (Armbruster, 2000, 2013; Carcedo, 1998; Carcedo et al., 2004; Maryon, 1971; McCreight, 1991; Untracht, 1975). For this study, a fourth stage is also included, which consists of the 4) *modification* of some items. Modified objects are identified because they present incomplete shapes, a mixture of techniques in the same artefact, or they combine worn or polished borders with fresh cuts and perforations. The variety of techniques in a single item would suggest that specific objects were transformed at some point of their life-histories.

Each manufacturing technique involves specific tools and actions that leave characteristic marks on the objects' surface and internal microstructure that can be identified to reconstruct the manufacturing sequences and choices made by the artisans, to propose potential *production groups*. The concept is used by Costin to identify craft specialisation from finished objects, when the production sites are not available, and it is defined "*as objects that were made together by producers sharing a technology"* (Costin, 1991, p. 33). These objects usually combine specific manufacturing techniques and typology (Armbruster et al., 2003; Costin, 1991; Costin & Hagstrum, 1995; Leusch et al., 2015). I differentiate here "production group" from "production event". I used the latter to interpret chemical clusters in chapter 5, and it specifically considered the composition of the metal used, i.e. to identify objects that were made at the same time, in a single melting event (Blackman et al., 1993; Freestone et al., 2009; Uribe & Martinón-Torres, 2012). In contrast, a production group may include objects made in single or multiple production events, but sharing particular technological attributes.

	Manufacturing techniques identified in SPA		N° of objects	%
	A- Forming techniques			
1-	Forging	Sheets	69	52
		Wires	3	2
		Hollow vessels (raising)	28	21
2-	Cutting		87	65
3-	Use of guide marks		27	20
4-	Use of templates		4	3
5-	Perforating		89	67
6-	Joining		3	2
7-	Folding		2	2
8-	Wrapping		2	2
	B- Decoration techniques			
9-	Embossing		7	5
10-	Chasing		18	14
11-	Engraving		9	7
12-	Openwork		3	2
13-	Appliqué		3	2
	C- Finishing techniques			
14-	Polishing surfaces		61	46
15-	Polishing edges		50	38

Table 25: Manufacturing techniques identified in SPA.
Note that the techniques listed here are the minimum number identified; it has to be considered that some techniques were "hidden" by later stages of work, therefore remaining undetected.

Lastly, it has to be noted that in metalwork some manufacturing marks can overlap or be removed by subsequent work (e.g. forging marks may be erased by polishing), by corrosion products or resulting from a poor conservation of the objects (e.g. silver or rich-silver alloys are prone to corrode). Moreover, techniques are not exclusive, i.e. same techniques can be used in different stages, for example cutting is used both to shape and decorate (Armbruster, 2011; Armbruster et al., 2003); or different techniques can be used by a single artisan. Therefore, the categories presented below are mainly based on direct or visible evidence and they do not represent a strict typology. Still, organising the data following the different manufacturing stages will facilitate the classification and discussion of the evidence from SPA.

6.2 Metallography: microscopic evidence of manufacture

Forty-four objects were sampled and etched to expose the internal microstructure; however, because of the high gold content, their etching was very difficult. Different etchings and timings were tested, but only 10 samples revealed their microstructure. In some cases, the grains were very clear, but in other samples they appear fragmentary or were very subtle, partially visible under cross polarised light (Table 26; full details in Appendix N°11).

The 10 successfully etched samples showed equi-axed hexagonal re-crystallised grains, lightly twinned demonstrating that samples were hammered and annealed (Table 26; Figure 53-55). In five cases the twin bands and grain boundaries were straight, suggesting that annealing was the last forming step (Figure 55). Conversely three cases showed slightly bent bands, suggesting that sheets were softly hammered as a last step (Figure 53-54). Grain sizes ranged between 9-38μm, which are small according to Scott (1991). However, given the thinness of some sheets, in some cases they covered the surface from side to side (Figure 55). These grains are characteristics of worked gold-alloys (Armbruster et al., 2003; Scott, 2012). Most samples also show a horizontal banding, indicting the direction of work (Figure 53-54).

Sample	Grains	Twin bands	Curvature of the bands	Size (average in um)	N° of measured grains
popm010	equi-axed hexagonal	lightly twinned	Straight	24.5	20
popm015	equi-axed hexagonal	not visible	-	31.0	16
popm024	equi-axed hexagonal	not visible	-	29.9	9
popm025	equi-axed hexagonal	twins	Bent	16.5	30
popm027	equi-axed hexagonal	twins	Bent	9.6	30
popm030	equi-axed hexagonal	lightly twinned	Straight	13.9	10
popm032	equi-axed hexagonal	lightly twinned	Straight	25.9	17
popm034	equi-axed hexagonal	twins	Bent	25.6	30
popm035	equi-axed hexagonal	lightly twinned	Straight	23.5	20
popm037	equi-axed hexagonal	lightly twinned	Straight	37.6	30

Table 26: Grain description of the 10 objects that were possible to etch.
Etchants are presented in Methods. The grain size is an average of the number of grains present in the last column.

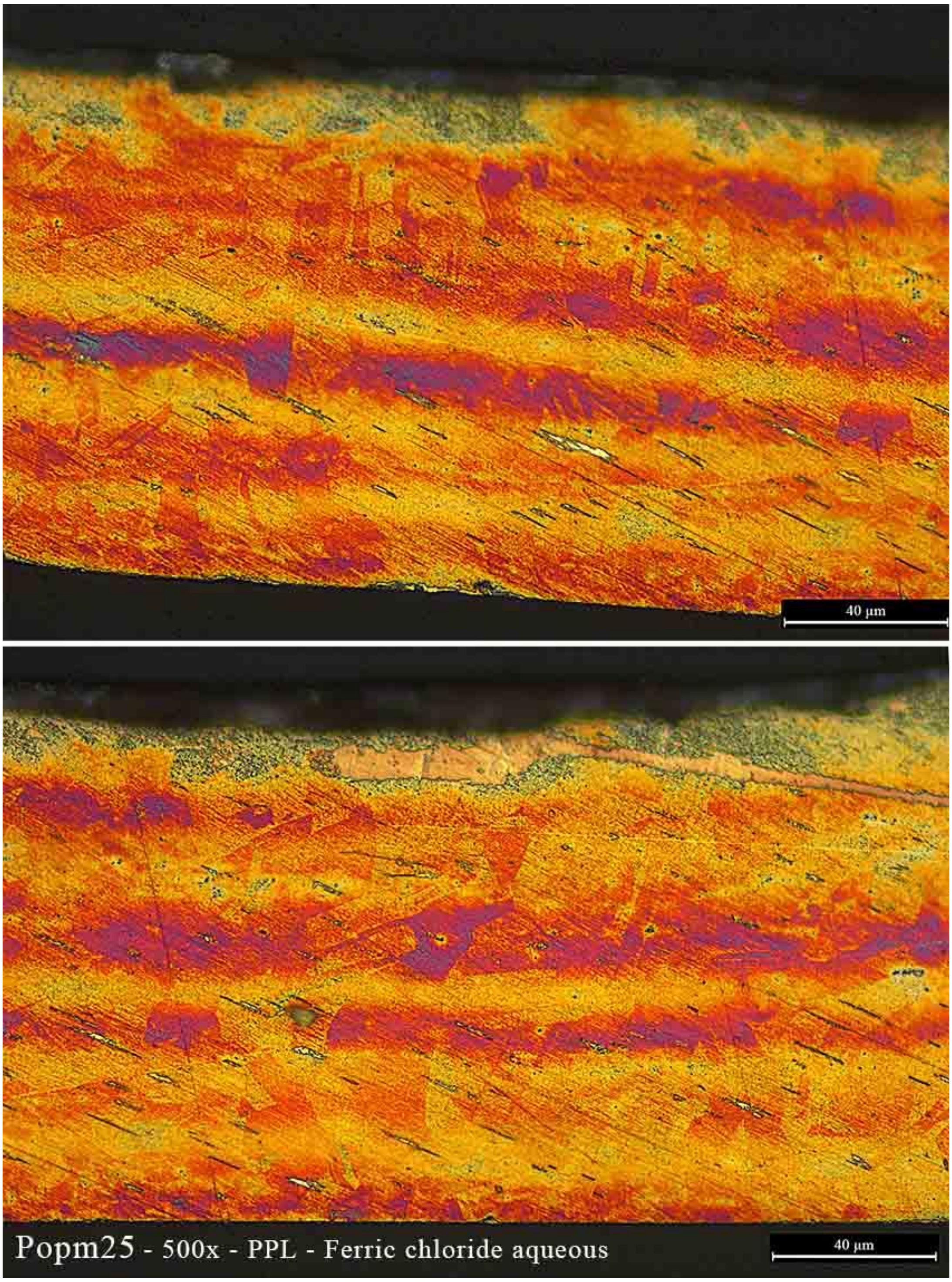


Figure 53: Optical microscope images under PPL of sample popm25.
Note the banding, the equi-axed hexagonal grains and slightly bent twin bands; the average grain size is ~27μm.

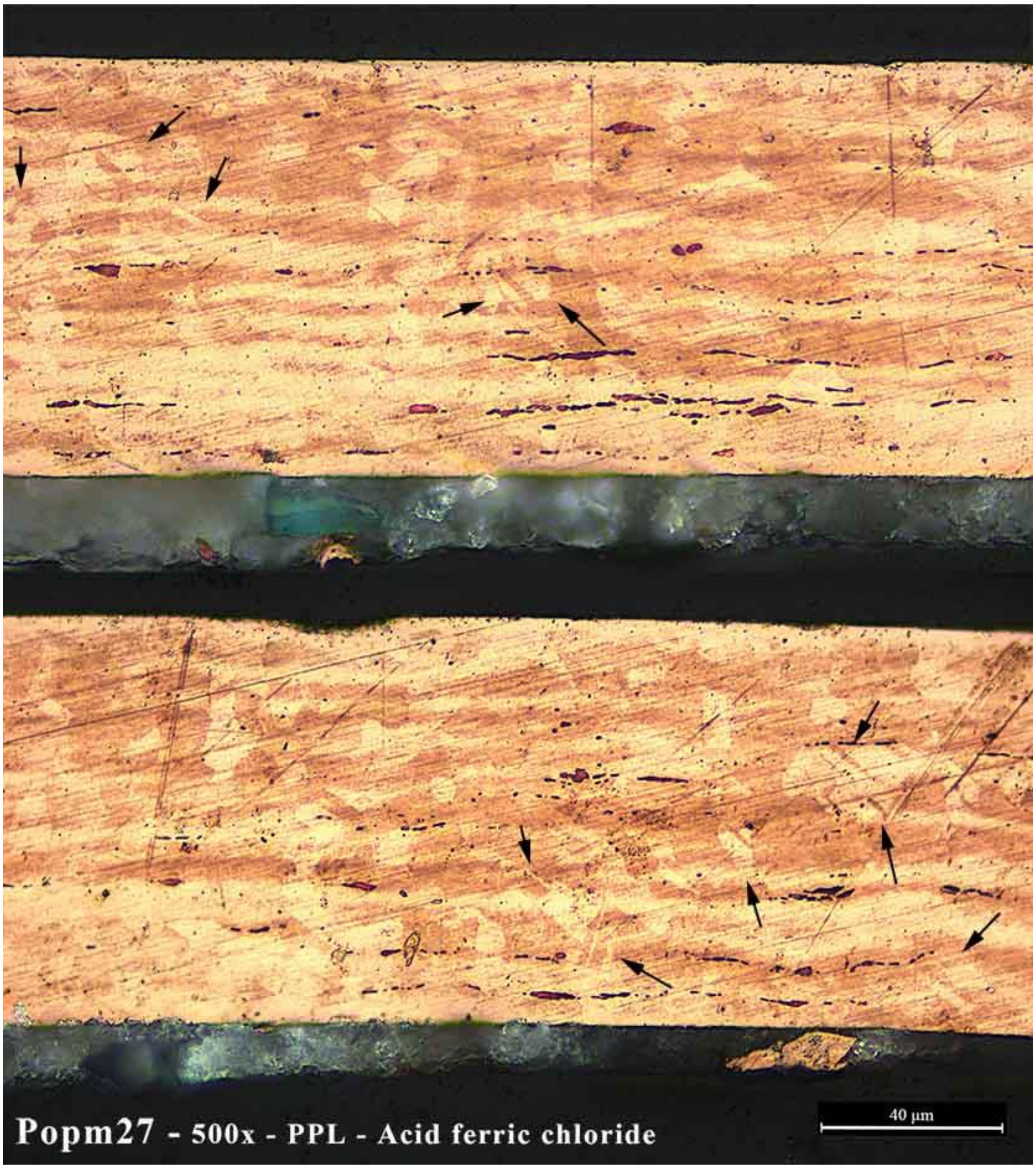


Figure 54: Optical microscope images under PPL of sample popm27.
Note the banding, the equi-axed hexagonal grains and slightly bent twin bands (indicated by the arrows); the average grain size is ~10µm.

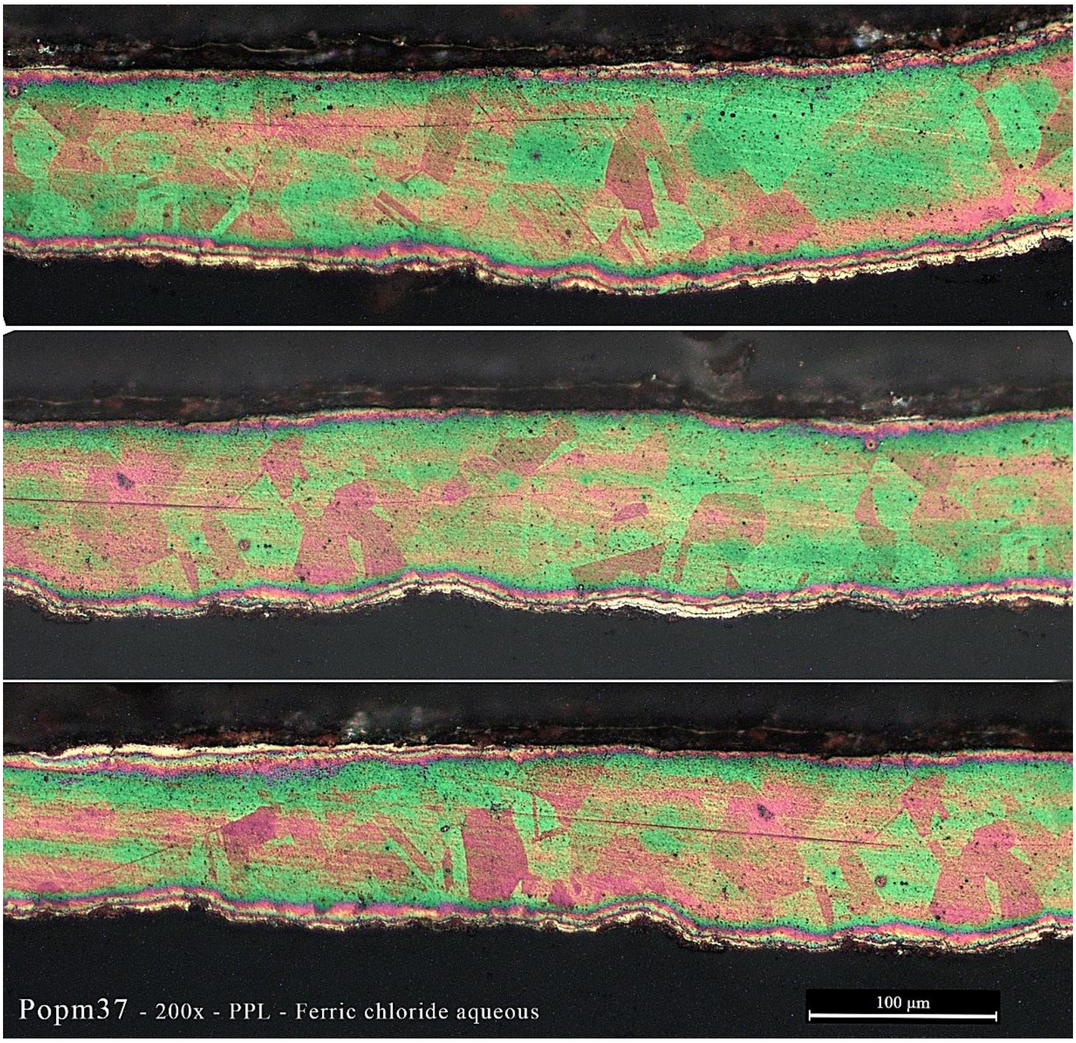


Figure 55: Optical microscope images under PPL of sample popm37.
Note the larger equi-axed hexagonal grains and straight twin bands; the average grain size is ~38μm.

6.3 Tool marks: macroscopic evidence of manufacture

As mentioned, every manufacturing step leaves marks on the surface of the objects (unless they are intentionally erased or obscured by subsequent work). Here the results of the observation of 133 objects by naked eye and using a digital microscope are synthesised. Different tool marks were identified and organised in 1) forming, 2) decoration, 3) finishing and 4) modification techniques (Appendix Nº3: 7).

6.3.1 Forming techniques

6.3.1.1 Forging:

Generally speaking, forging is defined as the direct processing of metal in cold, by applying hammering and annealing, to deform the metal and produce sheets or wires (Armbruster, 2000, 2013; Carcedo, 1998). In the assemblage from SPA, three types of forging are identified and will be described separately: these were aimed at making 1) sheets, 2) wires and 3) hollow vessels by raising (Maryon, 1971; McCreight, 1991; Untracht, 1975).

Forging is also called hammering, however in this thesis the word *forging* will be used when talking about the specific forming technique to shape the metal, whereas *hammering* will be used to describe the action of beating a hammer against something (either a metal or another instrument) that can be used in different manufacturing stages (Armbruster, 2000). Forging is a basic, but not an easy technique. To succeed, the craftsmen need a deep understanding of the alloys used, their annealing temperatures and malleability; to calculate the amount of metal required for the expected size of the final object; and to choose the appropriate tools to achieve the desired thickness (Carcedo, 1998).

6.3.1.1.1 Forging sheets

To produce metal sheets, forging may start from preformed items such as cast plates, rod-shaped bars (Armbruster, 2000, 2013; Armbruster et al., 2004; Perea, 2010) or from gold lumps (Carcedo, 1998). Hammering begins from the edges towards the centre, and produces a plastic deformation that enlarges the surface by reducing the thickness and broadening the sides. A second step is to flatten and continuing stretching the sheet until it reaches the desire thickness (Figure 56). Constant episodes of annealing are necessary to soften the metal - as revealed in the metallography -, except if gold is relatively pure. In that case, gold can be forged at room temperature (Armbruster, 2013;

Carcedo, 1998). Hammering may be applied directly on the surface of the metal, or indirectly by covering the metal with soft materials, e.g. leather or wood (Figure 57), to better distribute the strength of the blow (Carcedo, 1998; Perea, 2010). During forging, the edges of the sheets become frayed, showing cracks and breaks (Armbruster, 2000; Armbruster et al., 2004).

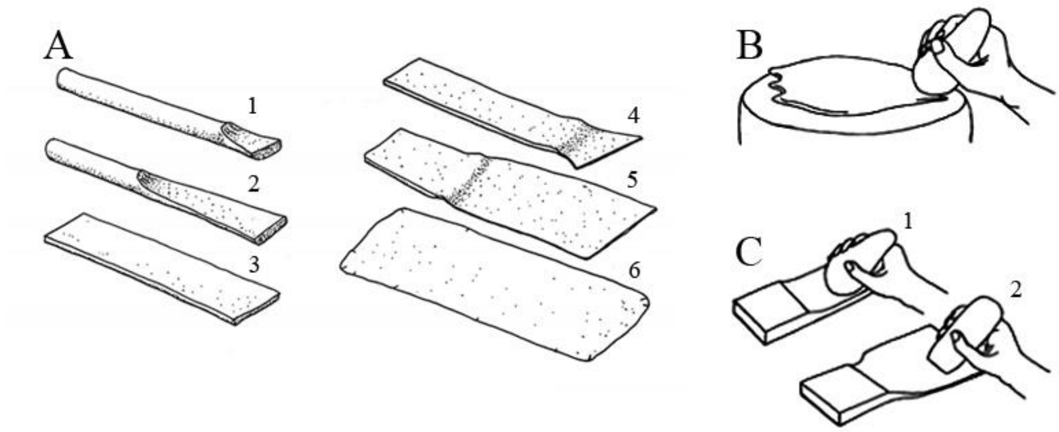


Figure 56: Sheet manufacture sequence.
Forging sequence from (A) a rod-shaped bar (modified from Armbruster, 2000, fig.42); and (B) from a gold lump (modified from Carcedo 1998, fig.1). C- Different stone hammers used during forging, note their (1) round and (2) flat face (modified from Carcedo1998, fig.2).

The tools used for forging are basically two types of hammers. A heavy hammer with a round face is used in the initial stretching stage, whereas the flattening is made using a hammer with a flat face and sometimes slightly lighter (Figure 56:C). Both tools are used against an anvil with a flat face (Armbruster, 2000; Carcedo, 1998). It is expected to find forging marks left in the object produced by the impact between the hammer and anvil, which compresses the metal leaving small, smooth and circular or elongated flattened patches (Figure 58:A-B). These are visible from both sides, except if a soft material (e.g. leather) was used at one or both sides of the sheet. When hammering marks are erased by subsequent work or by polishing, they can be identified in x-ray radiography, as a cloudy texture due to the uneven thickness produced by hammering (Figure 58:C; Armbruster, 2000, 2013; 2003; Lang, 2005). Usually, anvils and hammers are very smooth, otherwise the texture of the stone surface would imprint in the metal as seen in Figure 58:A-B (Carcedo, 1998). Another evidence of forging are the irregular and frayed edges. To obtain regular contours, the edges have to be cut off and subsequently ground and polished (Armbruster, 2000).

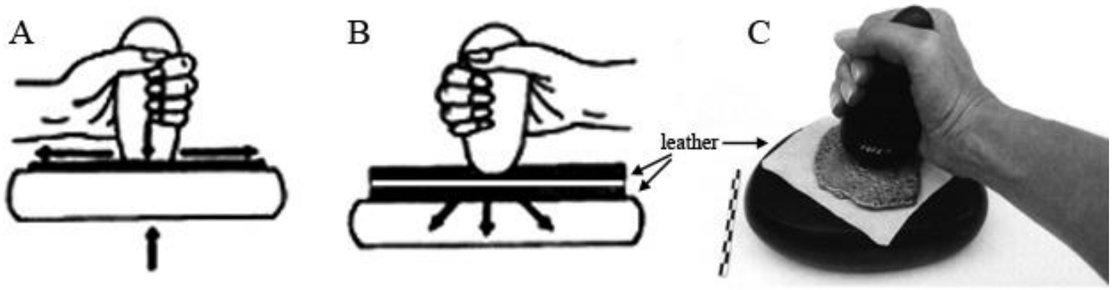


Figure 57: Hammering techniques.
A- Direct hammering: when the hammer blows are applied directly on the metallic surface. B-C- Indirect hammering: when the sheet is hammered above, below or in between leather (modified from Carcedo, 1998, fig.1 and photo 1).

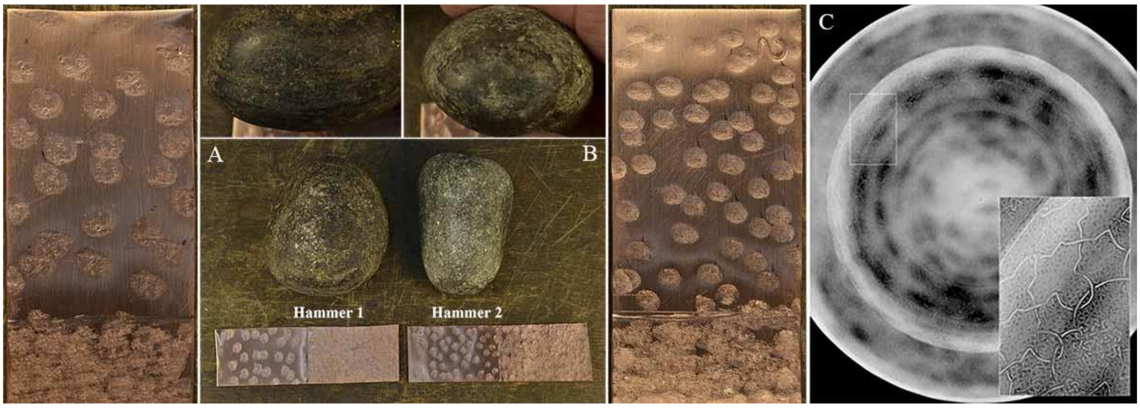


Figure 58: Hammer marks.
A-B- Unpolished hammer marks seen from the surface of two experimental copper sheets hammered with stone hammers (experiment and images courtesy of Brian Clarke, metalsmith). C- Hammering marks by x-ray radiography. Note in C the "cloudy" texture reflecting the different thickness generated by the hammer blows (image modified from Lang, 2005, fig. 3.11).

In the assemblage of SPA, considering that all artefacts are composed of thin sheets (up to 1.0mm thick, average of 0.2mm), it is believed that all the objects were forged, but direct evidence of this was in some cases removed through subsequent work. As such, hammering marks present as concave depressions on the surface were identified in 99 artefacts (74%; Figure 59). They all look as part of the forming stage of the metal, including 2D (n=69, 52%) and 3D items (n=30, 23%). The 2D objects are flat sheets used to make headbands, headdresses, pendants and attachments, amongst others; rings and bracelets were formed by bending the flat sheets. In the case of the 3D objects, 27 of them (20%) were formed by raising (i.e. goblets, bells and jugs), a technique that will be explained in the following section. Additionally, in the three portrait-vessels, hammering marks were identified in specific areas suggesting the use of hammering to perfect details of the decoration (Figure 59:D).

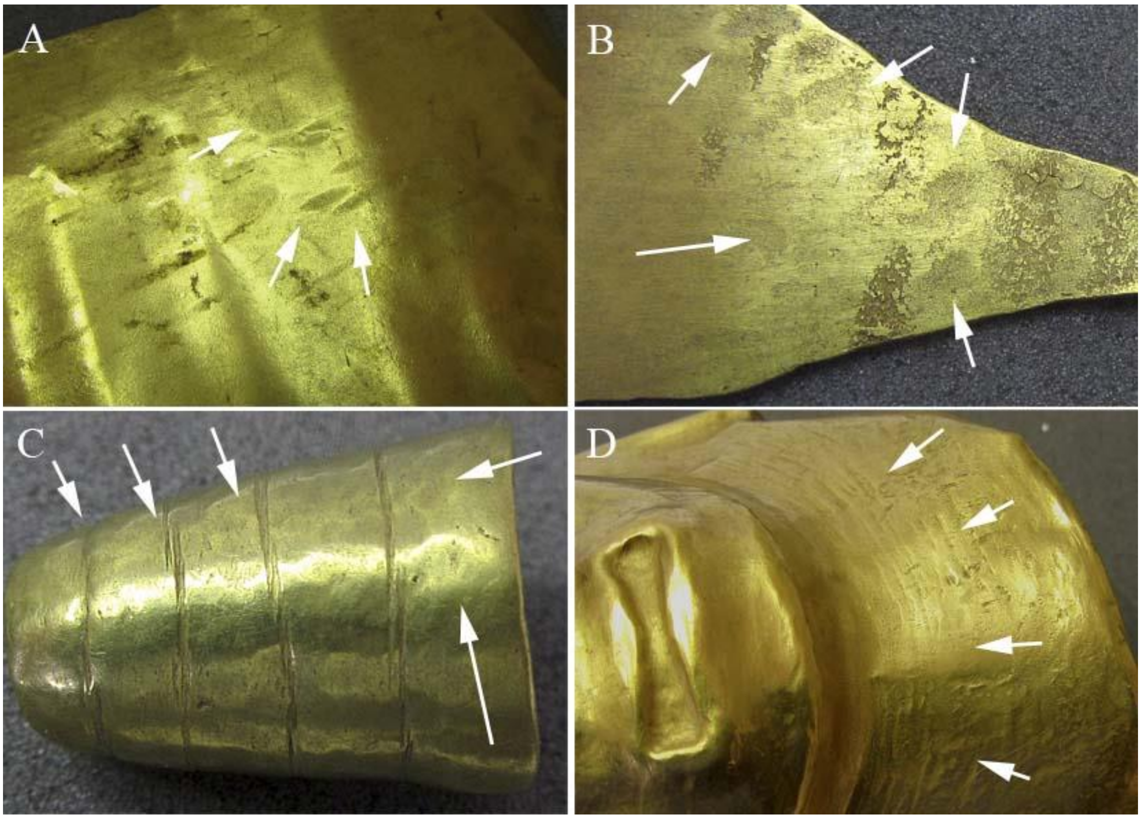


Figure 59: Hammering marks in archaeological objects.
A) Bracelet popm109, B) headdress popm125, C) bell, popm60 and D) portrait-vessel popm137. Note the concave marks of elongated and oval (A), more circular (B-C) and crescent-shaped (D) shapes on the surface (white arrows).

As mentioned, forging marks can be erased by treating the surface, e.g. polishing it; or they can be difficult to see if the object is small or it was hammered between pieces of leather. Of the entire collection, only the small pendant popm47 was available for x-ray radiography. Because of its size, hammer marks are not obvious in this pendant, but the patchy texture revealed in Figure 60:A supports the use of forging in their manufacture. This interpretation can be extended to other six identical pendants found in the same burial (B.16) in Casa Parroquial (popm50-51/73-76) that were most likely made by the same technique. These pendants present a side that is smooth to the touch, whereas the other side is rough (possibly the side facing the anvil during hammering). Four rectangular attachments popm77-80 from the same B16, the square attachment popm81 from B18 and the headdress popm85 from B11, present the exact same surface features, with evidence of forging (Appendix Nº5: 1). Given the similarities, it is very likely that the 13 objects were forged by the same technique, using similar tools.

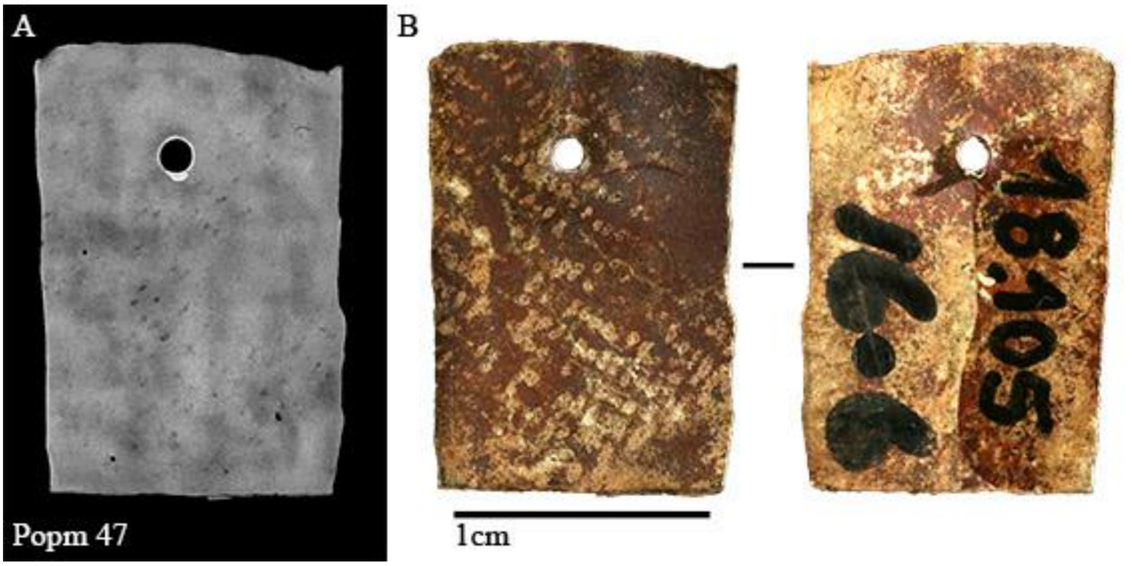


Figure 60: Pendant popm47 from Casa Parroquial, seen by (A) x-ray radiography. Note the patchy texture generated by hammering and (B) at normal view from both sides.

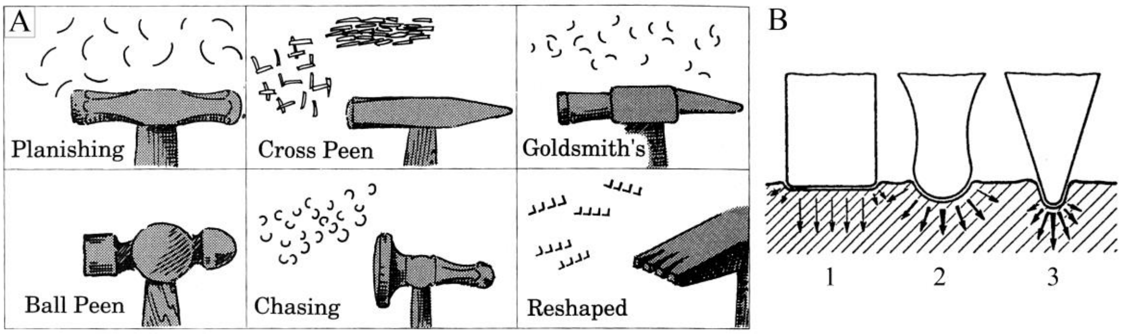


Figure 61: Types of hammering marks.
A- Hammer marks left on the metallic surface by different hammers as an indication of the imprints produced by different types striking surfaces (modified from McCreight, 1991, p. 18). B-Schematic representation of the impact of hammers with different striking surfaces. 1-Flat impact surface, 2- Rounded to spherical impact surface and 3- Fine or wedge-shaped surface (modified from Armbruster, 2000, fig. 38).

The different shapes and sizes of the hammer marks (Figure 59) suggest that a variety of hammers were used, with faces of different curvatures. To have an idea of the marks left by different hammers, imprints left by modern hammers with different strike surfaces are depicted in Figure 61. Note that the shape and size of the head will imprint different patterns on the metallic surface (Armbruster, 2000; McCreight, 1991). Within SPA, some object present similar hammer marks, such as 16 ornaments including headbands, bracelets and pendants from Larache, deposited in burials 356, 358 and 359 (popm93, 106-108, 110-112, 118-124, 132, 142; Figure 62). The resemblance may suggest that the same or very similar tools were used to forge these items.

Evidence of frayed, uneven and cracked borders produced by forging is found in 15 objects (11%) only (Figure 63), suggesting that these items were directly shaped from an ingot, without perfecting the edges; in the remaining flat objects, the edges were cut and/or polished to obtain the final shape, as it will presented in the following sections.

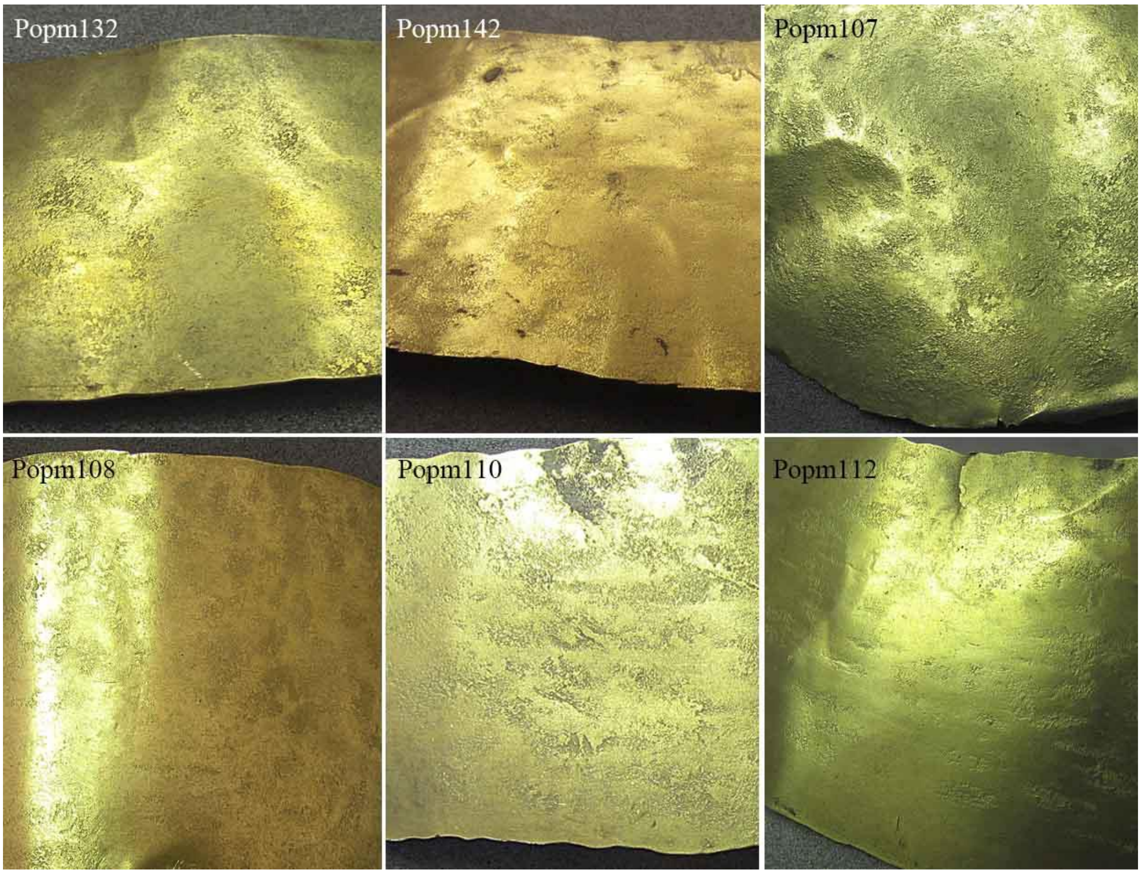


Figure 62: Hammering marks and surface treatment identified in 16 objects from Larache.

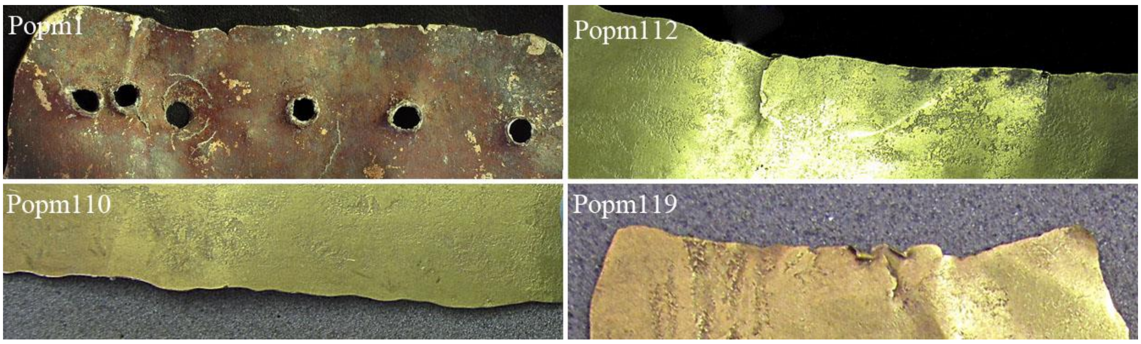


Figure 63: Examples of frayed edges.

6.3.1.1.2 Forging wires

Wires are defined as a continuous object of uniform cross-section, which may be as thin as a hair or as a thin flexible rod (Untracht, 1975). Wires are shaped by forging a bar, sharply reducing the cross-section while increasing its length. Constant annealing is necessary during the process. They usually start from a square or polygonal section that is rounded by hammering or grinding (Figure 64). Indications of this process are unfinished round sections or irregularities that were left unpolished.

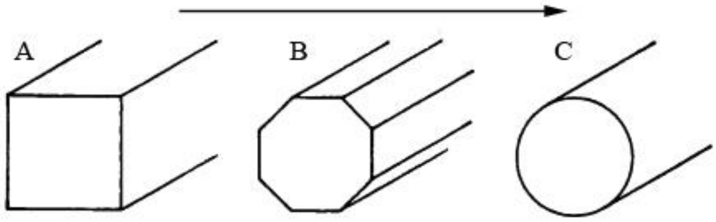


Figure 64: Schematic representation of the transformation of bar of square section to a round rod during forging (modified from Armbruster, 2000, fig.43).

In SPA three rings (2%) were made from wires of 2mm thick (popm103-105; originally, there were six rings in total, but three are currently lost, see Figure 14:B-C). The presence of grooves in the inner part of ring popm103 indicates that they were made from a square ingot or bar that was hammered and polished to obtain a round section that was subsequently bent to create a loop (Figure 65). Rings popm104 and 105 are better made and polished, therefore no imperfections were noted (Figure 66). The forming sequence of this type of rings is proposed by Lechtman (2003b), who found identical rings in Tiwanaku site but made of arsenical-copper (Figure 67). The difference between rings from Tiwanaku and SPA, besides their composition, is that rings from SPA instead of having a rectangular section as shown in Figure 67, were forged to get a round section that was flattened after bending, probably using a grinding stone, as evidenced by the round section in the loops and the flat areas and scratches on the shanks (Figure 66:C-D). It is very interesting to note that the manufacture of the ring popm103 from Larache, burial 359, is of lower quality than the other two rings from the same cemetery but from burial 356, which show better finishing treatments. In addition, the loops were made bending the opposite sides: in popm103 the left shank was placed on top, whereas in popm104-105 it was the right shank. These features suggest that these sets of rings were probably made by different artisans (one more experienced than the other), but following the same sequence and principles. Moreover, by grinding the sides, there is a potential attempt to imitate the rectangular section seen in the rings from Tiwanaku, but achieved in a different way.

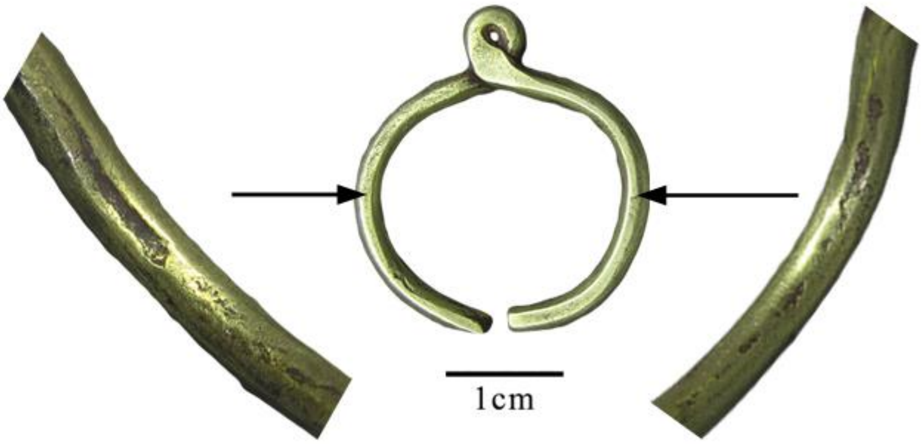


Figure 65: Wire-ring popm103, showing grooves in the inner sections of the shanks resulting from hammering and grinding. Larache, burial 359.

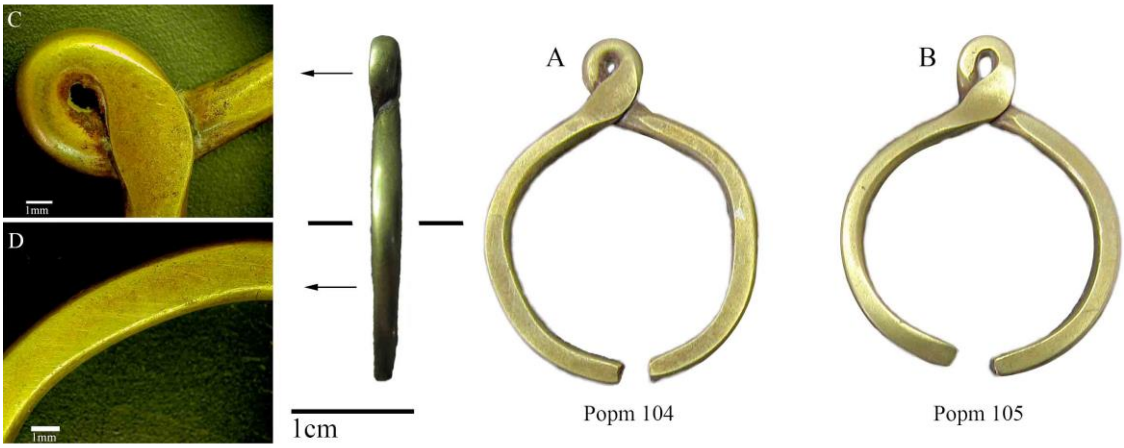


Figure 66: Wire-rings popm104 (A) and popm105 (B) found in Larache, burial 356. Note the round section of the rod in the loop (C), which was subsequently ground (D).

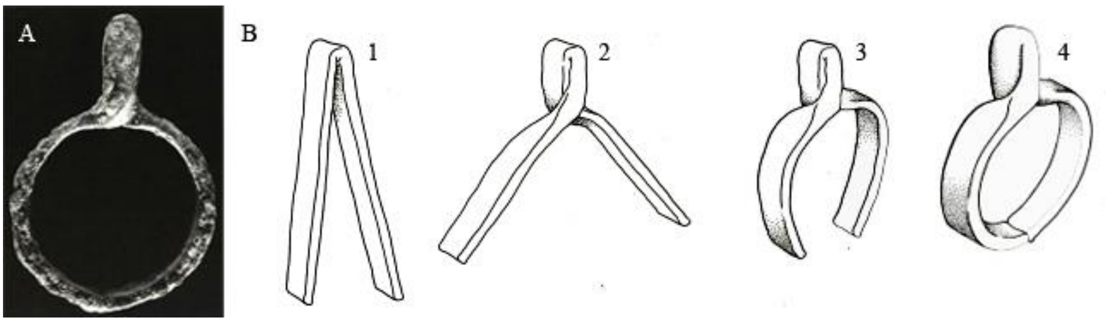


Figure 67: A- Rings of the same type as popm103-105 are found in Tiwanaku site but made in arsenical-copper. B- Schematic manufacture sequence of the wire rings proposed by Lechtman (2003b), fig.17.23-17.24.

6.3.1.1.3 Raising: forging hollow artefacts

This is a specific technique used to produce hollow objects from flat sheets - such as bowls, cups and beakers - by compressing the metal using hammers and stakes (vertical anvils). Starting from the centre, a flat disc is hammered against a wooden stake from the convex side. The sheet is constantly rotated allowing the compression and contraction, raising the walls and achieving a seamless 3D shape (see a full sequence in Appendix Nº2: 17; Carcedo et al., 2004; Hill & Putland, 2014; Untracht, 1975; Warwick, 1978). This is a complex and slow technique that includes several steps such as numerous cycles of hammering using different hammers and stakes shapes (Figure 69:A); thickening and reinforcing the rim (Figure 69:B); squaring the bottom, using a circular and flat vertical stake (Figure 69:C); to smoothen the metal shape with soft materials (e.g. leather, horn, wooden mallets); and to remove hammer marks by planishing. Constant annealing is key during this process (Armbruster, 2000; Carcedo et al., 2004; Maryon, 1971; McCreight, 1991; Untracht, 1975).

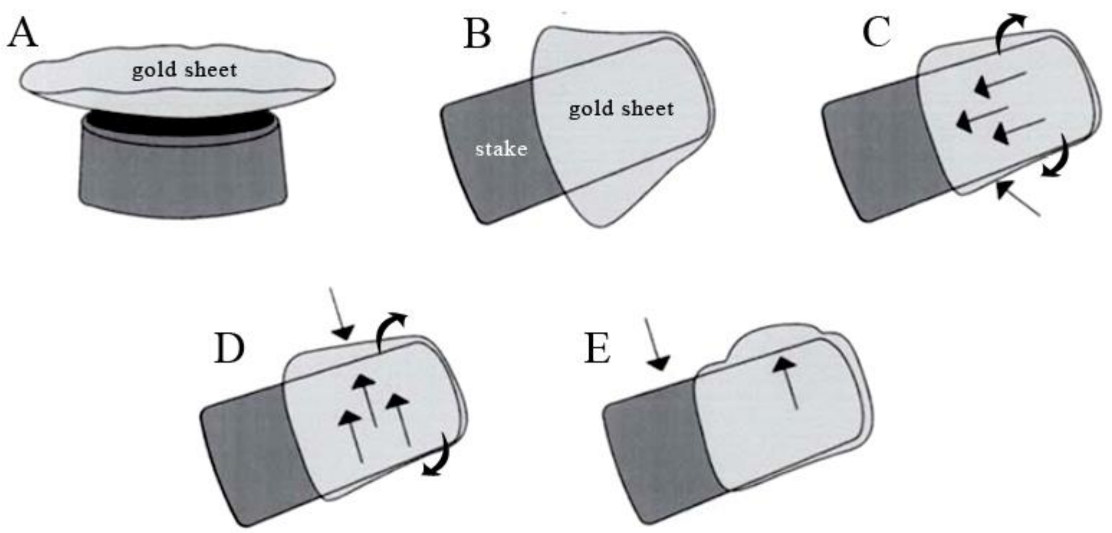


Figure 68: Raising technique.
Sequence proposed by Carcedo (modified from Carcedo et al., 2004, fig. 10). A-preparing the sheet by hammering, B-E- using a stake to hammer and raise the walls.

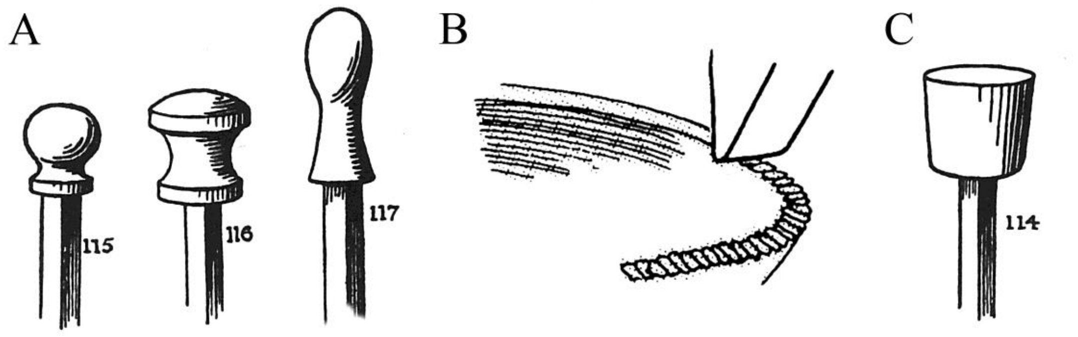


Figure 69: A- Examples of stakes used for raising. B- Process of thickening the edges (modified from McCreight, 1991, p. 61). C- Example of a bottom stake made of wood (A and C modified from Maryon, 1971, figs. 114–117).

The main indication of the use of this technique is the absence of joint lines - either horizontally or vertically - in the body of the thin-walled 3D artefact. Twenty-eight artefacts from SPA (21%) fit with the use of this technique: 21 small bells, 6 goblets and

1 jug (Figure 70). During the revision of these objects there was no indication of joint lines (inside or outside), the bases were flat and even, and there were no metal layers overlapping on the body.

In the case of the bells, the interiors were neither hammered nor polished, rejecting the possibility that joint marks on the inside were erased; it is likely that small stakes were used to shape them. In spite of the different designs, a clear pattern is observed in their size and general look. They all are between 1-3cm in height, with a cylindrical or truncated cone shape (Figure 70:A). Fifteen have straight bodies that were decorated with horizontal bands (Figure 70:A1-2); five cases have a neck or waist near the rim produced by hammering and pushing in the metal from the exterior (Figure 70:A3-4); and only one has a plain and straight body (Figure 70:A5). Most cases were found in sets of two, three and seven; each set was found in a specific burial and were identical in composition, dimensions, design and manufacture techniques, indicating that each set of bells were made by a single person and probably at the same time.

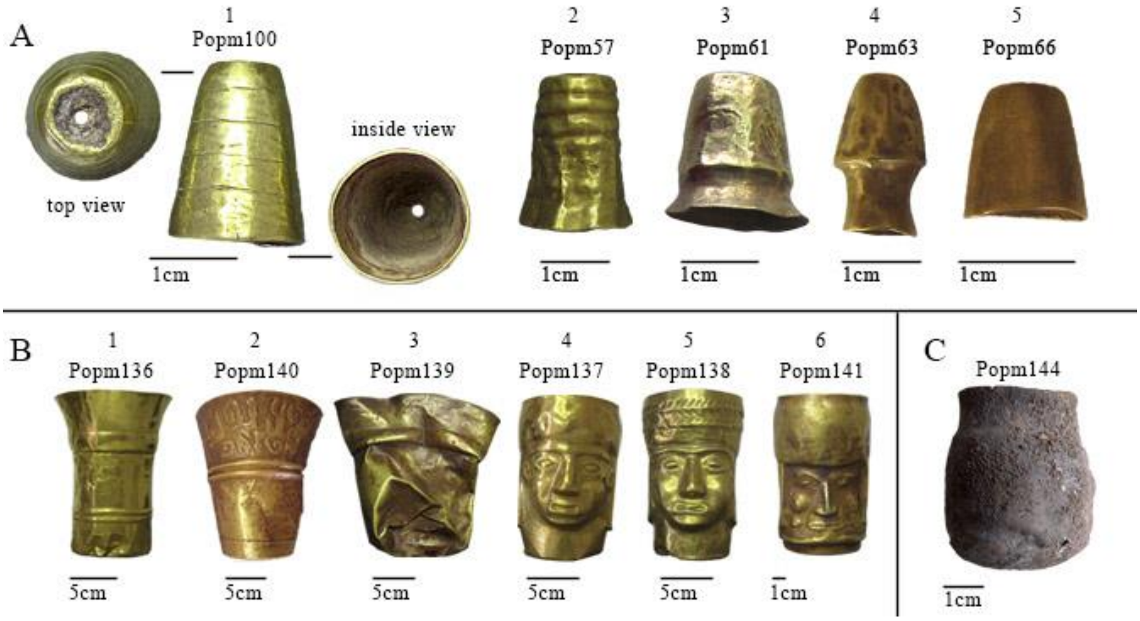


Figure 70: Raised archaeological objects.
Images of the bells (A), goblets (B) and (C) jug made by raising. Note that the "bells" described in SPA did not have a clapper or tongue; they were used by tying several together, producing sounds when they hit each other (Gudemos & Casanova, 1998). However, an ornamental use as hair pendants is not ruled out.

Technically speaking, the goblets are the most complex items found in SPA (Figure 70:B). Their manufacture requires a lot of work and time, great expertise and precise tools, starting with the shaping of the initial plate that needs the right amount of metal to reach the desire size; together with the raising process, complex decoration and finishing treatments (Armbruster, 2000; Carcedo et al., 2004).

There are two types of goblets: *keros* (n=3; Figure 70:B1-3) and portrait-vessels (n=3) (Figure 70:B4-5). The *kero* is the classic Tiwanaku drinking goblet, extensively used during the Middle Period to serve and drink fermented beverages in feasts, celebrations and rituals (Janusek, 2003). Its shape is highly standardised (Figure 71), and the type found in SPA corresponds to the "*type 3.1*" described by Janusek as "*keros with a protruding exterior torus*[14]" (Janusek, 2003, pp. 60–61). In SPA, the three *keros* were different: popm139 has a single torus, popm136 combines a simple and double tori, whereas popm140 has a double torus and a protruding base (Figure 70:B). Portrait-vessels are also characteristic from Tiwanaku. Representing specific individuals, these goblets were used in ceremonial contexts. In many cases, these individuals appear chewing coca (Janusek, 2003). In SPA, the three portrait-vessels are naturalistic representation of different individuals seen from the front, using a hat or turban with a layer hanging behind (a textile or hair?); only one individual is chewing coca (popm141).

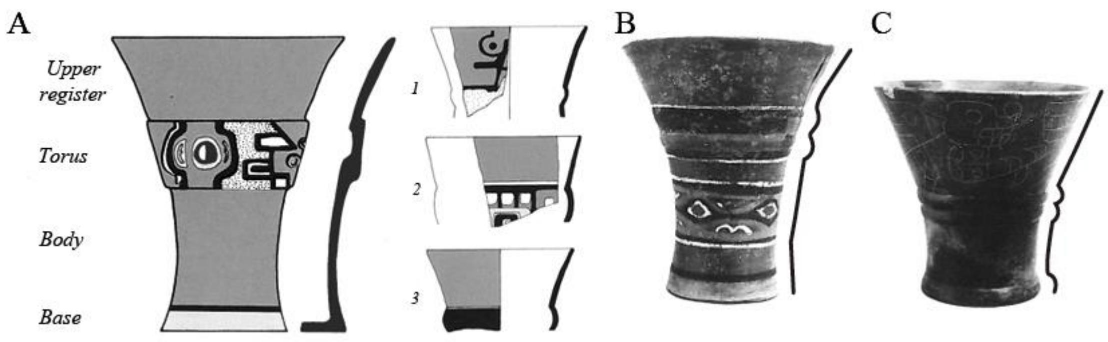


Figure 71: Tiwanaku keros.
Tiwanaku kero type 3.1 described by Janusek (2003), with protruding exterior torus. A- Kero with one torus; A1-A3 are variations in the torus shape. B- Kero with outer double torus and C- Kero with double torus and protruding base (modified from Janusek 2003, fig. 3.38-3.40).

The goblets appear in two cemeteries: Larache and Casa Parroquial. In the former, a set of two *keros* and a portrait-vessel was found in burial 358; in the latter two *keros* were deposited in burial 18 and the portrait-vessel in burial 1. Because of the complexity of their *chaîne opératoire*, a full description of the manufacture of these items will be summarised below in section 6.3.5, after the decoration and finishing techniques are explained. However, regarding the forming stage of these vessels, extra indications of the use of raising are the presence of flat and thick rims, indicating that they were thickened (Figure 69:B); and right-angled bases, suggesting that the bottoms were squared (Figure 69:C).

[14] Singular: torus, kero. Plural: tori, keros.

The last object that is probably made by raising is jug popm144 (Figure 70:C). Unfortunately this item is heavily corroded and possible joint lines and other manufacture traits are obscured. To confirm the use of raising in the jug and the other objects, X-ray radiography would be necessary. This technique would reveal hidden joint lines that would point to a work bending and joining one or several sheets that at present cannot be completely ruled out.

6.3.1.2 Cutting:

Cutting is a technique used in different manufacturing stages, e.g. to form and decorate artefacts. Cutting techniques are relatively easy to identify when the edges were not polished, leaving clear marks on the surface; but it can also be inferred when the edges are very straight and even. As mentioned in the previous section, when a sheet is forged, the borders tend to crack and break. According to Armbruster, the only way to obtain straight edges is by cutting and grinding them (2000; Armbruster et al., 2004). In SPA visible cut marks were identified in 87 artefacts (65%); in 68 of them (51%) cutting was used to give the main form of the items, whilst 19 objects (14%) showed evidence of cutting, but not necessarily to shape them (e.g. cut ends). Indirect evidence of cutting is identified in 12 objects (9%), with straight and thoroughly polished edges making impossible to identify the specific techniques used, but clearly suggesting that they were intentionally cut (Figure 73). Fifteen items (11%) have more than one cutting technique.

	Cutting techniques	**N° objects**	**%**
1-	Perpendicular cutting	9	7
2-	Slide cutting	65	49
3-	Uncertain cutting technique	24	18
4-	Indirect cutting evidence (straight and even edges)	12	9
5-	Not visible cutting marks	38	29

Table 27: Number of objects with different cutting techniques identified in the assemblage of SPA. In some cases, more than one type of cutting technique was found in a single object.

Overall, two main cutting techniques are identified (Table 27): a) 65 objects (49%) present long cuts of irregular length, showing some stopping points (Figure 72:D-F) and b) nine artefacts (7%) show short and regular cuts (Figure 72:A-C). The first suggest the use of a blade or sharp point that was pressed and slid along the surface to split the metal (Armbruster et al., 2004), whereas the second suggest the use of a small blade that was struck perpendicularly to the metal sheet. In 24 artefacts, relatively fresh cuts were observed but they were not sufficiently diagnostic to be classified in either of the two groups proposed above.

Considering the techniques identified, pressing and sliding an instrument was the most utilised in SPA, while perpendicular cuts with a blade were applied in specific cases only. Both techniques were not used in a same object, i.e. when more than one cutting technique was identified, they combined uncertain cutting technique (i.e. polished edges) and fresh slide cuts (n=5), old and fresh slide cuts (n=8) or uncertain and perpendicular cuts (n=1). Interestingly, half of the objects combining different cutting techniques belong to Casa Parroquial (n=8). Perpendicular cuts were only used to shape a few discs and bands from Larache (n=4) and Coyo-3 (n=3); and only one item from Casa Parroquial and Solcor-3.

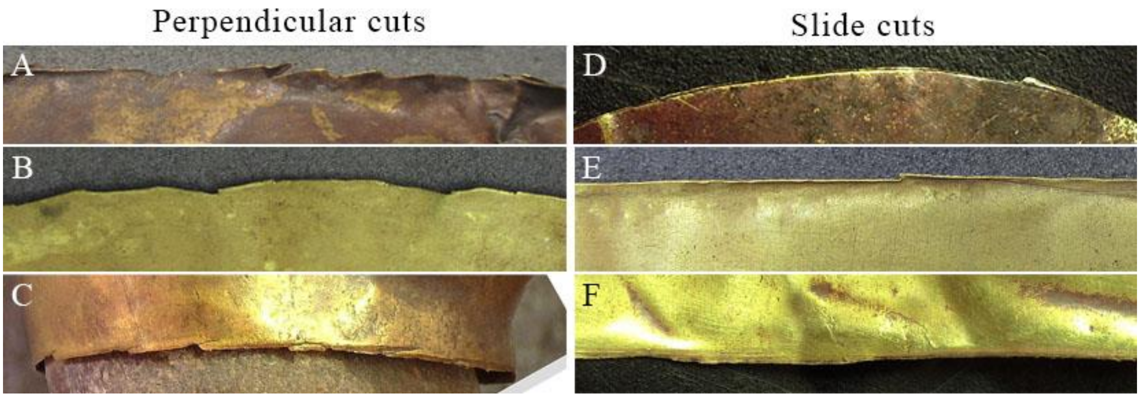


Figure 72: Cutting marks.
Different cutting marks found in the materials from SPA. A-C) Evidence of perpendicular cuts, note the short and regular strokes. D-F) Evidence of slide cutting, note the long and regular lines. A- popm87, B-popm109, C-popm133, D-popm30, E-popm53, F-popm28.

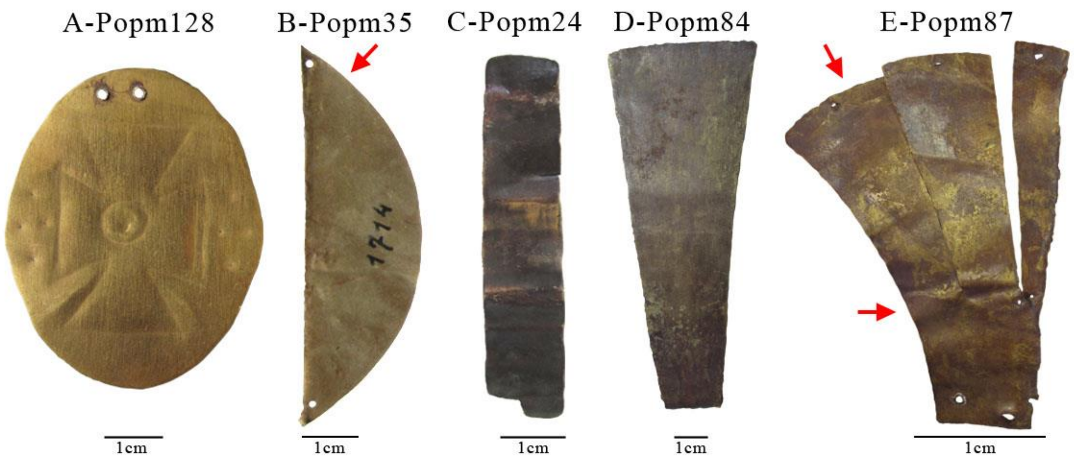


Figure 73: Objects with indirect evidence of cutting.

6.3.1.2.1 <u>Use of guide marks</u>

In 27 artefacts (20%) a line or multiple lines near the cut edges were identified. It is possible that they represent guide marks drawn before the shapes were cut (Figure 74:A-D; Armbruster, 2000). They were used to outline the main shape or the decoration.

Nonetheless, the marks are not always well defined or even, which suggests that some of the lines may have been mistakes produced during cutting (Figure 74:E). Similarly, but not for cutting, in *kero* popm140 drawings marks were made to guide the embossing work.

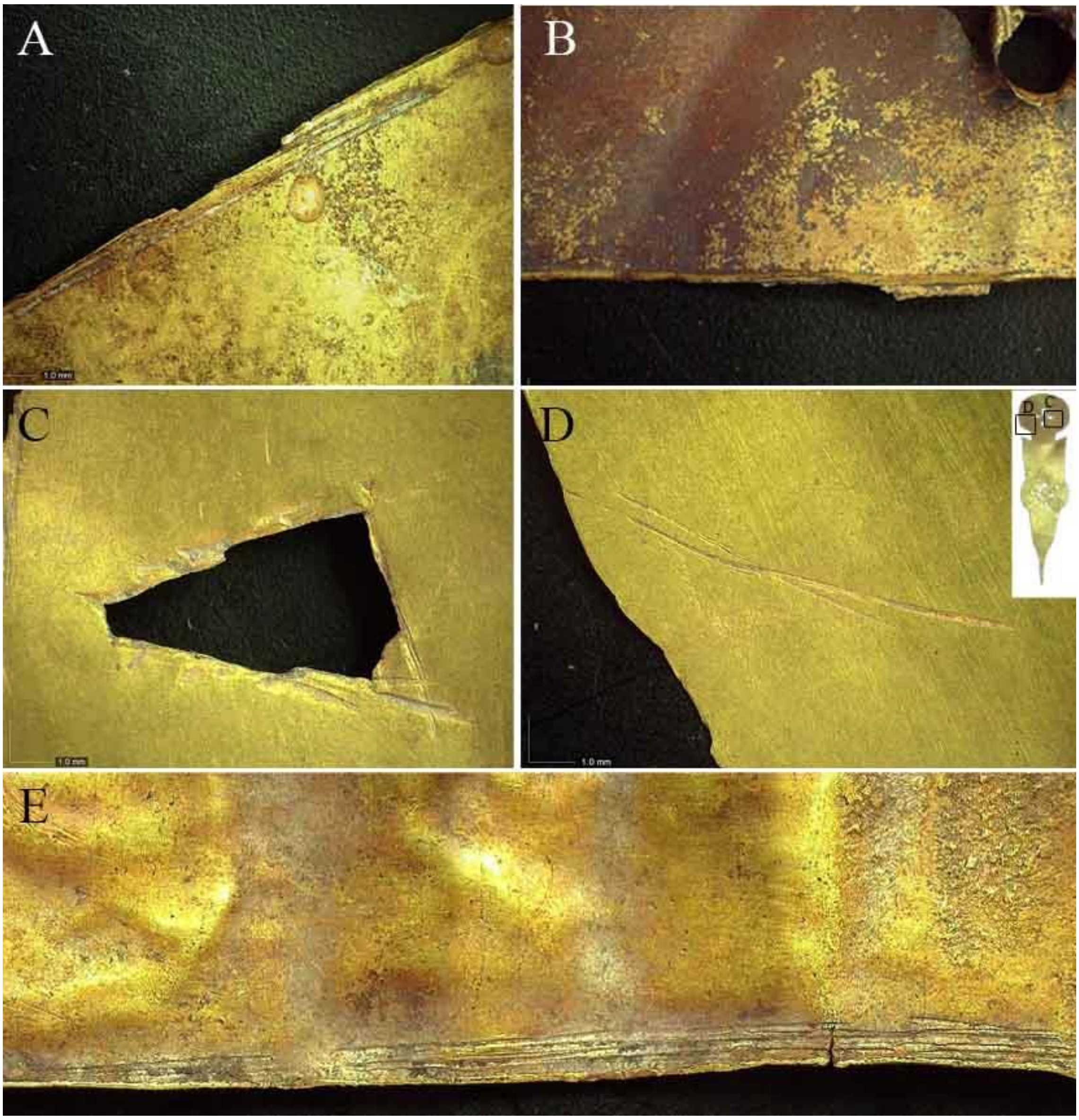


Figure 74: Guide marks on the surface or archaeological objects.
A) Pendant popm119, B) pendant popm78, C-D) headdress popm125, E) attachment popm15. In D, the marks are showing a design that was not followed at the end.

6.3.1.2.2 <u>Use of templates or patterns</u>

In the assemblage, there are groups of objects that were made following the same design, so they look very similar (e.g. the bells). However, there are two pairs of objects whose shapes are so similar that they appear to derive from a single template. In these cases when these objects are stacked, they match perfectly: headdresses popm82-83 (Figure 75) and attachments popm77-78 (Figure 76), both from Casa Parroquial, burial

16. The headdresses have the same shape, their lobules have the same size and are located at the same distance in both ornaments (Figure 75:B). The only difference between both are in the appendices: in popm83 this is slightly bent, whereas in popm82 it is straight. Still, this variation could be result of working the metal after the shape was established with the template. The attachments popm77-78 also fit perfectly. The borders have the same shape and angles, and the perforations are located in the exact same places (Figure 76:A-B). Another option is that these items were directly cut together; in this case, further experiments using different techniques to cut one or more sheets together would help to evaluate the different possibilities.

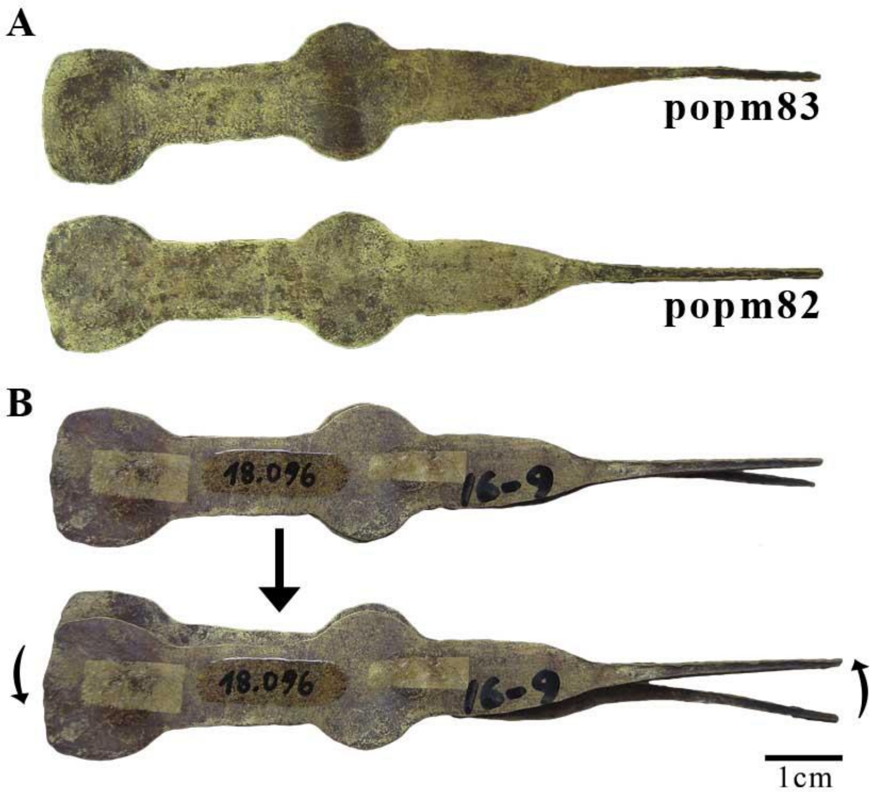


Figure 75: A- Headdresses popm82 and popm83. B- Note how similar they are when stacked.

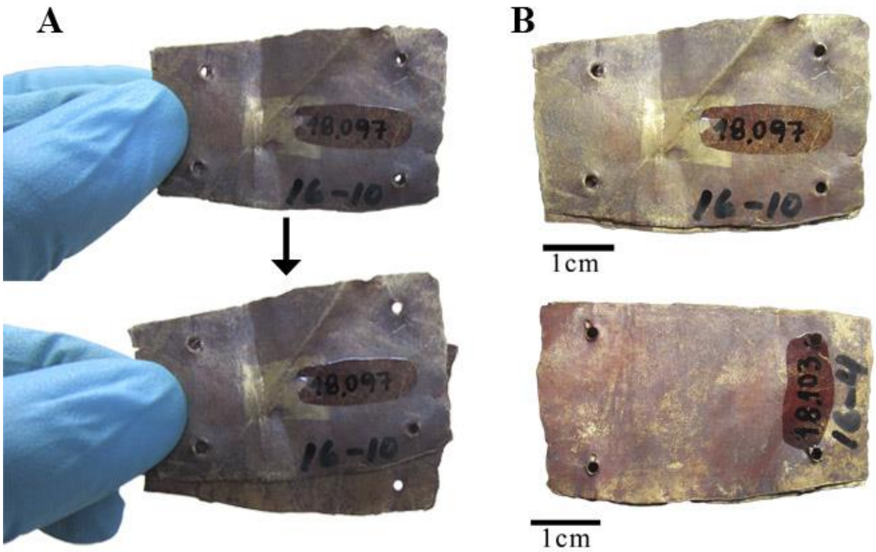


Figure 76: Attachments popm77 and popm78.
The location of the perforations (A) and shape (B) are exactly the same. B- Both sheets stacked together, view from both sides.

6.3.1.3 Perforating

Most of the objects in SPA were perforated one or more times, including pendants, bracelets, attachments, headbands and bells. In total 89 artefacts (67%) and 173 perforations were recorded. Eight of those 89 ornaments present more than one type of perforation. To perforate a metal sheet, metal tools with sharp blades and tips were used. They were probably made of bronze or copper, and hardened by forging and sharpening. To perforate, the support is key: pieces of wood with small holes (so-called nail holes) can be used as anvil, allowing the tool to cut though the sheet and preventing its deformation. The tools are hammered against the sheet, displacing and cutting through the metal. In this process burrs are formed on the back, which may be left untouched, flattened or removed using a grinding stone (Armbruster, 2000; Armbruster et al., 2004; Carcedo, 1998).

Based on the action made to perforate, three perforation techniques were identified: those made by a) punching a tool through the sheet, b) by cutting the surface and pushing the metal through or c) rotating a tool against the metallic surface (Table 28).

	Perforation techniques	N° of objects	%
1-	Punching	62	47
2-	Cutting	26	20
3-	Rotation	3	2
4-	No perforations identified	44	33

Table 28: Summary of the types of perforation marks

a. *Punching* (Figure 77): This technique was identified in 47% of the objects. In these artefacts, because of the direct impact, the metal surrounding the perforation is curved towards perforation, producing sometimes a slightly raised surface (Figure 77:B,D). Most of the sections are circular in shape (in 56 objects), and a few are rectangular (n=2), irregular (n=2), and triangular (n=2; Figure 77:D,F,G). A common characteristic in 30 artefacts is the presence of a large burr at the back showing the imprint of a point (Figure 77:A). This feature and the circular section suggest that most perforations were made using a pointed-conical tool, such as a sharp burin or punch. Fourteen objects from Casa Parroquial present identical perforations (Figure 77:A) indicating the use of the same tool and technique (popm17-18, 47, 50-51, 73-81).

Another characteristic of most of these perforations is their remarkably fresh aspect. This may suggest that the objects were not heavily used before deposition, or alternatively, that the back was never exposed to wear; i.e. the objects were presumably attached or sawn to some media, and were perforated directly on the substrate.

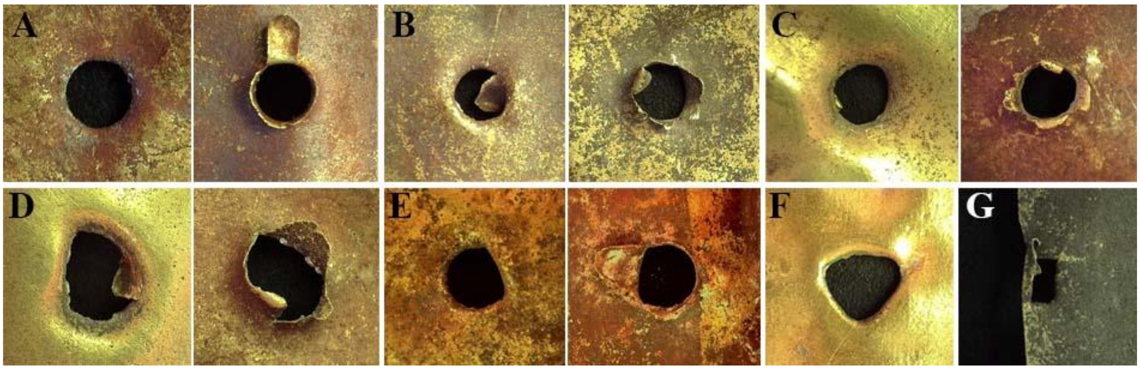


Figure 77: Perforations made by punching (showing both sides).
A- popm78, B- popm77, C- popm111, D- popm112, E- popm80, F- popm93, G- popm48.

b. *Cutting* (Figure 78): Less common, this technique is identified in 20% of the artefacts, most of them from Larache (14 out of 26). In these objects, the perforation is made by cutting the surface with a small blade and pushing the metallic flaps to open it (Armbruster, 2000). Here the surface remains flat, and the burrs at the back are irregular in shape and size. The internal section of the perforations present tiny notches, probably the result of the cut itself or produced when the flaps were pushed back (Figure 78:C). The sections are less regular, 14 cases are circular and 12 are irregular. Tools needed in this case would have a small blade, such as a chisel, though the use of the tip of a long blade may also work; and a punch to push the metal.

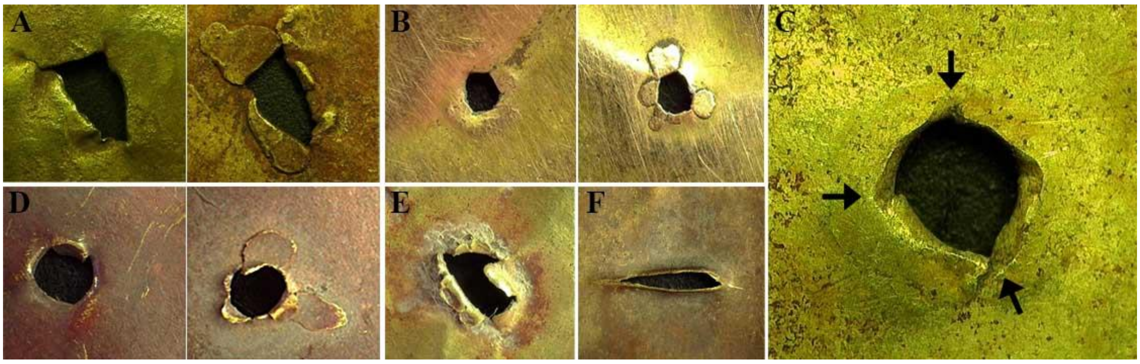


Figure 78: Perforations made by cutting (showing both sides).
Note the notches inside the perforations; see arrows in C. A-popm106, B-popm27, C-popm107, D-popm26, E-popm28, G-popm87.

In many cut perforations, the burrs at the back are completely (Figure 78:A-B) or partially flattened (Figure 78:D). The former represents a technological feature applied during manufacture (see below), whereas the latter would suggest that these objects were used, flattening only parts of the metallic ridges. In both cases however, flattening may deform the circularity of the perforations and remove the raised areas, so it is possible that some punched perforations may look like they were cut, producing some overlap between both categories. Further experimental research assessing the effect of flattening on punched and cut perforations would clarify this point.

c. *Rotating*: This rare technique (for this assemblage) was found in three pendants only: popm27, 35 and 128. Here, the perforations are circular and very neat. Circular scratches are found surrounding and inside the perforation. The burrs produced are very short and regular in size, and the surface remains flat (Figure 79:A-C).

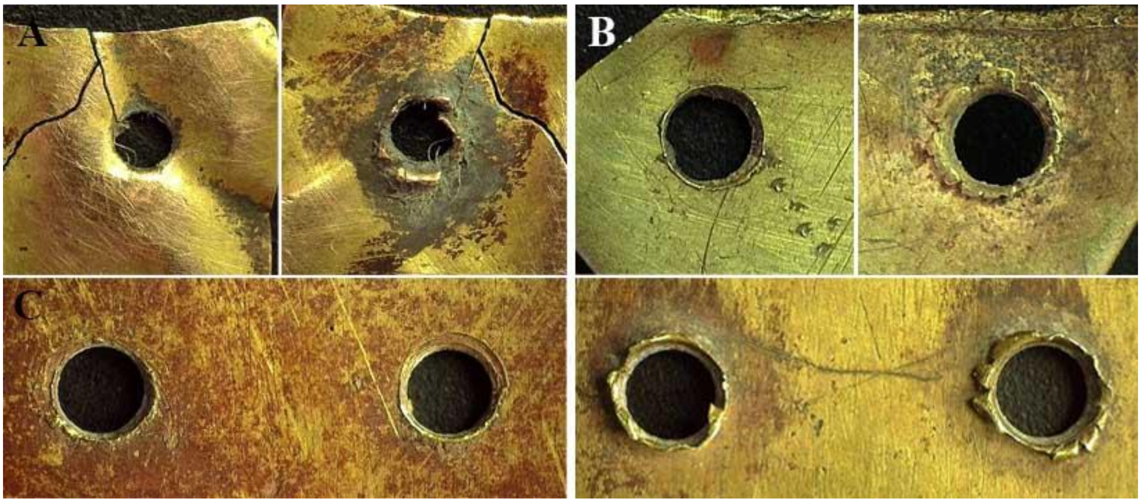


Figure 79: Perforations made by rotation (from both sides). A- popm27, B- popm35, C- popm128.

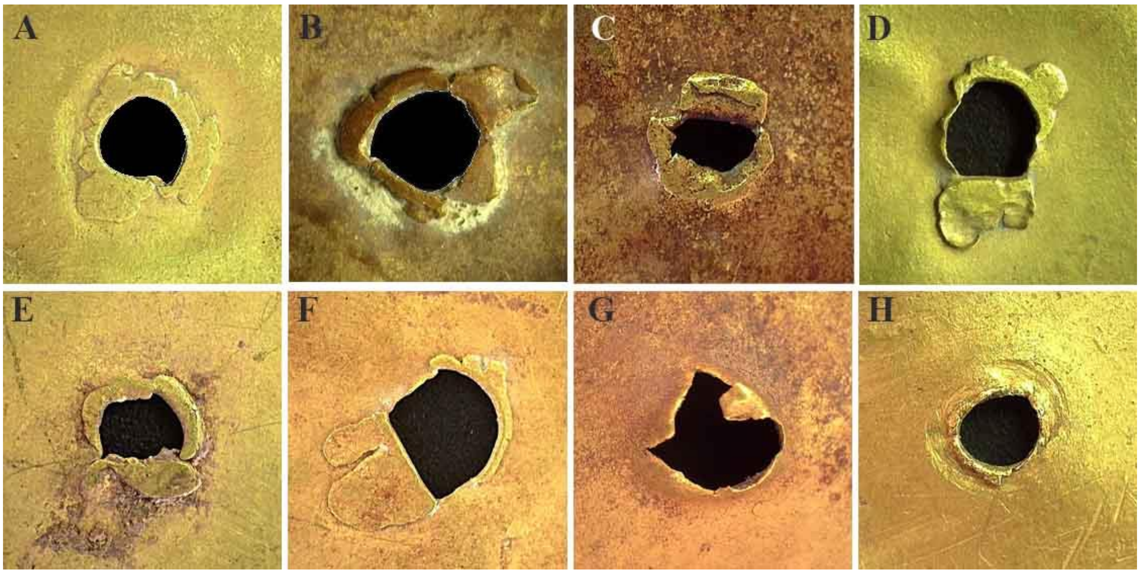


Figure 80: Perforations treatment.
Flattened (A-F), untreated (G) and removed (H) burrs. A-popm123, B-popm87, C-popm132, D-popm90, E-popm142, F-popm91, G-popm109, H-popm118.

As mentioned, another technological feature identified on perforations, is the treatment given to the burrs. In 52 objects (39%) the burrs were left untreated (Figure 80:G); in 25 cases (19%) they were left and flattened against the surface (Figure 80:A-F); and in 7 cases they were removed (5%; Figure 80:H). Most of the flattened perforations were found in Larache, with 17 objects representing a 63% of the items with flattened perforations. In Larache however, different "qualities" of flattening are visible; see that in Figure 80, A-B are carefully flattened compared to C-F. In many cases, the flattened burrs appear on the front face of the ornaments, suggesting that this feature was probably intentional and it was used as decoration. It is noteworthy that particular groups of objects present identical perforations, suggesting that the same technique and tools were used (Figure 81).

1)
-- 7 objects
-- Larache
-- Burials 356, 359
-- Punching /flattened

2)
-- 2 objects
-- Larache
-- Burials 358, 359
-- Punching /untreated

3)
-- 3 objects
-- Larache
-- Burials 358, 359
-- Cutting/flattened

4)
-- 12 objects
-- Larache
-- Burials 1714, 358, 359
-- Cutting /flattened

5)
-- 12 objects
-- Casa Parroquial
-- Burials 16, 18
-- Punching /untreated

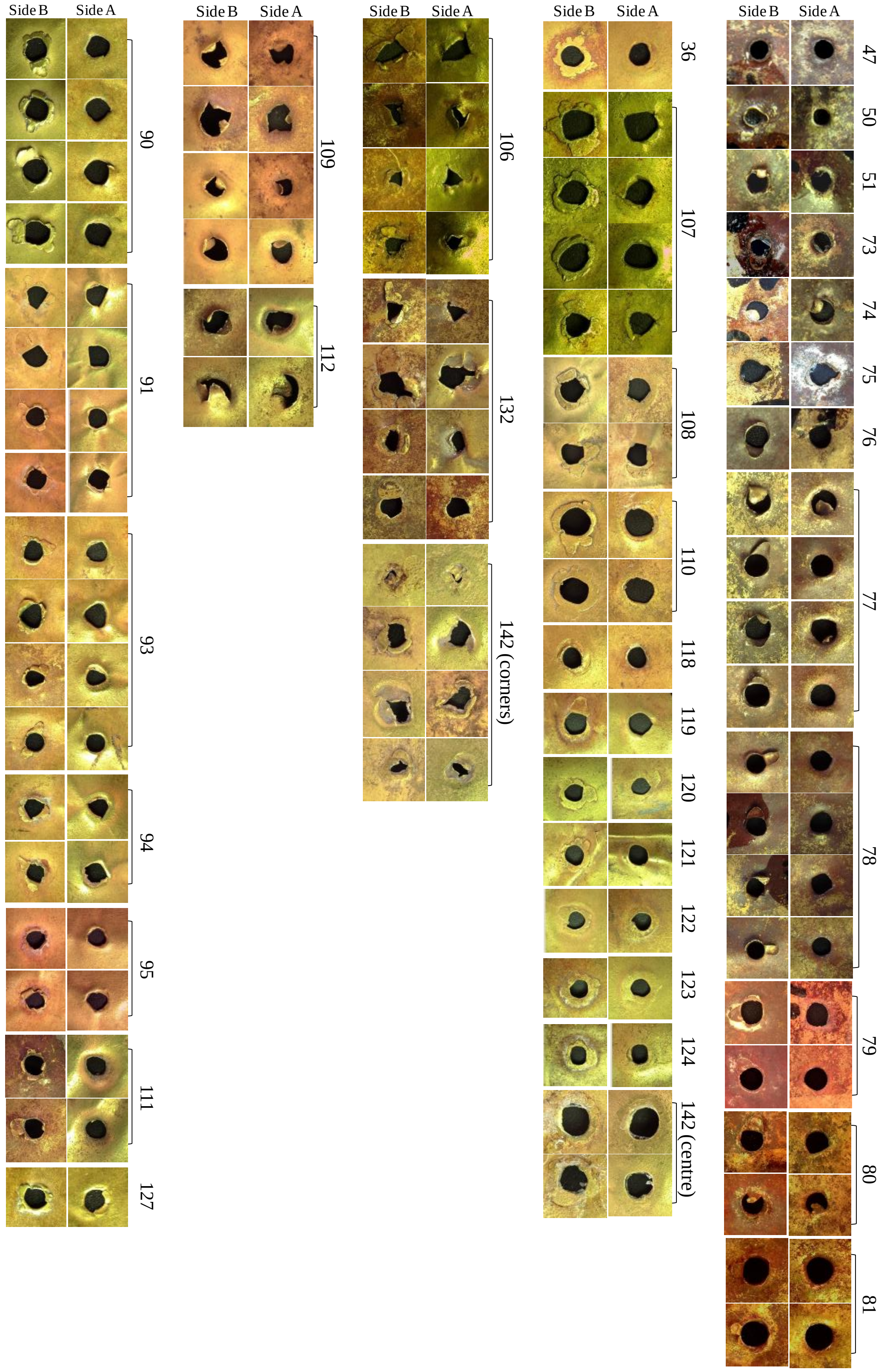


Figure 81: Groups of objects showing identical types of perforations.
The different colours are due to different light conditions when taking the photography.

6.3.1.4 *Other forming techniques*

Particular forming techniques seen in specific artefacts are described here. They include the use of joints, folding and wrapping.

6.3.1.4.1 <u>Joining</u>

Unions between parts - either metallic or non-metallic - are virtually absent in SPA, with the exception of three rings (popm89, 113/114, 117). The aim in these cases was to decorate the ring, fixing a metallic adornment on the band. Whereas the adornment in popm89 was lost (Figure 82), a gold disc (currently detached) and a silver hollow flower were attached to rings popm113/114 (Figure 83) and popm117 (Figure 84), respectively.

The three rings share some technical similarities. In all three, the artisans left the metallic band open, bending both ends to produce a flat surface where to fix the decoration (Figure 82:A). Popm89 and popm113 show the preparation of the surface by scratching it, leaving a rough texture to help fixing the solder or adhesive (Figure 82:B, Figure 83:C-E). Because in popm117 the adornment is still firmly attached, these features were not visible (Figure 84). The disc (popm114) attached to the band (popm113) also shows scratches, suggesting that both surfaces - the band and the adornment - were prepared to be joined.

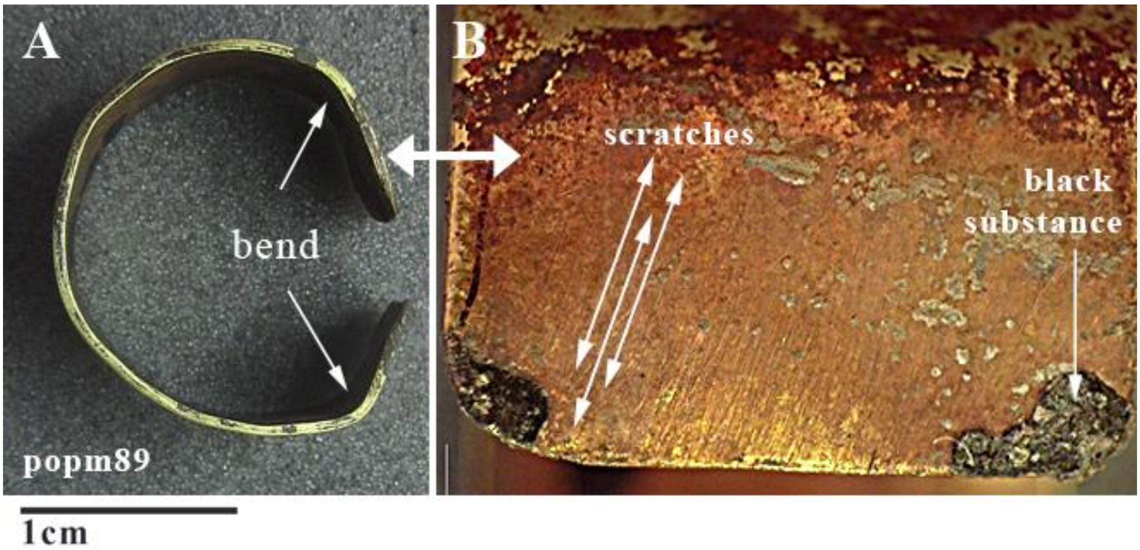


Figure 82: Ring popm89 (CP, burial 3), without adornment.
Note the bending of the band (A) to prepare the surface, the scratches (B) and the black substance attached to it.

Apparently, the adhesive used was not metallic. In popm113/114 and popm89, a brittle and dark-grey substance was observed, especially in the disc (Figure 83:E). The pXRF analysis on the dark-grey areas of popm89 shows slightly higher silver content, compared to the composition of the ring; whereas in popm113/114 the dark-grey substance appeared slightly higher in copper, compared to the alloy (Table 29). However, the pXRF values are exploratory and cannot be taken as conclusive indications of soldering: as the appearance of the substance was not metallic, light elements or indeed organic compounds potentially used as glues would not have been recorded.

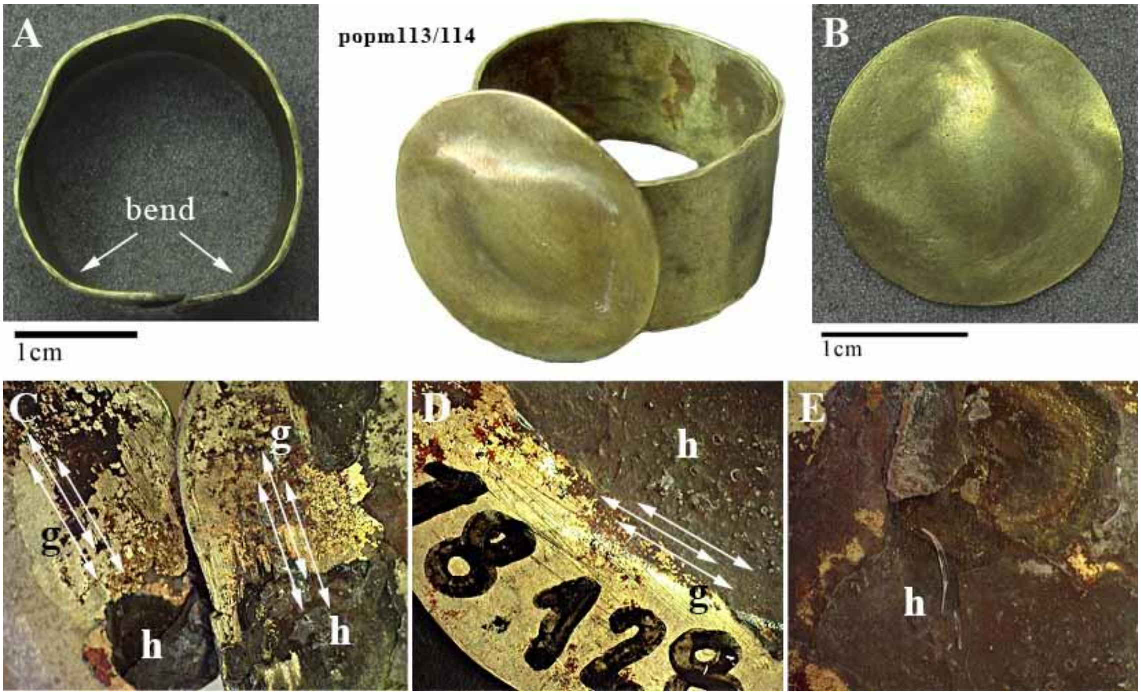


Figure 83: Ring popm113/114 (Larache, burial 359) with a disc for adornment, currently detached (B). In both parts - the band and disc (C-E) - scratches (g) and a black substance was identified (h). Note how the band was bent to prepare a flat surface (A).

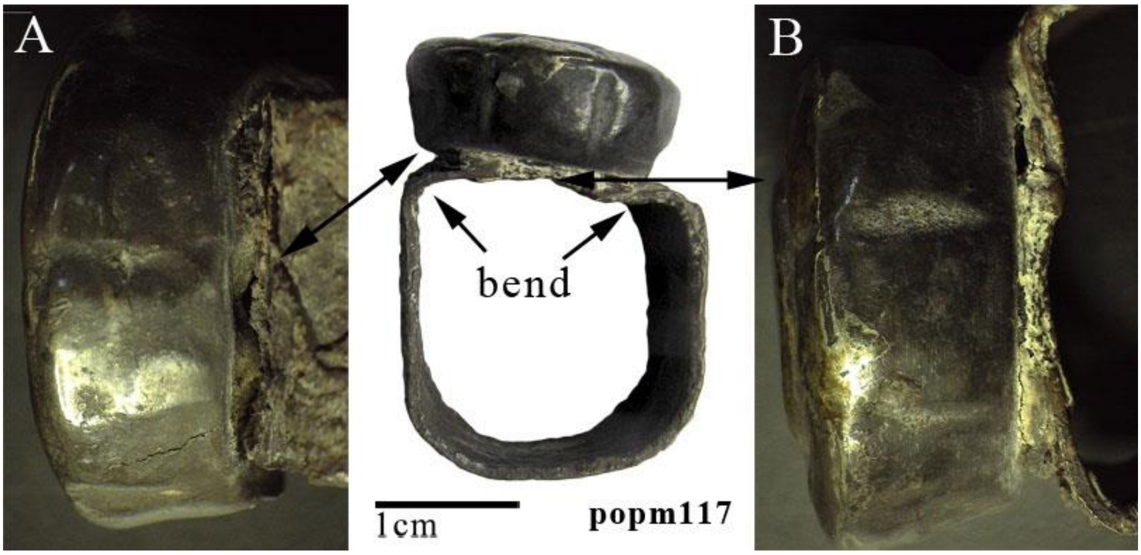


Figure 84: Ring popm117 (Unknown cemetery). A- side view. B- top view.
Note the adornment firmly attached to the band. The band was also bent to generate a flat surface.

Id museum	Id lab	Section of the ring	Area	Cu%	Ag%	Au%	Total%
18.119	popm89	Band	Metal	3.2	28.0	68.8	100.0
			Substance	3.8	**32.6**	63.6	100.0
18.128	popm113	Band	Metal	2.7	36.3	61.0	100.0
	popm114	Disc	Metal	2.9	36.3	60.8	100.0
			Substance	**6.7**	38.4	54.9	100.0

Table 29: Chemical composition of rings popm89 and popm113-114 and the joining substance, by pXRF. Results are normalised to 100%. Note that copper and silver is slightly higher in the dark material, compared to the metal composition.

6.3.1.4.2 Folding

Another peculiar example is the use of irregular and coarse folds to shape an artefact. This technique was identified in Casa Parroquial only, in a headband formed by two identical sheets (popm17-18). In this case, evidence suggests that the main shape was given by folding and flattening a large sheet of gold by hammering (Figure 85).

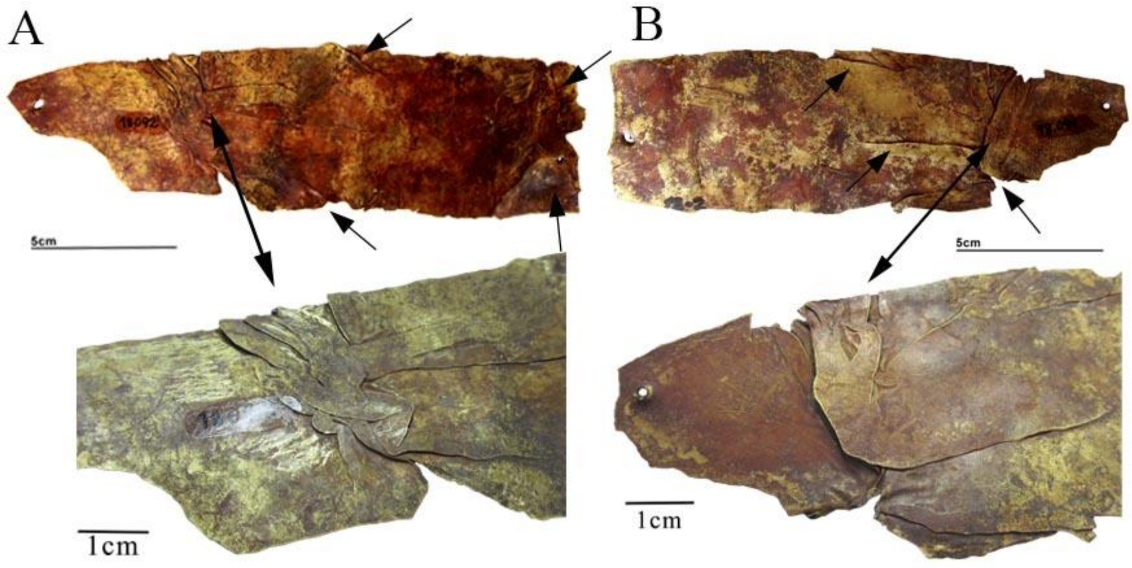


Figure 85: Folded headbands popm17 (A) and popm18 (B).
Note the folds on the surface. The folds shaped the main part of the ornaments; cuts are also visible in some areas of the edges. The different colours of the images are due to different light conditions when the photographs were taken.

6.3.1.4.3 Wrapping

It is noteworthy that so far all objects described have been made entirely in gold or silver. There are, however, two artefacts that were wrapped in thin gold sheets: an axe from Larache (burial 358) and an inhalation tube from Solcor-3 (burial 107). In this case, gold was used as a complement or as decoration, oriented to completely cover the material underneath. Here it will be shown how the sheets were shaped and wrapped, the decoration will be described in section 6.3.2.

The work seen in axe popm126 is very unusual and has not been found in other objects of the South Central Andes yet (Figure 86). It appears to be a cast copper axe (based on the presence of areas of green corrosion, see Figure 86:D) subsequently wrapped in gold sheet, and then encircled by silver bands that are now corroded. Joint lines are found parallel to the long axis and at the front edge, indicating that the sheet was hammered first (Figure 86:B-C,E), cut following the length of the axe, and then wrapped and flattened against the cast body. Vertical and horizontal polish marks are visible from the surface (Figure 86:B). The gold sheet is very firmly attached to the body, suggesting that heat could have been applied to strengthen the bond with the body, although it is possible that the heat generated during hammering may have sufficed to achieve this.

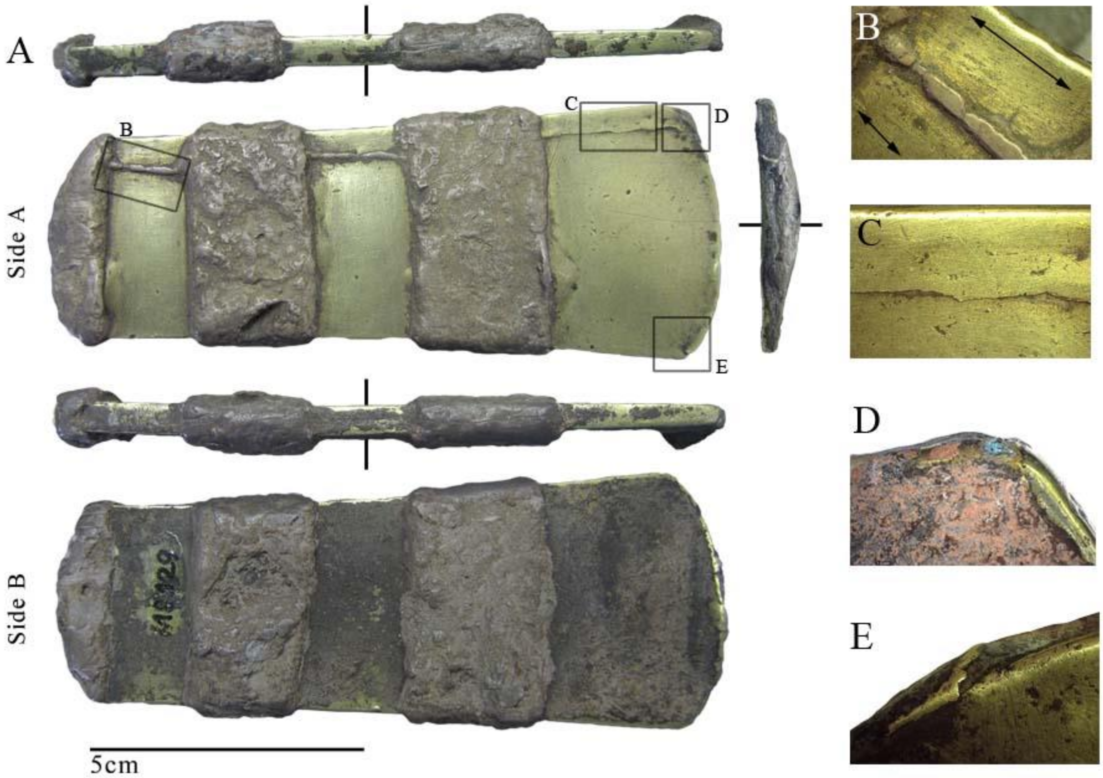


Figure 86: A- Axe popm126.
B- Detail of the surface and the joint line covered with silver. The arrows show the direction of the polish marks. C- Detail of the joint line. D- Detail of the green corrosion. E- Detail of the joint lines in the edge.

Regarding the three transversal silver bands attached: two were surrounding the body, and one was covering the narrow end. There is not much indication of how these bands were fixed to the gold sheet and what the material actually is. It is not metallic and it looks like stiff putty in texture, being possibly silver corrosion. The pXRF detected 100% silver, which is clearly missing some light elements that were not possible to read. There were no visible joint lines in the bands, but part of the silver substance was found in the joint of the gold sheet (Figure 86:B).

Finally, categorised as "axe", this item has a flat working end (not sharp) and it is thin and regular in thickness. It has been already pointed out that many metalwork hammers are usually described as "*axes with worn edges*" (Armbruster et al., 2003, p. 257; Perea, 2010). It is possible therefore, that in this case, the objects is not an axe, but a hammer that was never used.

The inhalation tube is basically a wooden tube with a feline head carved on one tip and on the body, which was covered with thin gold sheets (0.1-0.2mm). The gold sections comprises three separate parts: two tips (still in place) and a strip covering the body which is currently loose (popm133-135; Figure 87:A). The tip surfaces are even with hammering marks, and no visible joint lines, folds or wrinkles. The only folds of metal are seen near the grooves, where the sheet was pressed, e.g. at the neck of the tip or the feline nose (Figure 87:B-C). The base of the tips, where the perforations are located, are flat and plain, suggesting that the sheet used was placed there first and then, by hammering and pressing, progressively expanded. Possibly, a technique similar to raising on a small stake was used to create a pre-form that was subsequently placed on top of the wooden tip and then pressed from the front to fit the wooden shape. There is another pair of tips (popm19) on the assemblage that were not analysed technologically for this work (Figure 87:H), but their appearance suggests that they were made in the same way as popm133-134.

The body of the tube was wrapped in a different way: it is a long and thin metallic stripe that was wrapped around the tube in spiralling motion (Figure 87:D). They started from the feline head, overlapping the stripe about 1mm and finishing at the proximal tip (Figure 87:D-G). The strip was cut at the ends, leaving small square flaps to fit underneath the tips (Figure 87:F-G). Even though no visible adhesive was detected, is it possible that a sort of adhesive was used to keep the stripe in place during its decoration. The stripe is regular in width and the borders are straight, suggesting that an instrument such as a ruler was probably used during cutting.

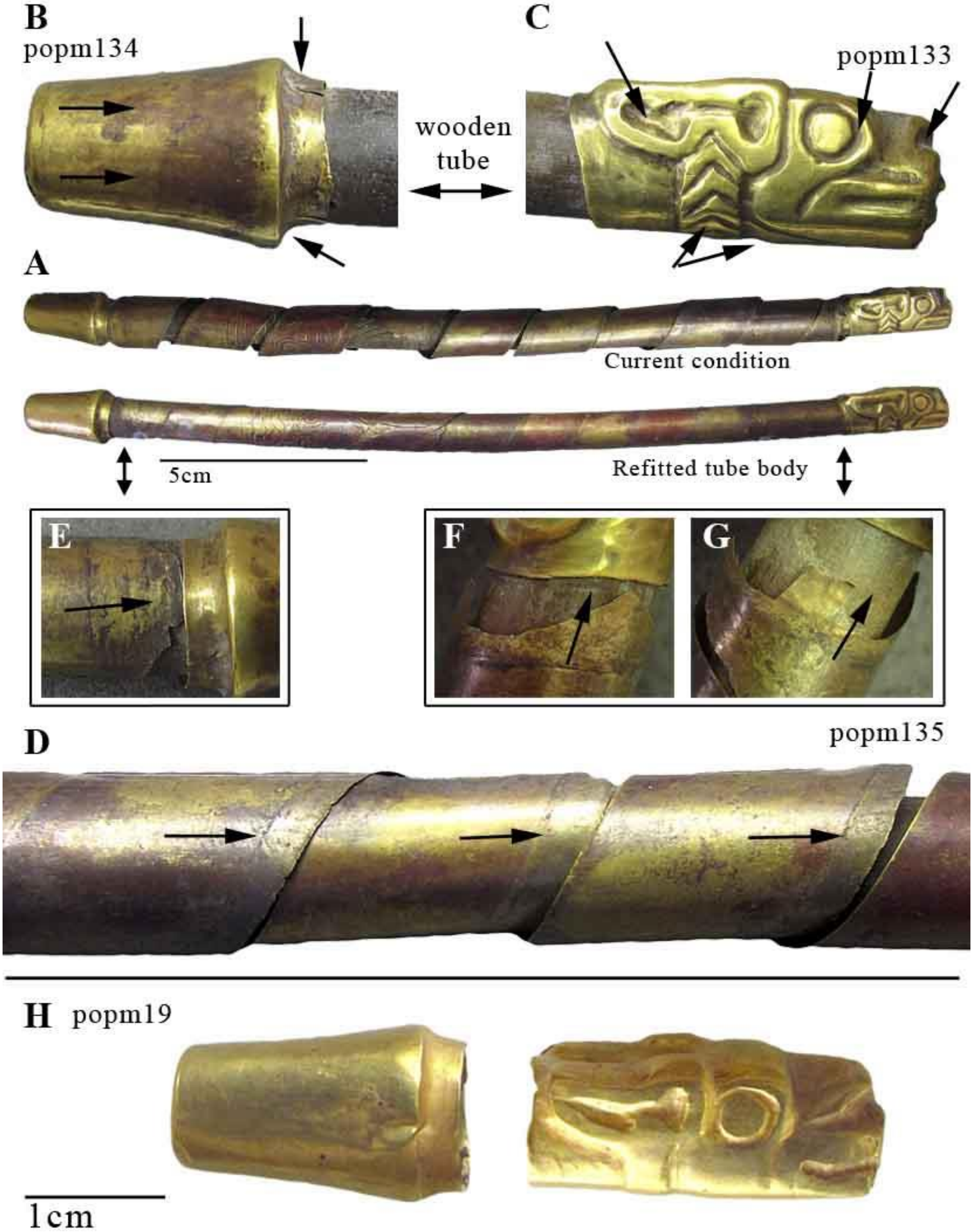


Figure 87: Inhalation tube popm133-135 and its parts.
A- View of the complete tube. B- Proximal tip (popm134), the arrows indicate the direction of the hammering and the pressure made around the neck. C- Distal tip (popm133), the arrows indicate the chased areas, following the design of the wooden head underneath the gold sheet. D- Detail of the body (popm135), the arrows point areas were the sheet overlaps. E- Detail of the proximal end of the wrapping sheet. Note the irregular flap that fits under the tip. F-G- Detail of the distal end of the wrapping sheet. Note the flaps that go underneath the feline head. H- Second pair of tube tips (popm19) found in SPA. In this case the wooden tube was destroyed due to poor burial conditions.

6.3.2 Decoration techniques

Once the main shape is obtained, an optional second stage is to decorate the objects. Overall, in SPA most objects are plain showing no decoration; only 36 artefacts present decoration (27% of the total assemblage), ranging from very simple geometric lines, to complex human faces. Most are bells (n=15) and goblets (n=6); and a few rings (n=4), attachments and pendants (n=4), tube parts (n=2), a headdress (n=1) and a jug (n=1). Techniques such as embossing, chasing, engraving and openwork were used in 34 artefacts (two were not available for study) that will be presented below (Table 30). Larache has more decorated items (n=21), mainly because of the bells (n=15) and goblets (n=3). In Casa Parroquial and other sites, only 1-4 objects were decorated.

	Technique	N°	%	Object: popm_
1-	Chasing	18	50	56, 57, 58, 115, 116, *117*, 130, 133, 135, *136, 137, 138, 139, 140, 141*, 145, 146, 147
2-	Engraving	11	31	59, 60, 98, 99, 100, 101, 102, *137, 138, 140, 141*
3-	Embossing	7	19	95, 128, 131, *136, 139, 140,* 144
4-	Openwork decoration	3	8	30, 67, 125
5-	Appliqué	3	8	89, 113, *117*
6-	Use of moulds	6	17	117, 133, 135, 137, 138, 141
7-	Use of inner support	15	42	56, 57, 58, 59, 60, 98, 99, 100, 101, 102, 115, 116, 145, 146, 147

Table 30: Decoration techniques identified in 36 objects from SPA.
Note that some objects may use more than one technique (in italics). Percentages are calculated considering 36 as 100%.

6.3.2.1 Embossing and chasing

Most of the decoration found in SPA was done by producing reliefs on the surfaces by embossing or chasing, as recorded in 25 items (69%). Both techniques expand the metal by hammering with different punches (Figure 88:A), pushing or sinking selected parts of the surface (Armbruster, 2000; Maryon, 1971; Untracht, 1975).

The technique is called embossing (or *repoussé*) when the work is done from the back, pushing the metal and raising the motif on the front. The punches are hammered perpendicularly against the sheet on wooden blocks or anvils covered with leather (Figure 88:B1,3). Chasing, on the other hand, is employed when the work is done from the front, sinking the surface to raise a motif. Chasing is used to give the designs sharpness and definition, to trace lines, sink large areas (e.g. backgrounds) and give texture to surfaces (Figure 88:C). When chasing, punches are hammered with an angle against the metallic surface (Figure 88:B2-3). Both techniques, usually reported together, expand the metal leaving raised surfaces (Figure 88:B3). Depending on the punch used (e.g. round, flat or wedge-shaped as blunt chisels, see Figure 88:A), different marks can be left on the surface

(Armbruster, 2000, 2013; Carcedo, 1998; Carcedo et al., 2004; Destrée, 1983; Maryon, 1971; McCreight, 1991; Tushingham et al., 1979; Untracht, 1975; Warwick, 1978).

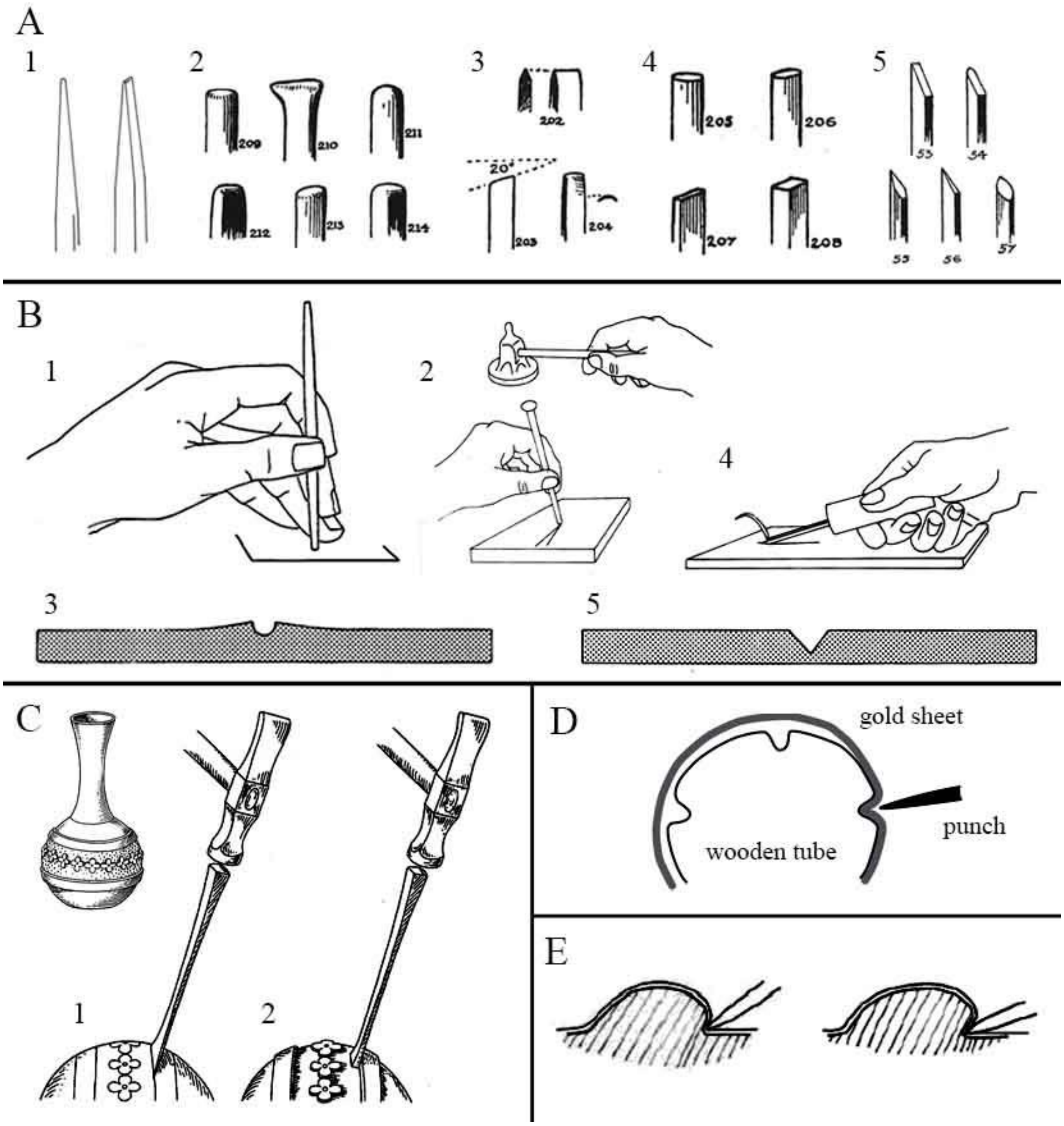


Figure 88: Embossing, chasing and engraving.
A-Embossing, chasing and engraving tools: 1-Pointy and wedge-shape punches, 2- Round punches for embossing, 3-4- Tracers and flat punches for chasing, 5-Burins or gravers for engraving- B-Angle to hold the punches and burins for embossing (1), chasing (2), engraving (4). Marks left on the metallic surfaces when embossing and chasing (3); and engraving (5). C- Chasing lines (1) and sinking the background (2) of a vessel. D- Chasing a wrapped sheet on a wooden matrix. E- The undercutting technique (Images: A1, B2-5 after Destrée 1983, figures 31,27; A2-5 after Maryon 1971, figures 53-57, 202-214; B1, C after Armbruster2000, figures 62,68; E after Corwin 2010).

Embossing was identified in seven artefacts from SPA (19%), all from different cemeteries: goblets (n=3), attachments (n=2), pendants (n=1), and jugs (n=1; Figure 89). Based on the width of the embossed lines, it is inferred that different punches were used: in the sheets popm95 and popm128, lines of ~0.5mm were made with a relatively blunt tip (Figure 89:A-B), whereas the working end used in the attachment popm131 was much wider and round, showing lines of ~3mm width (Figure 89:C). In the jug popm144 and *keros* popm136, 139, and 140, the *tori* (horizontal bands) and designs on the body were raised and pressed from the interior as well (Figure 89:D-E).

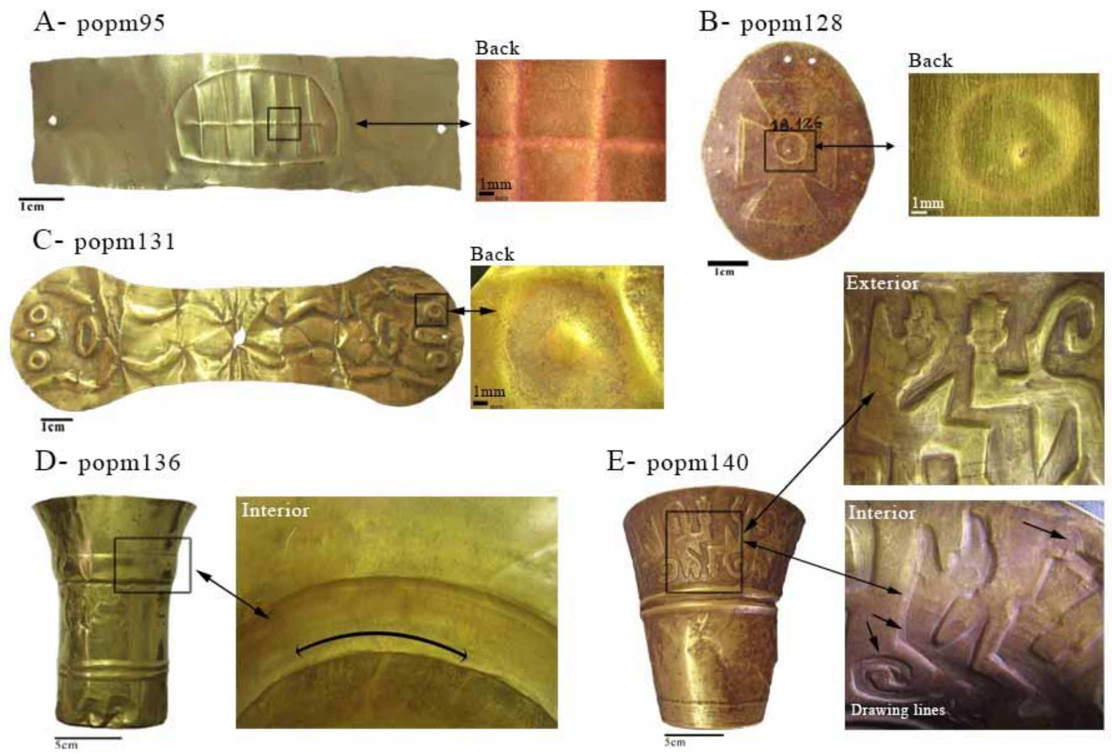


Figure 89: Artefacts decorated by embossing.
From A,D- Larache, B- Unknown cemetery. C- Sequitor Alambrado, E- Casa Parroquial.

Different types of chasing techniques were identified in 18 artefacts (50%), including the goblets (n=6), bells (n=8), rings (n=2) and tube parts (n=2) (Figure 90). Chased lines are seen in 11 artefacts, however based on their features, different tools and techniques were used. For instance, bells popm56-57 and ring popm130 showed relatively thick lines (~0.5-1.0mm) suggesting the use of blunt pointy tool, with relatively flat-square end (Figure 90:C,E). Whereas the set of bells popm58, 115-116 and popm145-147 have very fine regular marks, as if a sharp blade was carefully struck perpendicularly against the surface, but removing no metal (Figure 91:A-B). The *keros* popm136, 139-140 also show fine lines chased to better define the *tori* (Figure 91:C), technique called undercutting (Corwin, 2010) in modern silverwork (Figure 88:E).

On the inhalation tube, as previously explained, gold sheets are wrapping a carved wooden tube (popm133,135). Here, the chased work was applied by pressing the gold sheets into the wooden grooves (Figure 88:D & Figure 90:A-B). Probably different blunt pointy punches were used to fit in the groves of the body and tip, ranging between ~0.4 to 0.8mm. The conservation of the wooden tube underneath the metal is crucial to understand how the desing of the body and the second pair of hollow tips were shaped (popm19; Figure 87:H).

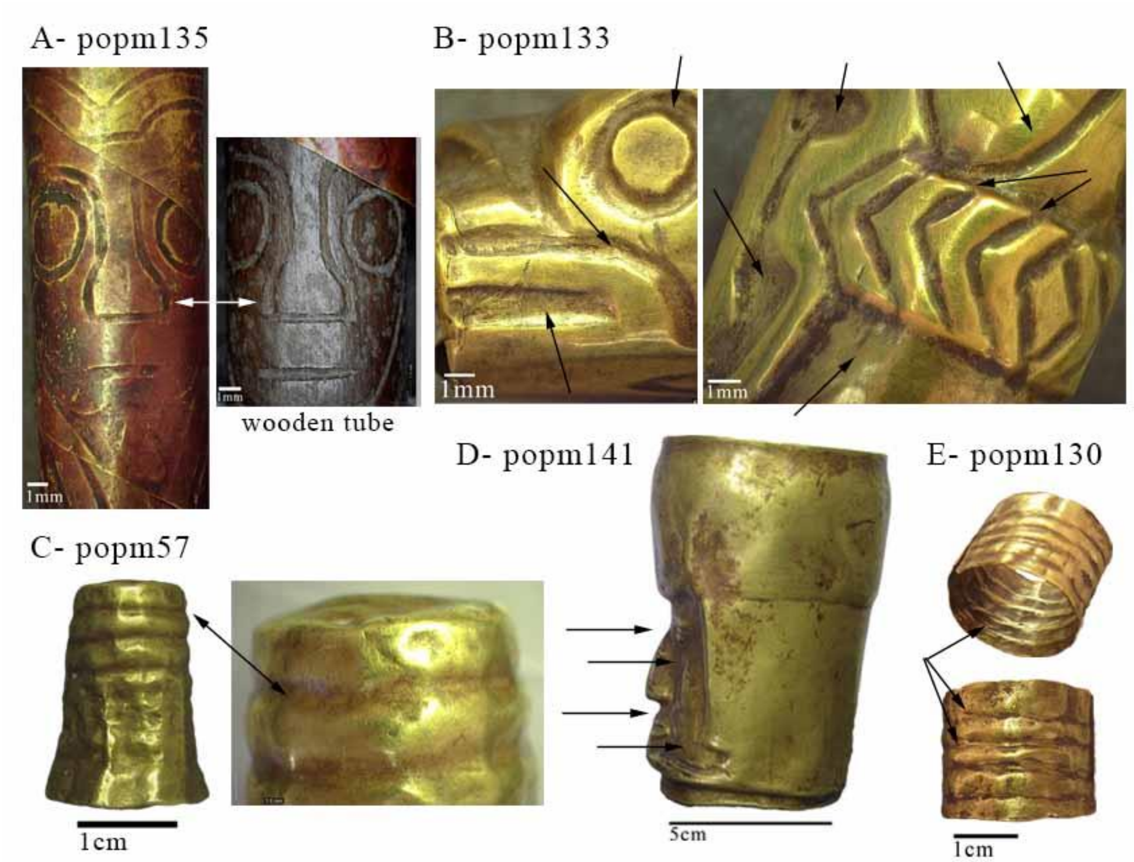


Figure 90: Artefacts decorated by chasing.
The arrows are indicating the chased areas. A-B- Inhalation tube parts, body and tip, C- bell, D- portrait vessel and E- ring.

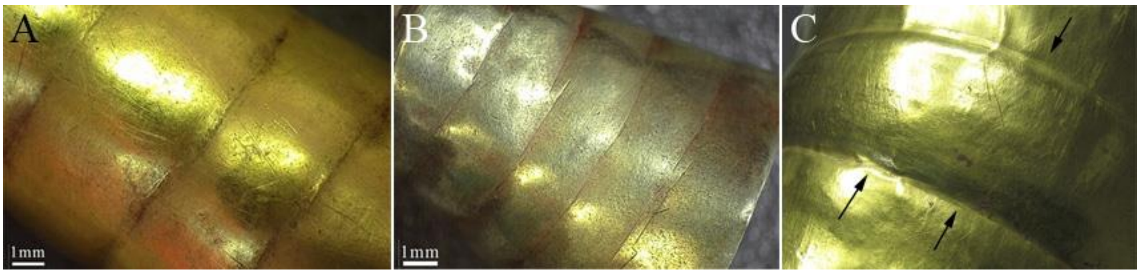


Figure 91: Artefacts with fine chased lines.
A-bells popm58, 115-116, B-bells popm145-147, C-undercutting in kero popm136.

The chasing work of the three portrait-vessels (popm137-138, 141) is characterised by a complete work from the exterior (Figure 90:D), showing a dull and rough texture in the inside (Figure 92). These features suggest that the faces were formed by placing a wooden matrix in the interior and then chased from the front, as proposed by Carcedo (2004) who has identified archaeological examples of these moulds in Peru (Figure 93). The different marks on the faces, however, indicate that a set of different tools were used: from flat punches to sink parts of the face, to blunt pointy tools to define the eyes and other features (Figure 103). Interestingly, the hammer marks near the rims in both portrait-vessels from Larache suggest that a similar tool was used to hammer both goblets.

Given the hollow shape and the careful work on the front side of the adornment in ring popm117, it is also possible that this item was chased using a wooden mould (Figure 84). The use of wooden moulds, however, is a minority in SPA being used only in six cases: the portrait-vessels (n=3), inhalation tube (n=2) and possibly ring popm117. In the case of the bells decorated with horizontal lines, the marks made on the outside are also visible from the inside, indicating that strength was applied to chase them. Still, the body was not deformed under this pressure, suggesting that a support was used during the decoration process.

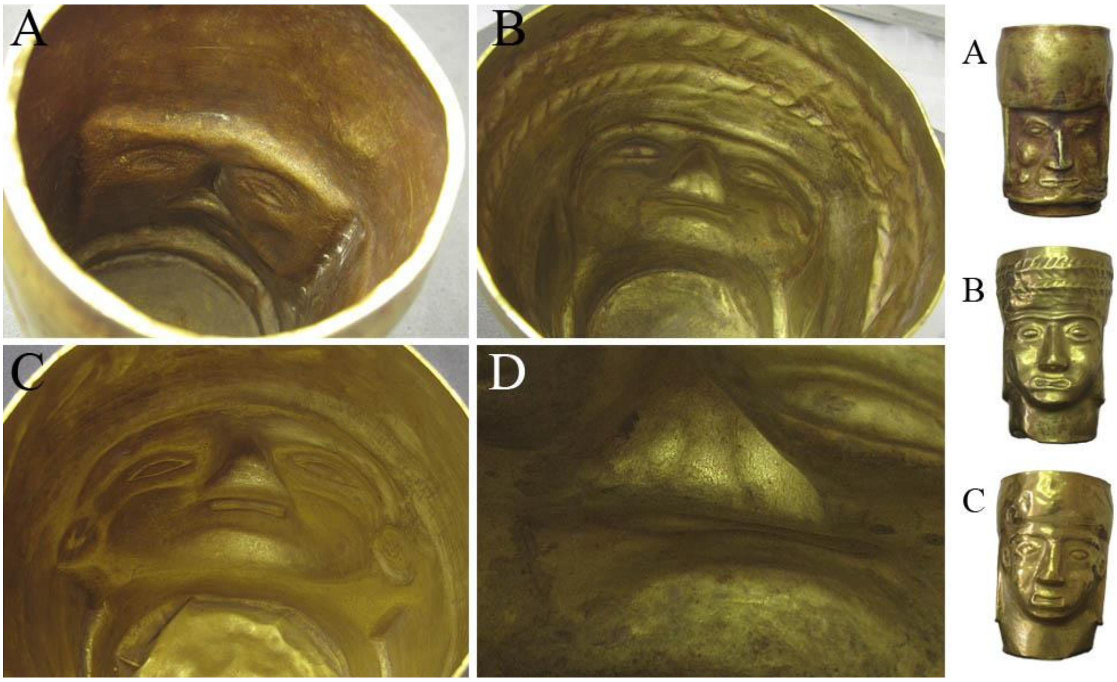


Figure 92: Detail of the inner part of the portrait-vessels.
Note the porous texture, more clear in image D. A- popm141, B,D- popm138, C- popm137.

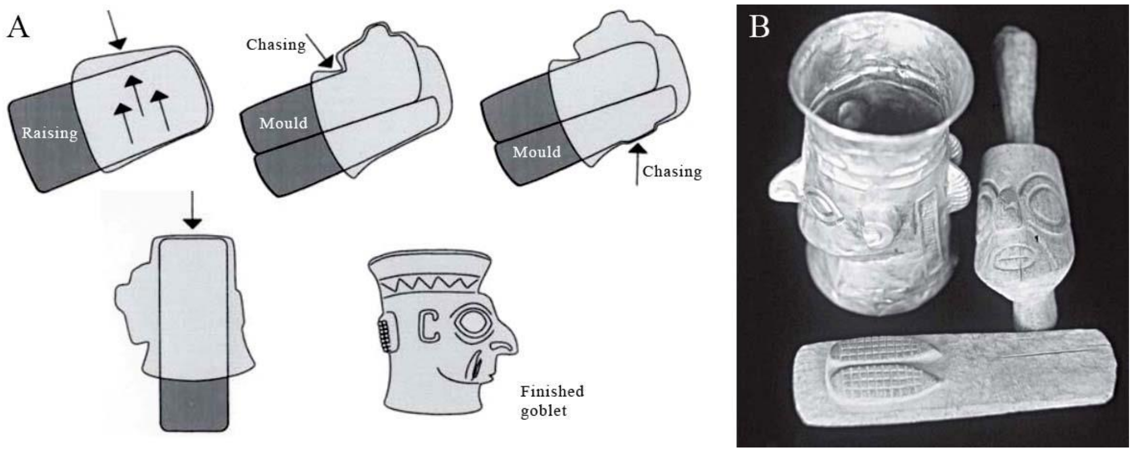


Figure 93: A- Sequence suggested by Carcedo (2004) to model the portrait-vessel.
B- Examples of the wooden moulds used in this process (modified from Carcedo 2004, figs.10-11).

The decoration seen in *kero* popm140 is an excellent example where embossing and chasing are combined. Chasing was used to sink the background from the front (Figure 88:C), sharpening the embossed figures (Figure 89:E). Also from the front, pointillism was used to draw the eyes, beaks and S volutes at the base (Figure 94:A-C; Armbruster et al., 2004; Labbé, 1998). Under the digital microscope, the dots show a rectangular section, indicating the use of a tool with flat square-sectioned end. Nevertheless, it is not very clear how the dots were made. In some cases, the length and space between dots are irregular, suggesting that each dot was made independently, most likely hammering a sharp tool in angle (Figure 94:A-B). Nevertheless, the dots in the S volutes were made in segments of ~6-7mm long showing similar spread (Figure 94:C), suggesting the use of a dented punch, similar to the one seen in Larnaud, France (Figure 94:D1; Armbruster, 2000, fig. 64). Possibly, a dented punch was used, being both hammered perpendicularly and also in angle, depending on the shape required (Figure 94:D2).

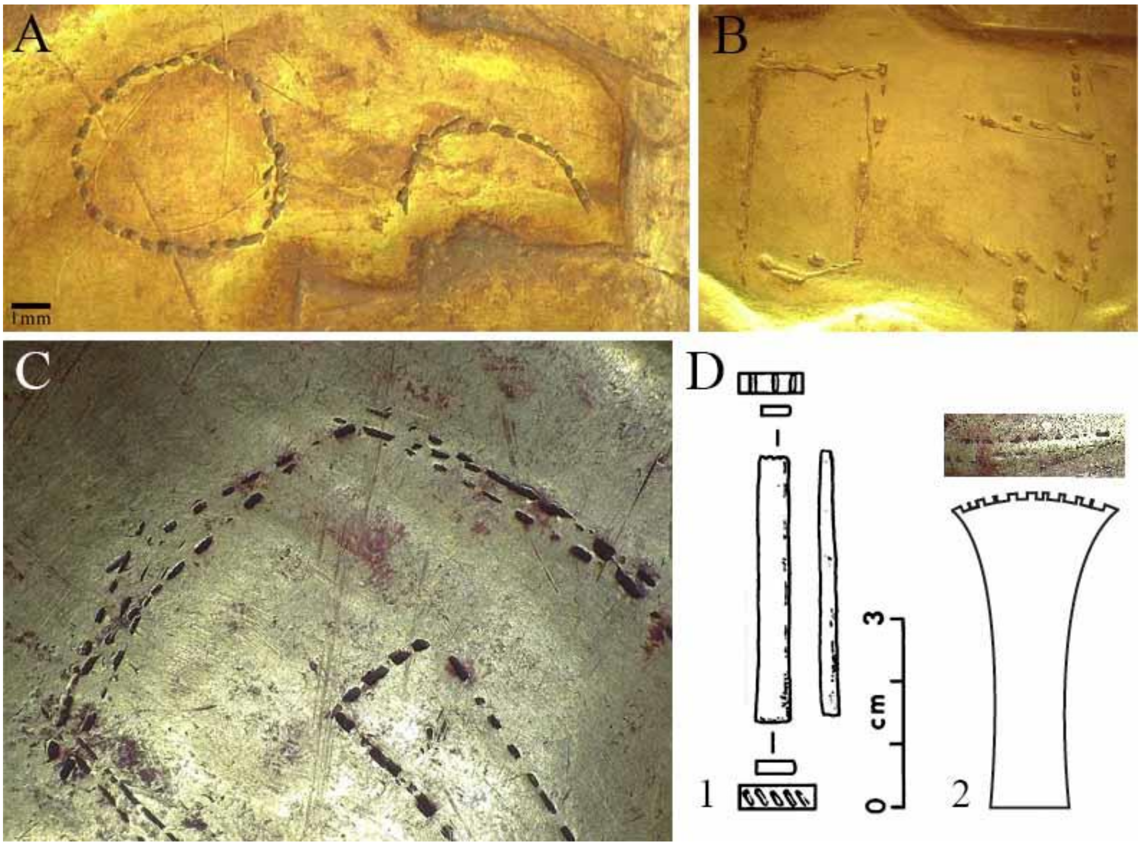


Figure 94: Details of the decoration using pointillism in kero popm140.
Details of the eye, peak (A), talon (B) of the avian figures and (C) S volutes at the bottom. D- Dented punches: Larnaud, France (1) (after Armbruster2000, fig.64) and a possible model proposed by the author (2).

6.3.2.2 *Engraving*

This technique is used to create incised lines, using sharp pointy tools called burins or gravers. These tools are held with the hand and pressed directly on the metallic surface cutting and removing metal (Figure 88:B4); therefore hammering is not used. Engraving leaves straight lines, a flat surface without ridges and usually the marks will not show at the back (Figure 88:B5, Figure 95; Armbruster, 2000, 2013; Armbruster et al., 2004; Carcedo, 1998; Destrée, 1983; Maryon, 1971; McCreight, 1991; Untracht, 1975).

Eleven objects show evidence of this technique (31%), with sharp straight lines of irregular length that did not bend the surface: a set of seven bells from Larache (popm59-60, 98-102) and two goblets from Casa Parroquial (popm140-141). Some of the lines however, are fairly shallow grooves. The bells were decorated by four horizontal lines around the body (Figure 96:A); whereas in the goblets, engraving was used to define details such us features in popm141 and the borders of the avian figures in popm140 (Figure 96:D-F). All bells, chased or engraved, are from Larache. It is interesting to see that the decoration technique used was the same in each set, supporting the idea that each group of bells was made by a single hand.

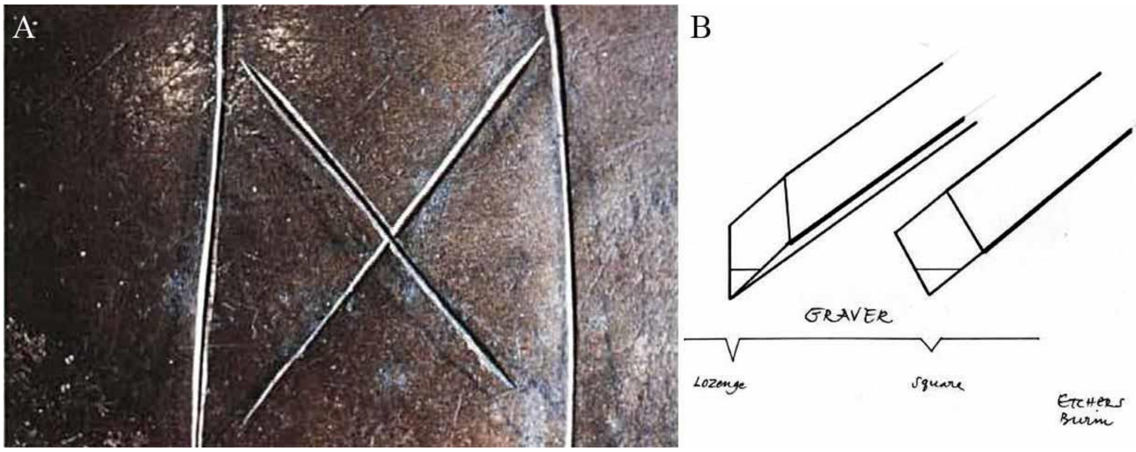


Figure 95: Engraving.
A- Engraving marks on a Moche copper jingle (Carcedo 1998, fig.21). B- Example of engraving marks on a surface (https://www.libraries.rutgers.edu/rul/exhibits/intersect/tools4.htm).

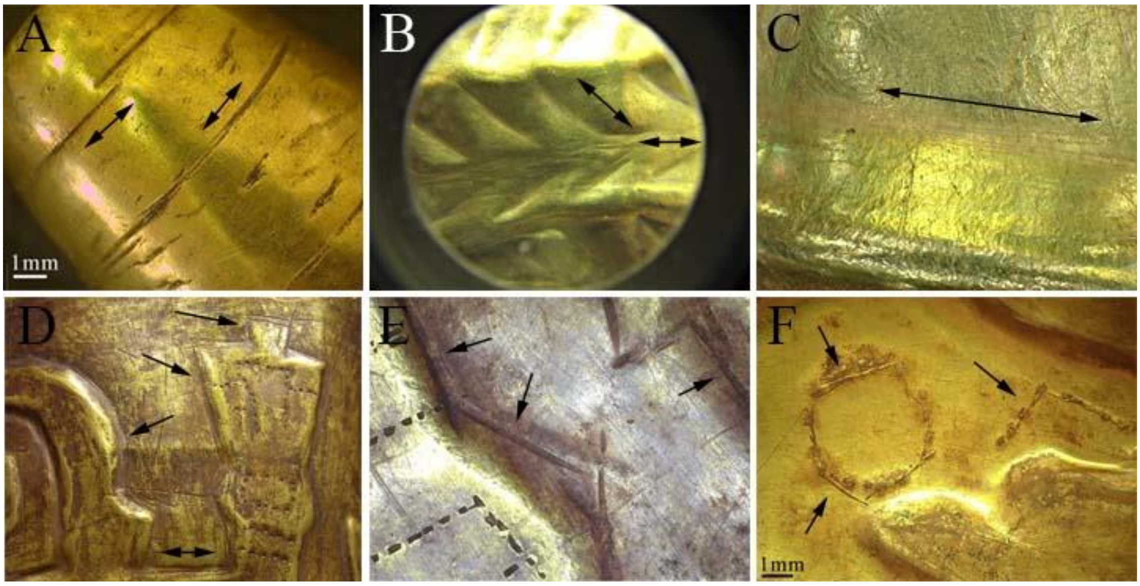


Figure 96: Artefacts with engraving lines.
A- Bell popm60, B- Portrait-vessel popm138, detail of the hat. C- Portrait-vessel popm136, detail of the torus D-F- Kero 140, details of the neck decoration. The arrows are indicating the engraved lines.

6.3.2.3 *Openwork*

This technique uses cut out pieces of metal to produce a design, and appears in three objects from SPA (8%). The attachment popm30 is a disc where six triangles and a central circle were cut out to create a star shape (Figure 97:B). Similarly, in the headdress popm125 eight triangles were cut out creating a pair of crosses in the centre of the body (Figure 97:A). Additionally, one section of quadrangular shape at each side of the body was cut out, creating a neck. In both artefacts, guide marks are visible indicating that the designs were sketched before were cut. Popm67 is an irregular shape with an internal circle cut-out (Figure 97:C).

6.3.2.4 *Appliqué*

It is based on affixing an ornament to another piece, both formed separately (Labbé, 1998). This technique was used in three rings (8%) popm89, 113/114, 117, previously described in section 6.3.1.4.1 (Joining).

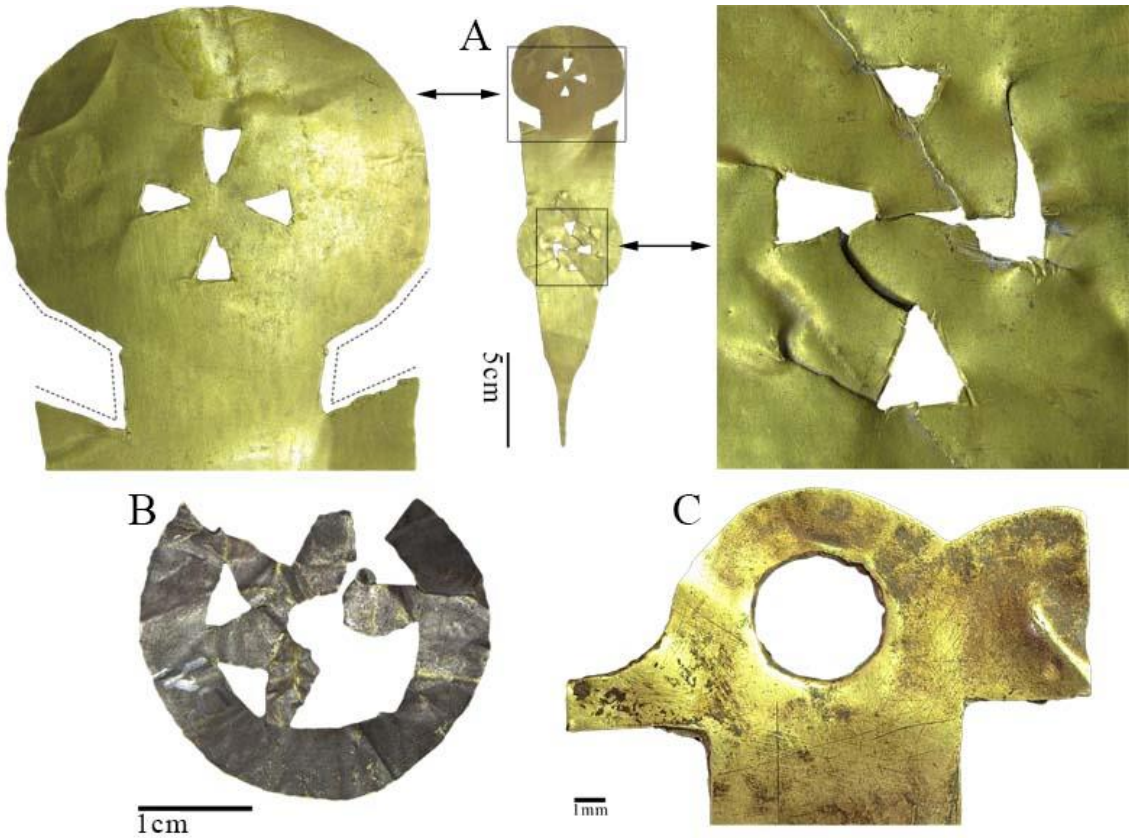


Figure 97: Artefacts decorated with openwork.
A- Headdress popm125. The dotted lines indicate the areas that were cut out from the original shape as well. B- Attachment popm30, C- Sheet popm67.

6.3.3 Motifs

Within the 36 decorated ornaments from SPA, 11 motifs and two unclear designs are identified (Table 31). Overall, the most common decoration is composed of geometric shapes, found in 24 objects: lines, circles, crosses and S volutes. These are followed by zoomorphic motifs (n=5) such as felines, birds and llamas; and anthropomorphic shapes, like human faces (n=4). Possible phytomorphic shapes are seen in two cases and unrecognisable designs are found in two objects.

Seventeen objects, bells and a ring, were decorated using parallel horizontal lines, generating several bands across the body (Figure 98:A). Also described here as decoration are the *torus* or bands on the body of the *keros* (Figure 98:E,H). A single and a double torus were combined in *kero* popm136, whilst one of each were embossed in *keros* popm139-140. Crosses are present in two objects: a headdress popm125 and a pendant popm128 (Figure 98:C-D). Despite using different techniques (open work and embossing), both are crosses made by four triangles pointing to the centre. The pendant popm128 also comprises a central circle and four dots at each side (Figure 98:D). The band popm95 shows a drawing composed of a circle with vertical lines that may represent a mouth, but this is not very clear (Figure 98:B).

Motifs	N°	%	Object: popm_
Geometric patterns			
Horizontal lines	17	47	56, 57, 58, 59, 60, 98, 99, 100, 101, 102, 115, 116, 145, 146, 147, 130
Torus	3	8	136, 139, 140
Cross	2	6	125, 128
Disc	1	3	113
Volutes	1	3	140
Mouth (?)	1	3	95
Zoomorphic			
Feline*	3	8	19, 133, 135
Avian	2	6	39, 140
Llama *	1	3	n/n
Anthropomorphic	4	11	131, 137, 138, 141
Phytomorphic	2	6	30, 117
Unknown	2	6	67, 144
			(*) Objects that are in the SPA assemblage but were not available for technological analysis.

Table 31: Decorative motifs present in SPA assemblage.
In total 36 objects present decoration in SPA, only 34 were analysed technologically. Percentages are calculated considering 36 as 100%.

Feline motifs, specifically the head or face, are found in the inhalation tubes: two distal tips (Figure 98:F) and a body (Figure 98:G). A composed figure with avian head, wings and a curly tale is present in *kero* popm140 (Figure 98:H); and in the same goblet there are horizontal S volutes at the base. A sheet cut with avian and a *llama* shape is found only once (Figure 98:I-J). Human faces are found in three portrait-vessels and the attachment popm131. The formers are very natural and realistic (Figure 92), while the latter is simpler and schematic, showing two faces at the opposite ends of the band linked by waves (Figure 98:M). Phytomorphic motifs (flowers?) are found in the ring popm117 and the attachment popm30 (Figure 98:K-L); a disc used as decoration in popm113-114 (Figure 83), and two unidentified designs were embossed in jug popm144 and cut-out from popm67 (Figure 97:C).

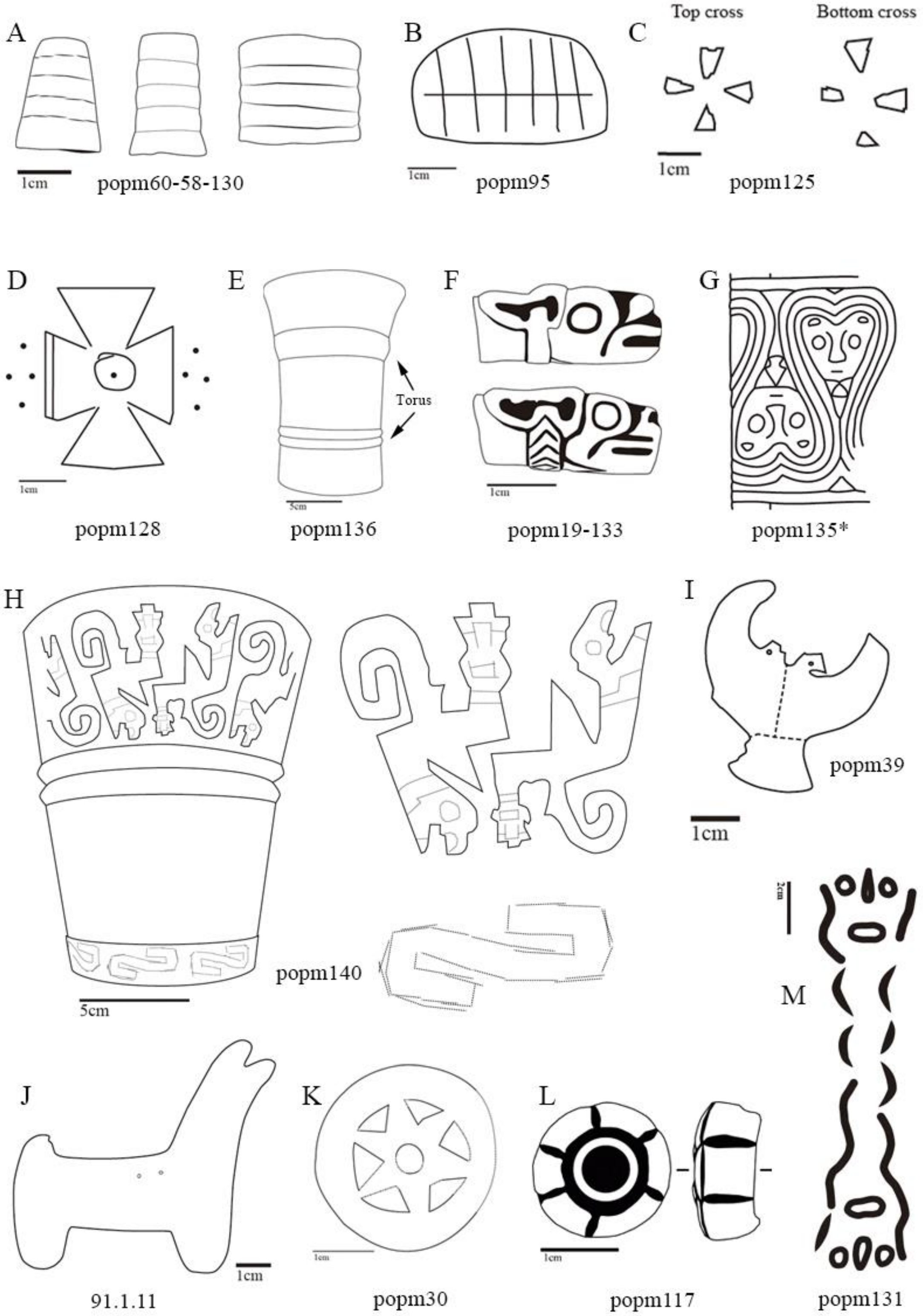


Figure 98: Different motifs found in SPA material.
*A- Horizontal lines, B- a mouth?, C-D- Crosses, E- Kero with tori, F-G- Feline heads and face, H- Avian and S volutes, I-Avian shape, J- Llama shape, K-L- Phytomorphic shapes, M- Anthropomorphic face. Black areas in F and L represent chased parts, in M are marking embossed lines. *Image re-drawn from Llagostera et al., 1988, fig. 13.*

6.3.4 Finishing techniques

The final stage is to smoothen and bring out the colour of the forged metal, removing scratches and imperfections by grinding, polishing or burnishing (Armbruster, 2000; Untracht, 1975). *Grinding* and *polishing* are abrasive techniques that remove part of the surface using grinding stones or loose abrasive materials, leaving scratches on the surface. Natural abrasives include sand, ashes, siliceous plants (e.g. horsetail); and a range of rocks such as sandstones, slate, pumice, flint, garnet, chalk or lime. Loose materials are mixed with grease, resin or water and applied to the surface using a cloth, leather or by hand; grinding stones are rubbed against the object (Figure 99; Armbruster, 2000; Destrée, 1983; Maryon, 1971; McCreight, 1991; Untracht, 1975). *Burnishing* is a compression technique, where lubricated hard smooth stones (e.g. agate or bloodstone) are pressed onto the surface until the metal shines (Armbruster, 2000; Maryon, 1971; Untracht, 1975). In SPA, polish marks were discovered in a large number of objects, both to treat the surface and the edges. Regular facets on the surfaces were also identified, suggesting that a compressing technique using a hard tool was applied to smoothen the surfaces and edges (e.g. smooth stones); similar to, but coarser than burnishing.

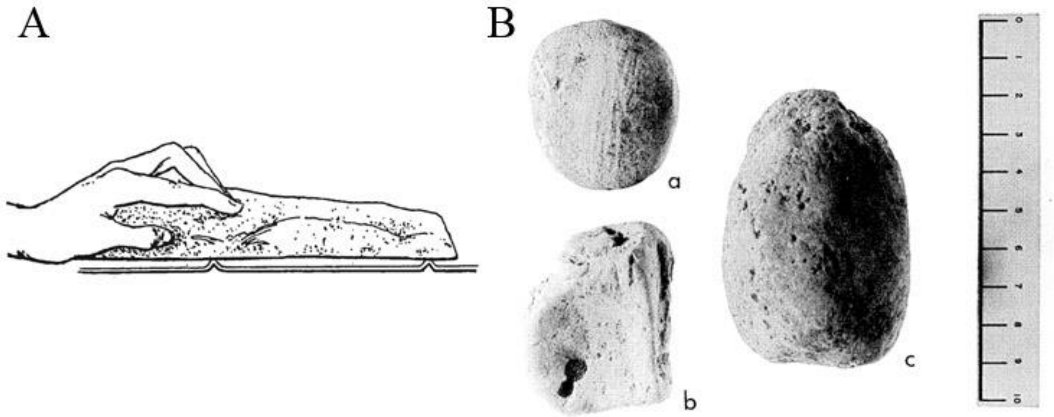


Figure 99: Examples of grinding stones.
A- Rubbing a grinding stone against the metal (after Armbruster, 2000, fig. 59). B- Calcite cakes used to polish metal objects at Batanes del Tablazo, northern Peru (modified from Lechtman, 1991b, p. 8).

6.3.4.1 Surfaces

Treated surfaces were identified in 61 objects (46%). In 38 objects, the surface showed fine multi-directional scratches, suggesting the use as polisher of an abrasive material (Figure 100); the three wire-rings were probably rubbed on a flat fine-grained grinding stone, based on the evenly reduced shanks (Figure 66; Armbruster, 2000; Li et al., 2011). Most of these objects are from Larache (n=21); from Quitor-1, all ornaments from burial 889 were polished as well (n=5); and none from Casa Parroquial. Twenty-three objects exhibited subtle facets, as if a hard object compressed the surface. There are two main types of "compressing marks": wide and shallow marks indicating the use of a tool with a flat-wide working end, discovered in 19 items from Larache (Figure 101:D-F); and narrow and relatively deep marks, indicative of a round narrow working end identified in three artefacts from Casa Parroquial, and one from Larache (Figure 101:A-C).

In 55 objects (41%), the surface appears very smooth to the touch (on one or both faces), even if no polish marks were visible. In these cases is not clear whether the surface was intentionally treated with a very fine material or they represent worn surfaces smoothened by use and manipulation. Fourteen objects were not polished (10%) and in 12 cases (9%) the surface treatment was not visible due to poor conditions (e.g. corrosion, small fragments).

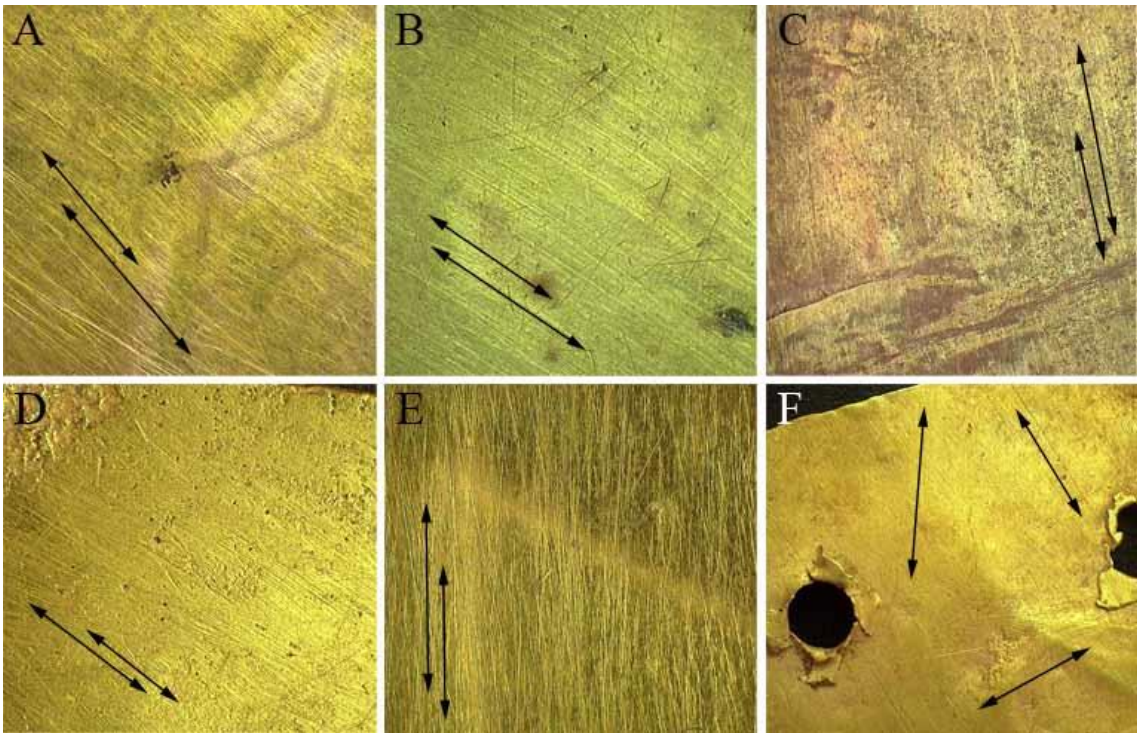


Figure 100: Detail of surfaces with scratches as polish marks.
A- popm27, B- popm35, C- popm39, D- popm125, E- popm128, F- popm16.

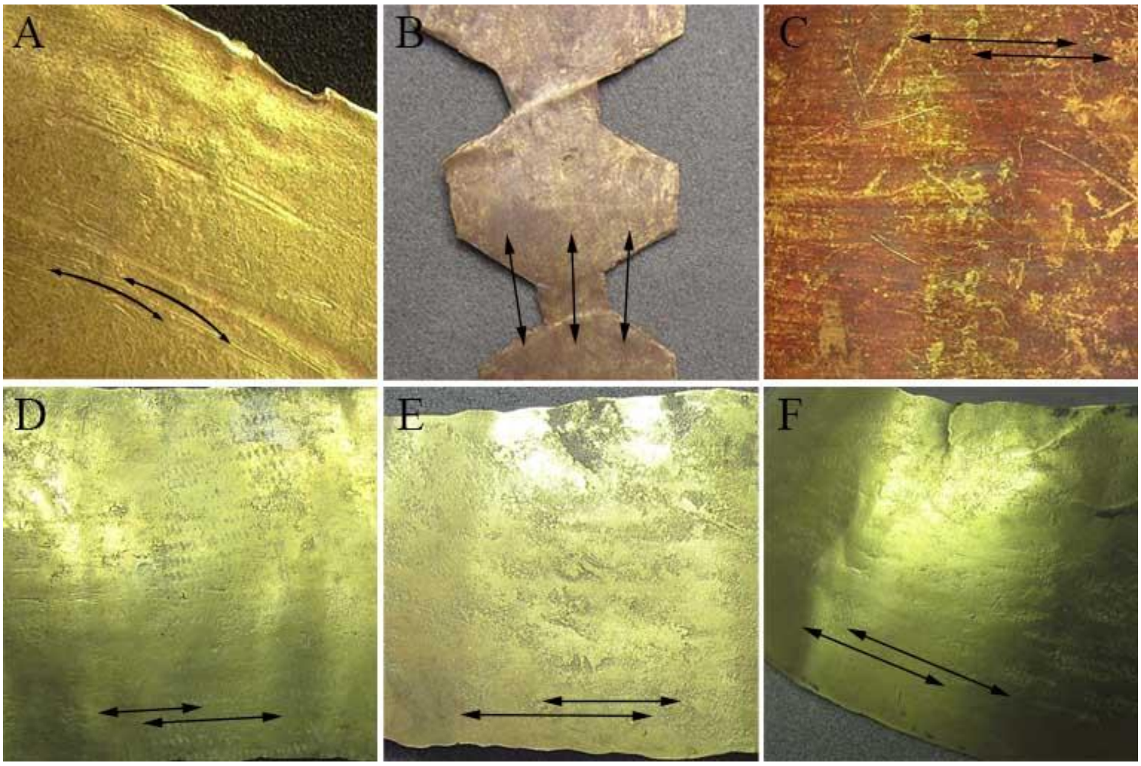


Figure 101: Detail of surfaces with smooth marks made by compressing techniques.
A- popm118, B- popm86, C- popm88, D- popm106, E- popm110, F- popm112.

6.3.4.2 Edges

The aim of treating the edges is to erase cutting or guide marks left during the manufacture of the object. Within the assemblage, 50 objects present polished edges (38%), in 55 cases edges were not polished (41%), 32 artefacts show worn out edges (24%), or polished by use, and in eight cases it was impossible to determine the edge condition (6%). Some artefacts contain more than one edge treatment.

Considering the treated edges, different techniques are used. Nine artefacts show round and smooth edges, suggesting that they were intentionally ground and polished using abrasive materials (Figure 102:A-C). In 13 cases the rims were even and showed small ledges hammered against the surfaces, suggesting the use of hard tool that was compressed and slid on the edge to smoothen it (Figure 102:D-G). Another feature observed in seven objects, is that instead of being polished, relative large sections of the edge (compared to the example above) were folded to give shape or obtain an even border (Figure 102:H-I). Another type of edge is seen in 22 objects, mainly bells. Here, the edge was slightly bent inwards and then smoothened (Figure 102:J). However, it is not clear whether in those cases the edges were intentionally polished, or they were smoothened because of their use. Overall, no clear patterns regarding the use of these techniques by sites or type of objects are seen, except in the case of the bells which all share the same treatment and all are from Larache.

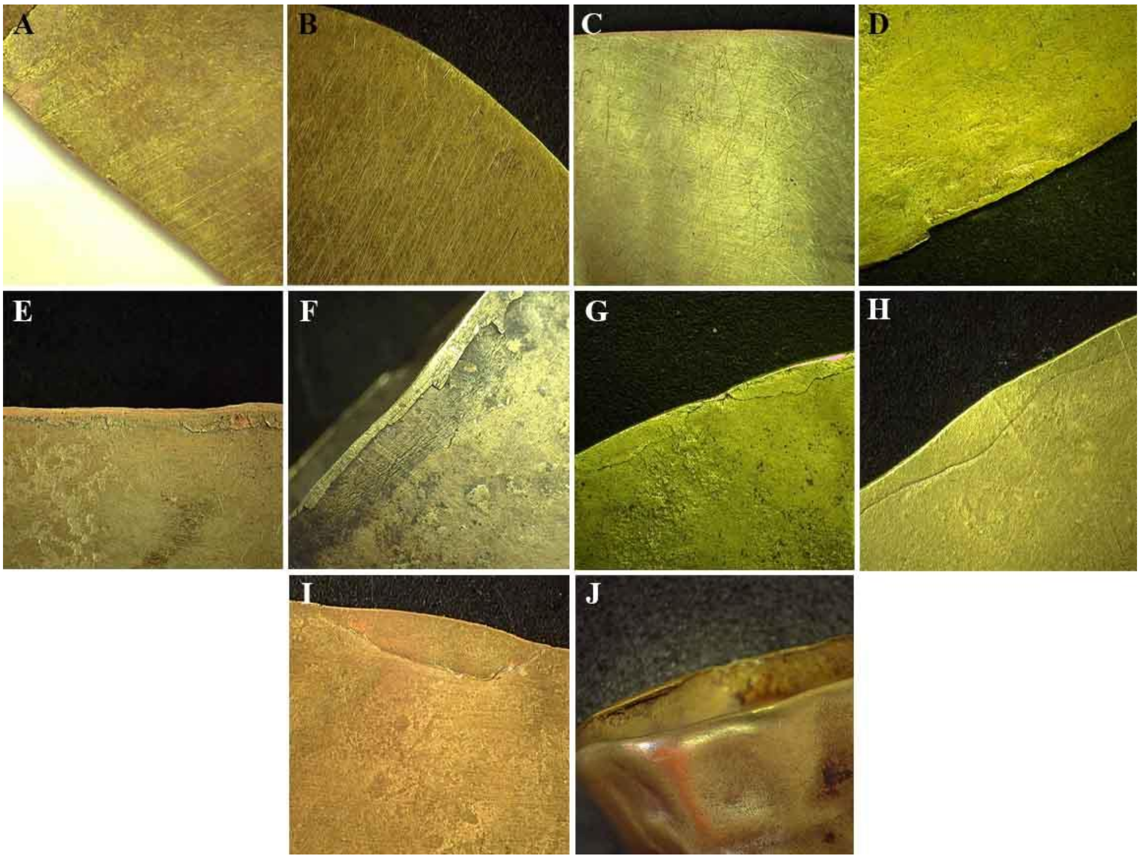


Figure 102: Details of some edges showing different types of polishing.
A-C- abrasive marks, D-G- small ledges flattened against the surface, H-I- large folded sections, J- slightly bent and smooth edges. A-popm52, B-popm128, C-popm35, D-popm106, E-popm112, F-popm33, G-popm107, H-popm90, I-popm93 and J-popm58.

6.3.5 The *chaîne opératoire* of the *keros* and portrait-vessels

Technologically speaking, the most complex items found in SPA are the six goblets, because of their long *chaîne opératoire* comprising many different techniques to produce unique 3D objects. The sequence would start with a plate as pre-form that is raised until the main shape is obtained, including thickening the rims and squaring the bases. In the case of the *keros* (popm136,139-140), this would form a tronco-conical vessel, with a small base and a large opening; the portrait-vessels probably started from a cylindrical shape.

Based on the inside marks, the *tori* in the *keros* were raised by compressing from the interior (Figure 89:D). The edges of the *tori* were defined from the outside by chasing, using a sharp instrument (Figure 91:C). In the case of popm140, the upper register (Figure 89:E) was decorated by embossing avian figures from the interior, and chasing (or sinking) the background from the front; pointillism (a sub-type of chasing) was used to draw the eyes and beak, engraved lines were made with a pointy tool to delimitate edges of the figures. At the base, a rectangular band was raised and within it a series of S volutes were chased by pointillism (Figure 94).

To decorate the portrait-vessels (popm137,138 and 141), a wooden mould was used. The mould was placed inside the vessel and chased from the front (Figure 93). The features were perfected by hammering (small and controlled blows); chasing was applied to define the eyes, mouth and face borders. Different tools were used for the latter; the surface marks suggest the use of pointy tools with both blunt and sharp working ends. The hat in the three cases was shaped and raised after chasing the face, by hammering from the inside of the vessel. The outer surfaces are smooth and shiny, suggesting that they were polished with a fine abrasive or burnished with a hard smooth stone. Polish marks are not always visible. In the case of the three goblets from Casa Parroquial (popm139-141), the bodies are so smooth that hammer and polish marks are almost invisible. In those cases, it is possible that the smooth texture represents a worn-out surface, smoothened by manipulation.

The three vessels from Casa Parroquial are very different from each other, making it difficult to suggest that they were made together. However, the goblets from Larache share some features that point to a single tradition, but not necessarily to a single "hand" or the same skill level. The set comprises two portrait-vessels and a *kero* found together. The portrait-vessels are very similar dimensions (base/rim/height in popm137: 69/142/92mm and popm138: 66/145/90mm) and the design of the faces (Figure 103:1). Additionally, both portrait-vessels share a specific detail, a slight inclination of the body (of 101º; Figure 103:2); some hammering marks such as those seen below the rim and neck, are the same as well. A subtle difference, however, is the quality of the work. The details in popm137 are better achieved than on popm138. The ears for instance are more clearly defined in the former, whereas in the latter they are blurry and misaligned (this may also be influenced by the shape of the wooden mould used; Figure 103:4). In popm137, the chasing work used to define the face includes the use of blunt and pointy punches, leaving fine lines and different hammer marks that are not visible in popm138 (Figure 103C). The bases are also different; in popm138 the base is flat, whereas in popm137 the centre is sunken. The same sunken base is seen in the *kero* popm136. In this case, the similarity of the decoration, the individuals' features, and specific details such as the inclination of the body suggest that both are part of the same tradition and sequence;

however, the difference in the quality of the chasing work and the bases may suggest that more than one craftsman was involved in the manufacture of these items, explaining the subtle variations.

Figure 103: Portrait-vessels from Larache, burial 358.

6.3.6 Modifications and repaired artefacts

Within the assemblage, 35 objects (26%) present more than one technique for cutting and/or punching, combine polished or worn edges with fresh cuts, are incomplete or have interrupted shapes. Because this variability is hard to explain based by technical constraints of the manufacture, it is proposed here that these objects were modified or repaired at some point of their life-histories. Moreover, given the changes on these ornaments, it is very likely that they "changed hands" more than once during their lives.

Twenty-seven objects (20%) show both later or different cuts and perforations, whereas five cases (4%) present only additional cuts and three ornaments (2%) only additional perforations. In general, the modifications tend to be of lower quality and rough, compared to the original work, which makes them more recognisable. In this classification, however, it is very likely that I missed objects that were completely modified or were heavily used, erasing all evidence of previous work. In those cases it would be impossible to identify them as modified, and they would be considered as objects without modifications. As such, it is important to emphasise that the objects discussed here represent the minimum number of modified objects; as discussed later in this thesis, the actual number is likely to have been much larger.

In 18 cases (14%), the modification intended to divide larger sheets to increase the number of ornaments that look alike, creating sets that were buried together. Example of this are six trapezoid pendants (popm119-124) found in Larache burial 358. These pendants show cracked and worn external edges that contrast with the fresh and sharp cuts used to divide them (Figure 104:A1-3). Guide marks were drawn before the cut, some of them in incorrect places (Figure 104:A4). Interestingly, all pendants fit together except the last one, suggesting that a seventh pendant is missing; whereas burial 1714 has an identical pendant (popm36) - same shape, perforation techniques, dimensions and composition (Figure 51) -, that fits perfectly in the gap (Appendix Nº5: 2). The only difference is its condition: popm36 is heavily worn, deleting the modification marks. The similarities indicates that these pendants were all modified together, but popm36 was separated from the lot, used afterwards and deposited independently (see later discussion in chapter 9:9.2.3).

Worn and fresh slide cuts, as well as guide marks are also combined in seven rectangular pendants (popm47,50-51,73-76), a pair of attachments (popm77-78), a pair of bands (popm79-80) and a square attachment (popm81) found in Casa Parroquial, burial 16 and 18 (Figure 104:B-E). Perforations are identical in the objects from Larache (cut perforations with flattened burrs) and Casa Parroquial (punched perforations with a conical-pointy tool, burrs not treated), suggesting that perforations were made after the cuts, as part of the modification.

In 9 items (7%), modifications were made in single objects, oriented to change their shape or design. In these cases, only one or two sides of the item were modified (with visible fresh cuts) and perforations were added, such as the attachments popm16, popm28, popm53, popm27 and popm35 (Figure 105). The last two ornaments have a curved side, suggesting that they were originally discs (Figure 106).

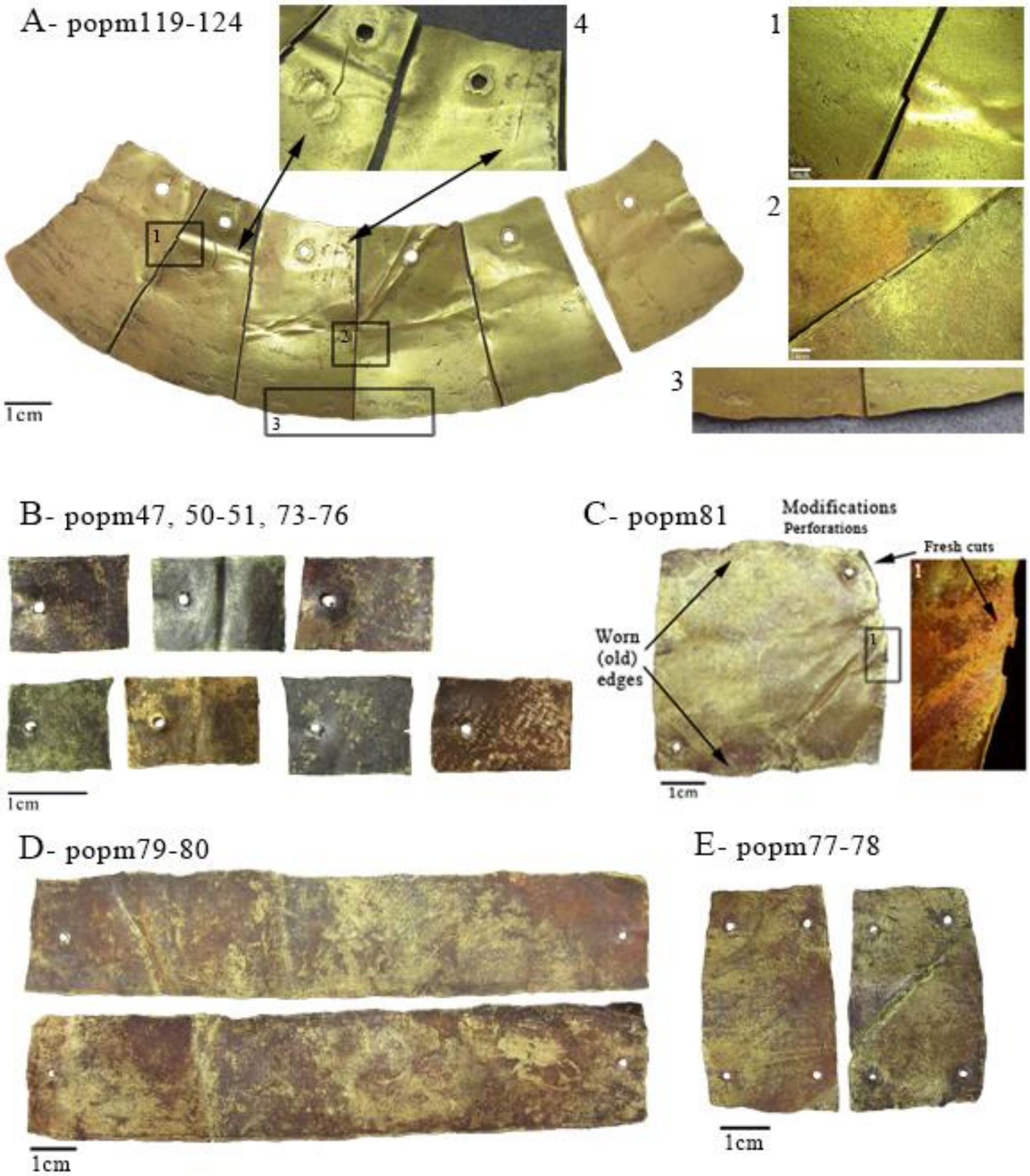


Figure 104: Items divided in several identical pendants and attachments.
A- Trapezoidal pendants from Larache, B-E- Pendants and attachments from Casa Parroquial.

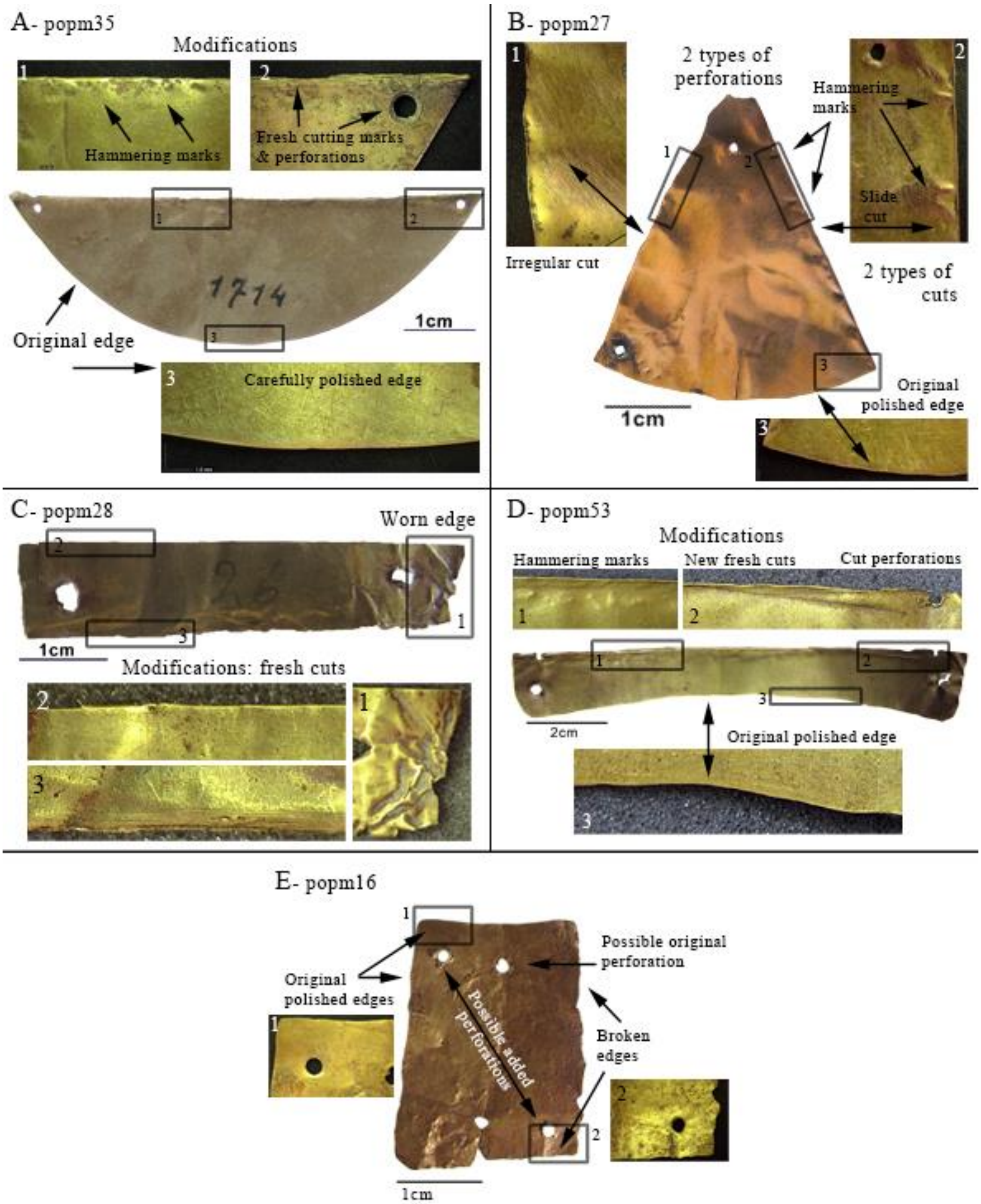


Figure 105: Items where their original shape or design was modified.

Based on the presence of a similar artefact with identical composition (popm84), it is proposed that the headdress popm86 was completely reshaped, from a trapezoidal sheet into a complex shape based on three lobules (Figure 107). In fact, it is possible that popm84 and popm86 were part of a single headdress, similar to popm87 that was broken up, given the rough marks at their bottom (Figure 106). In popm125 the modifications changed the original shape creating a neck and adding openwork decoration at the centre. Some unfollowed guide marks are still visible on the surface (Figure 107). It is interesting that popm125 and the six pendants popm119-124, all of them modified, were found in the same burial 358, from Larache. Also included here is the headband made of two folded bands popm17-18. It not very clear in this case, but it is plausible that the shaping of these bands may have been a modification of a pre-existent sheet that was roughly folded, hammered and cut (instead of being melted; Figure 85).

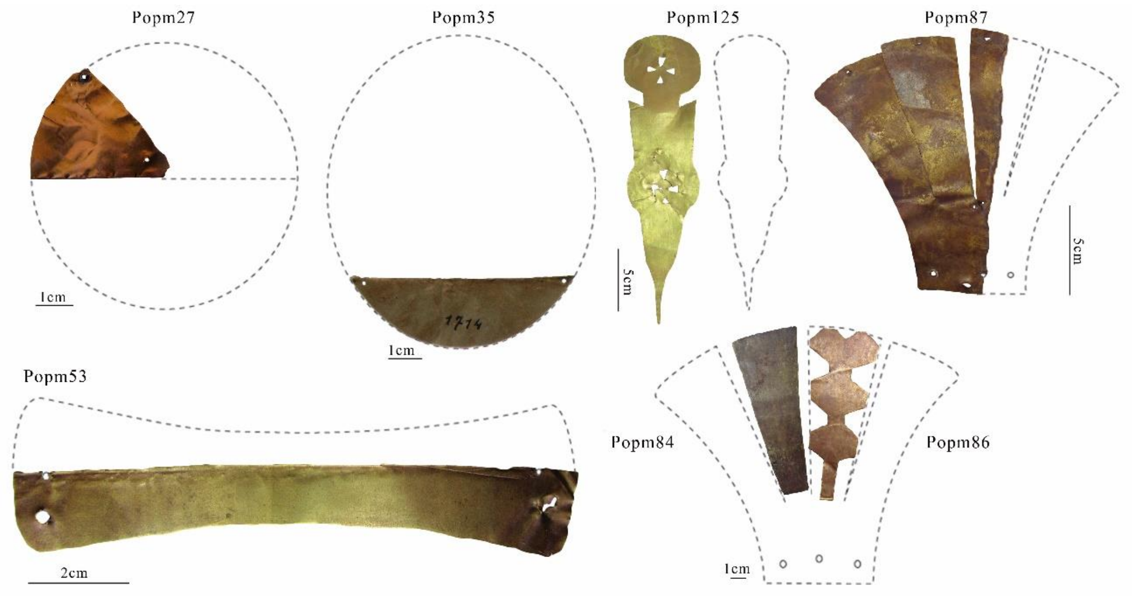


Figure 106: Reconstructed objects. Suggested original shapes are drawn by a dotted line.

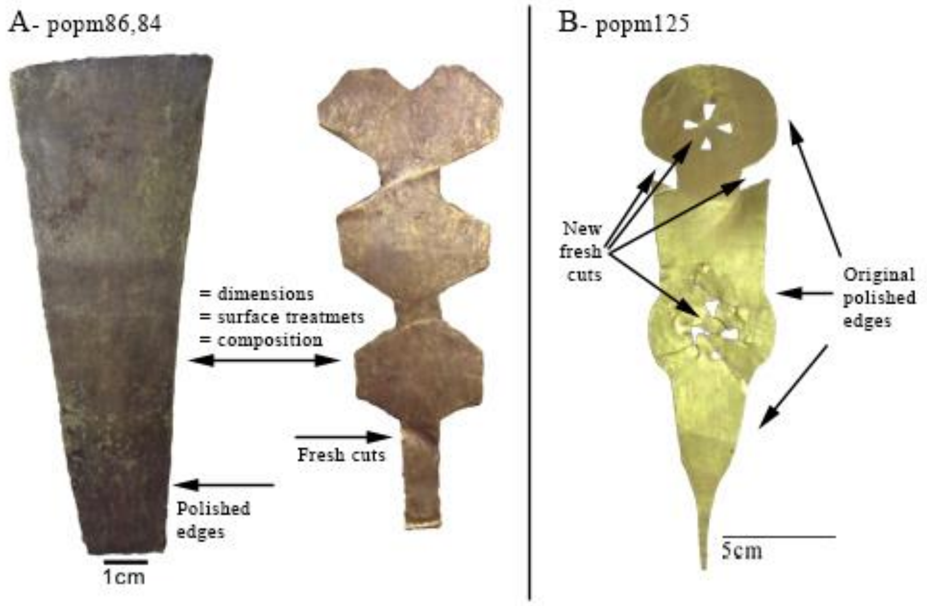


Figure 107: Re-shaped and decorated items. A- Headdresses from Casa Parroquial, B- Headdress from Larache

Presenting both fresh and worn edges, in five cases the objects were deliberately fragmented, simply cutting into one or two ends (popm9, 11, 15, 87, 150). No clear intention to create a new shape or divide a larger piece was identified in these cases (Figure 108 and 106). Finally, in four objects additional perforations were added to repair (e.g. popm1, 10 and 87) or to better attach the sheet (e.g. popm142; Figure 108:C4-D).

Complex life-histories are seen in popm27 and popm87, with the presence of more than one modification technique, suggesting several interventions. In popm27, two ways of cutting and perforating are present (Figure 105:B); whereas in popm87, different techniques were used to cut the edge and perforate the ends of the appendices (perpendicular cuts with a blade), and to repair the thin appendix (punched and round; Figure 108:C).

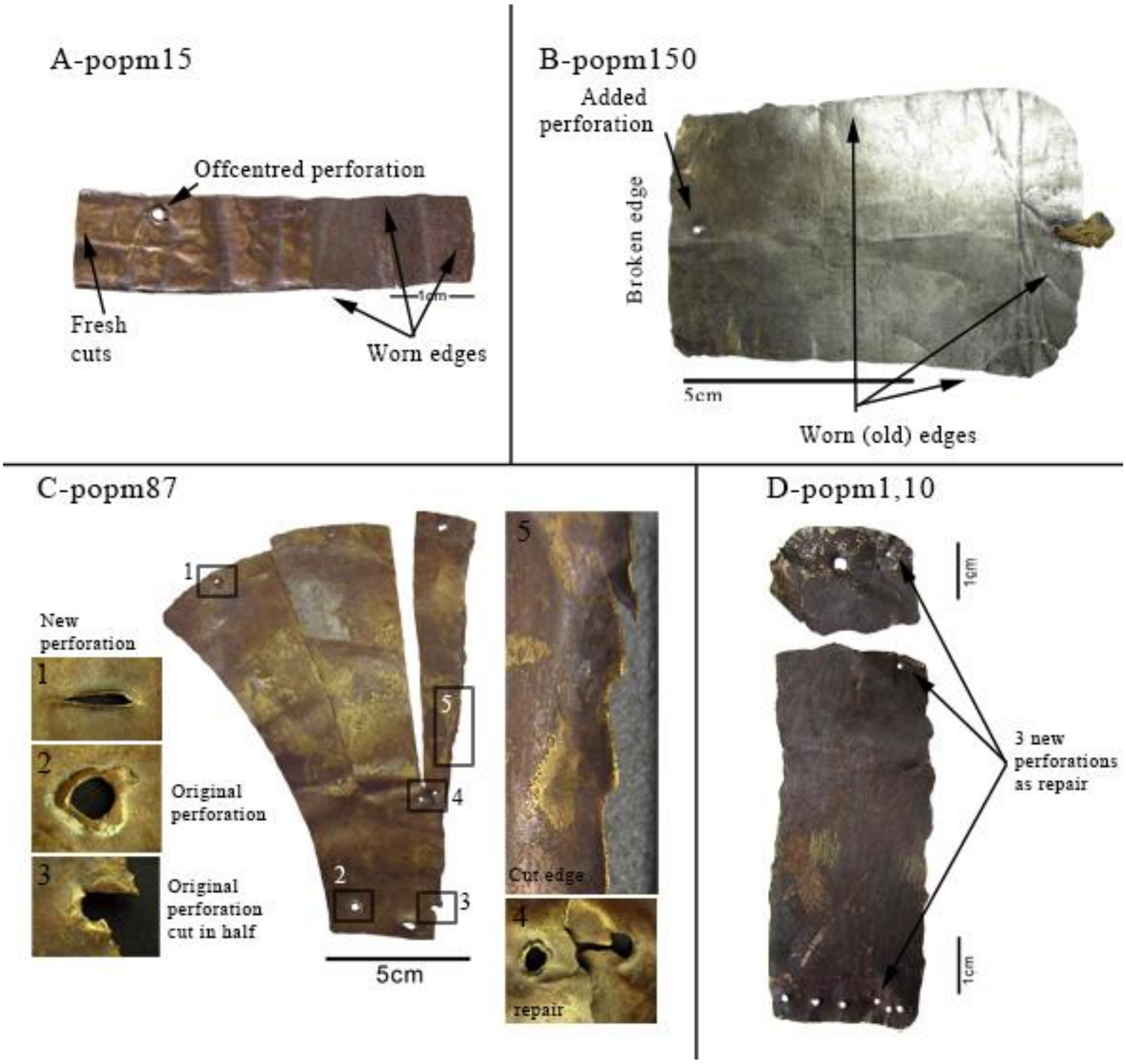


Figure 108: A-C- Cut artefacts and C-D repaired items.

Overall, modifications -including deliberate fragmentation and repairs- are rough and unpolished, obtained by cutting and perforating, i.e. by "cold" mechanical techniques. The use of guide marks to outline the new design suggests some planning. Considering that all modifications look fresh, and many were grouped within the same burials (22 artefacts in 4 burials), there is every reason to propose that these modifications were locally made, shortly before the objects were deposited. To understand these cases, the time factor is key; i.e., the modifications identified here would have occurred sometime after the objects were made, at different moments of their life-histories. Modifications then would represent later interventions, either to change their original shapes or to repair them.

Finally, three objects have modifications that are different compared to the rest, indicative of relatively long and complex life-histories, suggesting that not all objects followed the same trajectories. For instance, the cuts in popm87 are the crudest and roughest of the assemblage, and the cutting technique used (perpendicular cuts) is not common in SPA (Figure 108:C5). Conversely, the modifications in popm35 and popm27 are very neat and the rotary technique used to perforate them is rare (Figure 105:A-B). It is possible then that these three artefacts were modified before they arrived at SPA, where popm87 and popm27 were subsequently repaired and re-cut for a second time (Figure 108:C4).

Thirty-three modified objects appear in five of seven cemeteries: Larache, Quitor-1, Quitor-5, Sequitor Alambrado and Casa Parroquial; in two objects the cemetery location is uncertain (popm28, popm53).

6.4 Summary

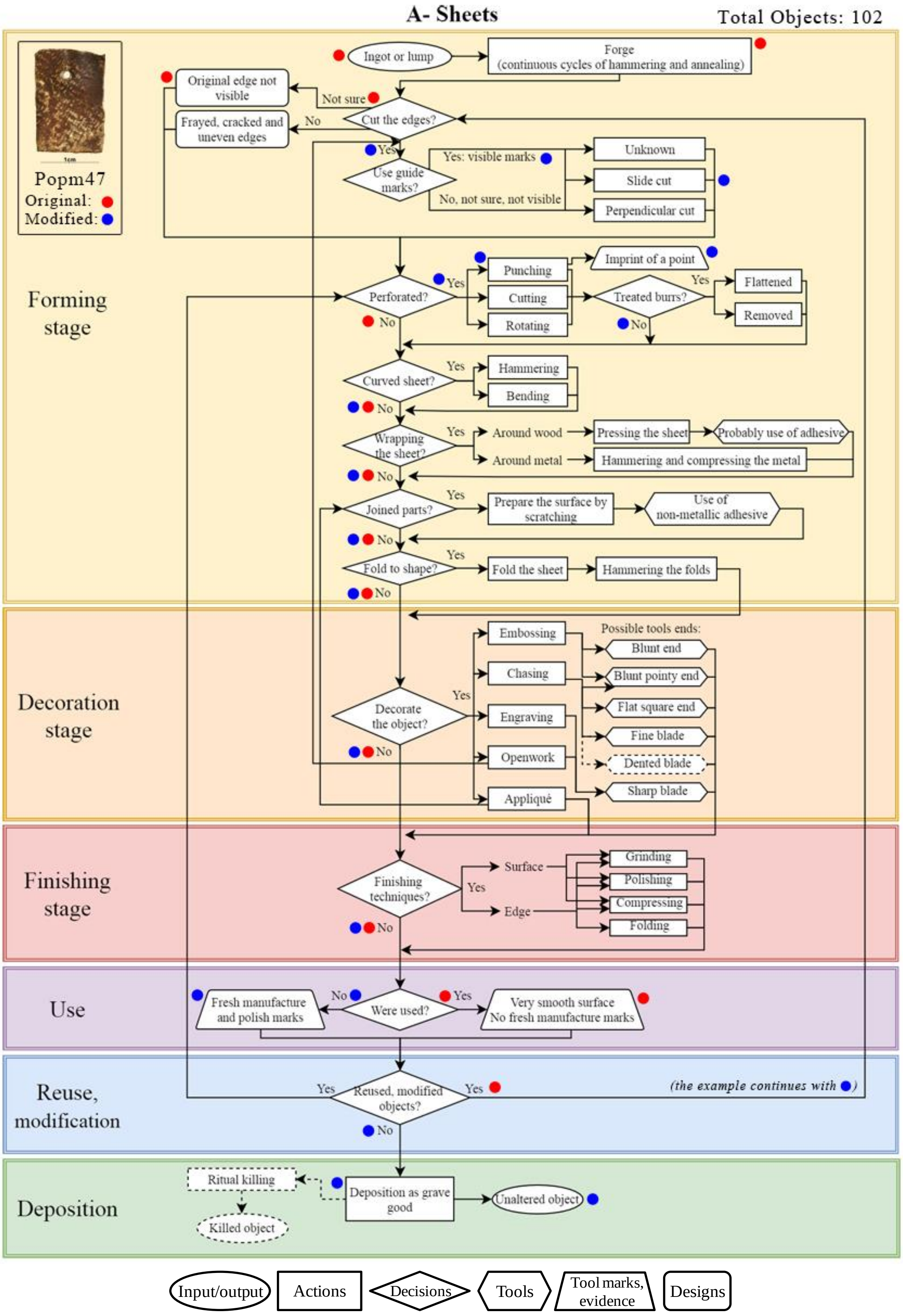
A variety of techniques were identified in SPA, the most common being forging, cutting and perforating. Tool marks and the microstructure reflect the application of cycles of hammering and annealing to produce sheets of different shapes. Forging shows different levels of complexity, starting with flat sheets, regular-section wires and hollow vessels, being the latter the most complex. A flow chart showing the different technical options identified in SPA is presented in Figure 109.

Cutting, by sliding a blade on the surface, was used to shape most objects; however, perpendicular cuts and as-forged borders (frayed and cracked) are also present in the assemblage. Perforations were made by cutting and punching the surface; the burrs at the back were left and in some cases flattened. Surfaces and edges were polished using abrasives and also compressing and using hard tools; however several objects did not show evidence of polishing, showing rough surfaces and fresh cuts instead. Overall, most of the metalwork appears coarse and rough.

Present but rare are objects with straight polished edges, perforations made with a rotating instrument, copper or wood objects wrapped in gold sheets, two-part rings joined, and a headband shaped by folding. Decoration is also exceptional, mainly produced by embossing and chasing. Based on the marks, decoration techniques and tools appear heterogeneous. Regarding the motifs, some patterns are repeated such as bells with lines, portrait-vessels, and inhalation tubes with feline heads; the remaining motifs are varied.

Based on the presence of different cutting and perforating techniques in a single object, fresh cuts and interrupted shapes, it is proposed that at least 35 objects were modified after their manufacture, revealing the complex life-histories of some of these ornaments, which may have involved more than one user. In general, the modifications are rough, very different from the original techniques used. Cuts were made by sliding a blade and perforations by punching and cutting through. In most cases the aim was to create new and more pendants or attachments perforating and cutting large sheets (or other ornaments) that were buried together; still in a few cases, the objective was to change the shape or re-decorate an item. Modified artefacts appear in almost every cemetery (5/7), but they concentrate in Casa Parroquial, and would characterise a local tradition of modifying finished objects.

Figure 109: Flow charts outlining the possible manufacturing sequences and the variety of technical options to produce the (A) plain sheets, (B) wire-rings and (C) hollow vessels.
Dotted lines indicate options not identified in that specific type of objects. Follow the red and blue circles to see the sequence proposed for three examples.



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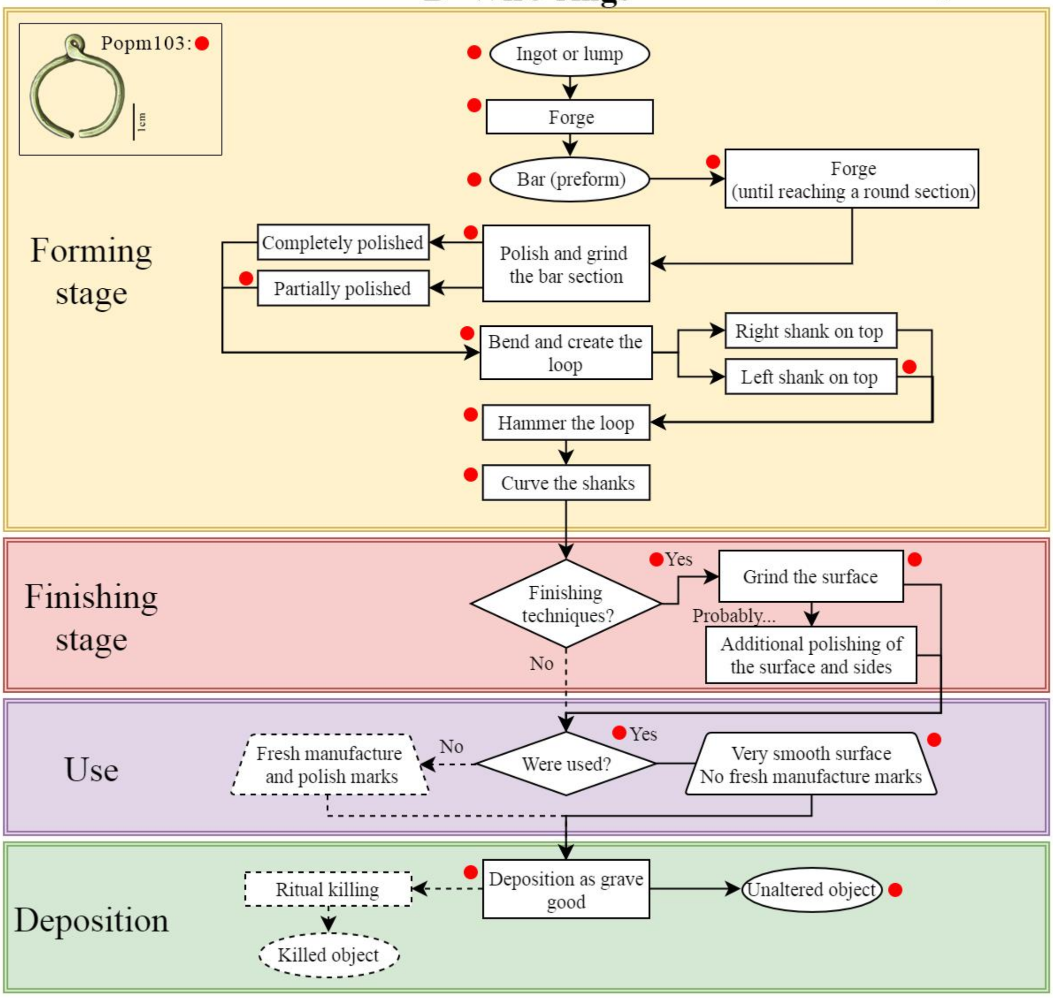
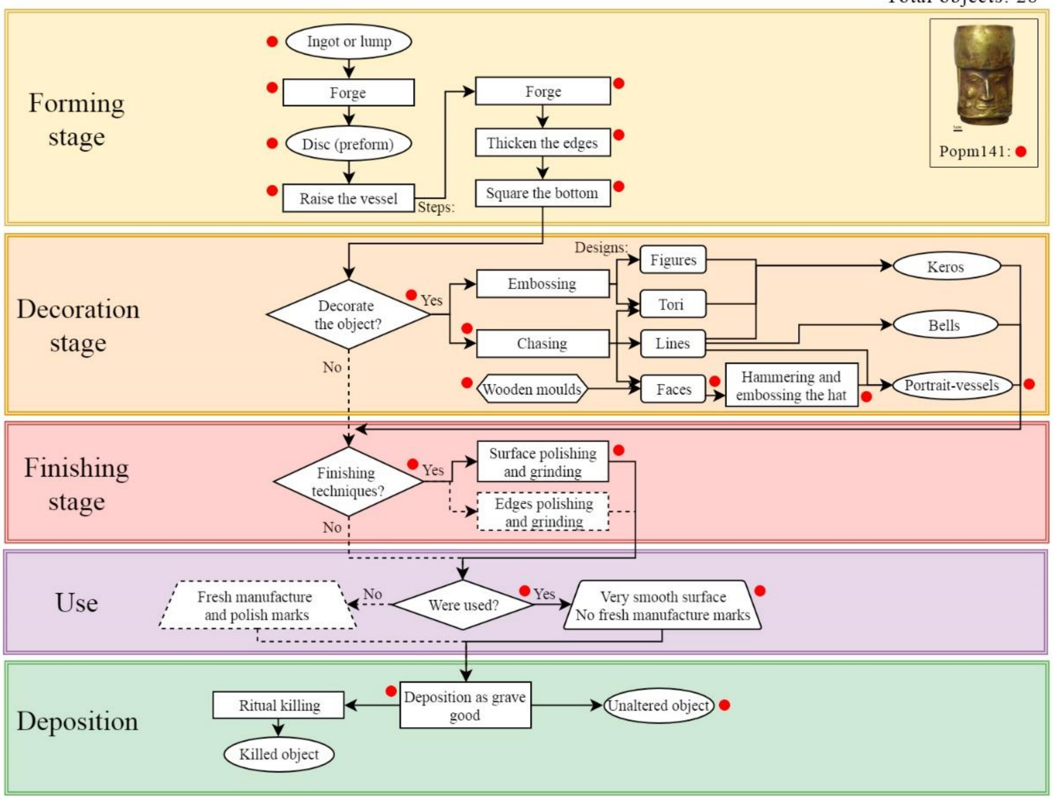
B- Wire-rings

Total objects: 3



C- Hollow vessels

Total objects: 28



6.5 Discussion chapter 6

6.5.1 Gold and silver technology in SPA: A heterogeneous assemblage

From a macro-perspective, all gold and silver objects found in SPA would seem part of a broad technological tradition, using plastic shaping techniques to produce thin, light and small to medium objects, with not much metal (the total assemblage weight 832gr, excluding the goblets) that were cut and perforated. Decoration was rare. The exceptions are the goblets, which are large and heavy, but still raised from a single sheet. Only one cast item is registered in SPA, axe popm49 from Casa Parroquial, that was not available for this work (Salazar et al., 2014 ; see Figure 164). The same technological characteristics are described for the goldwork in NWA (González, 2003, 2004b; Tarragó et al., 2010). This "sheet technology" contrasts and coexists with a copper-based metallurgy mainly producing cast and solid objects (Cifuentes, 2014; González, 2004a; Salazar et al., 2011, 2014).

However, this description is too general and conceals a heterogeneous assemblage, composed of multiple microstyles represented by different forms, quality and technical options taken along the *chaîne opératoire* (Wallaert, 2012). Whereas some technological features are more common, such as cutting by sliding a blade, perforating by punching and cutting, untreated or flattened burrs, and both polished and unpolished surfaces; other techniques are relatively rare and unique within the assemblage such as forging wires, use of perpendicular cuts, perforating by rotation, wrapping sheets on wood or copper supports, joining two parts and raising large goblets (Figure 109).

A difference in the quality and complexity of the work is identified as well, suggesting the work of specialists with different levels of skill. For instance, there are artefacts made by long technological sequences, complex techniques, with special attention on finishing treatments (Appendix Nº2: 18). They include the 28 hollow objects made by raising, which require great expertise and skill in their manufacture, as well as specific equipment (Armbruster, 2000; Carcedo et al., 2004; Untracht, 1975; and more); 15 ornaments of smooth surfaces and straight edges that were carefully finished by grinding and polishing, standing out from the general assemblage; and nine artefacts made by uncommon techniques, such as the wire-rings, the axe and tube wrapped in gold and the rings with attachments.

It is proposed here that these 52 items (39%) relatively *finely-made*, reflect the work of experienced and skilled artisans, showing special attention in finishing techniques to produce well defined and shiny artefacts. If attributes such as labour investment and skill are considered as proposed by Kuijpers, Costin and Hagstrum (Costin, 1991, 2005; Costin & Hagstrum, 1995; Kuijpers, 2017, 2018), the 1) forming of these objects -especially the goblets and the bells, using a complex technique such as raising-, 2) the even and well defined shapes, 3) the careful and thorough treatment of edges, surfaces and perforations, and 4) decorations; would represent first, the employment of additional steps in the *chaîne opératoire* and therefore, more energy to produce them, compared to undecorated and unpolished items. And second, a qualitative difference in more care, control and technique mastery in terms of skill, showing high proficiency and dexterity. An example of this is the conic-bells, which have standardised dimensions, design and manufacture techniques within each set, suggesting the work of relatively highly skilled artisans able to reproduce identical small objects. If considering Kuijpers (2017) specialists classification, these objects were probably made by *master crafters* or very skilled *common craftspeople* (see chapter 3).

On the other hand, a second group comprising the remaining 79 objects of the assemblage (59%) were made by shorter technological sequences -compared to the finely-made group above-, and applying coarser techniques with no emphasis on finishing treatments (Appendix Nº2: 19). They are flat ornaments with unpolished or coarsely polished surfaces. The borders of these objects show unpolished and uneven cuts, and shapes are slightly irregular. Most perforations are rough with untreated burrs, however in some artefacts, burrs were flattened. Only few artefacts are decorated. Moreover, when sets of identical objects are identified, e.g. pendants 47, 50-51, 73-76 or popm119-124 (Figure 104), they are not as standardised in shape as bells in the finely-made group. Overall, in the *coarsely-made* group both the labour investment and skill of the artisans' work appear to be less than the finely-made group, showing no special attention in obtaining even and polish borders or burnished surfaces (Costin & Hagstrum, 1995). Given the quality of these items, they were probably produced by *common craftspeople*, creating good-enough ornaments; or even *amateurs*, in cases that stand out for their lack of care or crude manufacture (e.g. popm1,10,33,34; Kuijpers, 2017). Although, this type of work may also reflect a quick production of skilled artisans, with no time to enhance details on surfaces, borders or perforations (Wendrich, 2012b).

In both groups a range of different forms and manufacturing techniques are identified, which together with the relative different skill, labour investment and standardisation levels, suggest that several producers were involved in the manufacture of this assemblage, including metalworkers with different degree of specialisation (Armbruster et al., 2004; Costin, 1991, 2005; Costin & Hagstrum, 1995; Kuijpers, 2017, 2018; Leusch et al., 2014, 2015). This technological diversity is identified in every cemetery from SPA included in this research, and it agrees with the chemical data that recognises varied gold sources. It also contrasts with other local crafts such as pottery, textiles, baskets and bead making which are highly standardised in their style (Carrión, 2014, 2015; Llagostera et al., 1988; Núñez, 1991; Stovel, 2002, 2005). This formal and technological variability most likely represents a mix of items essentially *acquired by trade or exchange*, as it has been proposed for the inhalation wooden tablets and tubes, which also show heterogeneous styles, technology and raw materials in SPA[15] (Horta, 2012, 2014; Llagostera, 2006a; Llagostera et al., 1988; Niemeyer et al., 2013). Furthermore, given the technological and compositional heterogeneity and variability of the grave goods from SPA, there is every reason to propose that these objects are primarily entering SPA as *finished objects*, instead of as metal. Yet, there is evidence to propose that certain items were locally made and modified, as it will be discussed in chapter 8.

6.5.2 The tools

Technical variation also reflects the use of different tools. In South America, hammers and anvils were made of hard stones intentionally smoothened and shaped to perform different tasks; these tools were specifically made for working metals, being very valuable for the indigenous metalworkers (Appendix Nº2: 20; Benzoni, 2017 [1572]; Carcedo, 1998; Grossman, 1978, 1972; Lothrop, 1978; Sáenz et al., 2007). However, stone tools are difficult to identify in the archaeological record, because they are usually unrecognised or mistaken for other instruments (Armbruster et al., 2004; Perea, 2010). Yet, the different sizes and textures of the hammering marks identified on SPA artefacts indicate the use of hammers of varied head-shapes, sizes and probably raw materials (Figure 59). Looking for metal traces in stone tools and experimenting to test the marks of different types of stone hammers would indicate possible shapes and sizes of potential hammers that we should seek in the archaeological record of the sites. The use of soft hammers such as mallets made of wood, bone, or tools covered with leather or cloths cannot be ruled out either, even though their marks are more difficult to identify on the objects (Armbruster, 2000; McCreight, 1991; Untracht, 1975).

[15] Different authors identify snuffing implements of Tiwanaku, San Pedro and *Circumpuneño* styles, together with a series of other unidentified styles.

Manufacturing marks also revealed the use of copper or bronze tools such as sharp and blunt chisels, or punches of different sections and ends (Armbruster, 2000; Carcedo, 1998; Untracht, 1975). Their use is not surprising, considering that the sheets in SPA are very thin (average 0.2mm), gold is relatively soft, and that copper and bronze instruments were already available at that period in SPA and the South Central Andes in general (Appendix Nº2: 21; Carcedo, 1998; Carcedo et al., 2004; Gluzman, 2007; Mayer, 1986, 1994). In SPA, such tools are being made, imported and used since the Late Formative and are abundant during the Middle Period; but it is proposed that they were used in crafts such as wood or bone carving (Cifuentes, 2014; Llagostera, 2004; Salazar et al., 2014). In particular, copper-based chisels and burins appear associated to individuals from Quitor, Solor, Solcor, Coyo and Beter (Cifuentes, 2014; Cifuentes et al., 2018).

6.6 Distribution by sites: technological clusters

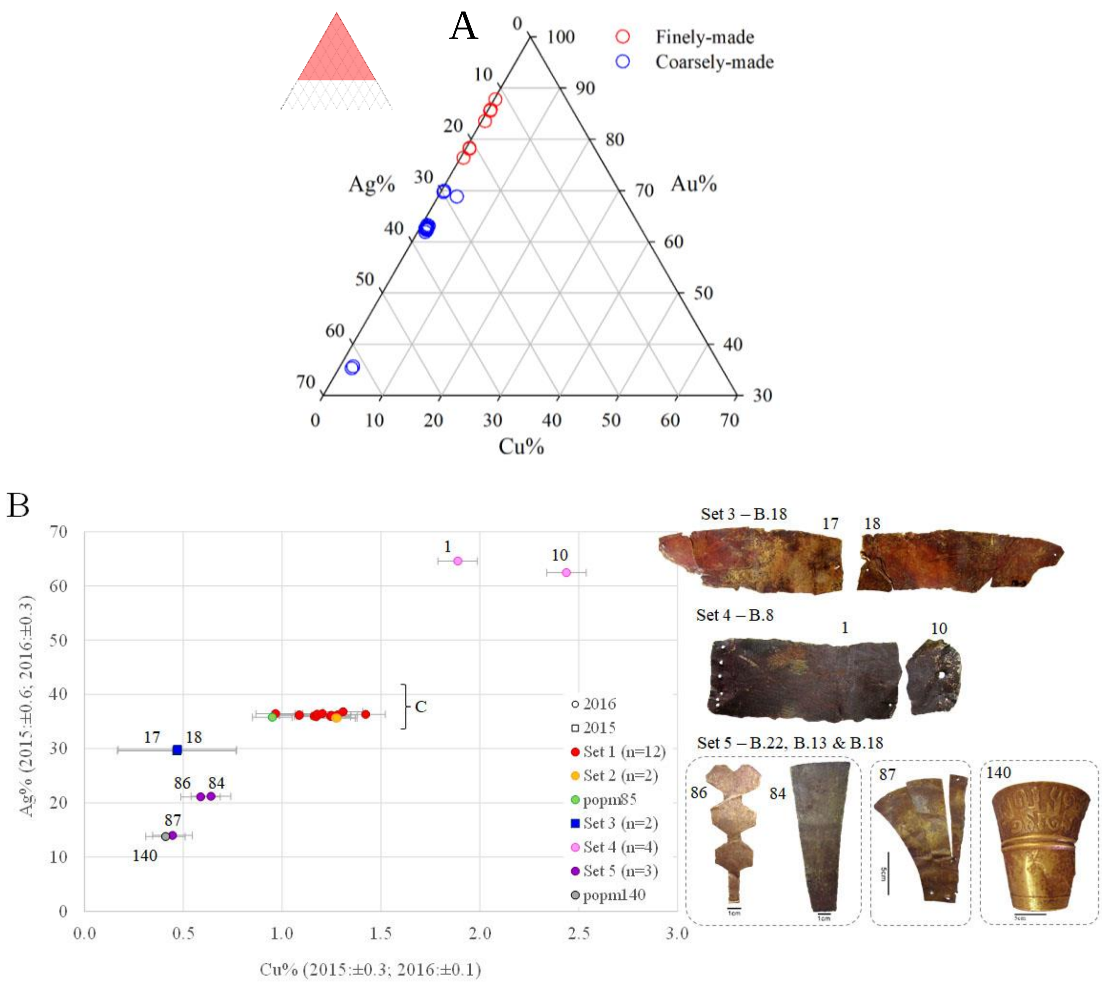
An advantage of this research is that most objects are contextualised, allowing a deeper understanding of how these objects were made. Therefore, despite the variability of the assemblage, when looking at site and burial level, it is possible to identify specific attributes combining particular techniques, tool marks, materials and gestures or motor-habits, revealing the work of single artisans and small groups of craftsperson working in parallel, both showing different skill and specialisation levels (Costin, 1991, 2005; Costin & Hagstrum, 1995; Gosselain, 2000; Martinón-Torres & Uribe, 2015; Wendrich, 2012b, 2012a; Whittaker, 1987). This approach, named "science-based archaeological connoisseurship" by Martinón-Torres and Uribe (2015), has delivered encouraging results in archaeometallurgical studies, identifying idiosyncratic techniques of particular artisans or workshops, with different specialisation and skill levels (Leusch et al., 2015; Martinón-Torres et al., 2011, 2014; Martinón-Torres & Uribe, 2015).

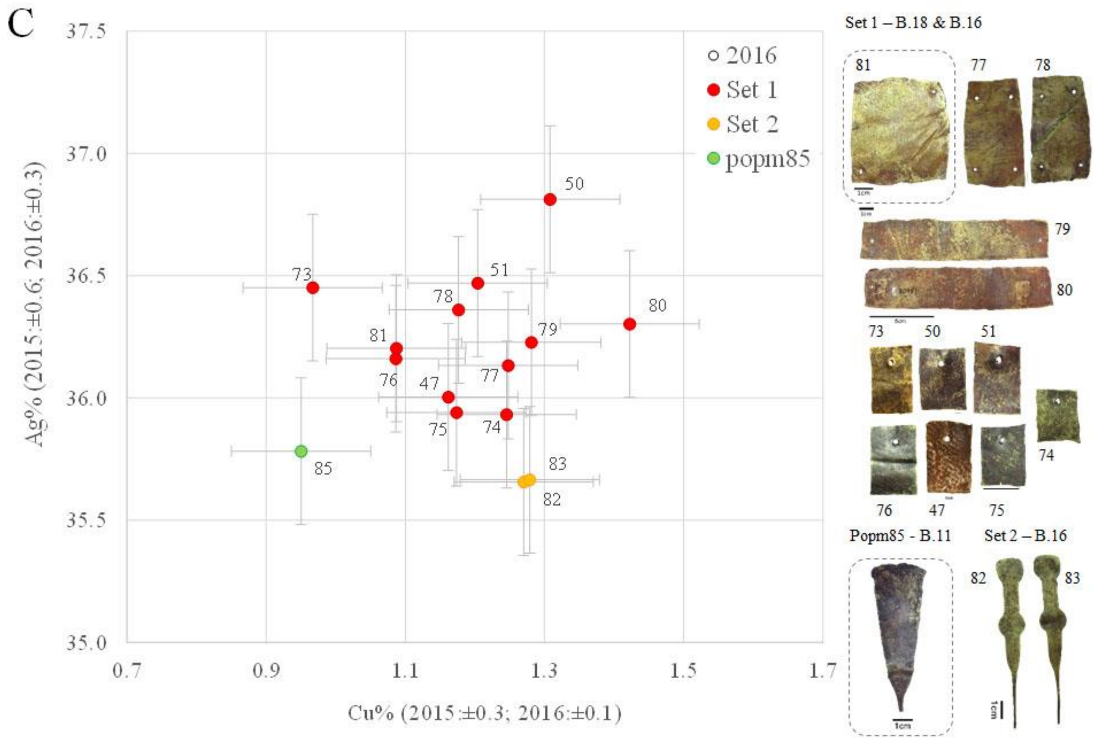
In this section, manufacturing traits will be organised in technological clusters that I will name "sets" to avoid confusion with the chemical clusters of chapter 5, these "sets" encompass artefacts that share identical manufacturing traits, to better understand their distribution and occurrence within the cemeteries and between burials. They will be presented with their chemical compositions, making the link with the chemical clusters identified in the previous chapter, to explore the potential presence and implication of batches and production groups.

6.6.1 Casa Parroquial (“CP”)

Both finely and coarsely-made items are present in CP. The former include 21% of the total assemblage with three goblets, three headdresses, and a ring (popm84,86-88,139-141); and the latter, 59%, comprise three headdresses, a headband of two parts, a ring and 14 attachments and pendants (popm1,10,17-18,47,50-51,73-83,85,89). Interestingly, their compositions group nicely showing that finely-made grave goods are all made of unalloyed native gold (<30%Ag), whereas the coarse-made objects are artificial gold-silver alloys (≥30%Ag, Figure 110:A). Overall, 20 of 34 artefacts were modified, presumably in CP, including both finely and coarsely-made items.

Figure 110: Casa Parroquial chemical compositions.
A- Au-Ag-Cu ternary diagram showing the composition of finely and coarsely-made artefacts. B- Scatter plot showing the composition and objects of different sets discussed in the text; C- Detail of sets 1, 2 and popm85. Dotted lines in the images separate objects from different burials in the same set.





Regarding manufacture, five sets of objects were shaped using the same techniques. In four of them, the technological attributes were identical suggesting the work of a single artisan. All are coarsely-made, so a relatively low skill is assumed compared to other finely-made objects (Gosselain, 2000; Leusch et al., 2015; Martinón-Torres & Uribe, 2015; Wendrich, 2012a). The fifth set is less clear, given that objects have only few visible technological traits. Still, considering typology and the good quality of the work, they could represent a production group.

Set 1: Pendants and attachments popm47/50-51/73-80, from B.16 and popm81 from B.18 (Figure 104:B-E). These 12 ornaments have different shapes, but their manufacturing techniques are identical. The forging technique produced a smooth surface at one side (no visible polish marks) and a slightly rough texture at the opposite side. The designs were outlined first (visible guide marks) and then cut unevenly by sliding a blade (Figure 111:E-I). The pendants were then perforated (one clean strike), using a pointy tool of circular section and the burrs were left untreated (Figure 111:A-D). Perforations and edges are unpolished and remarkably fresh, except for a few borders with evidence of wear. The similarity and consistency between the marks is remarkable, suggesting the work of a single person. Chemically, the whole set plots in a tight cluster (Figure 110:C), which together with the manufacturing traits, suggest that set 1 is the product of an individual melting event, coming from an single metal load and worked by an individual artisan.

Set 2: Also from B.16, headdresses popm82-83 shared identical design and were forged probably following a template (Section 6.3.1.2.2, Figure 75). The edges were trimmed and coarsely polished; the surface was left unpolished. The appendices were hammered and vertically compressed. Overall, the objects are worn, no fresh marks are visible. Given that both headdresses share the same composition (Figure 110:C, plotting together with set 1) and manufacturing techniques, it is reasonable to propose that they represent a batch, made with metal of a single casting event and shaped by an individual artisan.

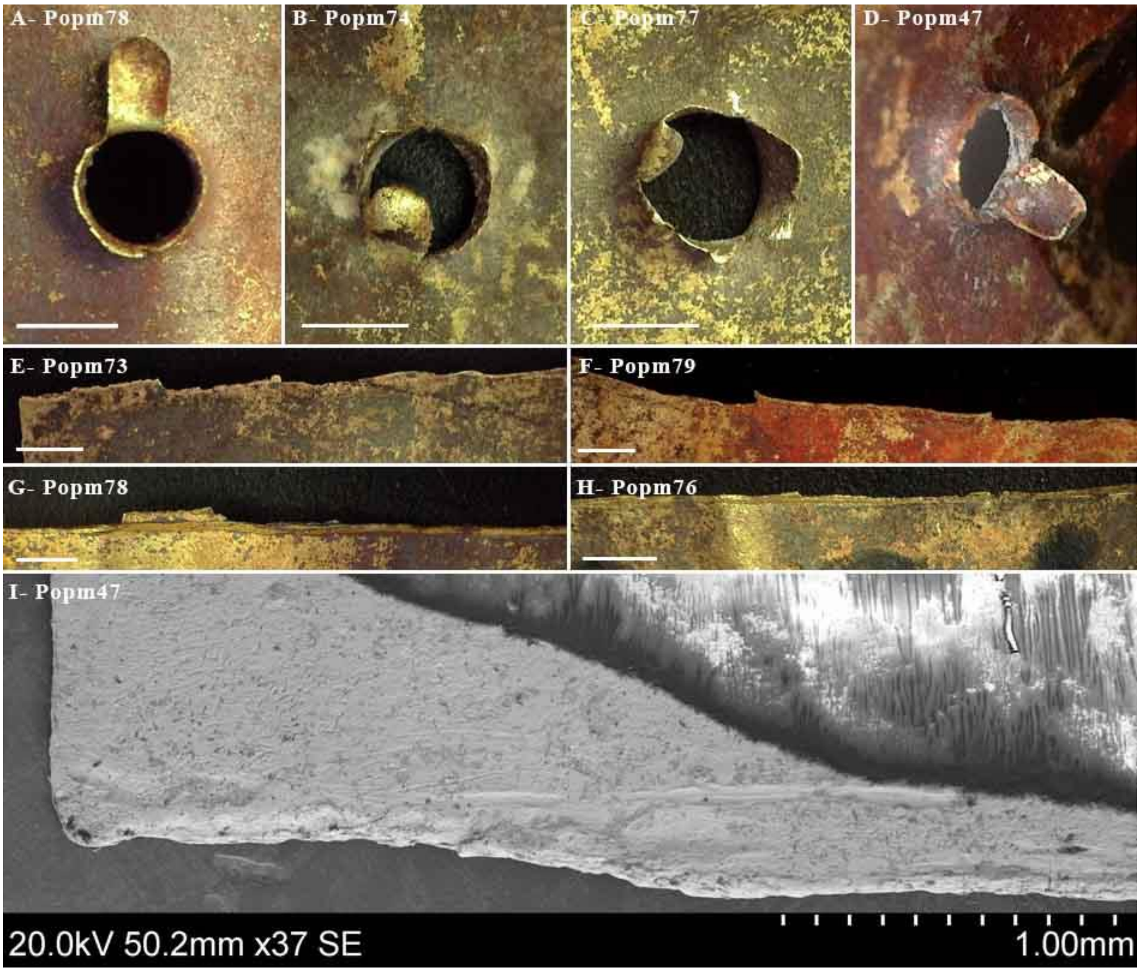


Figure 111: Manufacturing details in set 1

Set 3: From B.18, includes headbands popm17-18. These two items were folded, hammered and cut, following a unique sequence within the total assemblage. This technique is rather rare, and I have not found so far references of something similar. The instrument used to perforate the ends and cut some edges left similar marks to those seen in pendants of set 1. Maybe, these headbands were shaped using the same techniques as set 1, but the evidence is not enough to be certain (Figure 85). The composition of both headbands is identical, suggesting that they are the product of a single production event (Figure 110:B).

Set 4: Comprises two pendants popm1/10, from B.8. Their hammering marks, surface treatment and perforations are the same. There are three small perforations interpreted as repairs that connect both parts (Figure 108:D). These objects have evidence of wear, reflected in their smooth edges and the possible fracture that was repaired. Their compositions are similar (Figure 110:B), but as a chemical group this is less tight than previous sets.

Set 5: Includes headdresses popm84 and popm86 from B.22 and popm87 from B.13 (Figure 107:A and 108:C). It is proposed here that popm84/86 were originally part of a four-appendix headdress that was broken into pieces (Figure 106); and that popm86 was modified later (see section 6.3.6). The original headdress would have been carefully forged, cut and ground, producing even and straight edges that were meticulously polished, together with both surfaces. Identical technical features are seen in popm87[16]. The visible perforations in popm87 reveal a careful work, made by cutting and pushing through the surface and flattening the burrs. This set includes two different compositions (Figure 110:B), one for popm84/86 and other for popm87. In this case, the manufacturing traits are not strong enough to identify specific "hands", but they do share a general way of working, relatively more skill and a better quality, compared to sets 1-4.

6.6.2 Larache

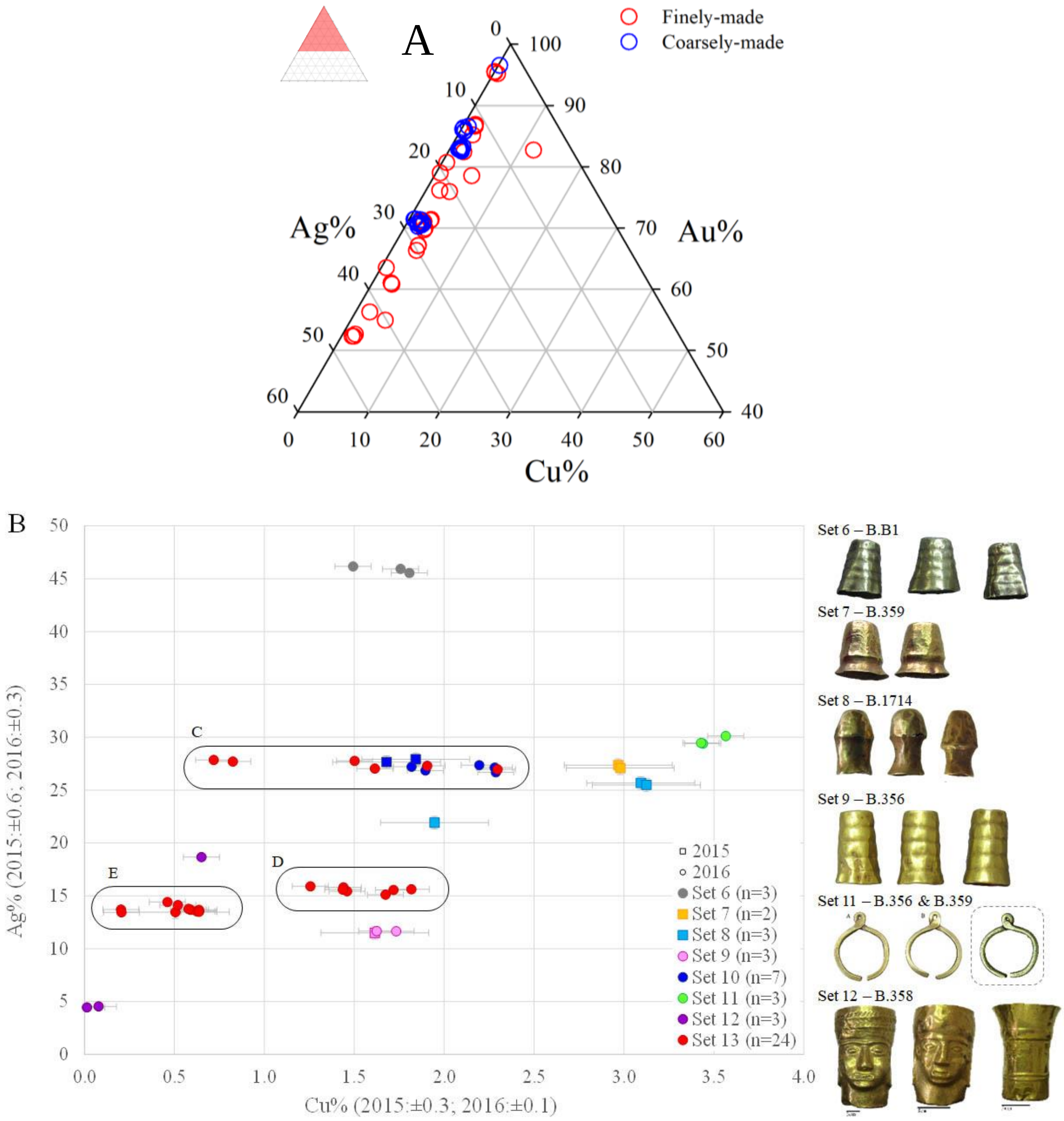
Most grave goods (55%) in Larache are finely-made using a range of different compositions, whereas 40% are coarsely-made items made of unalloyed natural gold (Figure 112:A). Modified objects are small in number, representing a 16% (10 of 62), but affecting finely and coarsely-made artefacts.

Regarding manufacture, eight technological sets were identified in Larache, using the same technological traits and skill. Sets 6-10 are finely-made bells, where each set shared identical designs (truncated cone), dimensions (1-3cm), manufacturing (raising), decoration techniques (bands or neck) and composition (Figure 112:B-C) suggesting the work of a single skilled craftsman, working with gold from an individual metal stock to produce a coherent and consistent batch. However, the five sets are different, suggesting that more than one artisan were raising bells. This pattern, characteristic from Larache, is observed in B.356, B.359, B.Body-1, B.Body-2 and possibly B.1714.

[16] In fact, the texture, colour and aspect of the three items (popm84, 86 and 87) is so similar that during the macroscopic analysis, it was thought that popm84 and 86 were the missing appendices of popm87, but the different compositions ruled out that option.

Set 11 includes three finely-made wire-rings found in B.356 and B.359 (popm103-105, Figure 65-67). These rings were made following the same technological sequence, but there they differ in some specific technical attributes, such as the side used to create the loop, or the fineness of the finishing treatments producing a slight quality difference between popm103 and popm104-105 (see section 6.3.1.1.2 above). These differences are very subtle and may reveal unconscious motor habits and different skill degrees between two people following the same sequence (Costin, 1991; Martinón-Torres & Uribe, 2015; Whittaker, 1987), but working with metal from a single casting event (Figure 112:B).

Figure 112: Larache chemical compositions.
A- Au-Ag-Cu ternary diagram showing the composition of finely and coarsely-made artefacts. B-D- Scatter plot showing compositions of different sets discussed in the text. Images of the three batches in set 13 (B-D) are given in Figure 113 below.



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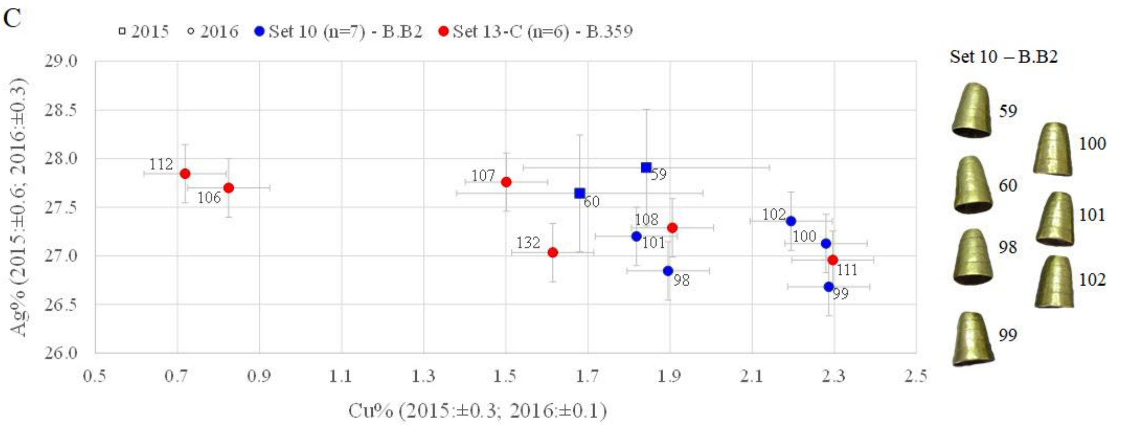
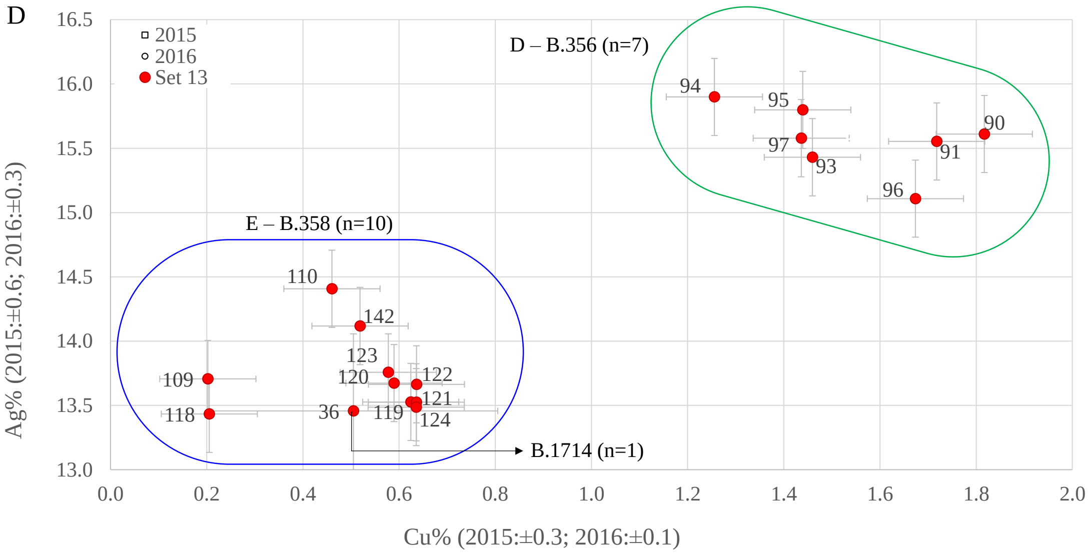




Set 12 comprises the three finely-made goblets from B.358 (popm136/137/138; Figure 70:B). As proposed in section 6.3.5, these objects were made by raising and chasing. In particular, the portrait vessels are remarkably similar in the shaping techniques employed, the inclination of the body and the design of the faces, including specific details such as the eyes, mouth, eyebrows and hat. Still, they differ in the shaping of the ears, the retouching of the facial features and the modelling of the bases (Figure 103). Given the similarities and subtle differences in their manufacture, it is possible that these portrait-vessels were made by two people following the same sequence, but showing different skill and dexterity. Additionally, compositions were different between the portrait-vessels (Figure 112:B), indicating that the metal used was produced in different casting events. Included in the same set is *kero* popm136, which has a different design but shares the same composition, quality and type of base with portrait-vessel popm137. It is possible that both popm136 and popm137 represent a batch made by the same artisan using metal from the same casting event, yet the evidence is not conclusive.

Set 13 comprises 24 coarsely-made pendants, attachments and headbands, distributed in B.356, B.358, B.359 and B.1714. Technologically speaking, they all look alike in shapes and manufacturing techniques. When looking at them in more detail, it was possible to observe that the hammering marks and surface treatment were the same in all pendants (Figure 62), but the cuts and perforations (Figure 81:1-4) combine three technological variations, that were alternated between the objects of the three burials, suggesting the work of more than one person. More specifically (Figure 113):

a) The seven ornaments in B.356 were cut and perforated with the same tools and techniques, although the surface treatment appear more polished than the objects from the other burials. Similar perforations were employed in popm111, popm132 from B.359 and popm109 in B.358.
b) The objects in B.1714 (n=1), B.358 (n=10) and B.359 (n=6) share the same cuts, perforations and surface treatment. However, they combined three types of perforations, three types cutting techniques for the edges, all of different qualities. All the ornaments, except two, present the same surface treatment: compressing a hard tool (e.g. stone) on the surface but still leaving visible hammer marks. Popm36 from B.1714 has evidence of heavy wear on edges and surface.

The distribution above suggests that the seven ornaments in burial 356 may represent the creation of a single person; whereas the ornaments in burial 358 and 359 are presumably the outputs of a group of artisans working in parallel, probably three craftspeople (Costin, 1991; Costin & Hagstrum, 1995; Wendrich, 2012b). Since hammering marks are consistent in all objects, compared to cuts and perforations that show different qualities reflecting most likely different skill levels, it is possible that there was one maker in charge of forging, and the shaping was a concurrent work of a small group of artisans. Considering compositions, they were divided in three tight clusters (Figure 112:B-D), one specific composition in each burial and were not mixed, pointing to the production of three independent batches, but made by the same group of artisans forming a characteristic production group. Most manufacturing marks were fresh, showing no use-wear, which could suggest that these objects were made locally in SPA, as it will be discussed later.

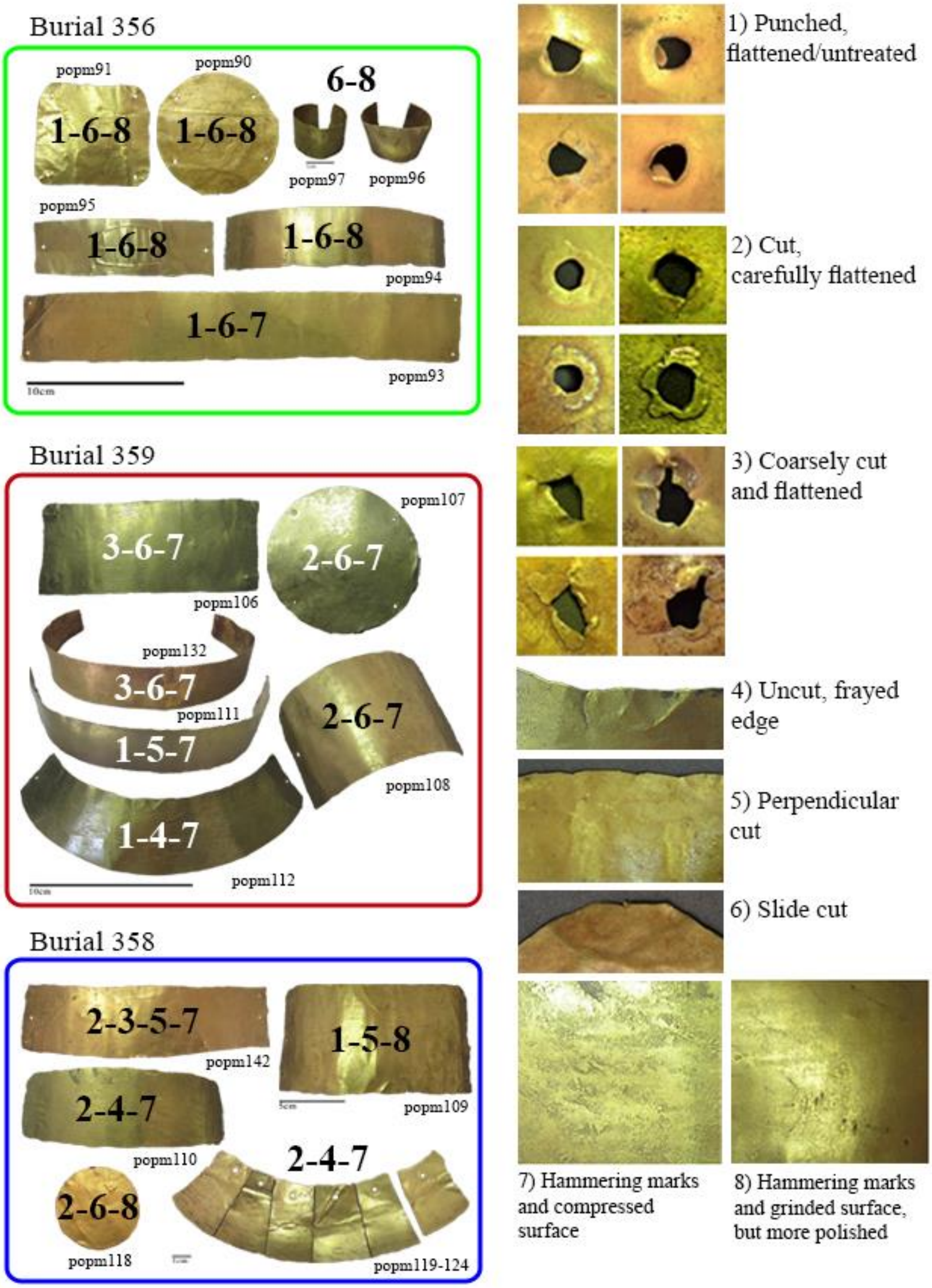


Figure 113: Manufacturing techniques of set 13, burials 356, 358 and 359 from Larache. The numbers in the objects indicate the combination of techniques in each item. Each bundle grouped in the rectangles, is made of a specific composition (see Figure 112:B-D).

6.6.3 Quitor-1 and Coyo-3

In Quitor-1, all precious metals were coarsely-made objects made of artificial gold-silver alloys, and only one object was modified (Figure 114:A). In this site, two technological sets are identified, which are technologically and compositionally coherent as a group, suggesting the work of a single person: set 14 with two small bands (popm5/48, their burial number is unknown), and set 15 with seven ornaments (rings, bells, headbands, popm32-34/37/150-152) from B.889. Similarly, in Coyo-3 all objects were coarsely-made using silver, except for the finely-made disc popm52 made of *tumbaga* (B.35). The only technological set identified (set 16) is a series of small discs with the same form that were shaped using perpendicular cuts, associated to B.35 and B.6. The composition of the three sets appear in tight clusters; still the analysis of silver objects cannot be used in much detail, given that they were heavily corroded (Figure 114:B).

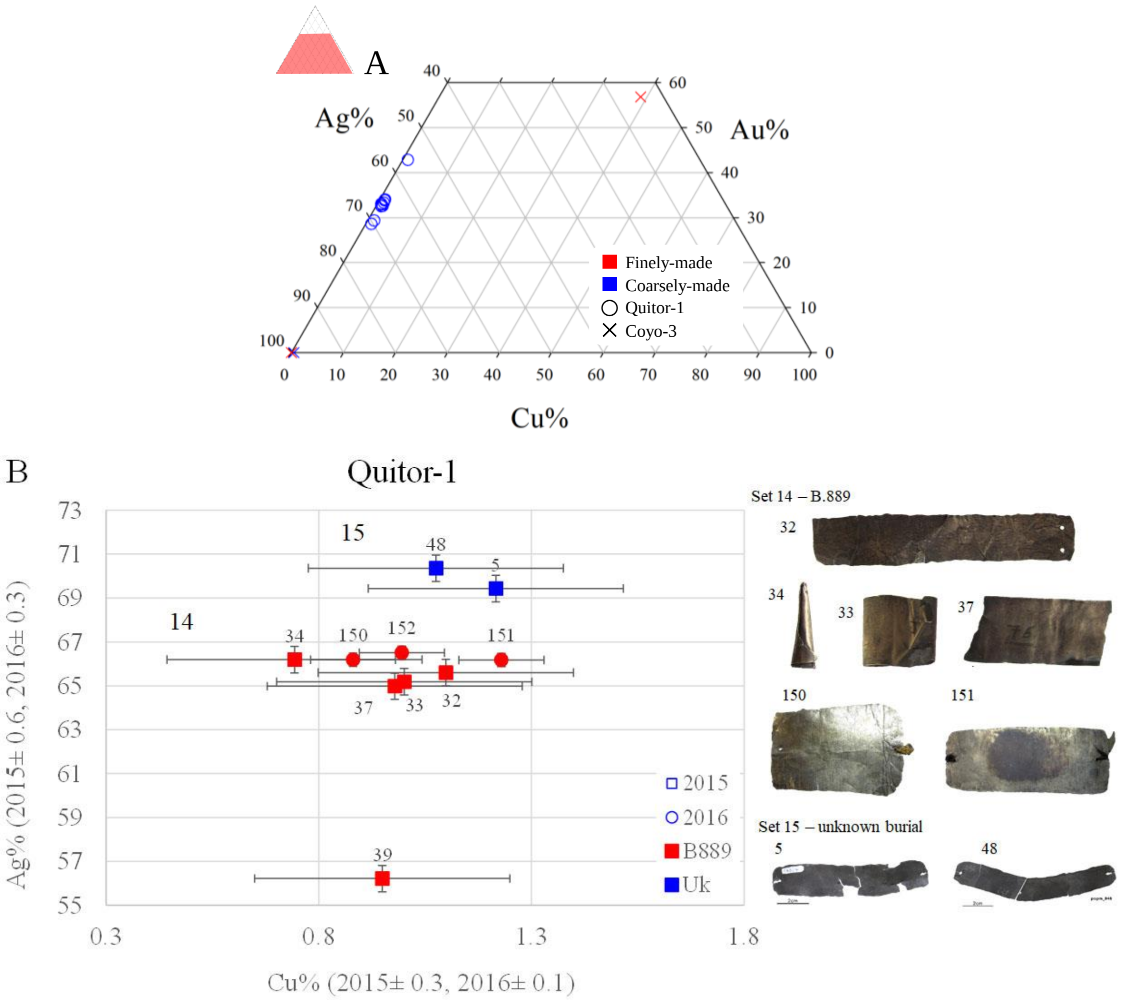


Figure 114: Quitor-1 and Coyo-3.
A- Au-Ag-Cu ternary diagrams showing the composition of finely and coarsely-made artefacts. B- Compositions of different sets discussed in the text.

6.6.4 Discussion: Batches and production groups

The integration of the chemical and technological information, together with the designs, decoration and their contextual distribution of the objects, has allowed to identify interesting situations regarding the production and deposition of the gold items found in SPA, revealing as well different ways in which gold would have been worked during the Middle Period. It was possible to detect a series of batches, production groups and other situations that are relevant because they inform us about a) the artisanal practices, identifying individual artisans and groups of craftsmen working these precious metals with different skill levels; and b) give us a better understanding of how these objects -or bundle of objects- circulated and were acquired.

6.6.4.1 Individual artisans and groups of craftsmen

In SPA there are, at least, nine cases where chemical and technological evidence corresponded, supporting the hypothesis of the work of a single artisan (Table 32). These cases include batches of 2-7 objects, made of the same metal, using the same manufacturing sequence and techniques, as shown in Figure 115:A. They include seven ornaments in B.889 and two bands of unknown burial in Quitor-1 (sets 14-15), sets 6-10 of bells in B.Body-1, B.Body-2, B.1714, B.356 and B.359 from Larache; and a pair of pendants in B.8 and headbands in B.18 from Casa Parroquial (sets 3-4). The consistency seen in the metal used, the way of shaping, cutting, perforating and decorating; together with the design of the objects, would represent the work of individuals with idiosyncratic techniques and skills, producing sets of objects that were acquired and deposited together in the same burial. Between the groups, conical-bells reveal the highest proficiency level, specifically seen in their small size and great standardisation within each set, suggesting the presence of artisans with high levels of experience and skill; compared to the headbands or pendants from Quitor-1 or Casa Parroquial which are much coarser and irregular in their make.

In four groups of objects, the combination of techniques would suggest the participation of more than one person in their making (Table 32), identifying production groups as defined in chapter 3 (*sensu* Costin, 1991). In these cases, objects were made either by using the metal of one, two or three melting events, but following the same technological sequence. In these examples though, manufacturing traits show subtle differences that would represent different "attributes of execution" or unconscious motor habits as defined by Whittaker (1987), that would indicate the work of different people (see also Costin & Hagstrum, 1995); in three cases, the resulting sets were deposited in more than one burial (Figure 115:B-E).

	Objects	Chemical clusters	Technological sets	Cemetery	Burial	Id, popm_
1	2 headbands	1	3	CP	18	17-18
2	2 pendants	3	4	CP	8	1, 10
3	3 bells	7	6	Larache	Body1	145-147
4	2 bells	10	7	Larache	359	61-62
5	2 bells	11	8	Larache	1714	64-65
6	3 bells	14	9	Larache	356	58, 115-116
7	7 bells	12	10	Larache	Body2	59-60,98-102
8	7 ornaments	18	15	Quitor-1	889	32-34, 37, 150-152
9	2 attachments	19	14	Quitor-1	no burial	5, 48
10	3 goblets	16, 20	12(+)	Larache	358	137-138
11	3 wire-rings	9	11(+)	Larache	356, 359	103-105
12	3 headdresses	5, 6	5	CP	13, 22	84, 86, 87
13	24 ornaments	13, 15, 12 (17)	13(+)	Larache	356, 358, 359, 1714	36, 90-91, 93-97, 106-112, 119-124, 132, 142
14	15 ornaments	4	1, 2	CP	11, 16, 18	47, 50-51, 73-85

Table 32: Correspondence table between chemical clusters identified in chapter 5 and technological sets presented above.
CP: Casa Parroquial. Symbol (+) identifies technologies were the work of more than one "hand" was identified.

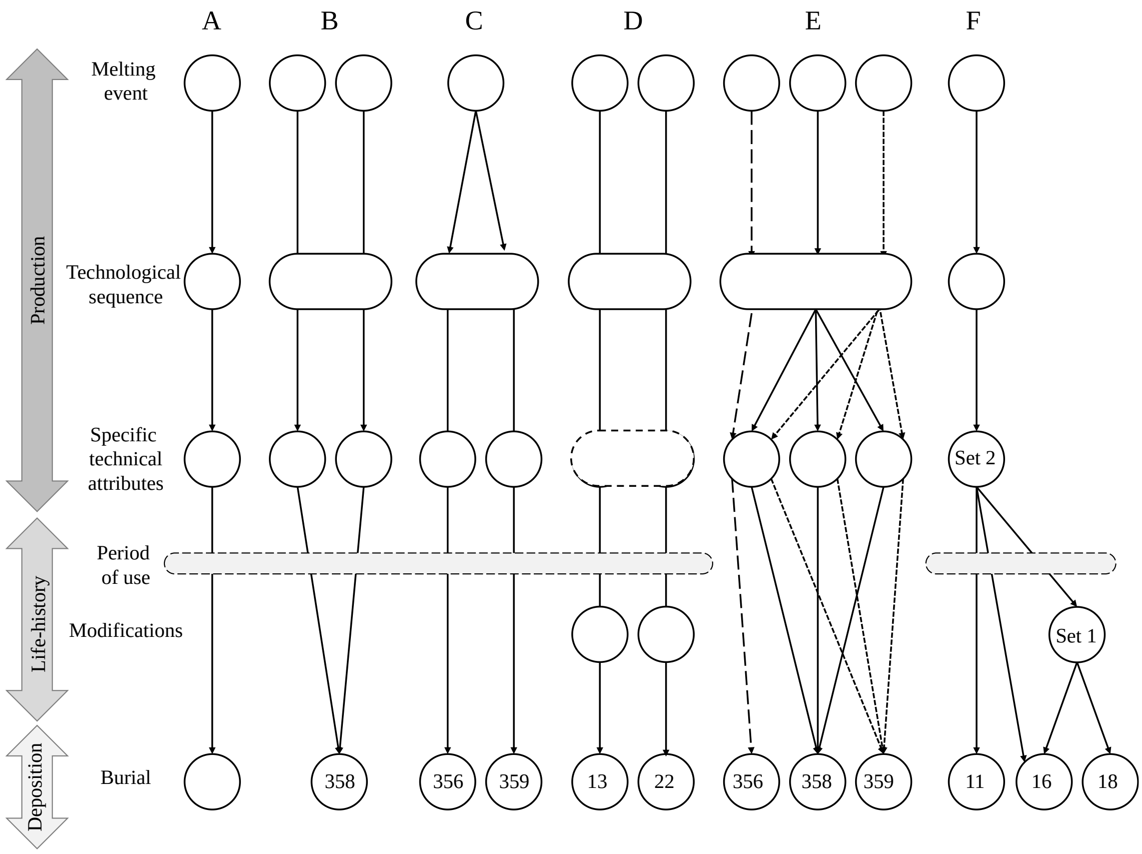


Figure 115: Diagram of the chaîne opératoire showing the production, life-history (consumption) and deposition of different sets of objects from SPA.
It identifies the work of individual artisans (A, F) and groups of craftsmen (B-E). Dotted ellipse in D, indicates that specific technological attributes are unclear. In case E, objects do not show evidence of use.

The first two examples are set 12 with three goblets in B.358 (Figure 115:B) and set 11 with three wire-rings in B.356 and B.359 (Figure 115:C), all from Larache. Based on the descriptions given above, it is possible to recognise enough similarities and differences to propose that the goblets (section 6.3.5) and wire-rings were made by more than one person (section 6.3.1.1.2), but following an identical technological sequence. Namely, an artisan would have made goblet popm138, and other made 136 and 137; each artisan working with their own metal. Similarly, wire-rings popm104-105 were made by the same craftsman and popm103 by another, all of them however, using the same metal stock. These examples include artefacts that show different quality in the details, but are similar in their shape and forming technology. Given the similarity of the objects, it is clear that specific details were passed, shared and presumably learnt between artisans, which would suggest the work of groups of specialists or workshops, where people are actively sharing techniques or are subjected to a formal or more controlled training (Costin, 1991, 2005; Costin & Hagstrum, 1995; Creese, 2012; Wallaert, 2012; Wendrich, 2012b, 2012a).

Similarly, but less certain, is set 5, which is composed of headdresses popm84/86 and popm87 in B.13 and B.22 from Casa Parroquial (Figure 115:D). These items are the two headdresses with appendices, which were cut and modified. The original ornaments would have been carefully forged, cut and ground, producing even and straight edges that were meticulously polished, together with both surfaces, showing high quality work. The thorough finishing treatment deleted all manufacturing traits, making impossible to identify particular "hands", but they do share a general workstyle. When compared with a similar headdress found in the NWA (Goretti, 2012; see next chaper 7, Figure 141), especially popm87, they share several technological details, such as the location and technique used for the perforations, as well as the shape, the surface treatment and the treatment of the cuts (grinded and polished). The similitude of all these ornaments and the proficiency of their making may suggest the existence of a specialised artisan or workshop producing complex and high-quality gold items, but using different types of gold. Their good quality however, did not prevent their modification and re-use in SPA.

The fourth example includes set 13 (Figure 113), of 24 coarse-made ornaments distributed in B.356, B.358 and B.359 from Larache (Figure 115:E). This is a production group composed of three batches. Each batch has their particular composition, but they follow the same technological sequence to make very similar ornaments. The combination of three different techniques to perforate and cut, showing different qualities and skill levels would suggest that artisans were part of the same "community of practice", i.e. a group of craftsmen sharing their knowledge and practicing together

(Wendrich, 2012a), possibly as an independent workshop (Costin & Hagstrum, 1995); but not necessarily under a formal training scheme, as proposed for the goblets or wire-rings. The quality of the work would indicate relatively low skill, compared to the finely-made objects described before. In terms of raw material, they have access to more than one type of gold, which was used in discrete melting events for each set (Figure 112:B-D). The batches may represent independent commissions produced at different times; or a production by units, making a complete set for each casting event (for a sophisticated example from China see Martinón-Torres et al., 2011, 2014). It is noteworthy that the chemical and technical connections between these three burials, both in the case of set 13, as well as the wire-rings. These technological connections certainly reveal close relationship between the individuals, a man and two women, that future DNA analysis would help to clarify.

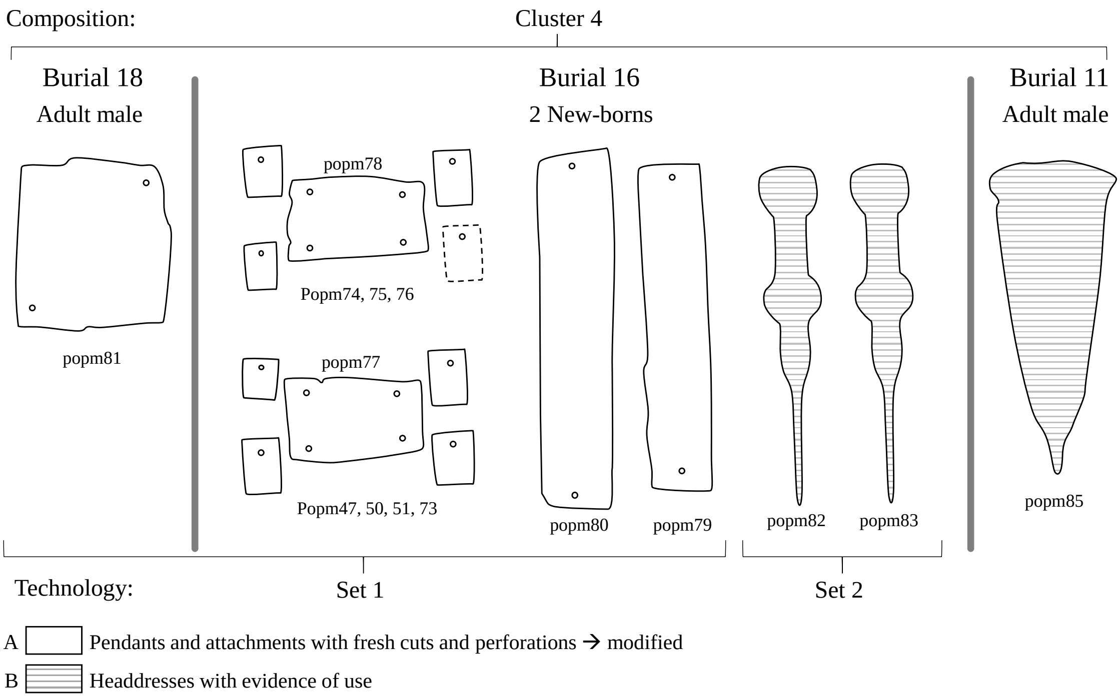


Figure 116: Sets 1, 2 and popm85 from Casa Parroquial

The last case includes 15 objects from Casa Parroquial deposited in three different burials: B.11, B.16 and B.18 (Table 32, Figure 115:F). This is a very interesting case where a later modification is identified, and the association between objects is inferred from their identical composition and specific manufacturing traits, present in more than one burial. This group is composed of sets 1 and 2, both coarsely-made (Figure 116). The main difference between both is that set 1 has fresh cut and perforation marks, whereas headdresses in set 2 are used and worn. These two sets share identical composition, which is also identical to a third headdress popm85 (Figure 110:C).

Headdress popm85 shares the hammer marks and surface treatment of set 1, but it has clear evidence of use (worn edges and surface) as objects in set 2. In terms of distribution, 11 of 12 ornaments from set 1 and both headdresses from set 2 are found in B.16, deposited with two new-borns. These objects form two identical bundles composed of a headdress, a long band, a rectangular attachment and four small pendants (Figure 116). Popm81, also from set 1, is a square attachment deposited in B.18, of a male adult; and popm85 is a headdress found in B.11, also a male adult.

Considering that a) set 1 have identical and fresh manufacture marks -except for some worn borders-, and both set 2 and popm85 have evidence of wear; b) the forging technique used on set 1 is similar to popm85; c) the combination of both working styles in burial 16; and d) the identical composition of all items. I propose that the 15 items do *not* represent a typical production group, understood as a group of objects made together by a particular group of craftsmen sharing a tradition (Costin, 1991, p. 33); alternatively, I believe they represent a batch of objects that was modified at some point of its life. In other words, they are a set of objects made together from a single metal stock that were subsequently used as ornaments, but at some point of the objects' life-histories part of the batch was modified to create new ornaments. Based on this, it is proposed that the original group comprised -at least- four items, including set 2 and popm85, where a fourth item (e.g. a sheet forged as popm85) was modified and cut into 12 pieces (i.e., set 1) to create specific grave goods for the new-borns. Set 1 in this case, would be the product of a single artisan (identical techniques), and given their fresh manufacturing marks, the work was completed just before the ornaments were deposited as offerings (see also Figure 170).

6.6.4.2 Considering the batches: not much gold after all

The batches identified above are interesting for several reasons. Firstly, they indicate that overall, the presence of 142 objects can be collapsed into a much smaller number of production events, indicating that several artefacts arrived to SPA as sets. This would reveal a more limited circulation of gold objects in SPA, especially those made of artificial alloys. Secondly, these batches give us a better idea of how precious metal objects were acquired in the past.

In the first case, the 34 objects from CP can be grouped in 15 metallurgical events. Artificial alloys represented in 18 artefacts (53% of the site assemblage) can be collapsed into three or four single metallurgical events, meaning that artificial alloys are not common within the site, compared to the larger number of natural alloys present in 16 artefacts (47%), and reduced to a maximum of 11 metallurgical events. In Larache, the 62 objects were grouped in 22 metallurgical events. Gold-silver artificial alloys are reduced from nine artefacts, to six events; whereas the use of unalloyed gold grouped 52 artefacts in 15 production events. In Quitor-1, the 10 ornaments are gold-silver alloys, however their production can be reduced to three metallurgical events. No batches are identified in the remaining cemeteries (Quitor-5, Coyo-3, Sequitor Alambrado, Soclor-3), except the pair of tips in Solcor-3 (and possibly the small discs in Coyo-3), but most items were made of unalloyed gold alloys (n=9), compared to four artificial alloys.

In terms of weight, the heaviest batch identified is the set of two goblets from Larache (popm136-137, see above) with 462gr of gold, followed by the coarsely-made set 13 from B.359 weighing 200gr (6 items), B.358 with 140gr (11 items), and B.356 with 64gr (7 items, see set 13). In the case of set 13, it is interesting to note how with such different amounts of metal, artisans were able to make very similar sets of objects. In CP, the batch of popm17-18 was 72gr, whereas the bundle of 15 pendants and attachments (set 1, 2 and popm85, see above) is 34gr.

Overall, 130 objects (excluding objects with unknown sites) can be reduced to 57 metallurgical events, where unalloyed gold is used in 61% of the assemblage, artificial gold-silver alloys in 25%, *tumbaga* in 7% and pure silver in 7%. Although we should remember that silver objects are underrepresented given their low archaeological durability and curatorial practices that have prioritised gold. Therefore, based on the composition of individual objects and batches, in SPA most of the assemblage was made using unalloyed gold with diverse silver and copper levels, compared to a smaller proportion of artificial gold-silver alloys; whereas the occurrence of *tumbaga* objects appears almost incidental.

The distribution of the batches within each cemetery sheds light not only on the making process of these artefacts, but also on their acquisition (Freestone et al., 2009). In CP, almost each batch was deposited in a single burial, suggesting that these items were made at the same time and acquired together in a specific moment. Having this in mind, it is noteworthy that 50% of the burials with noble metal grave goods in CP (n=5) have only one gold item, which would potentially mean one act of acquisition. However, if the batches are considered instead of the number of ornaments, burial 22, 16 and 8 would also represent a single acquisition act, in spite of the larger number of objects. Consequently, it appears that in CP the access to gold was relatively limited, in the sense that most individuals with noble metals (8/10, 80%), despite the number of gold artefacts, obtained their gold ornaments in a single opportunity (note that of the 22 bodies excavated in CP, only 10 had gold grave goods, therefore gold was not used by all members of the community, as it will be explained in chapter 9). The only exception is individual B18, who shows a compositional and typological heterogeneity, indicating that each object (6 in total) was made of different types of gold, probably from different origins and at different times (not as sets). Most likely, these items were acquired during the life of the individual either as gifts or by exchange (see further discussion in chapter 10).

In Larache the distribution is inverted. There are two burials (B.B1 and B.B2) with sets of mono-component gold grave goods, indicating one act of acquisition; whereas the other four burials analysed (B.356, B.358. B.359., B.1714) contain sets and single objects of different compositions, which would imply multiple acts of acquisition, probably from different producers and gathered throughout the lives of the individuals. The presence of varied styles and differential evidence of use within the assemblages of each burial would support this proposal (e.g. the coarsely-made ornaments and finely-made goblets in B.358, both sets with very different manufacturing styles). Consequently, and contrarily to CP, most individuals in Larache apparently had multiple opportunities to gather or receive gold artefacts used as grave goods (although the acquisition of several objects from different producers at the same time may still be an option).

6.7 Final summary

In this chapter, the manufacturing techniques of the assemblage has been analysed and discussed. The main findings are summarised as follows:

First, all objects in SPA belong to a general tradition of sheet production (except axe popm49), using hammering, annealing, cutting and punching to produce thin and light objects. However, within this tradition objects show a variety of techniques, different qualities and care in details (e.g. finely-made and coarsely-made); suggesting that these objects were made by multiple producers with different skill and levels of specialisation. The latter, together with the virtual absence of local metallurgical remains related to gold or silver production, suggest that most items were imported to SPA as finished objects.

Secondly, several objects show relatively long life-histories of intensive use and later modifications or repairs. Overall, the techniques used (e.g. slide cutting and perforating by cutting and punching) and the quality (coarse) are very similar in all modified items, with a few exceptions; in almost all cases modifications left fresh marks. These items appear in almost every cemetery (5/7), comprise both finely- and coarsely-made items and in most cases were deposited in groups. The tools necessary for these changes are chisels, punches, hammers and anvils.

Third, the analysis by sites and burials produced interesting results regarding by who and how some of the ornaments were made. In the case of Casa Parroquial, Larache and Quitor-1, the combination of specific manufacturing techniques, their quality and composition has revealed different scenarios where the work of individual artisans or groups of artisans of different skill and dexterity can be recognised.

Fourth, the existence of batches within cemeteries points towards a production based in part on single metallurgical events generating sets of ornaments that were acquired by particular individuals. At the same time, the results highlight that overall, in a span of *ca.* 500 years, these production events were irregular and probably intermittent, resulting in a few acquisition events (for reference: 57 production events in 600 years = one every 11 years).

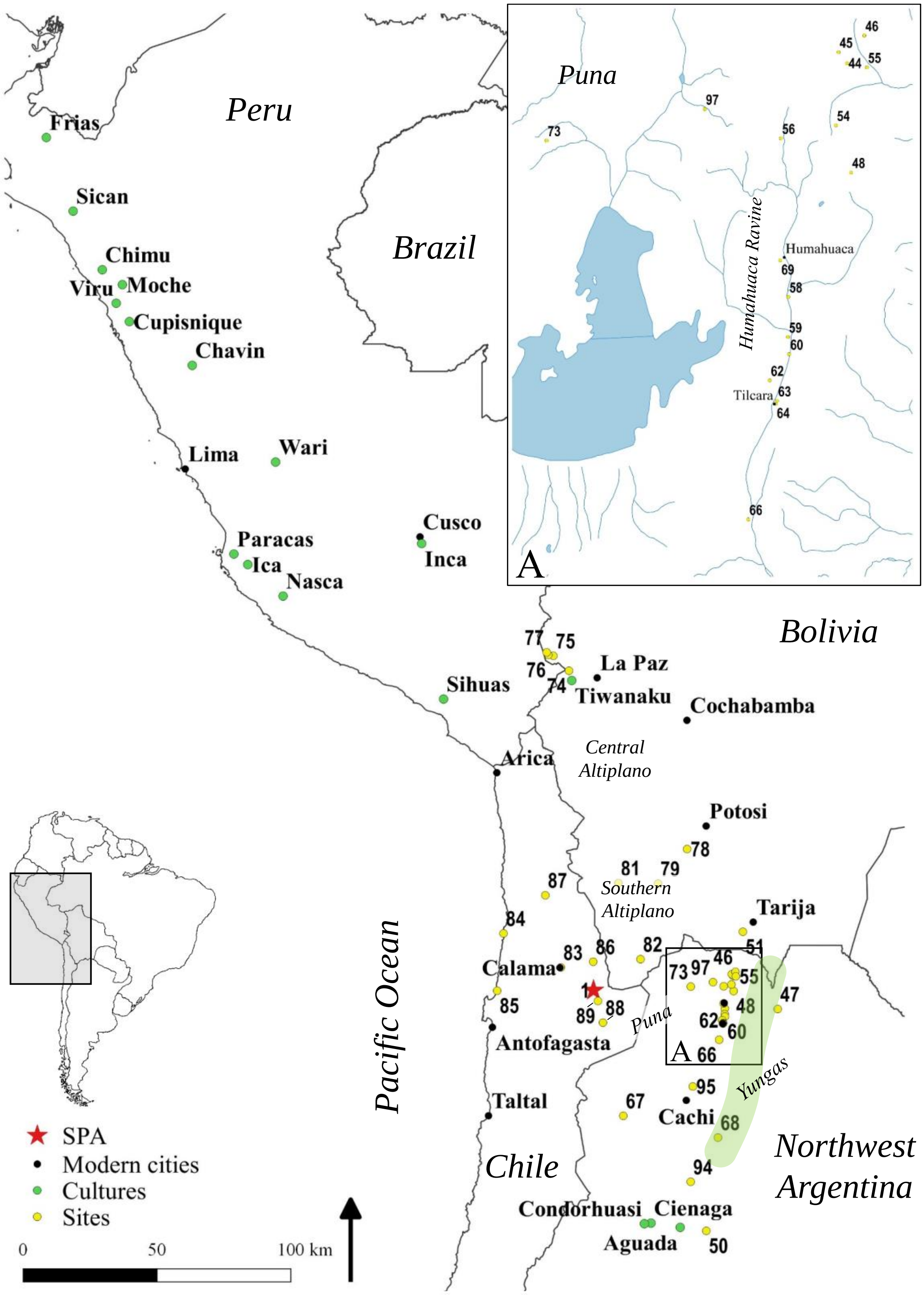
Fifth, the distribution of the batches are different between cemeteries, which are reflecting different conditions and probably different access to gold. For instance, people in CP have a few gold items per burial being mainly mono-component, reflecting only one manufacture and acquisition act. The only exception is the male adult in burial 18, which contains a range of different gold alloys. In contrast, individuals from Larache contain more grave goods, and in most cases combining different compositions and manufacturing techniques, suggesting that grave goods were acquired in several opportunities.

Chapter 7. Comparative material from the Central and South Central Andes

This chapter focuses on comparing the evidence obtained from SPA with other gold and silver objects from the SCA (Figure 117), concerning their chemical composition and manufacturing techniques. The sample gathered includes published data, as well as analyses made by myself during the course of this research. Several museums were visited, and online catalogues were used too, a full list of the institutions is given in Appendix Nº3: 8. It was possible to collect 460 chemical analyses and study the manufacture of 109 objects (plus published images).

In previous sections it was proposed that objects from SPA came from elsewhere. I will show here that most likely candidates are NWA and Tiwanaku. Further, evidence would suggest that objects from the southern *Altiplano* (Lipez), Cochabamba and maybe Nasca were also imported and used in SPA.

In section 7.1 the chemical composition of gold and silver objects from SPA, Central Andes ("CA") and SCA is compared. Section 7.2 synthesises the analysis of objects from Bolivia (7.2.1), NWA (7.2.2) and northern Chile (7.2.3), recognising their main manufacture traits. These findings are discussed in section 7.3, identifying SPA objects made with technologies that appear to derive from NWA (7.3.1.1), Tiwanaku (7.3.1.2) and the southern *Altiplano* (7.3.1.3). Section 7.4 discusses the differences between SPA cemeteries, based on their relation with other areas. A final summary is given in section 7.5.



1 SPA	56 PV de la Cueva	69 Los Amarillos	83 Chorrillos cemetery
44 Rodeo Colorado	58 Muyuna	73 Doncellas	84 Urco cove
45 Molino Viejo	59 San Jose	74 Pariti island	85 Hornitos-1
46 Cuesta Azul	60 Huacalera	75 Moon Island	86 Caspana
47 Manuel Elordi-1	62 Juella	76 Sun Island	87 Guatacondo
48 Co Morado	63 La Isla de Tilcara	77 Khoa Island	88 Tulan-54
50 Yaminas-1	64 Malka	78 Yura	89 Yona-2
51 Tolomosa	66 Pucara de Volcan	79 Cobrizos	94 Rincon Chico
54 Titiconte	67 Tebenquiche	81 Colcha K	95 Potrero de Payogasta
55 Huayra Huasi	68 Pampa Grande	82 Sud Lipez	97 Tabladitas

Figure 117: Map of the Central and South Central Andes showing the sites and cultural groups mentioned in this chapter.

7.1 Chemical composition

In this section, I explore how the compositions of SPA materials compare to gold and silver assemblages from the Central and South Central Andes, including objects from Peru (n=229), Bolivian *Altiplano* (n=69), NWA (n=120) and northern Chile (n=42; Figure 117). In total, 460 analysis were gathered (155 analysis were performed by the author and 305 were published material, see Appendix Nº3: 9-10) and compared to the 145 analysis from SPA. The 605 analyses reflect the composition of 927 objects, given that some figures are the average of several objects (e.g. Sican assemblage in Shimada et al., 2000). In general, results show that the compositional profile of SPA closely agrees with the compositions seen in Bolivia and NWA, suggesting that deposits from these areas were used in the manufacture of SPA objects (still, trace elements will be needed in the future to confirm these connections). Meanwhile, objects with high-copper content share similarities with Nasca materials.

As mentioned, the results presented here combine published analyses, as well as analyses made by myself. In the latter case, the same instruments, methods and protocols used to analyse SPA artefacts were employed; however, published results include a range of different analytical techniques, made in different years and frequently under unknown conditions. Therefore, caution has to be taken when comparing these results, which should be considered as indicators showing general trends. Another question is how to interpret these data; i.e., what does it mean that two objects of different areas have the same composition? In this case, because only major elements are examined, overlaps will be understood as the use of gold deposits of similar characteristics (i.e. comparable silver and copper levels), rather than assuming that both items were made from the same melting event. Likewise, in the case of artificial alloys (i.e. high silver and/or copper levels), this would indicate that similar alloy practices have been practiced in both areas. Of course, similarity in the major element composition between two objects is not directly indicative of the same origin. However, when larger datasets are combined, and integrated with stylistic and technological analyses (see later discussion), suggestive trends can be indentified.

Overall, compositions in SPA plot within the general trend seen in other areas of the CA and SCA, as shown in Figure 118. Still, when results are plotted by areas some more specific patterns appear.

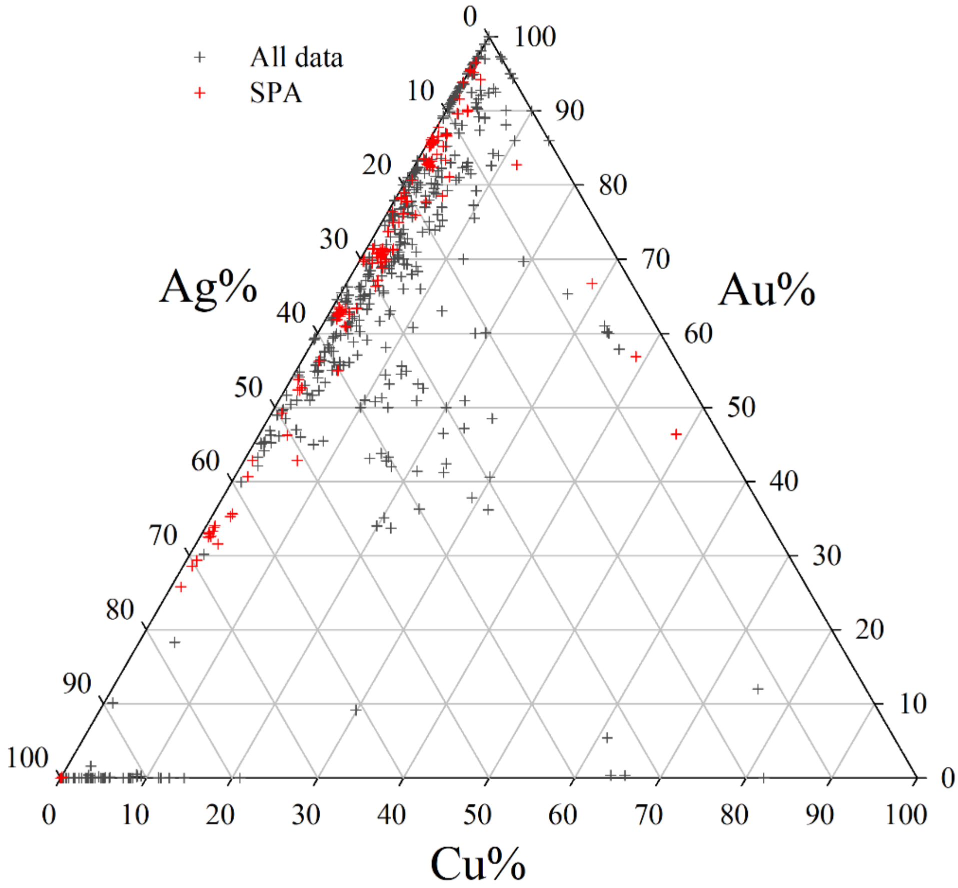


Figure 118: Au-Ag-Cu ternary diagram comparing compositions between SPA (red, n=145) and the Central and South-central Andes (black, n=460).

7.1.1 Comparing bulk chemical compositions by areas

From the north coast of Peru, SPA compositions overlap with Cupisnique, Viru, Frias, Moche and some Sican objects, all of them using gold with silver levels around 10-45% (Figure 119). It should be noted, however, that a large part of Sican metalwork include artificial gold-silver-copper alloys, not seen in SPA. A similar profile is observed in Chavin and Wari artefacts from the central coast of Peru, and Inka objects from Cusco (Figure 120). In these cases, silver levels remain between 10-45%, although copper levels appear slightly higher compared to most SPA objects. The similarity would indicate that in both regions gold deposits of 10-30% silver were used, with copper levels around 4%. Yet, contrary to SPA, evidence of relatively pure gold, with silver content under 10%, is almost inexistent in the north and central coast, except for two Inka objects.

Chavin objects were analysed for trace elements, detecting PGEs (rhodium, palladium, iridium and platinum) in amounts ~1000ppm, which were seen as diagnostic of gold deposits from the north and central coast of Peru (Schlosser et al., 2009); these elements have not been detected in SPA so far (see chapter 5). In the case of Inka artefacts, their compositions are more difficult to compare, given that it is known that during Inka rule, all gold and silver mines of the *Tawantinsuyu* were property of the Inka and their product was exported to Cusco where it was worked by highly trained specialists (Lechtman, 2007). Therefore, it is expected that the compositions of Inka objects would include metal from different areas.

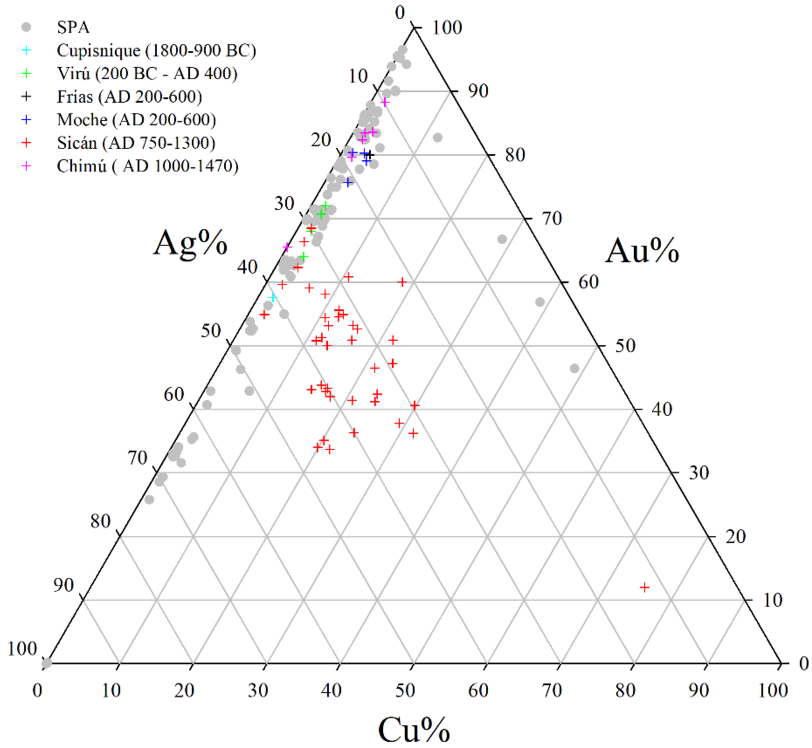


Figure 119: North coast of Peru (n=58)

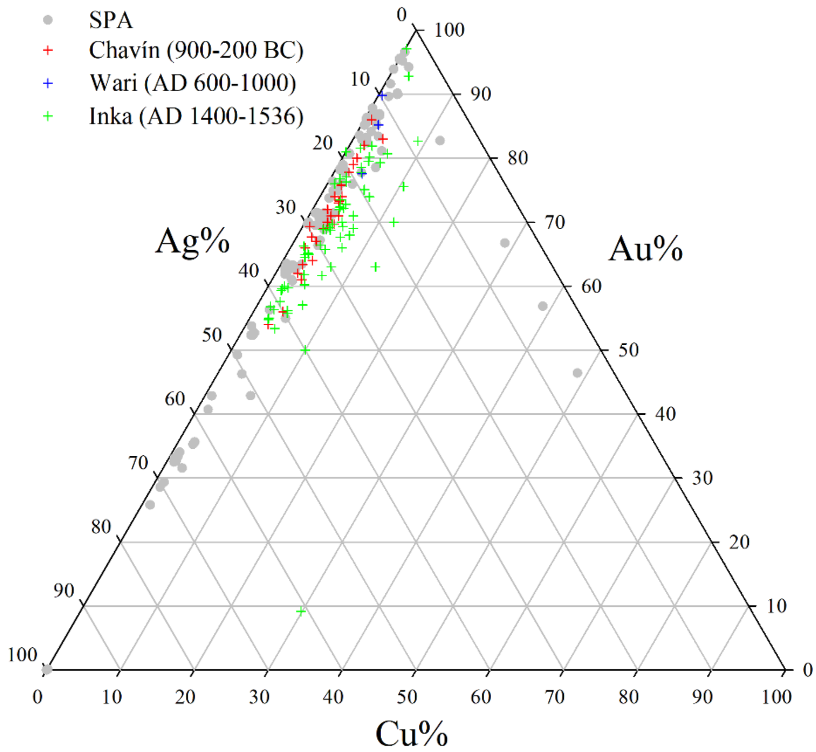


Figure 120: Central Peru and Inka objects (n=97)

The south coast of Peru shows a different picture (Figure 121). First, the majority of objects were made of gold with natural silver levels (>30%), evidencing only rare use of artificial alloys. Second, there is a group of objects made of relatively pure gold, especially in Paracas, with silver levels below 10%. Still copper levels are varied between 0-10%, which may suggest the presence of a) alluvial deposits with low-silver and high-copper content (still under 10%), or b) pure alluvial gold that was mixed with copper during its collection or melting (Guerra & Rehren, 2009; Hauptmann & Klein, 2009). Third, Nasca has the only objects composed of relatively pure gold and high copper (19% and 26%Cu; Schlosser et al., 2009), indicating the use of artificial alloys where copper was added. These two objects are the only ones with compositions similar to the high-copper ornaments found in SPA.

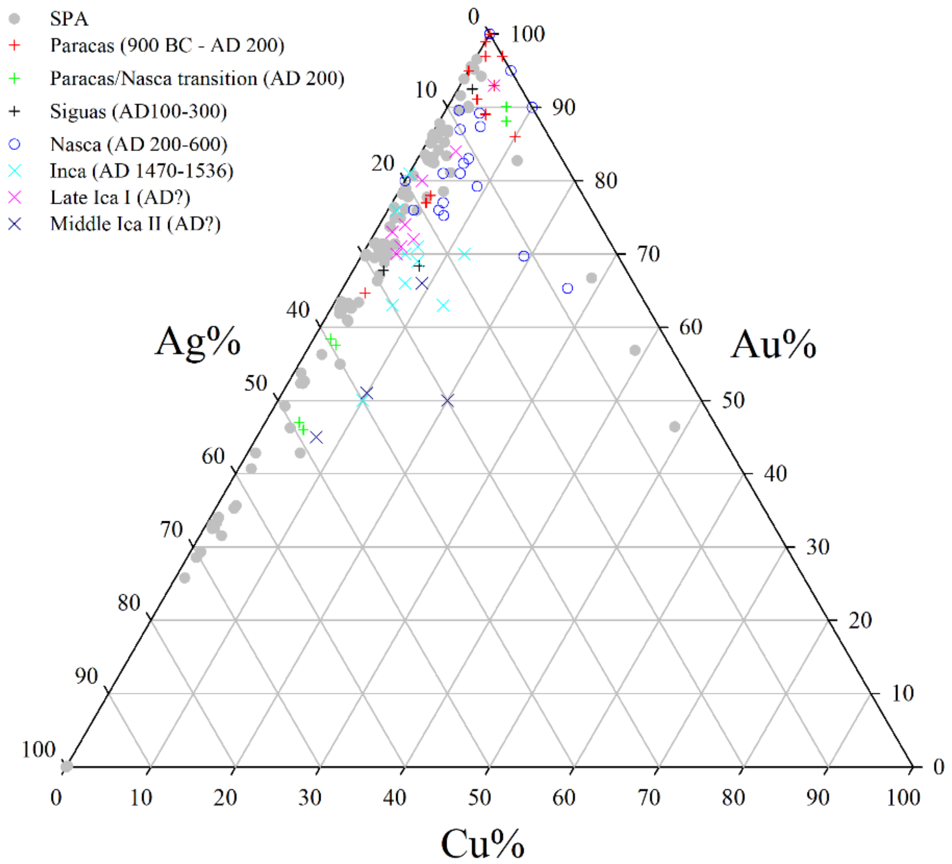


Figure 121: South coast of Peru (n=72).

From Bolivia, few analysis have been carried out heretofore (n=69, Figure 122). Because all objects are from relatively old museum collections (MUSEF, MQB), many lack a specific location. However, a group of 14 objects are known to come from the site of Tiwanaku (central *Altiplano*) and from three different areas of Potosí (Yura, Cobrizos, ColchaK; southern *Altiplano*). Again, compositions are similar to those from SPA, but of special interest is a group of objects made of pure gold with silver below 10% and negligible copper content. This type of composition is uncommon in Peru or NWA. Artificial alloys between 30-55% silver are also present, apparently being more frequent in the southern *Altiplano* (although the number of analysis is small to propose a significant pattern). The analysis identified an important number of silver-copper alloys, mostly between 0-15%Cu, and two around 65%Cu.

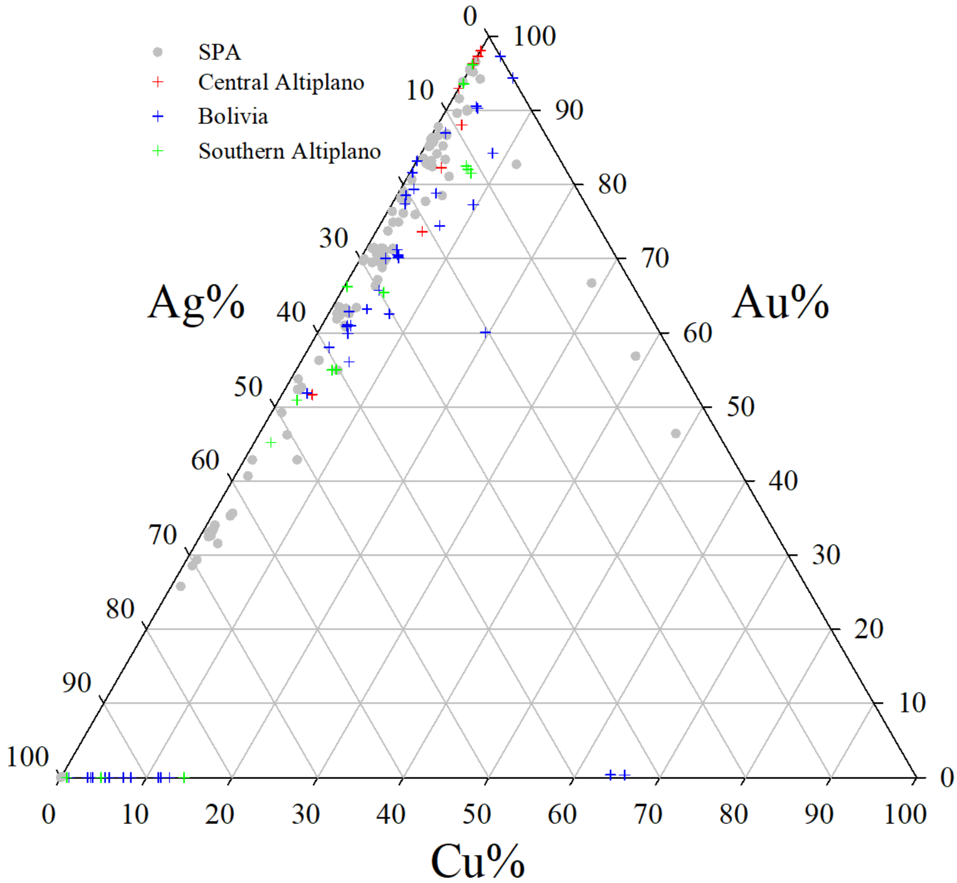


Figure 122: Bolivia (n=69)

From northern Chile, fewer objects were analysed (n=42, Figure 123). Overall, most items are made of natural gold with low copper levels. Two items are artificial alloys: a gold-silver alloy with ~50%Ag and a silver-copper alloy with ~20%Cu. Similar to Bolivia, there is a group made of pure gold with less than 10% silver and 0-5% copper. Two points need to be noted though: first, of 42 objects analysed, 32 are a set of identical beads from the site Yona-2, located at the southern end of the Atacama Salt Flat (Figure 117:89). These show a gradual variation in silver, from 3% to 10%, with no copper content, probably reflecting the internal variation within a single alluvial deposit. Therefore, relatively pure gold (low silver and low or no detectable copper) is used in objects from Bolivia, mainly around Tiwanaku, and northern Chile near SPA, even though no alluvial or placer gold deposits are identified in northern Chile, and the closer alluvial deposits are located in NWA (see chapter 2:2.2.2). Second, the objects analysed from northern Chile are from the Formative Period (400BC-AD400) and hence earlier than the SPA collection, therefore they can only be used as a reference to suggest that similar sources may have been available during the Middle Period.

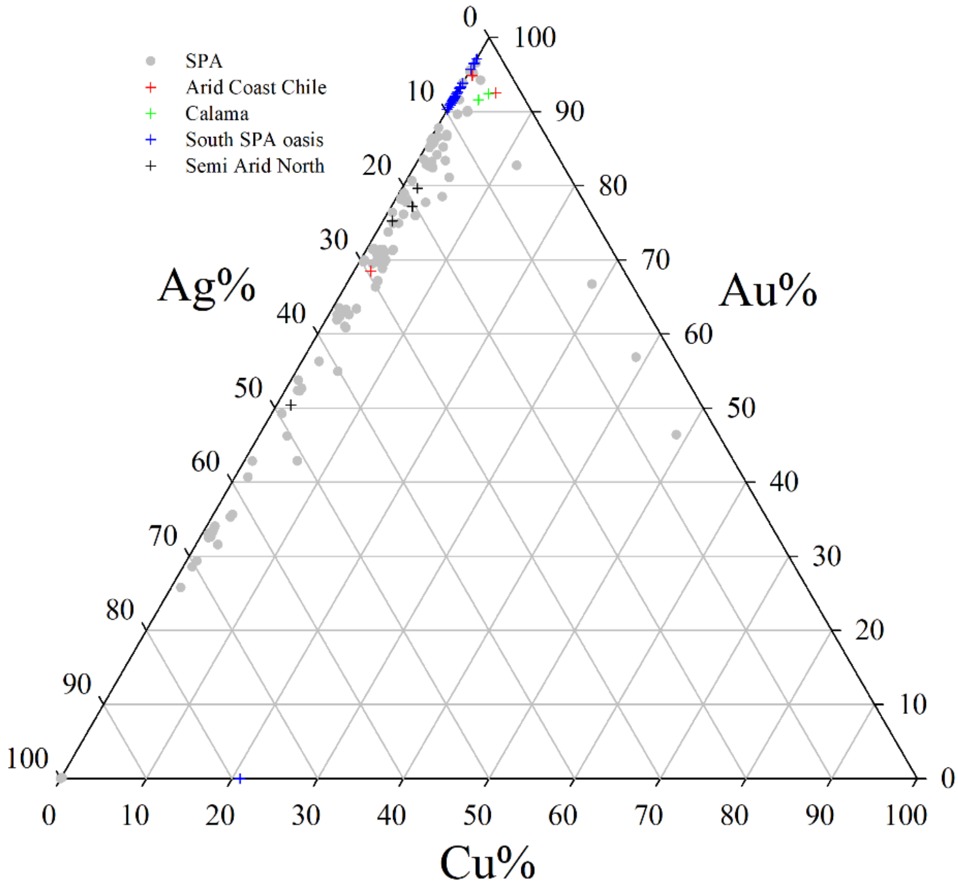


Figure 123: Northern Chile (n=42)

The last group of artefacts analysed comes from NWA, and this shows the best match with the assemblage of SPA. As seen in Figure 124, compositions from NWA have a wide range of silver variation, between 15-70%Ag levels, with low copper contents mostly under 4%; very few objects contained silver levels below 15%. The use of artificial gold-silver alloys (>30%Ag) is common, as well as the use of silver (relatively pure) and silver alloyed with copper (up to ~12%Cu). From the *puna*, most items are gold-silver alloys, rich in silver (>40%Ag) and silver alloys with copper. The compositions from the Humahuaca Ravine completely overlap with SPA's compositions: silver contents are between 5-60% and copper is below 4% in most objects. Objects from the lower-elevating *yungas* grouped near natural gold compositions, with silver below 20% and artificial gold-silver alloys between 40-55%Ag

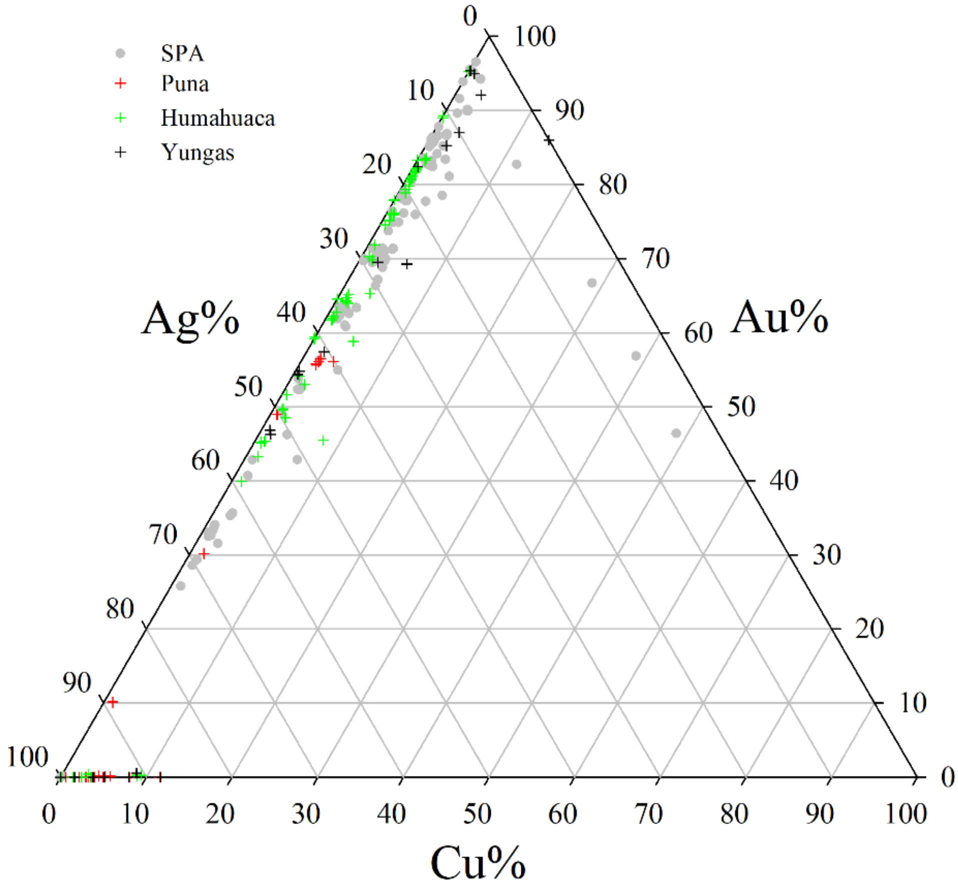


Figure 124: Northwest Argentina (n=120)

7.1.2 Summary

Overall, the chemical composition of SPA objects scatter within the distribution of other objects from the broader region, where the use of natural gold deposits, as well as artificial alloys, is documented. When scrutinised in more detail, it is evident that objects from south Peru, Bolivia, NWA and northern Chile are particularly similar, which could suggest the use of the same or similar gold sources, slightly different from the deposits and alloying technology prevailing in central and north Peru.

In previous sections, it was proposed that given the variety of compositions and manufacturing techniques seen in SPA, it was likely that these objects came from elsewhere. Looking at the compositions of objects from other areas, it is possible to propose some provenance pointers to be tested in future work. For instance, the only objects containing high-copper and low-silver - as seen in four ornaments from SPA - are Nasca. Although no Nasca materials are identified in SPA, Llagostera (1995, fig. 14) describes a "nascoid" motif in a textile from SPA (Appendix Nº2: 22). This connection has not been established before, and it certainly needs further scrutiny. However, it is possible that these objects represent exceptional cases where items travelled long distances from the Nasca Valley (or nearby regions) to finally end up at SPA.

From Bolivia the sources of low-silver gold stand out (<10%Ag) that were used in a small group of objects, but which are rare in objects from Peru or Argentina. In SPA, gold of similar purity was used in a specific set of grave goods from Larache and Sequitor Alambrado. The presence of pure gold in early sites from northern Chile (e.g. Yona-2, which is relatively close to SPA) raises the question of whether undiscovered local or nearby sources of pure gold may have been available; however, as discussed in the next section, in the case of SPA, the style of these objects would support a non-local origin.

The compositions from NWA, specifically from the Humahuaca Ravine, are very similar to most objects found in SPA. They present a wide gold-silver variation, including natural silver contents *ca.*5%Ag, 10%Ag and between 15-30%Ag; as well as artificial gold-silver alloys, up to 70% and 90%Ag. Copper, meanwhile, is consistently low. Given the similarities between NWA and SPA compositions, it is very likely that metal sources and artificial alloys produced in the NWA were used in the manufacture of SPA grave goods.

Both in Bolivia and NWA, silver-copper alloys (without gold) are common. In SPA, only a few silver items survived post-deposition conditions, as most of them were completely corroded and lost during the excavations or subsequent storage. However, their presence in neighbouring areas indicates that silver technology was certainly available and close enough to be introduced to SPA as well.

Summing up, based on the chemical composition of archaeological objects it is reasonable to propose that most of the metal found in SPA may come from Bolivia and NWA, which agrees with the geological data of those areas, as seen in Figure 8. This tendency is clearer when compositions dated from the Middle Period (excluding central and north Peru) are plotted together (Figure 125). It is hence possible to observe how objects from NWA and Tiwanaku overlap with SPA materials. It is also interesting to note the overlap with Nasca artefacts. Yet, this proposal is based on a relatively uneven sample, where some areas are underrepresented (e.g. Bolivia); future analysis may change and complete this picture. However, these patterns can be used to guide further exploration of these purported connections, using trace elements for example, in SPA, Bolivia and NWA assemblages. The latter would clarify and refine these potential links.

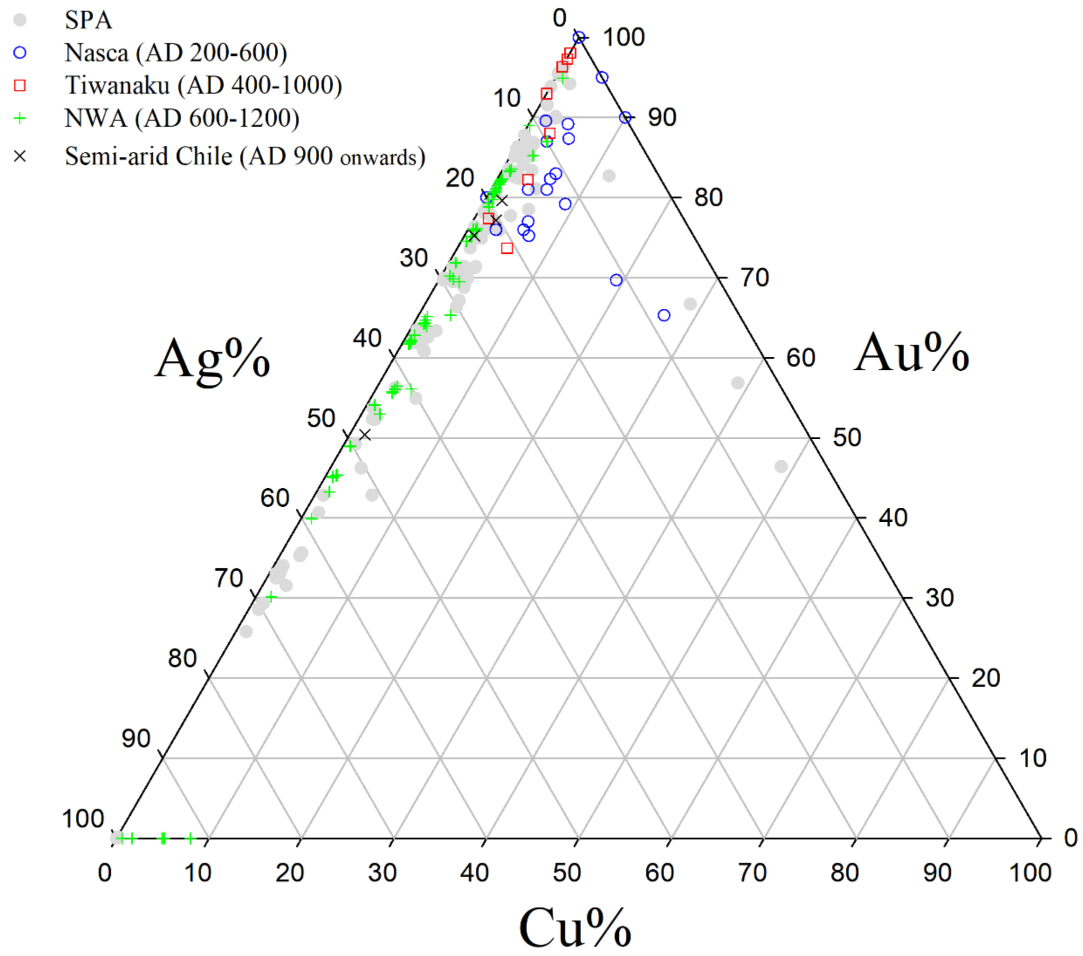


Figure 125: Compositions of samples dated to the Middle Period (AD 400-1000)

7.2 Manufacturing techniques

In this section, manufacturing techniques and technical traits from objects in three areas - central *Altiplano* (Lake Titicaca Basin), southern *Altiplano* (Potosi, Lipez) and NWA - are characterised and summarised. These traits will be compared to SPA objects during discussion in the next section.

One-hundred and nine objects were directly analysed from neighbouring areas (Table 33). Published material and artefacts from museum's online catalogues were also employed to identify specific features when the images were good enough. Not all the materials analysed in this chapter are from the Middle Period (AD 400-1000). For some regions gold was found in early sites (before AD 400), such as those from the arid north of Chile, or Malka and Pampa Grande in Argentina; whereas in Argentina, several sites with precious metals are dated *ca.*AD 900 and onwards. However, given the similarity of some of the items (e.g. the bells in Huaira-Huasi or the *kero* in El Volcan), it was decided to include these sites anyway.

Country	Region/area	Museum	Site	Dates	Nº objects studied
Bolivia	Titicaca basin	MQB	Tiwanaku	AD 400-900 (?)	7
	Department of Potosí		Yura, Cobrizos, Colcha K	-	7
Total Bolivia					*14*
Argentina	Puna	ME	Tebenquiche	AD 700-900	1
		ME-MEC	Doncellas	-	7
	Humahuaca Ravine	MEC	Malka	AD 300-500	2
		ME	P.V. de la Cueva	AD 692-982	4
		MEC	Muyuna	AD 898-1157	1
		ME	La Isla de Tilcara (El Morro)	AD 900-1200	15
		MEC	Huacalera	AD 900-1200	21
		MEC	San José	AD 1020-1271	2
		MEC	El Volcán	AD 1021-1635	1
	Yungas	MLP	Pampa Grande (Los Aparejos)	AD 260-430	1
			Huaira Huasi	AD 1200-1536	4
Total Argentina					*59*
Chile	Arid North	CCTC	Chorrillos cemetery	400-200 BC	2
		-	Caleta Urco	400 BC-AD 400	1
		-	Hornitos-1	400 BC-AD 400	1
		IIAM	Yona-2	400 BC-AD 400	32
Total Chile					*36*
TOTAL					**109**

Table 33: List of objects from other areas analysed for manufacturing techniques. See locations in Figure 117; museums' acronyms are given in Appendix Nº3: 8.

Unfortunately, only a few artefacts from Bolivia were accessible for this research (n=14), all of them from an undated collection from the Musée du Quai Branly– Jacques Chirac, but I am still using them to explore potential technological differences in two areas of interest: central and southern Bolivia. For Bolivian objects in general, online catalogues from museums in Europe or USA were very helpful, yet no museum in Bolivia had online photos of their collections, which are the most numerous assemblage. Importantly, I was cautious in the use of museum collections, given that in many cases the location, chronology or cultural association of specific items were uncertain. In these cases, only objects of clear Tiwanaku style were considered, while acknowledging the risk of circularity in this approach.

Two main problems were faced when searching for information on Tiwanaku metallurgy in particular. As mentioned, a limited number of objects were directly analysed and published material is almost inexistent, making our comparative corpus rather small. Besides, most Tiwanaku objects were looted and acquired by museums and private collections, therefore their contexts are usually unknown and their location is general (e.g. a region, or a particular locality at most). Additionally, most museums and collectors usually prefer beautiful objects, therefore most of the comparative material gathered from Tiwanaku are lavish items with Tiwanaku iconography. The latter has produced an artificial bias, neglecting small, plain and ordinary gold objects.

7.2.1 Artefacts from Bolivia

From Bolivia, 14 ornaments were analysed, including pendants, headdresses, small discs and rectangular attachments (Figure 126). The objects were collected in 1903 by the mission Créqui-Montfort and are currently stored in the Musée du Quai Branly–Jacques Chirac (Paris). The objects come from two different areas: excavations in the site of Tiwanaku, central *Altiplano* (Figure 126:A) and Yura, Cobrizos and Colcha K, southern *Altiplano* (Figure 117 and Figure 134).

7.2.1.1 The central Altiplano: Tiwanaku and Lake Titicaca

There are seven ornaments from the Tiwanaku site, all of them thin hammered sheets shaped by cutting, except for the headdress popm153 that was directly hammered from an ingot and popm155 that was raised (Figure 126). The marks suggest that cutting was made by sliding a blade in popm159, and by perpendicular cuts in popm156. The edges of the other objects were polished with an abrasive material, obscuring any cutting evidence. All perforations were made by punching a pointy tool of circular section (the imprint of a point is still visible at the back) and burrs were left untreated. Surfaces are polished with abrasive materials. Artefact popm155 is the broken top section of a conical-bell, which was made by raising. The perforation is incomplete, suggesting that the bell was broken before it was finished.

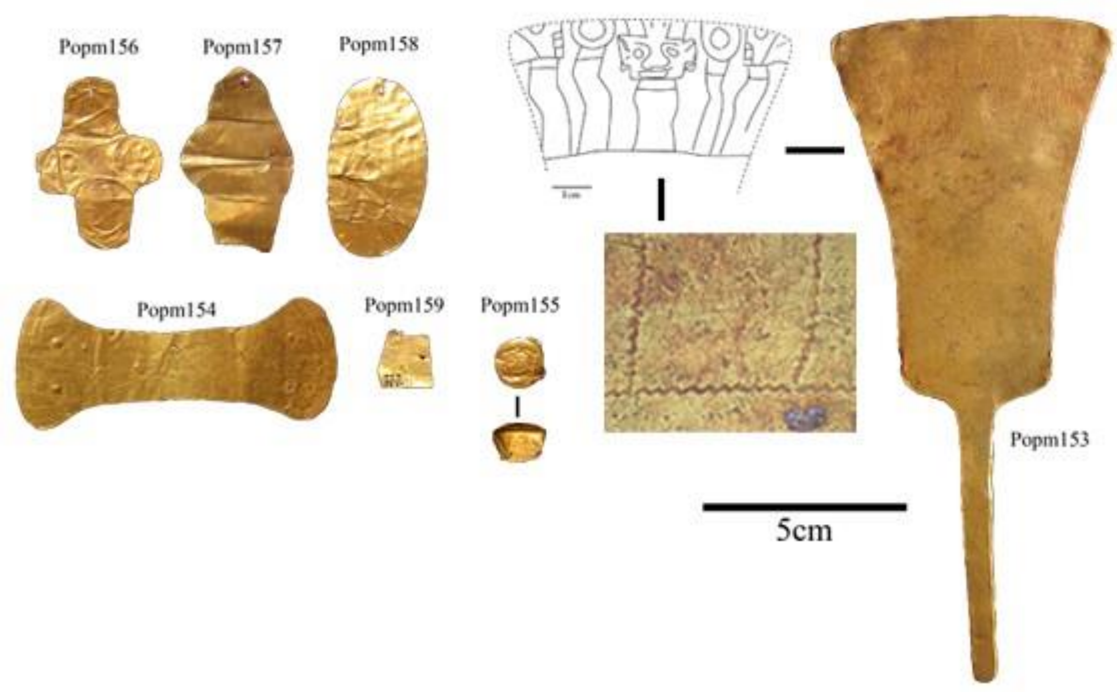


Figure 126: Bolivian objects analysed from Tiwanaku.
MQB, catalogue nº71.1908.23.251, 71.1908.23.250, 71.190823.249, 71.1908.23.246, 71.1908.23.248, 71.1908.23.254, 71.1908.23.253.

Three items are decorated. Popm154 and popm156 have embossed dots and lines, made with a fine round tools; whereas headdress popm153 was engraved using a technique called wiggle or zigzag cut (Figure 126-127; Maryon, 1971; McCreight, 1991). This technique uses a flat graver that "*is held at a steep angle, and "walked" forward, rocking from side to side*" (McCreight, 1991, p. 22). The same technique is observed in several zoomorphic pendants recovered from the Lake Titicaca (Figure 128:A), the Island of the Sun and the Moon (both in Lake Titicaca, Delaere *pers. comm.* 2016 and Young-Sánchez, 2004, fig. 1.8); and other objects of Tiwanaku affiliation (Figure 128:B, see other examples in Appendix Nº2: 23-24). The engraving was used to draw different details of the figures represented. Interestingly, the wiggle cut is replaced by pointillism in similar objects, such as some gold pendants found in Pariti Island (Figure 129:A). As discussed later, the pointillism marks are of the same type that those found in *kero* pop140, from Casa Parroquial (Figure 129:B).

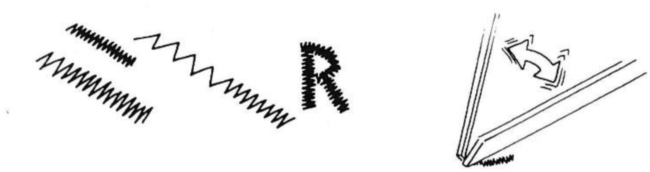


Figure 127: Wiggle or zigzag cut technique after McCreight (1991, p. 22)

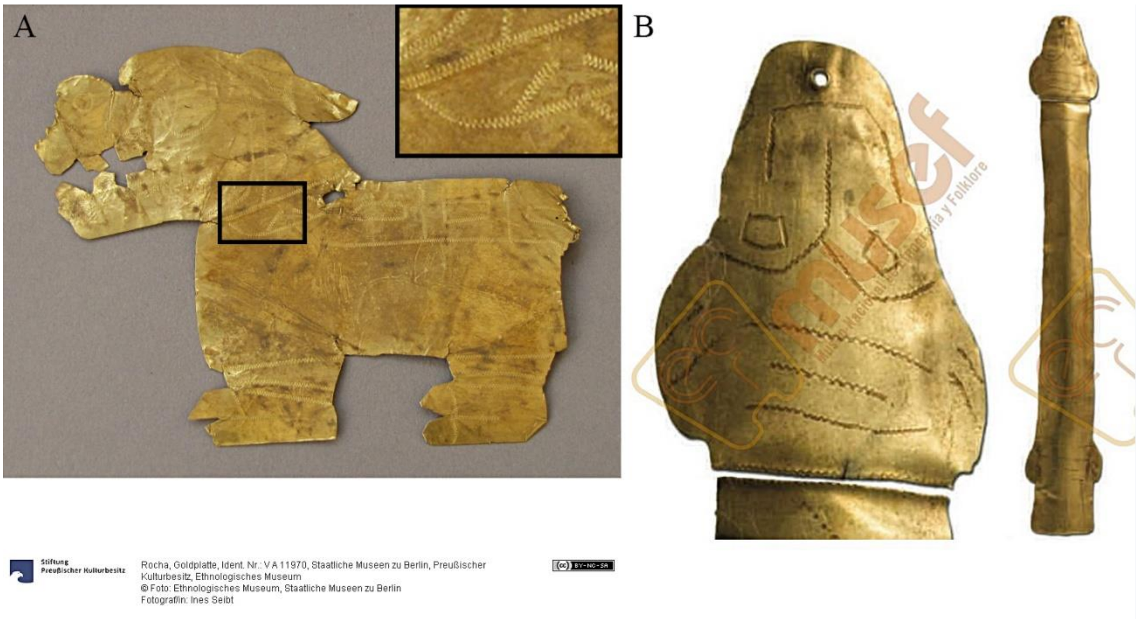


Figure 128: Examples of drawing by wiggle cuts.
A- Pendant found in the Lake Titicaca. EM, catalogue number VA11970. B- Pendant of uncertain provenance, MUSEF, catalogue number 27224 (modified from Férnandez, 2016, pp. 142–143).

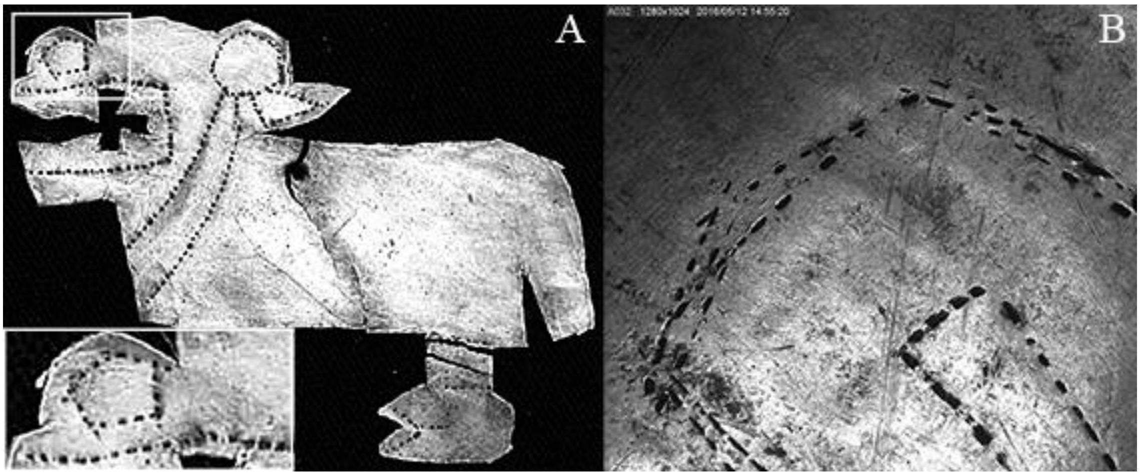


Figure 129: Pointillism.
A- Gold pendant from Pariti Island (after Korpisaari et al., 2012, p. 13). B- Note that the same technique is used in kero popm140 from Casa Parroquial (SPA).

In terms of craftmanship, popm154 and 158 show a finer work with well-defined shapes, even and polished edges and surfaces; in contrast, popm156-157 are coarser in their manufacture, with more irregular shapes and edges. Other pendants from Tiwanaku and Pariti, similar to popm156-158 have been published by A.R. González (1992), however only drawings were available and no further technological comparison was possible (Appendix Nº2: 25). Pendant popm154 is very similar to other pendants from Lipez (see below).

The objects analysed here are relatively simple compared to other Tiwanaku artefacts published (Figure 130-133; Appendix Nº2: 23-27). The main examples of Tiwanaku goldwork are from the San Sebastian treasure (Figure 130; found in

Cochabamba, Money, 1991), the offerings of the Pariti Island (Bennett, 1936, figs. 30–31; Posnansky, 1957, plate 89) and the Kalasasaya grave goods (Korpisaari, 2006, fig. 5.29; Money, 1991, figs. 6-7; see Figure 131 below). Striking examples are also found in museums and collections (e.g. the Fritz Buck collection in Korpisaari, 2006 and; Sagarnaga, 1987; Figure 132; Appendix Nº2: 23,26-27). It is noteworthy that there are only few gold or silver artefacts from Tiwanaku recovered via archaeological excavation. As Posnansky noted in the early nineties (1957, p. 131), most Tiwanaku objects were looted, and those that were not melted, were acquired by museums and private collectors. Taking all the findings gathered until now into account, there are interesting features to note:

1. Regular use of raising: both in San Sebastian and Pariti Island, there are 12 bowls and goblets of different types and sizes (Figure 131). Most examples are plain, but some are decorated such as those reported by Bennet (1936) from Pariti: a portrait-vessel and two *keros.* One *kero* was embossed and chased on the upper section, showing a similar arrangement to that in *kero* popm140 from SPA; the portrait-vessel has a modelled face, similar to the *kero* found in the MFAH (Appendix Nº2: 23). Bells made by raising are also common: there are around 15 bells in the MUSEF from the Titicaca basin (M. Soledad Férnandez *pers. comm. 2017*) and one from Tiwanaku (fragment popm159). The *Museo de Metales Preciosos* in La Paz, also holds a large number of these bells.
2. Rare use of casting: It is identified in three small objects of Tiwanaku style only (Figure 133).
3. Wiggle cut and pointillism: Both techniques are used in small discs, zoomorphic pendants, headdresses and *keros* from in Tiwanaku and the Lake Titicaca, to draw features or complex designs (Figure 129; Appendix Nº2: 23-24).
4. Lapidary work: Stone inlay appears in some Tiwanaku ornaments (n=4); whereas several headdresses, masks and *keros* present cavities that may have contained stones in the past (Figure 130-131; Appendix Nº2: 26-27). This technique is not seen in metal objects recovered in SPA, NWA or south Bolivia during this period (even though stone incrustations are found in SPA wooden objects).
5. Complex decoration: Specific ornaments from San Sebastian and Kalasasaya, such as headdresses and pectorals, were lavishly decorated combining embossing, chasing, openwork and lapidary techniques (Figure 130-131; Appendix Nº2: 26-27).

6. Cutting complex shapes: compared to other areas, complex shapes obtained by cutting appear to be common in Tiwanaku, such as the feline figures or headdresses (Figure 132, Appendix Nº2: 26).
7. Different qualities of work: Both finely- and coarsely-made Tiwanaku items are found. Some work shows high skill and dexterity, such as the San Sebastian treasure, where all objects appear evenly cut and thoroughly polished. Other artefacts are of lower quality, showing less care in details such as the pendants popm156-157 (Figure 126:A; Appendix Nº2: 29), with uneven edges and visible cutting marks. However, most items appear to be finely-made.
8. Recurrent motifs: from decorated ornaments, the most common motifs are feline heads; schematic birds with open wings, anthropomorphic faces and the Tiwanaku main deity.
9. No reuse or modifications: no evidence of reuse or modified objects were found so far. However, a few small pendants recovered from the Lake Titicaca, may be perforated fragments cut from larger items (Delaere *pers. comm. 2016)*.

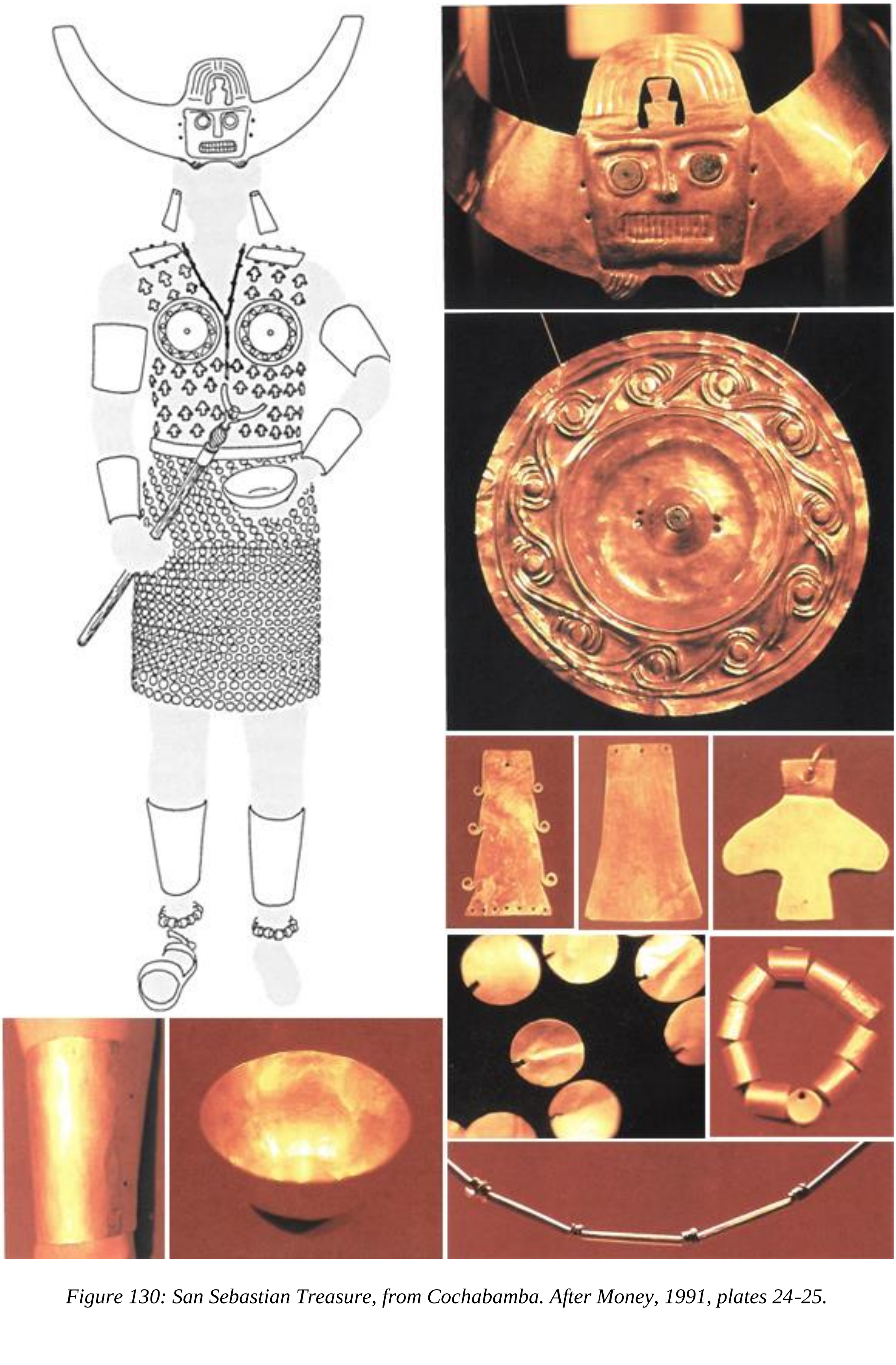


Figure 130: San Sebastian Treasure, from Cochabamba. After Money, 1991, plates 24-25.

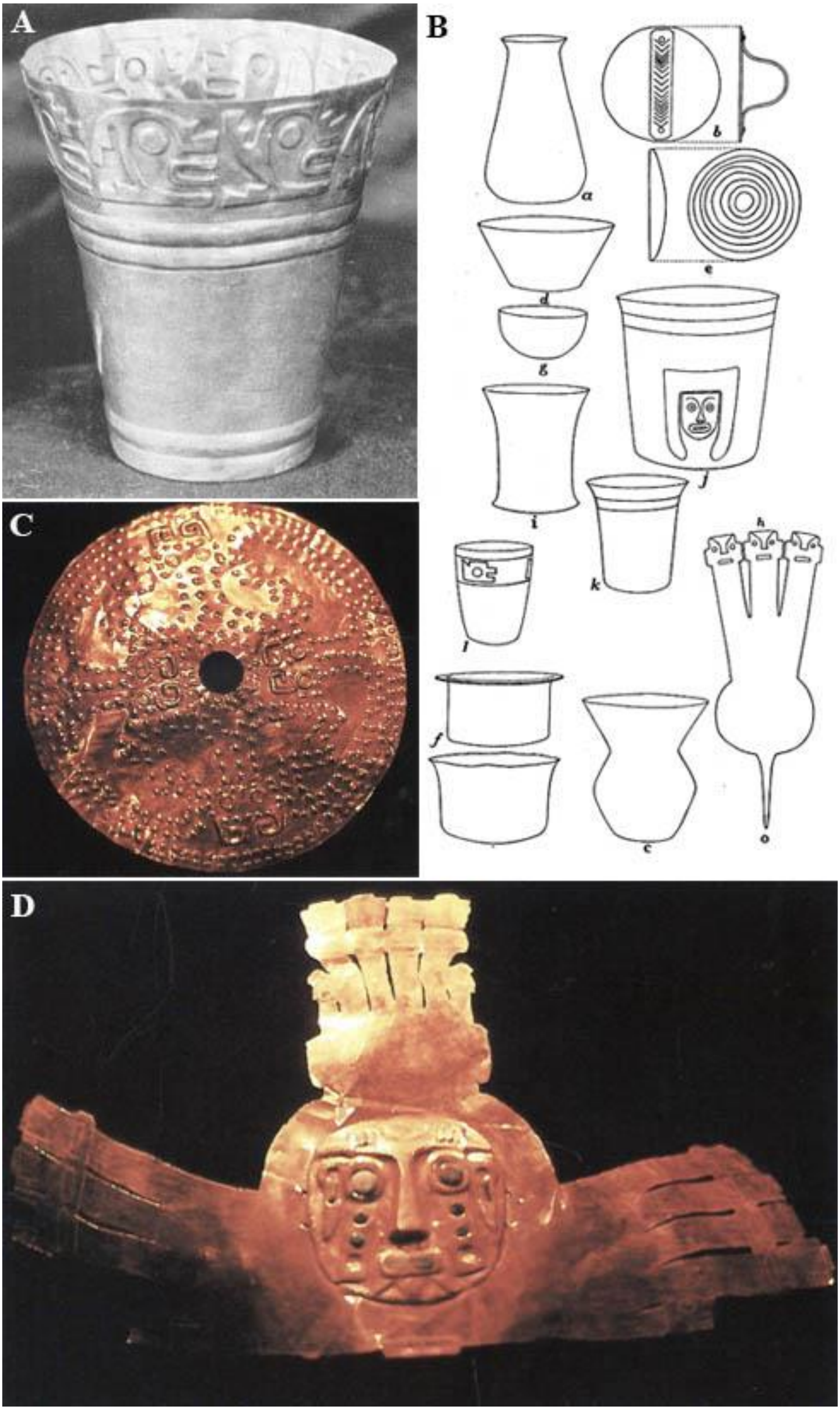


Figure 131: Tiwanaku ornaments from the Titicaca Basin.
A-B- Keros, raised vessels and other ornaments from Pariti Island, After Bennet, 1936, fig.30-31. C-D- Kalassaya temple, after Money, 1991, plate 25.

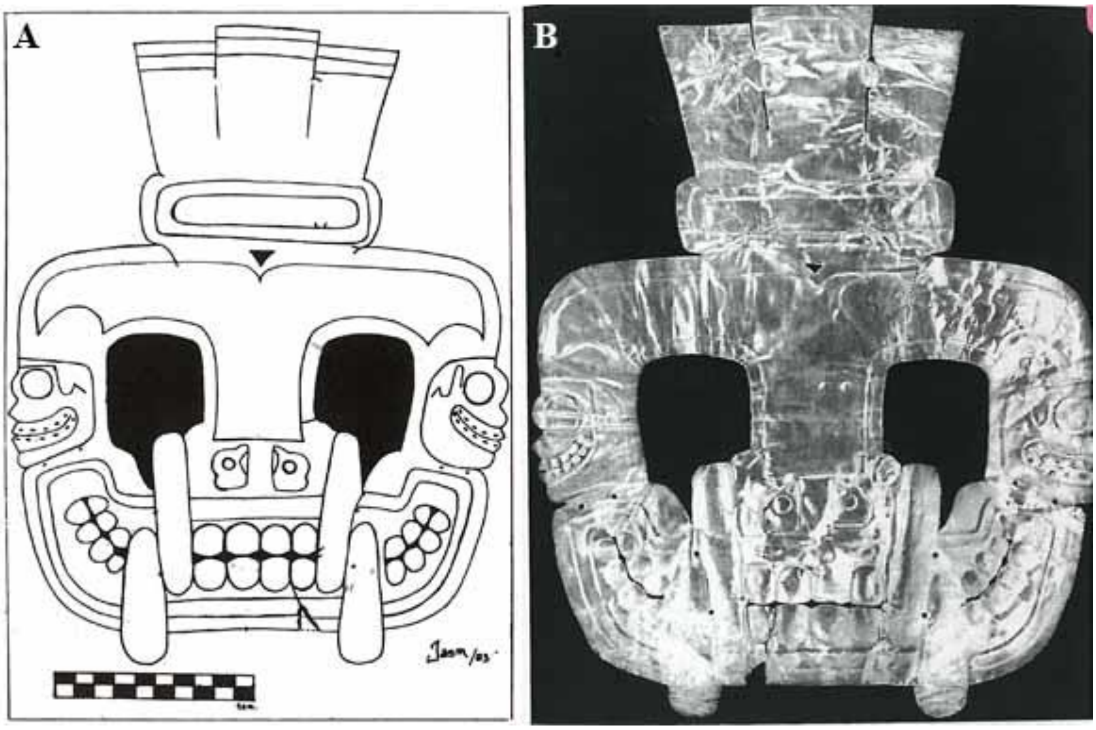


Figure 132: Tiwanaku silver mask from the Fritz Buck collection (after Korpisaari, 2006, fig. 5.31; Sagarnaga, 1987, p. 107).

Figure 133: Tiwanaku style cast objects.
A-B- detail of pins with mythical birds (after Young-Sánchez, 2004, figs. 2.38-2.39). C- Both sides of a small pendant, NMAI.

7.2.1.2 The southern Altiplano: Potosi, Lipez

From Potosi (Figure 117), a further seven artefacts were studied (Figure 134). The four items from Yura (three pendants and a headdress) were finely-made: cut to shape, surfaces and edges were completely polished. Pendants popm160a-b were identical in shape (probably from a template) and decorated with embossed dots. Perforations were made by punching a pointy tool; in popm160-161, burrs were flattened, whereas in headdress popm162 burrs were left untreated. The latter was also decorated with embossed lines, representing a feline face.

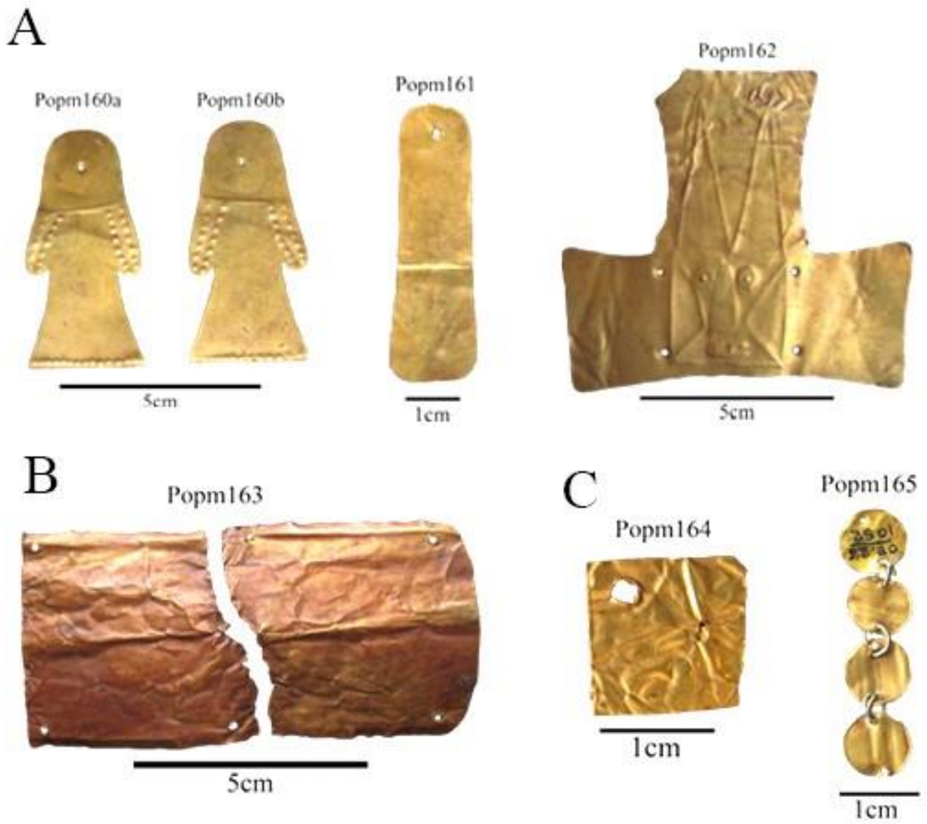


Figure 134: Bolivian objects analysed from A- Yura, B-Cobrizos, C-Colcha K. MQB, catalogue nº 71.1908.23.243, 71.1908.23.244, 71.1908.23.245, 71.1908.23.242, 71.1908.23.2447, 71.1908.23.1053, 71.1908.23.1052.

The artefacts from Cobrizos (popm163) and Colcha K (popm164-165) are rougher in their manufacture. Popm163 is a rectangular sheet, broken in half and subsequently repaired, as indicated by the two extra perforations near the broken sides that probably held a string or wire. Both surfaces and edges were polished, erasing any cutting evidence. Popm164 is a small square fragment with a crude perforation. It looks like a piece of a strip that was cut by sliding a blade, with still visible cutting marks. Popm165 is a set of four small discs, cut by perpendicular blows of a chisel, with two small perforations punched at opposite ends. Edges and surfaces were left unpolished. Standing out within this group is the relatively good quality of pendants popm160-161, which is better than any of the other 14 objects analysed. The shape of pendants popm160 resembles a fish or maybe a bird with closed wings.

Interestingly, in the Natural Museum of the American Indian of New York, there is a series of 28 gold ornaments from Sud Lipez, located a little further south of Yura, Cobrizos and Colcha K. The ornaments include pendants ("bow-tie", birds, oval and irregular in shape), U-shaped pectorals, discs and a bell (Figure 135). Almost all ornaments are decorated with embossed lines and dots, depicting faces and geometric shapes. From the catalogue images (one image per object only), all pendants appear very well cut, with even and polished edges, erasing any cutting or guide marks. Surfaces also look polished, and perforations are perfectly round in almost all cases. There is a bell, certainly made by raising, that was chased to produce seven horizontal bands, very similar in morphology and quality to SPA bells. The bird pendant is more naturalistic than the pendants from San Sebastian, with decorated wings, tail and neck. The quality in general is notably good, being considered as finely-made ornaments, together with the pendants from Yura.

Looking at the materials from the southern *Altiplano*, some important features to consider are:

1. The use of raising appears to be less common in this area, being only represented by one bell.
2. Embossing is the main technique used to decorate gold items, imprinting dots and lines to form different motifs.
3. Cutting "rounded" shapes: compared to Tiwanaku pendants, when complex forms are cut they are wide, rounded and curvy; this feature is emphasised by the polishing of the sides (e.g. Figure 135:15-22).
4. Fine quality: almost all objects appear to be of very good quality, showing care in the finishing techniques, especially in polishing edges and surfaces.
5. Recurrent motifs: most pendants are decorated with faces (continuous eyebrows, eyes, mouth) and geometric figures (circles, rectangles, triangles, lines). A bird pendant was also part of the group. The bow-tie shape pendant appear to be more abundant in this area.
6. Reuse or modifications: possible evidence of reuse is the small sheet popm164, given the combination of worn ad fresh cuts. Two objects were repaired: popm163, with

two additional perforations near the broken edge and one disc in popm165, also with an extra perforation.

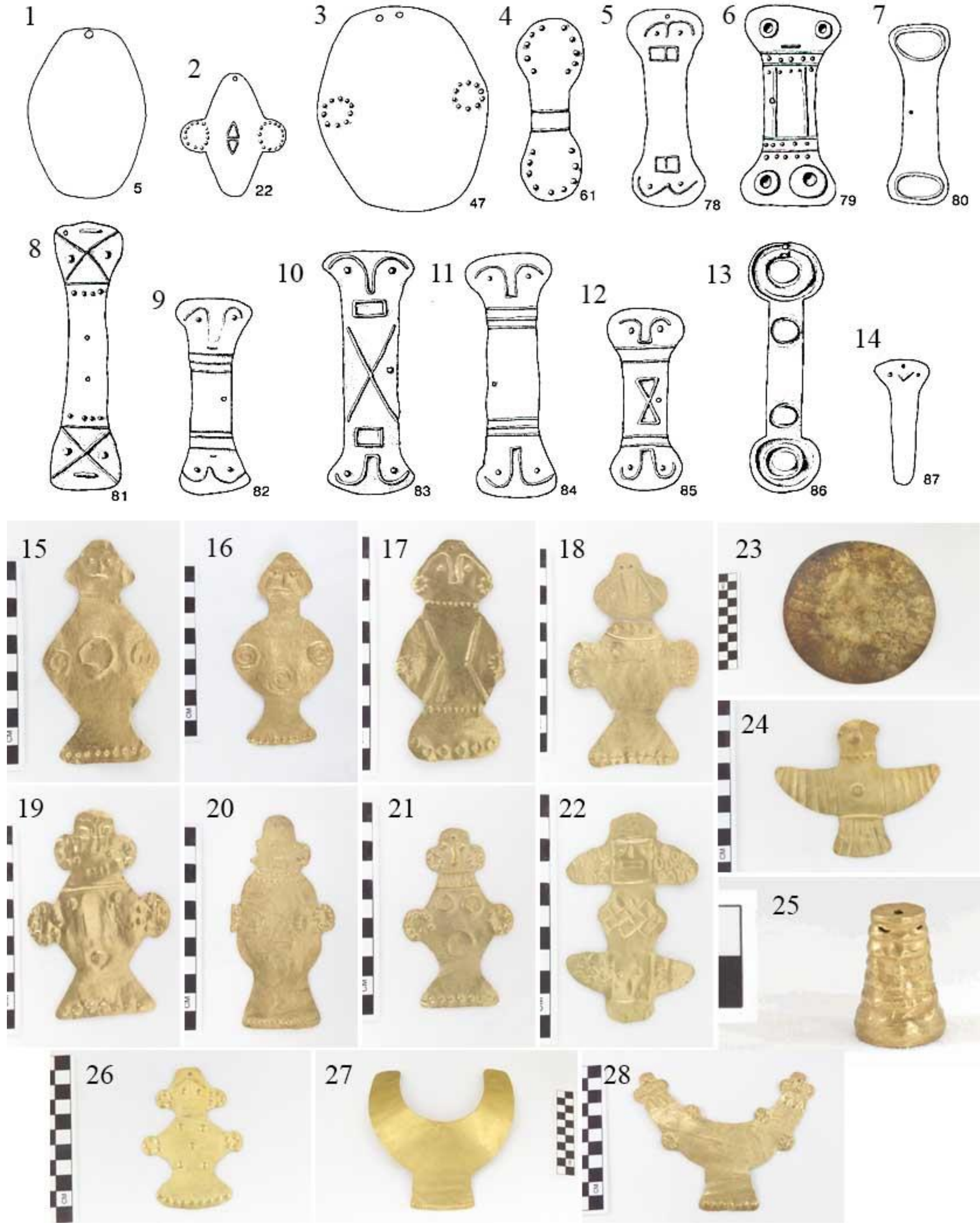


Figure 135: Pendants, bells and pectorals from Sud Lipez.
Courtesy, NMAI. Catalogue number: 1-15/9252, 2-15/8275, 3-15/9253, 4-15/9262, 5-15/9273, 6-15/8291, 7-15/9263, 8-15/8273, 9-15/8272, 10-15/9271, 11-15/9275, 12-15/9276, 13-15/9264, 14-15/9248, 15-15/9283, 16-15/9284, 17-15/9282, 18-15/9280, 19-15/8266, 20-15/9281, 21-15/8265, 22-15/8270, 23-15/9260, 24-15/8274, 25-15/9251, 26-15/8267, 27-15/8261, 28-15/9279. Drawings 1-14 after A.R. González (1992, plate 3).

7.2.2 Artefacts from Argentina

From Argentina, I was able to study 59 artefacts from different areas: the *puna*, the Humahuaca Ravine and the *yungas* (mountain rainforest). Ornaments are varied including pectorals, pendants, attachments, bowls, bells, goblets, beads, masks, rings, headbands, headdresses and bracelets.

7.2.2.1 The Argentinean Puna

The eight artefacts from the *puna* are typologically different, and manufacturing techniques include objects made of sheets and one cast item, pectoral popm189 from Tebenquiche (Figure 136).

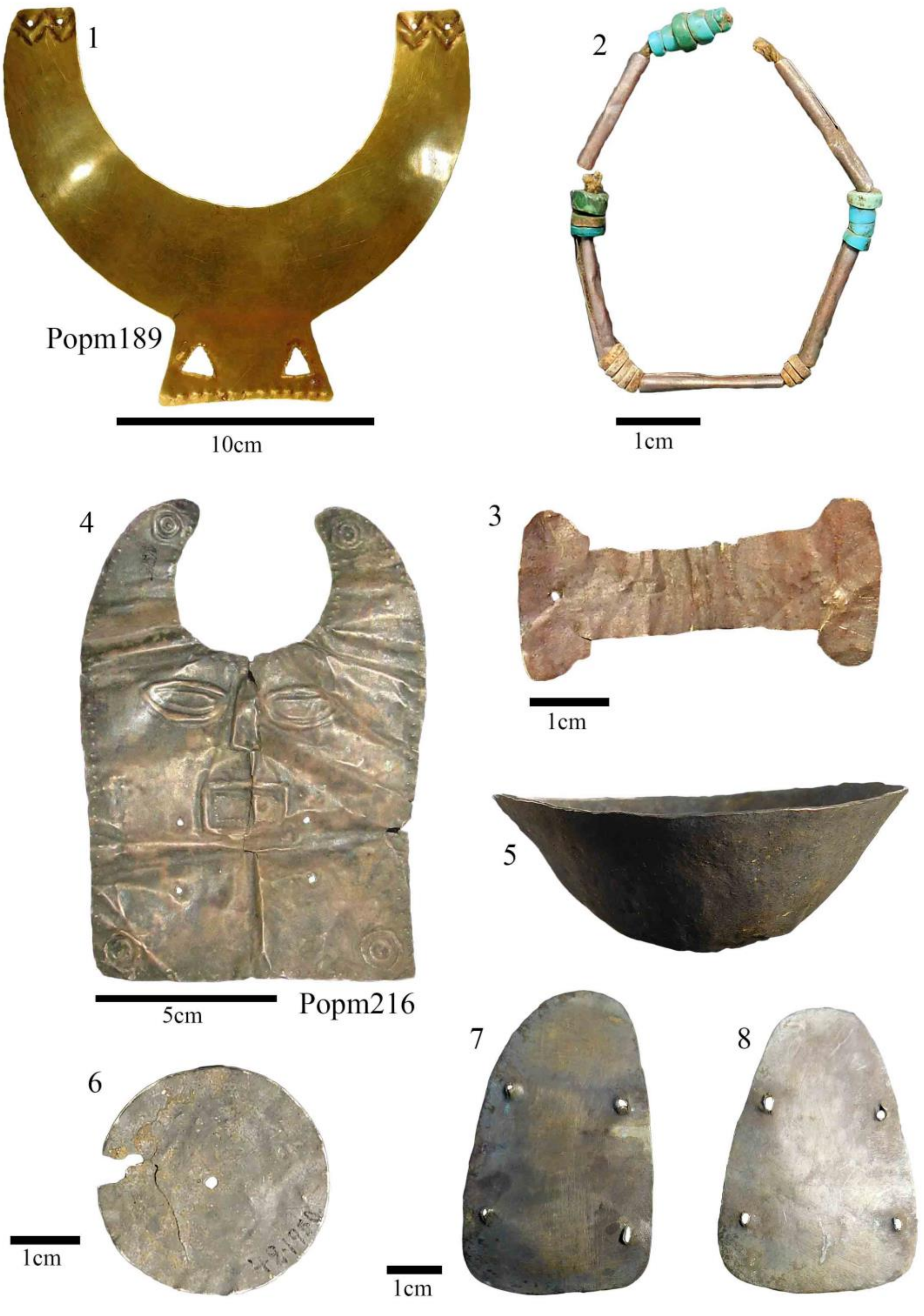


Figure 136: Artefacts from the Puna.
1- Tebenquiche (N°52.33). 2-8- Doncellas (2:41-1526, 3:42.1260, 4:42-2568(1675), 5:42-2118, 6:42-1950, 7-8:43-1303). Museums: 1-3, 5-8: ME, 4: MEC.

The evidence of casting in popm189 is its thickness (0.4-0.7mm), sturdiness and the cooling marks at the back (Appendix Nº2: 30). This ornament was decorated by chasing (chevron lines), embossing (dots) and openwork (triangles). Of interest are the perforations that were made by rotation, still looking fresh and unused (Figure 137:C). The front of the pectoral and the edges were thoroughly polished with an abrasive material. The quality of this pectoral shows high skill and careful work. The use of rotation to perforate is identified as well in a high-quality bird pendant from Catamarca (Figure 137:A-B), probably from the Aguada culture (AD 500-900), according to Goretti (2012, figs. 72, 174).

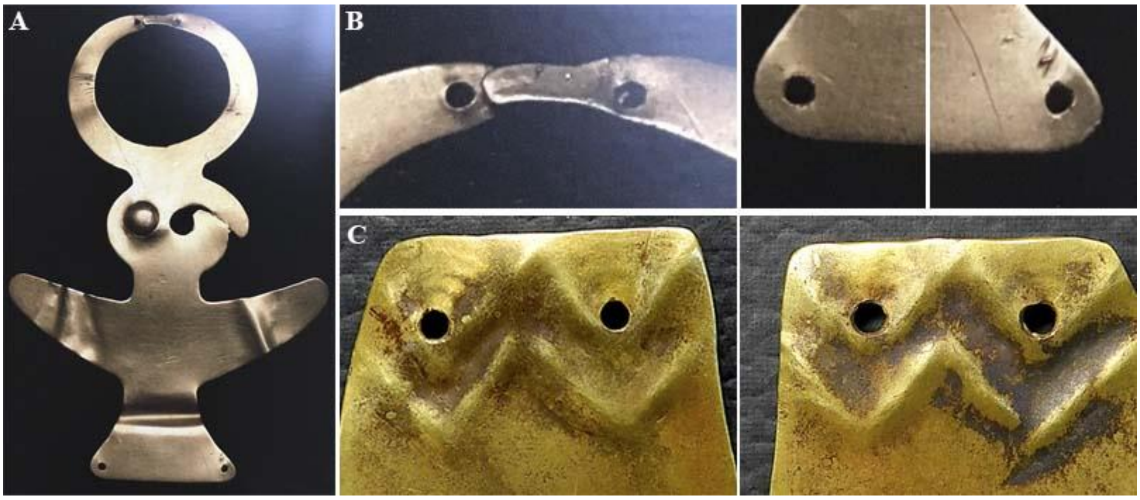


Figure 137: Rotation technique.
Documented in a (A-B) Aguada bird pendant and (C) popm189 (after Goretti, 2012, fig. 174).

Raising was used to shape bowl nº5 (Figure 136), two portrait-vessels and five bells published (Figure 138). Two irregular perforations made by cutting at the bottom of the bowl indicate an ornamental use, possibly attached to clothes or a hat. The bells are from the same type found in SPA, with chased lines forming horizontal bands.

The remaining items are varied in manufacturing techniques and quality. The most complex artefact is mask popm216. This mask was hammered and cut to shape, producing even edges that were polished, as the surface. It is decorated by embossing, depicting a face with long ears and dots. Each corner has three concentric circles, and dots are covering the borders. Four perforations made from the back by punching a round section tool are located in the centre, the burrs are small and were left untreated and visible from the front.

Disc nº6 was carefully cut by sliding a blade on the surface, probably using a template or a guide given the perfection of the circle. The surfaces were polished, but edges were not; the central perforation is round and it was polished as well; burrs were removed. Overall, it is a finely made item. Attachments nº7-8 are carefully cut as well, showing even and polished edges, however the shapes are slightly irregular, and were probably cut by freehand (without a template or guide). The perforations in these two cases are rough, made by punching a blade tip and partially opening them. Burrs were left and they look relatively fresh. Finally, pendant nº3 has an irregular bow-tie shape, with uneven and unpolished edges. The perforation was cut and burrs left flattened at one side. It is the crudest ornament of the group.

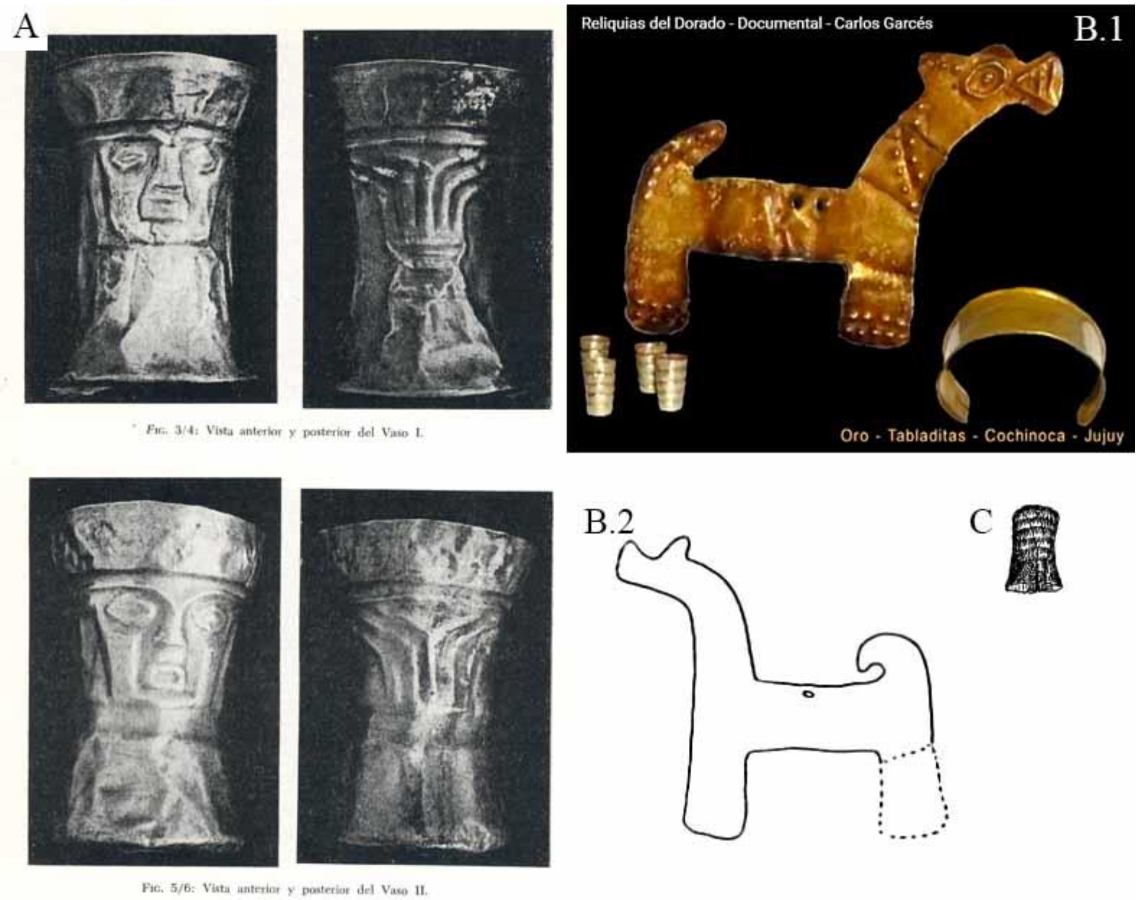


Figure 138: Other published artefacts from the Puna.
A- Two keros from the "Doncellas hoard" (after Rolandi, 1974, figs. 3–6). B- Tabladitas site: B.1- Gold artefacts from the documental "Reliquias del Dorado" by C. Garcés, yet I was not able to trace the location or other images of those ornaments; B.2– Gold llama pendant (after Ventura, 1985, fig. C3). C- Silver bell from the Pucará de Rinconada (after Boman, 1908, fig. 136b).

Published material also identifies two pendants with llama shape in the site of Tabladitas (Figure 138:B); one of them decorated by embossing, adding dots to the body and a face with feline features. Summing up, the main characteristics seen in the *puna* are:

1. A mixed assemblage. The main characteristic of this group is its diversity. In a small group of eight objects, 1) hammering and cutting to shape, 2) raising and 3) casting were identified as manufacturing techniques. This diversity (replicated in

compositions as well) most certainly reflects objects that are coming from different areas. Especially in the *puna*, which is considered a crossing point (Nielsen, 2013).

2. The use of rotation to perforate in one item.
3. Decoration: the main techniques identified are embossing and chasing. Openwork is used once.
4. The quality of the items is varied, ranging from rudimentary work such as pendant nº3 to a very skilled example in pectoral popm189.
5. Recurrent motifs: llama-shaped pendants, anthropomorphic and feline faces.
6. Reuse or modifications: No item from the *Puna* shows evidence of reuse or modification.

7.2.2.2 Humahuaca Ravine

From Humahuaca, 46 objects were studied. Two sites concentrate 78% of the findings: Huacalera, with 21 grave goods and La Isla de Tilcara-El Morro ("LIT") with 15 (Figure 139). In each case, the grave goods were found associated to a specific individual in a single burial with a range of other goods such as copper, pottery, stone and bone artefacts (Debenedetti, 1910; Nielsen, 2001; Pelissero, 2014; Tarragó et al., 2010). The remaining objects belong to Pueblo Viejo de la Cueva ("PVC", n=4), San José (n=2), Malka (n=2), El Volcan (n=1) and Muyuna (n=1; Figure 140).

Overall, most items were hammered and cut to shape, producing thin pendants, attachments, headbands and folded bells; raising was used in one *kero* and two bells (Figure 140:D-E). *Kero* popm190 was shaped and polished with particular care. It is decorated with three bands in the centre made by embossing and chasing; the edges were thickened and the base squared. Its shape is very similar to *kero* popm136 from Larache. The two bells from San José are of same size and weight, but one was decorated by chasing producing six bands, and the other bell is plain with a neck. The same types are present in SPA. Interestingly, three distinctive techniques – relatively unique in the areas studied so far – are identified: soldering, anticlastic raising and bimetallic ornaments with gold and silver parts; these techniques will be described later.

For most ornaments the shapes are even and well cut, but their treatment vary between sites. For instance, in Huacalera and Muyuna most edges are smooth and worn, with no evidence of deliberate polishing; in LIT edges were not polished, leaving visible cutting marks; and in PVC and Malka all edges were intentionally polished with abrasive materials or by compression. Still in Huacalera and LIT, some items were poorly shaped, showing irregular and unpolished edges (e.g. popm181, 202-204, 210).

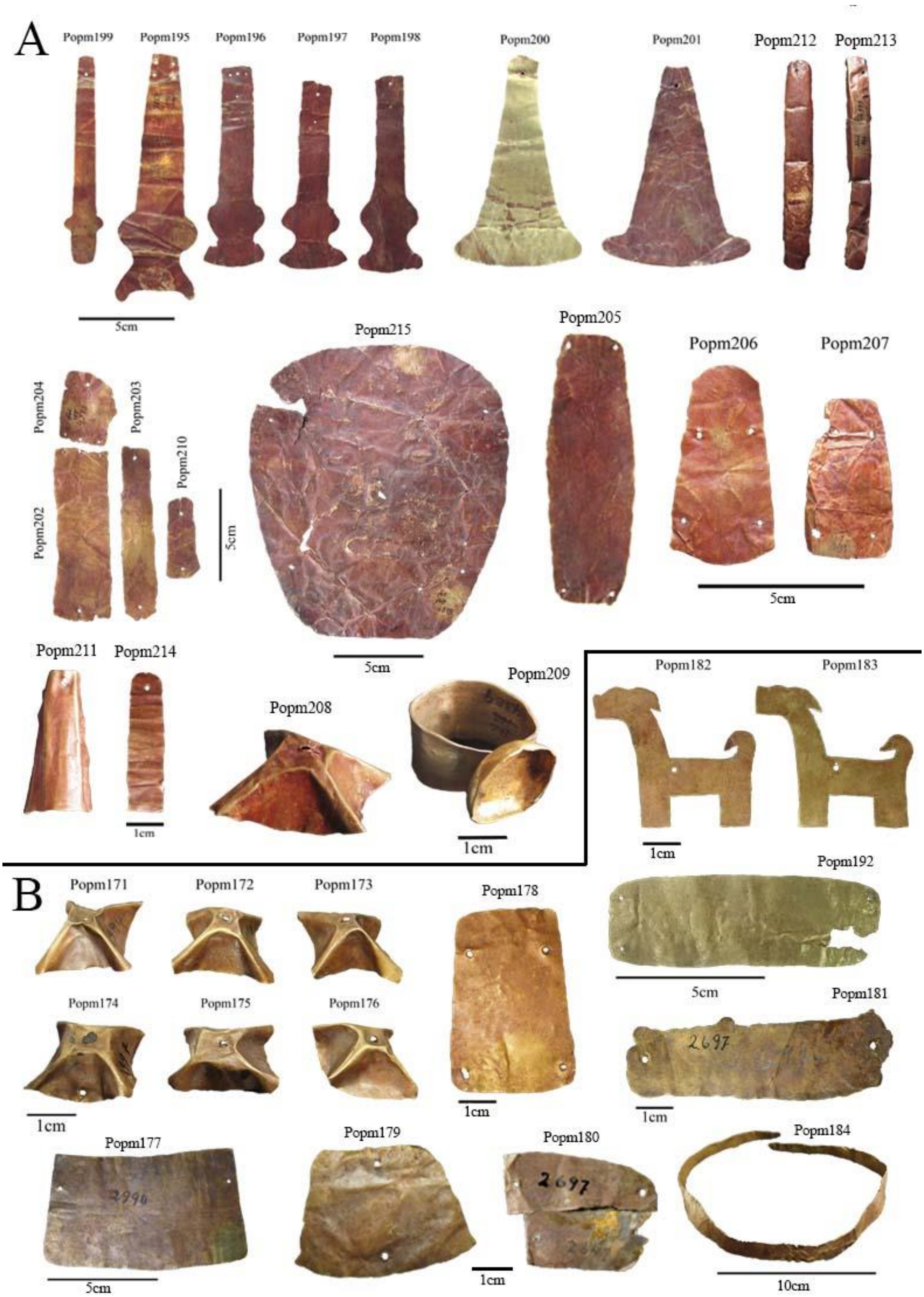


Figure 139: Humahuaca Ravine objects.
A- Huacalera (MEC) and B- La Isla de Tilcara, El Morro (ME).

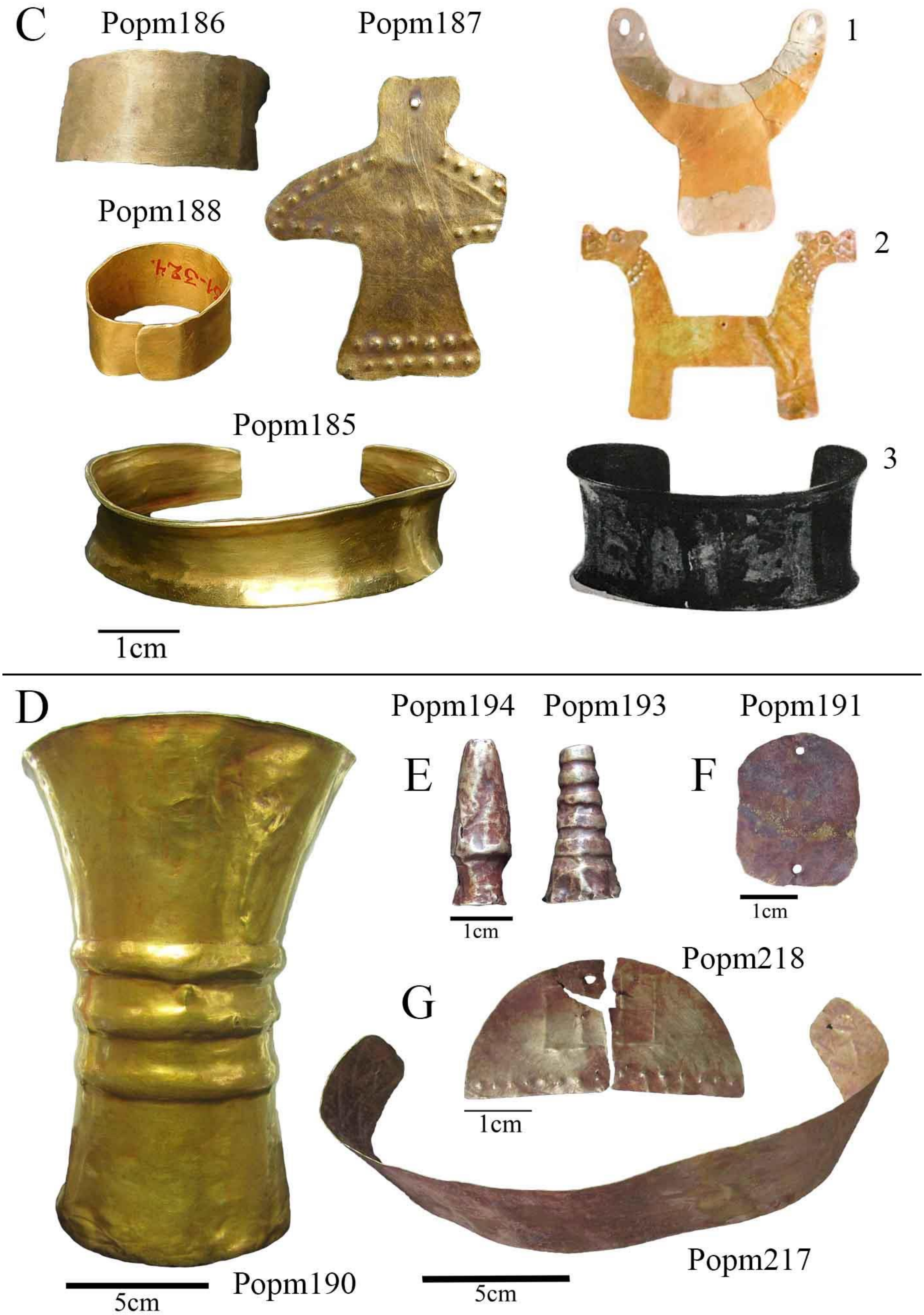


Figure 140: Humahuaca Ravine objects.
C- Pueblo Viejo de la Cueva (ME) (3 after Casanova, 1933, fig. 72; 1-2 after Tarragó et al., 2010, figs. 12–13), D- El Volcan (ME), E- San José (MEC), F-Muyuna (MEC), G- Malka (MEC).

The surfaces in most cases were not polished (n=24, 52%), still the use of abrasives was observed in 16 objects (35%) from LIT (n=5), PVC (n=4), Huacalera (n=3), Malka and San José (n=2 each) and Volcan (n=1). In LIT, the abrasive employed appears to be a compact material (e.g. a coarse grained stone) that left regular scratches on the surface of five ornaments. Compression on the surface using a smooth and hard material, similar to the evidence in some objects from Larache, is identified in five ornaments from Huacalera and one from PVC.

The most common perforating technique is punching a pointy tool of circular section (66%), leaving round holes with the imprint of a point at the back. However, irregular perforations with burrs of different sizes and notches suggest the use of a blade to cut the surface in 10 artefacts (22%) from Huacalera (n=8) and Malka (n=2). Burrs were left untreated in 70% of the objects (n=32), flattened in 20% (n=9) and removed in 2% (n=1). Carefully flattened burrs, such as those seen in Larache or popm87 from Casa Parroquial (Figure 141), are rare and were only identified in the two *llama* pendants from LIT and a headdress from NWA of unknown location (Figure 141), but dated from the Middle Period (Goretti, 2012, p. 169).

Figure 141: Headdress from NWA (unknown context) and Casa Parroquial, popm87

Out of the 46 objects, only seven are decorated (15%): one is a ring with appliqué, and the other six are a mask, a bell, a *kero*, two pendants and a headband that were embossed and chased. Motifs are lines, dots and an anthropomorphic face in the mask. One decorated pendant is bird-shaped. In LIT there are two pendants with camelid shapes, similar to another pendant reported in PVC (Figure 140:C2) and two from Juella (Debenedetti, 1910, fig. 175).

As previously mentioned, there are three particular techniques in this area, not seen in the other regions. First, the use of metallic soldering in ring popm209 (Figure 139:A). This ring, specifically the band, is similar to the rings found in SPA and ring popm188 from PVC. The band is relatively rectangular, hammered and polished; the ends were bent to create a flat section where the appliqué was soldered. The composition of the three metallic parts of the ring are different (Table 34): the band contains the highest silver levels (45%Ag) and the soldering metal shows the highest copper (3.4%Cu).

Ring popm209	Cu%	Ag%	Au%
Appliqué	0.6	20.1	79.3
Soldering	3.4	31.3	65.3
Band	2.0	45.0	53.0

Table 34: Alloy composition of the three parts of ring popm209, by pXRF.
Note that the composition of the soldering is preliminary, because the conditions of the pXRF analysis were not ideal, i.e., the area analysed was small and the area analysed was in angle, and not flat.

The second technique is used in bracelet popm185 from PVC (Figure 140:C). This bracelet stands out because of the high quality of its making. The main shape was achieved by anticlastic raising, a specific technique used to produce two curves in opposite directions, taking the shape of a saddle (Figure 142). The same technique was probably used in a second bracelet found at the site that was not available for this research (Figure 140:C3) and maybe in the bracelet reported from Tabladitas (Figure 138:B1). The finishing of the bracelet is extremely well done, probably one of the finest work seen in this research so far, with thoroughly burnished surfaces, and round and smooth edges.

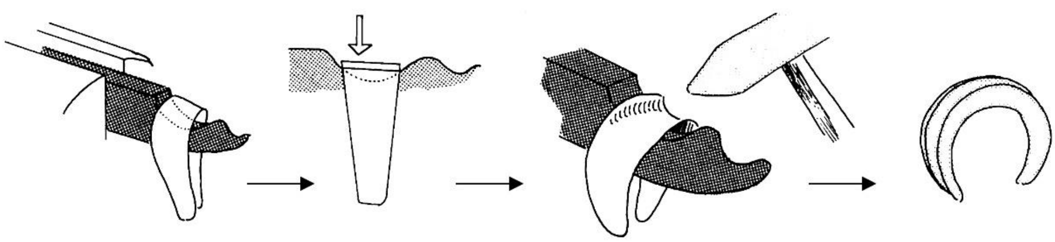


Figure 142: Anticlastic raising: sequence of manufacture (after McCreight, 1991, p. 62).

The third technique is the use of a gold sheet on a silver object, producing a bimetallic effect (Figure 140:C1). The U-shaped pectoral from PVC was not available for study, but from descriptions of archaeologists that saw the pectoral, it appears that a gold sheet was placed to cover the front and centre of the silver pectoral, leaving the ends exposed (M.E. Albeck, *pers. comm. 2017*).

Considering the manufacture of all the objects analysed, three levels of skill or dexterity are identified: finely-, coarsely- and poorly-made. Ten objects were finely-made, including pendants popm187, 195, 199, 218, rings popm188, 186, 209, *kero* popm190, bracelet popm185 and headband popm217. These items were evenly cut and thoroughly polished, and perforations were neatly made. It is noteworthy that in PVC, all ornaments are finely-made, they use special techniques such as anticlastic raising or bimetallic ornaments, and some are decorated. At the opposite end of the spectrum, there are five items that were poorly-made. In those cases the shapes are irregular and poorly defined, the edges are uneven and neither edges nor surfaces were polished. They comprise attachments popm202-204, 210 and 181. The remaining 31 ornaments stand somewhere in the middle, equivalent to the coarsely-made artefacts from SPA. These artefacts have defined shapes, but the edges and surfaces appear worn and not polished (some have visible cutting marks); perforations were made by punching or cut, but burrs were not treated.

Figure 143: Gold attachments and bands from Los Amarillos. Images courtesy of Axel Nielsen 2017.

A technological consistency is observed between the assemblages of Huacalera, LIT, Muyuna, San José and the site Los Amarillos (Figure 143) on the one hand; and PVC, El Volcan and Malka on the other. The first group strongly resembles objects in the SPA assemblage in the shapes, types of ornaments and their manufacture with different qualities; whereas the second group includes only finely-made ornaments, showing high skill and good quality, using complex techniques and paying especial attention to details and finishing treatments.

Evidence of reuse or modifications is not common, and is only seen in five objects (11%). From Huacalera, three attachments (popm202-204) have the same composition and fresh cuts and perforations, suggesting that they were cut from a single sheet. The cuts are coarse and were not polished. Also from Huacalera, popm214 is a pendant that has two half perforations on its sides, suggesting that the pendant was reshaped. From LIT, pendant popm180 was cut in half, also with coarse and rough cuts that were not polished. Fresh cuts are also seen in the attachments from Los Amarillos (Figure 143). Given the above, the main characteristics seen in Humahuaca gold and silver metallurgy are:

1. A limited use of raising: Raising is represented in *kero* popm190 from Volcan and the two bells from San José. Still, this number is not exact, because it is said that in PVC four *keros* were found, which are currently unavailable (as part of a private collection); together with another *kero* from Hornillos (M.E. Albeck, *pers. comm. 2017*).
2. There is a set of objects made by unique and uncommon techniques: soldering, anticlastic raising, and bimetallic ornaments. These techniques would reflect the work of specialised and skilled artisans.
3. Limited decoration: A few ornaments are decorated, with the main techniques being embossing and chasing to produce dots, lines and anthropomorphic faces.
4. Different qualities: There is a variety of qualities, even within sites. A few items show great skill and high quality in their manufacture, such as bracelet popm185 from PVC. However, most grave goods are coarsely-made, showing relatively good work, but without emphasis on details or finishing techniques.
5. Recurrent motifs: As in the *puna*, there are several *llama* or camelid pendants; only one bird pendant appears in PVC. Also present is one anthropomorphic mask.
6. Reuse or modifications: Seen in five objects only. They are indicated by fresh cuts and perforations in otherwise worn objects. These cuts are rough and where not polished or further treated.
7. The assemblages of this area (especially Huacalera and LIT) are very similar to the overall assemblage of SPA.

7.2.2.3 The Yungas

Towards the east and south of the Humahuaca Ravine, the landscape changes into a mountain rainforest known as the *yungas*. From this area, five objects were analysed: four conical-bells from Huaira-Huasi and a pendant from Los Aparejos en Pampa Grande. Given their design, shapes and composition, the conical-bells were made in pairs, using raising as the main technique and chasing to form the bands (Figure 144:A). Polishing marks were not visible on the surface, but they are still smooth to the touch. Compared to the bells in SPA that were finely-made, the quality of the specimens from Huaira-Huasi is lower, falling within the group of coarsely-made ornaments. Another gold conical-bell of the same type is reported in Cerro Morado, but no images were found (Ventura & Scambato, 2013).

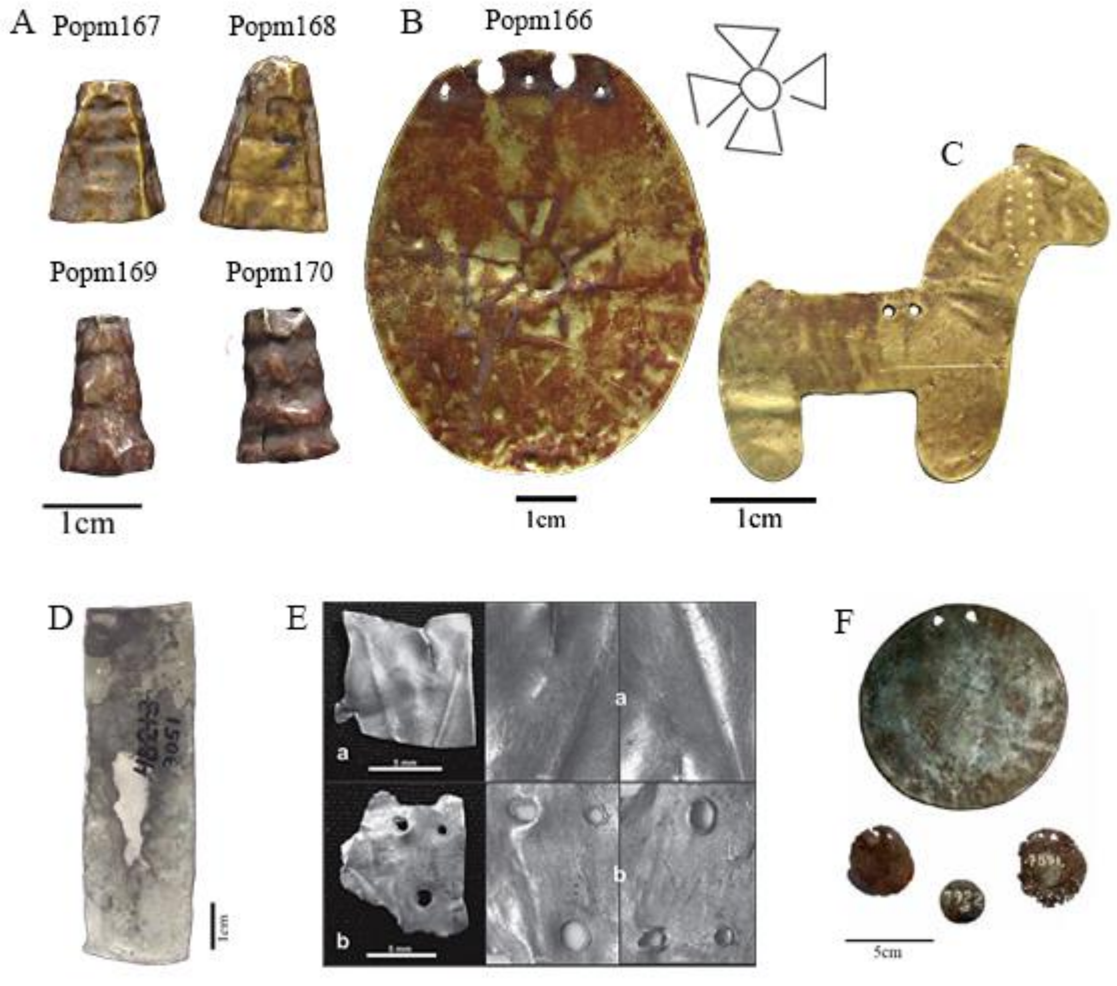


Figure 144: Gold and silver objects from the yungas.
A- Bells from Huaira-Huasi and B- Pendant from Los Aparejos de Pampa Grande; MLP. C- Pendant from Manuel Elordi-1 (Image courtesy of Beatriz Ventura 2017), D- Ingot from Titiconte, MEC, E- Fragments from Yaminas-1 (after Miguez, 2014, fig. 3), F- Discs from Pueblo Viejo de Rodeo Colorado (after Ventura & Scambato, 2013, fig. 20).

The fifth object analysed shows better quality: it is an oval pendant decorated with a motif resembling a Maltese cross chased in the centre (Figure 144:B), very similar in shape and design to pendant popm128 from SPA. To suspend the pendant, three perforations were made at the top by punching. Both surface and edges were carefully polished with abrasive material. Of similar manufacture and quality is a *llama* pendant reported by Ventura (1985) in the site of Manuel Elordi-1 (Figure 144:C). The pendant was cut to shape, being completely polished and deleting any cutting evidence. Embossed dots and lines marked the features of the animal. Two perforations were made to suspend it and its burrs were left untreated.

Other objects reported from this area, but not available for this research, are two small gold fragments (Figure 144:E), showing even cuts and polished surfaces from Yaminas-1 (Miguez, 2014); rectangular silver plates (ingots?) from Titiconte (Figure 144:D) and Tolomosa; small gold (n=?) and silver (n=4) pendants from Pueblo Viejo de Rodeo Colorado (Figure 144:F); gold and silver sheet fragments from Cerro Morado; a silver bracelet from Cuesta Azul and a silver disc from Molino Viejo (Ventura & Scambato, 2013). Only a few features can be listed, given the small number of objects analysed from the area:

1. The use of raising is seen in four, maybe five bells. Their quality is relatively coarse compared to bells from SPA.
2. The two pendants analysed are finely-made and were decorated.
3. Decoration was made by embossing and chasing
4. Motifs are a *llama*-shaped pendant and a Maltese cross
5. There is no evidence of reused or modified artefacts

7.2.3 Artefacts from Chile

From Chile, only a few gold artefacts from outside SPA were analysed: three pendants, one tube and a set of 32 beads (Figure 145). All these objects are from early sites (Formative Period, before AD 400). The pendants and tube were hammered, cut to shape and polished. In popm219 and popm149 surfaces were polished with an abrasive; popm148 was not polished. Both popm219 and popm149 were decorated with the same technique: embossed dots arranged in lines, alternating the surface of work and producing a high and low relief effect. Perforations were cut (popm148, 219) and punched (popm149). Interestingly, the shape and the presence of cutting marks in popm149 suggest that the pendant was modified.

The set of 32 beads from Yona-2 (located at the south end of the Atacama Salt Flat) are very irregular in shape, but of similar sizes. It is possible that these beads were made by hammering small gold grains. Their composition with silver levels between 3-10% and not detected copper (see previous section) would support the use of unalloyed native grains. The front of the beads was polished with a hard abrasive material, leaving regular scratches in different directions; while the back was not polished. The technique to perforate the beads is not clear. The circular marks and the presence of notches within the perforation suggest that a small blade was punched and twisted. Experiments trying different perforation methods would give light on this aspect.

In terms of quality, ornaments can be grouped in two: popm149 and 219 are finely-made, whereas popm45/72 and 148 are coarsely-made. Other finely-made objects from the area are three elaborate pendants from the Formative Period (400BC-AD400) that appear in Guatacondo and Tulán-54 (Figure 145:F-G1). The decorated pendants are strikingly well made, they are completely polished and were decorated by cutting out parts and embossing. From the image, it looks like the top perforation in G1 may have been made by rotation. Also from Tulán-54, there is a wooden piece shaped as a *condor* head that was wrapped with gold sheets and adorned with green stones (Figure 145:G2) and a pendant very similar in shape and decoration to popm219 from Caleta Urco (described in Núñez et al., 2017). For Tulán-54 ornaments, Nuñez and colleagues suggest that all of them are foreign items introduced from elsewhere (2017). Associated to the Later Period of Inka influence, a bell is found as grave good in Caspana (Figure 145:E); and from the semi-arid north, there is a headdress of unknown location and date, but very similar to the ones seen in NWA and SPA (Figure 145:H). Overall, however, this variety of artefacts is not very similar to the SPA assemblage. Based on all the objects registered, the main features identified in northern Chile are:

1. Different qualities: From the Formative Period pendants are of very good quality, showing fine work; whereas the beads from Yona-2 are cruder.
2. Combination of complex and more simple decoration: the artefacts from Guatacondo and Tulán-54 are extremely sophisticated in their shape, which was obtained by cutting and embossing; whereas the decoration in pendants popm149 and 219 was simpler, using only embossed dots.
3. Wrapping and lapidary: These techniques were used to cover and decorate a wooden figure; apparently multiple sheets were used to wrap the figure.
4. Recurrent motifs: dotted lines, the character with the radiate head (*"personaje de cabeza radiada"*) and a bird (*cóndor*).
5. Raising is rare (one bell only) and it appears associated to a Later Period burial.

6. There is at least one modified pendant, which was cut and perforated.

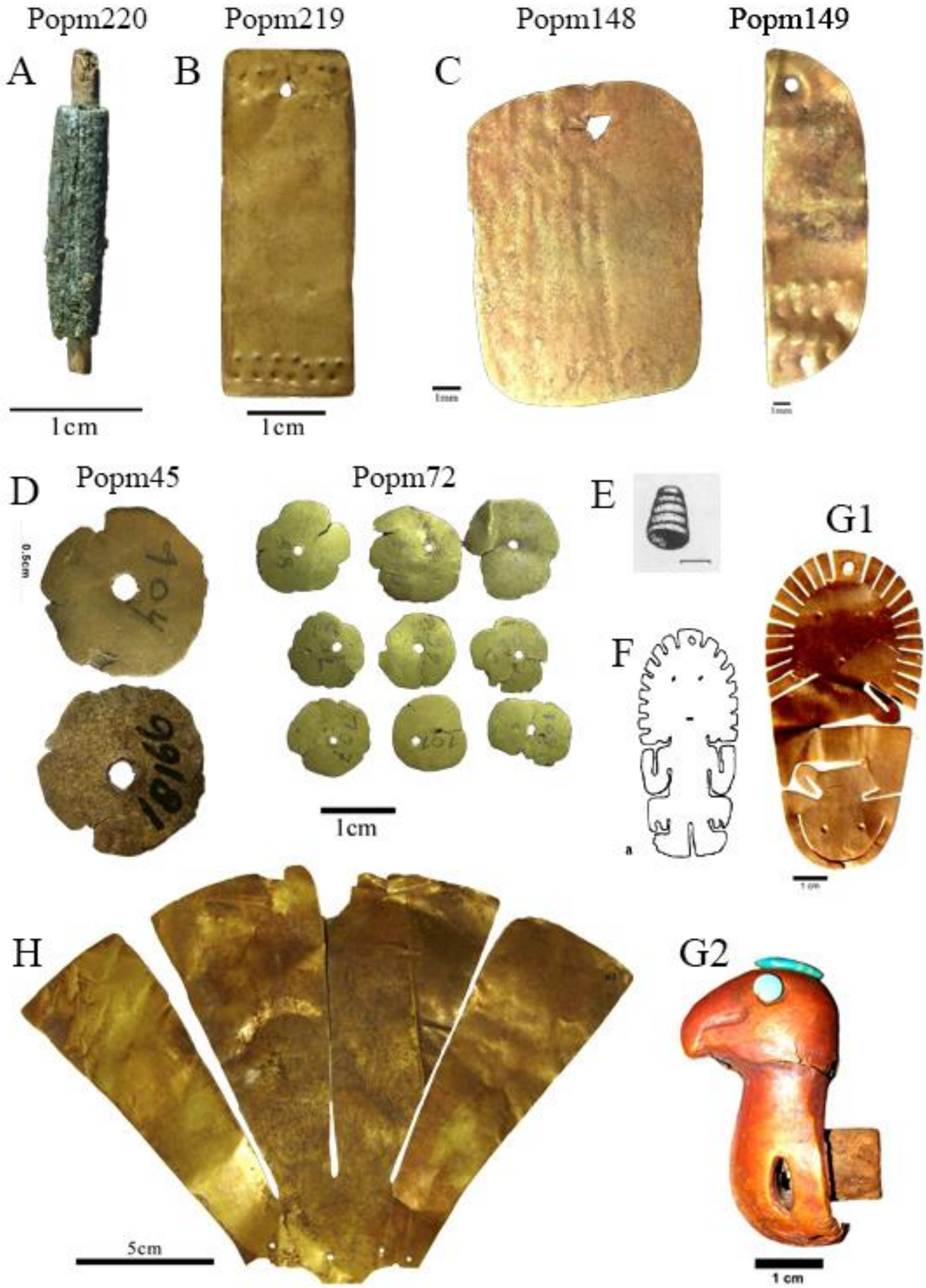


Figure 145: Gold artefacts from Northern Chile.
A- Hornitos-1, B- Caleta Urco, C- Chorrillos Cemetery (CCTC), D-Yona-2 (MSPA), E- Los Abuelos Cemetery, Caspana (after Ayala R. et al., 1999, fig. 7); F- Guatacondo (after Horta, 2004, fig. 20), G-Tulán-54 (after Núñez et al., 2017, figs. 16–17); H- Copiapo, Semi-arid North (MChAP).

7.2.4 Summary

Based on the materials available, a series of technological characteristics were outlined for each area (see a summary in Table 35). Here I highlight some of them, of particular significance.

In the case of central Bolivia, the characteristics identified in the Titicaca basin would represent aspects of the Tiwanaku metallurgical technology. The same technology was probably shared in the eastern valleys of Cochabamba, where the San Sebastian treasure was found. It should be emphasised that it is beyond the scope of this thesis to define Tiwanaku metallurgy, here I only tried to identify relevant technological features, studying a limited number of finished objects. Some key characteristics recognised are the use of raising, wiggle cut and pointillism, and producing complex shapes by cutting, embossing, chasing, and stones inlay amongst others.

From southern Bolivia, the careful work expressed in polished edges and surfaces stands out, specifically in bow-tie shaped pendants. The decoration of these pendants with embossed confronted faces is also characteristic of this region.

From NWA stand out the sets of pendants and attachments of different sizes and shapes, very similar to those seen in SPA. *Llama*-shaped pendants appear almost exclusively in this area, together with perforations made by rotation, and discs with embossed or chased Maltese crosses.

	Bolivia		**Argentina**			
	Central *Altiplano*, Tiwanaku, Cochabamba	**The southern *Altiplano*: Potosi, Lipez**	***Puna***	**Humahuaca Ravine**	***Yungas***	**Northern Chile**
Raising	Several vessels and conic bells	1 conic bell	5 conic bells	2 bells and 1 *keros* (maybe 4 *keros* more)	5 conic bells	1 conic bell
Casting	3 items	N.D.	1 pectoral	N.D.	N.D.	N.D.
Soldering	N.D.	N.D.	N.D.	1 ring	N.D.	N.D.
Wrapping with gold/silver sheets	N.D.	N.D.	N.D.	1 wooden tube	N.D.	1 wooden figure
Decoration techniques	Embossing, chasing, engraving, wiggle cut or pointillism, stone inlay, openwork	Embossing, chasing	Embossing, chasing, openwork	Embossing, chasing, bimetallic items	Embossing, chasing	Embossing, chasing, stone inlay, openwork
Designs	Plain pendants and complex items, lavishly decorated with intricate shapes, using openwork	Relatively simple pendants	Relatively simple pendants	Relatively simple pendants	Relatively simple pendants	Relatively simple pendants. Complex shapes.
Quality of work	Different qualities, however most items are finely-made	Finely-made	Finely and coarsely-made	Finely-, coarsely- and poorly-made	Finely and coarsely-made	Finely and coarsely-made
Recurrent decoration motifs	Feline heads; schematic birds with open wings, anthropomorphic faces and the Tiwanaku deity	Anthropomorphic faces, geometric figures (circles, rectangles, triangles, lines), a bird. The bow-tie shape pendant appear to be more abundant in this area.	Llama-shaped pendants, anthropomorphic and feline faces	Llama-shaped pendants; only one bird pendant, anthropomorphic masks	Llama-shaped pendants and Maltese cross	Dotted lines, the character with the radiate head (*"personaje de cabeza radiada"*) and a bird.
Modifications, repairs	N.D. Possibly new perforations in fragments recovered in Lake Titicaca	N.D. Possibly in 1 pendant. Two objects were repaired.	N.D.	Documented in 5 items. Repairs in 3 cases.	N.D.	Documented in 1 pendant.
Observations			Rotation to perforate. It is an heterogeneous assemblage	Use of anticlastic raise technique.		Objects are not from the MP.

N.D.: Not documented

Table 35: Summary of the main technological characteristics documented by area.

7.3 Discussion chapter 7

In chapters 5 and 6 it was proposed that most objects in SPA were presumably arriving as finished objects, being produced elsewhere. In this chapter, some regional characteristics were identified, based on the chemical composition and manufacturing techniques of a series of objects. In this discussion I will combine elemental and manufacturing information with designs and decoration, to propose that certain objects in SPA were made and travelled from other areas. I argue that nearly 25% of the objects from SPA were most likely produced and imported from Tiwanaku, including the Titicaca Basin and Cochabamba Valley; whereas ~27% was probably imported from NWA, and 1% was possibly produced in the southern *Altiplano*. These finds would have major impact in the interpretation of gold users in SPA, because they suggest that the use of noble metals was not only relating users to Tiwanaku, but also to neighbouring areas.

By sites, it is observed that Tiwanaku and NWA objects appear mixed, although the majority of Tiwanaku objects are found in Larache, whereas most items from Casa Parroquial would correspond to a NWA tradition. Interestingly, the Tiwanaku goblets from Casa Parroquial may have been made in the Cochabamba Valley, a secondary centre of the Tiwanaku sphere. The comparison provided here includes objects from the SPA cemeteries that were not available for analysis, such as 27 ornaments from Larache (including two of necklaces of 15 and 11 tubular beads; Appendix Nº5: 3).

This discussion is organised in two sections. First, in section 7.3.1, the foreign technologies present in SPA will be identified, including objects that were probably made in NWA (7.3.1.1), Tiwanaku (7.3.1.2) and the southern *Altiplano* (7.3.1.3). Section 7.4 shows how these objects are distributed in the different cemeteries of SPA.

7.3.1 Foreign technologies in SPA

7.3.1.1 Northwest Argentinean technology

Overall and looking at the evidence gathered from the three regions, the objects that most resemble SPA assemblage are those from Humahuaca Ravine (NWA). They share shapes, types, manufacturing techniques and composition.

In particular the gold grave goods from Huacalera, La Isla de Tilcara, Muyuna, San José and Los Amarillos are very similar to the pendants and attachments from Casa Parroquial, Quitor-1 and the coarsely-made ornaments from Larache. They are quadrangular attachments with perforations in four or two corners, small rectangular or trapezoidal pendants, bands used as bracelets and thin long headbands. All are plain and partially polished. Compositions are also similar, with low levels of copper as seen in Figure 146. Some differences should be noted, though. Band-rings, headdresses and conical-bells are more frequent in SPA, whereas from NWA are gold folded bells, *llama*-shaped pendants and embossed masks are more common.

It is estimated that 38 objects from SPA would come from NWA (27%). Unfortunately, - and even though composition (Figure 146, black crosses), appearance and techniques are very similar - in 32 of them the evidence is not conclusive, because of the simplicity of the items. The 32 items include 19 from Casa Parroquial (popm1,10,17-18, 47,50-51,73-83,85); seven from Quitor-1 (popm32-34,37,150-152); two from Sequitor Alambrado (popm15-16), one from Quitor-5 (popm26), and three from uncertain cemeteries (popm24,28,55; see Appendix Nº5). An exception are six objects (4%) with particularly strong evidence to support that they were made in NWA: three from Casa Parroquial, two from Larache and one of an unknown site (Figure 147). The composition of these SPA ornaments and NWA material is coherent, as seen in Figure 146.

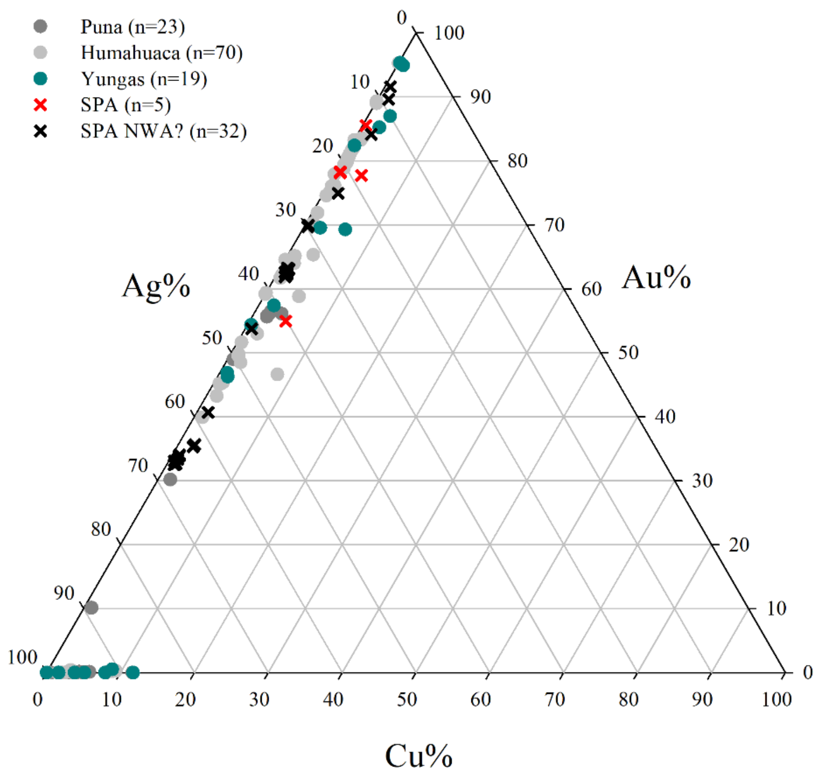


Figure 146: Au-Ag-Cu ternary diagram comparing NWA (Puna, Humahuaca and Yungas) compositions against five ornaments from SPA (red crosses; pendant 91.1.11 was not analysed) and other artefacts of NWA aspect (black crosses).

From Casa Parroquial, there are three reused ornaments that are proposed as parts of two headdresses with four appendices: popm87, 84 and 86. These finely-made objects have straight and even edges that were ground and polished, as were their surfaces. Popm87 still preserves some of the original perforations, which were punched with a pointy tool and the burrs were carefully flattened. The flattened burrs were certainly considered part of the decoration, because they were left visible on the front side.

An identical and complete headdress is reported in NWA (Figure 141). It shares the same design and manufacturing techniques as popm87. The perforations in particular - located in the same place as popm87 - used the same tools and technique; and burrs were flattened and left visible at the front. The only difference between the headdresses is the decoration in the example from NWA. Considering the similitude between the ornaments from both areas and the fact that headdresses in SPA often appear cut and modified, it is likely that these artefacts were imported from NWA, and were modified in SPA. Another similar headdress is reported from Copiapo (northern Chile, Figure 145:H), however its shape is slightly different to popm87 and the headdress from NWA.

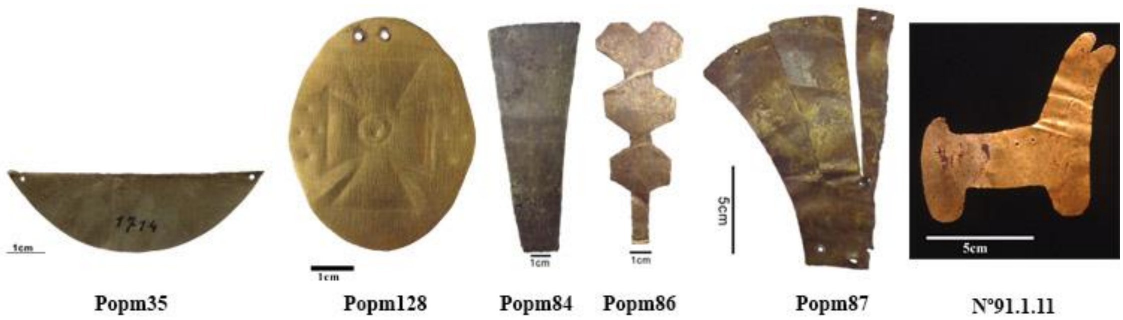


Figure 147: SPA objects that are probably from NWA.

Likewise, pendant popm35 (Larache) and popm128 (unknown site) present technical and decorative traits that relate them to NWA. Technologically speaking, both pendants are finely-made, being two of the finest items of the assemblage. Both pendants were carefully cut, ground and polished; polishing marks are very regular on both sides, producing a smooth and shiny surface. But most significant are the perforations made by rotation, an infrequent technique observed heretofore in two objects from NWA only. The two Argentinean examples using this technique were fine-made too, employing great care, skill and dexterity, as were popm35 and 128 (Figure 136:1 and 137:B).

Popm35 is an undecorated part of a disc that was reused, and the perforations are part of the modification. Given the good quality of the modification, it was proposed in chapter 6 that popm35 arrived at SPA already modified. Given the use of rotation, it is possible that popm35 was made and also modified in NWA. Regarding popm128's decoration, it has a Maltese cross embossed in the centre and four dots at each side. This particular motif is identified in other pendants from NWA (Figure 148:A) such as popm166 from Pampa Grande, which is very similar to popm128 (Figure 144:B). As a motif though, the Maltese cross is recurrent in Tiwanaku iconography too, being depicted in pottery, stone and metals (Figure 148:B-D) from the period.

Finally, the only *llama*-shaped pendant from SPA was found in Larache (Figure 147). Unfortunately, the pendant was not accessible for analysis, but from the available images, some technical traits are deduced. For example, the sheet was cut to shape and polished. The edges look smooth and the surface shows some regular scratches interpreted as polish marks. Two small perforations were punched. Considering that all the *llama*-shaped pendants are in NWA, it is very likely that the pendant from Larache also came from NWA.

Figure 148: The Maltese cross in other pendants and objects.
A- Pendants from NWA (after Goretti, 2012, p. 163); B- Detail of a Tiwanaku style (B) headdress and (D) Kero (Young-Sánchez, 2004, fig. 3.28,6.36); C- Tiwanaku rock sculpture (Posnansky, 1957, fig. LXXV.A.a).

7.3.1.2 Tiwanaku technology

Overall, Tiwanaku objects are more sophisticated and complex in their manufacture than those from SPA or NWA. But still, within SPA an important group (n=36, 25%) of gold ornaments can be tentatively traced to the central *Altiplano*, made with Tiwanaku technology. They include *keros* (n=3), portrait-vessels (n=3), wire-rings[17] (n=6), pendants (n=2) and 27 conical-bells[18]; yet the manufacture of the latter are less conclusive as will be discussed later. All these grave goods – except two – come from Larache, and their compositions are consistent with those of Bolivian and Tiwanaku objects (Figure 149).

There is a series of indications supporting an *altiplanic* manufacture for the *keros* and portrait-vessels. First, their style. The gold *keros* in SPA represent the classic

[17] Out of six examples known in SPA, three rings are lost and were not analysed in this research.
[18] Out of 27, 6 bells from SPA are lost and were not analysed in this research.

Tiwanaku style with the hyperboloid form, flaring rims and tori as decoration (Appendix Nº5: 1-2). According to Janusek (2003), *keros* – commonly made in ceramic and wood, but also documented in metal and stone – are very standard in their design and dimensions, which are 16-20cm in height and 12-18cm in rim diameter. These are the same proportions seen in metallic *keros* from SPA (and from El Volcan, NWA) with *ca.*17cm height and 15cm diameter. The style of the tori, also replicate the forms seen in pottery: a) double, triple or two separated tori such as those in popm136 and 140, or b) a single large rounded torus such as popm139. Pottery *keros* were produced on a massive scale during Tiwanaku IV and V periods (AD 500-800 and 800-1150, respectively) by highly trained specialists (Janusek, 2003). Likewise, portrait vessels found in SPA are the metallic version of Tiwanaku portrait vessels made in pottery, wood and stone (Figure 150). Like the *altiplanic* examples, portrait-vessels in SPA are naturalistic representations of single individuals, portrayed with a characteristic circular hat. In SPA, in only one portrait-vessel the individual was represented chewing coca, feature common in pottery, stone or wooden vessels (Janusek, 2003).

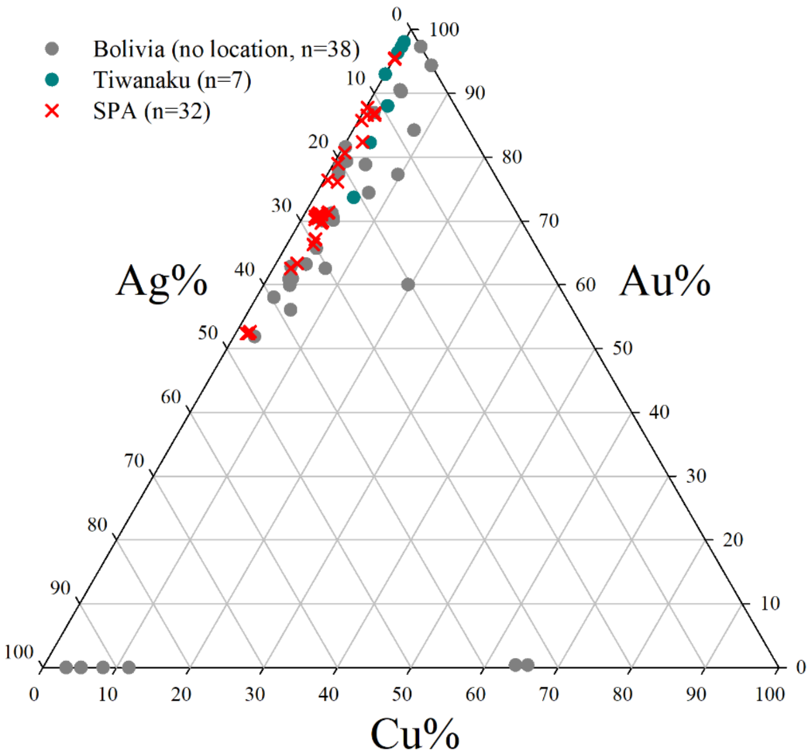


Figure 149: Au-Ag-Cu ternary diagram comparing compositions from Bolivia, Tiwanaku and SPA.

Second, the evidence of specialised production. a) As proposed in chapter 6 at least two people were employing the same technological style in the shaping of the goblets from Larache. b) Raising is a complex and slow technique that needs specialised training, and a range of tools – such as hammers and stakes – of different shapes and dimensions, as well as moulds and other materials to decorate the vessels. c) Raising as technique is common in the Titicaca basin, being represented by different vessels with varied shapes and sizes. d) *Keros* and portrait-vessels in particular, were highly valued ritual objects that followed relatively strict codes, reflected in standardised designs made by "*specialists intimately familiar with the hieratic iconography of Tiwanaku elites*", as observed by Janusek (2003, pp. 60–61).

Figure 150: Tiwanaku portrait-vessels.
Made of A-B. Wood, from SPA (image A from the author; image B after Berenguer, 2000, p. 91; Le Paige, 1964, fig. 127.2); C- Stone, Ethnologisches Museum, V.A.64570; D- Pottery (after Sagárnaga, 2007, fig. 1).

Therefore, considering the importance of these vessels, the complexity of the forming technique, the equipment required, a common use of raising in the central *Altiplano*, and the evidence that two skilled people were sharing the same technological style; it is reasonable to propose that *keros* and portrait-vessels were made by a group of specialists or in workshops, where people are actively sharing techniques or are subjected to a formal training, and where the "correct way" of making a *kero* can be controlled and taught (Creese, 2012; Wallaert, 2012; Wendrich, 2012b, 2012a). Although no Tiwanaku metallurgical workshops have been found so far, this model agrees with evidence at the Tiwanaku urban centre – and other centres under Tiwanaku influence –, where other craft specialists (e.g. potters, panpipes makers) were grouped in households and neighbourhoods (Janusek, 1999). These conditions would promote communication and exchange of ideas, as would allow contact in practice, where different "ways of doing" are learned and transferred (Wendrich, 2012b, 2012a). Furthermore, the composition of goblets popm136-137 made of pure gold with silver under 10% also supports an *altiplanic* connection, given that gold of such purity is common in Tiwanaku objects, but heretofore rare in south Peru or NWA.

The same workshop model would explain the manufacture of the wire-rings from Larache. Identical wire-rings, but made in bronze have been excavated in Tiwanaku, and shaped with the same manufacture sequence observed in the wire-rings of SPA (Figure 65-67; Lechtman & Macfarlane, 2005). Interestingly, their making also identifies two individual artisans, both clearly working within the same technological style.

The final connection with Tiwanaku is given by the decoration techniques and motifs used in *kero* popm140 from Casa Parroquial. First, the use of embossing and chasing to decorate the upper section of metallic *keros*, as in popm140, is reported in a gold *kero* from Pariti Island (Figure 131:A-B), reflecting in both examples great expertise and skill. However, more relevant is the use of pointillism in popm140, because this technique has been identified only in the central *Altiplano* and related to Tiwanaku objects (see section 7.2.1.1). Second, the design represented in popm140 (the *condor*) is a recurrent Tiwanaku motif, usually seen in pottery and stone work (Appendix Nº2: 31). However, some particularities of the figure such as the curly tail, the spiky wing, the S volute at the bottom and the orientation of the figures alternating them up and down, are remarkably similar to a design reported by Posnasnky (Figure 151:A) in a *kero* from Cochabamba (1957, plate LIc). It is possible then, that popm140 from Casa Parroquial was made with Tiwanaku techniques and style, but in Cochabamba, the same place where the San Sebastian Treasure was found.

Figure 151: Condor design from Cochabamba, SPA and Tiwanaku.
Note the similarities of the motifs between keros from (A) Cochabamba and (B) popm140 from SPA: both the condor and the volutes. C-D- Condor designs in pottery from the site of Tiwanaku as comparison (modified from Posnansky, 1957, fig. XXVIII.a, XXXV.c, XXXVII.a-b, LI.b).

Other objects that probably come from the Titicaca basin are the small raised conical bells; however, their assignation as Tiwanaku seems less consistent for the moment. As seen in the goblets, these bells were made by raising, a technology that was certainly employed and mastered in Tiwanaku. They are usually found in pairs or small groups, showing an internal consistency in their forming techniques and designs, suggesting that were made together by a single person. Still, designs vary among groups, indicating that several people were making bells (although the contemporaneity of the work is not clear at this point). Most of them are decorated with horizontal bands made by chasing or engraving. In SPA there are two variants: a plain body (n=1) and a plain body with a neck (n=5). The variant with neck is also found in San José, in Humahuaca (Figure 140:E). These bells are relatively widespread across the SCA, but at a low frequency (1-4 bells, Figure 152). The only exceptions are Larache in SPA with 21 bells (still, they may be 27 in total, given that six bells are reported, but were not found in the museum) and the Titicaca Basin with at least 40 bells. Unfortunately, I did not have access to the bells from the Titicaca area, therefore their number were estimated by personal communication with colleagues and images found online, still the real number is unclear. In the few images obtained, most bells appear to have horizontal bands, yet the identification of the variants registered in SPA would remain pending.

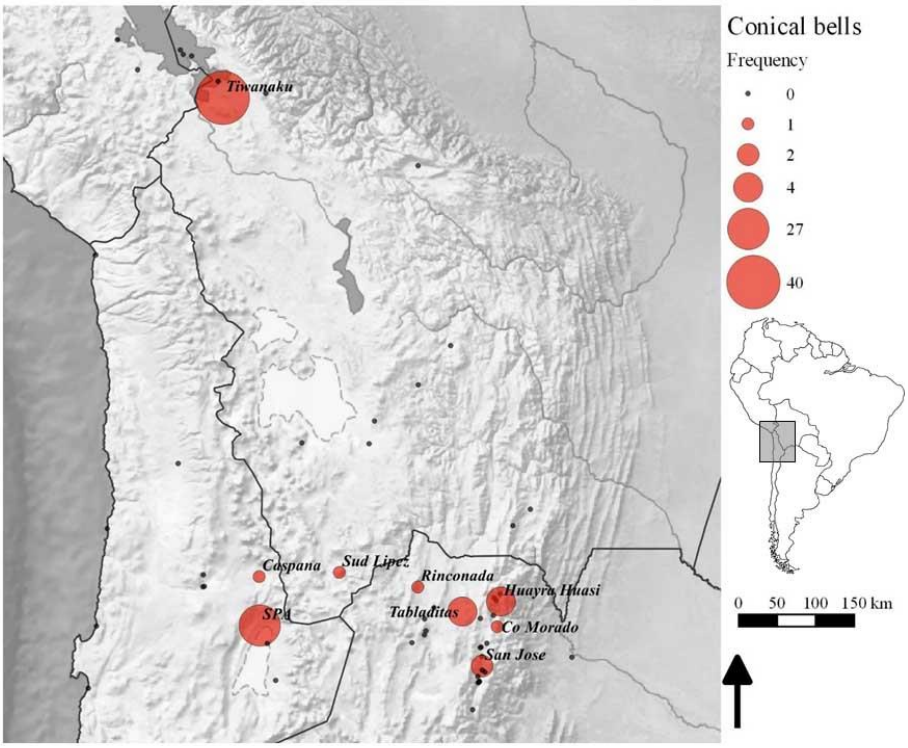


Figure 152: Frequency of the conical bells documented in SCA sites.

Therefore, arguing in favour of an *altiplanic* production of these bells, is 1) the high frequency of bells reported in the Titicaca Basin compared to other areas (Figure

152), 2) the use of raising and 3) the fact that several skilled artisans were making these bells. Still, it would be interesting to confirm whether the variants with neck seen in SPA are also present in the Titicaca Basin. If these categories are absent, they may represent a “local” production that would need further study.

Other objects that may come from the *altiplano* are popm67 and popm30. Popm67 is a finely-made small piece with a very particular shape that constantly appear in Tiwanaku iconography. I propose that this piece was made to be inlayed in another object, probably a wooden tray (Figure 153). Several wooden trays of Tiwanaku style have this shape carved; however I was not able to find a tray that has the space to fit this piece. Popm30 is a disc decorated with openwork. Considering that in the *altiplano* a number of objects were decorated with openwork and pedants were cut with complex shapes, it is possible that this item was imported from there.

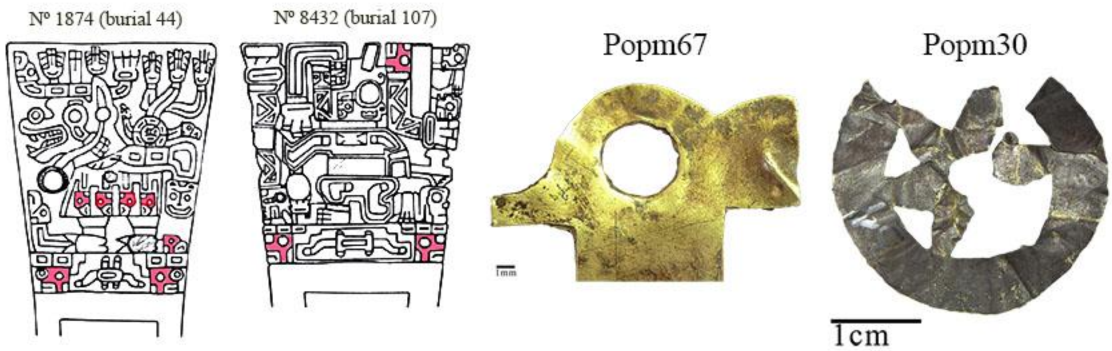


Figure 153: Popm67 and popm30. Tiwanaku style trays indicating shapes similar to popm67.

7.3.1.3 Southern Altiplano technology

Based on their shape, manufacturing techniques and composition (Figure 155), there is one object (1%) that may come from Sud Lipez: popm53 (Figure 154:A). Popm53 is an undecorated bow-tie pendant that was modified. Its manufacture is fine in quality, with even and thoroughly polished, edges and surfaces. The pendant and its making are very similar to the pendants reported in Sud Lipez (see Figure 135). However it has two particularities: two tiny perforations, one at each end, and the lack of decoration. From the southern *Altiplano*, only one pendant was identified with two perforations (Figure 135:8), - they usually have one perforation at the centre - and none were plain. Similar pendants appear in NWA (see Figure 136:3 from the *puna*), but most are showing a perforation at one end and usually decorated with embossed dots (Figure 154:B).

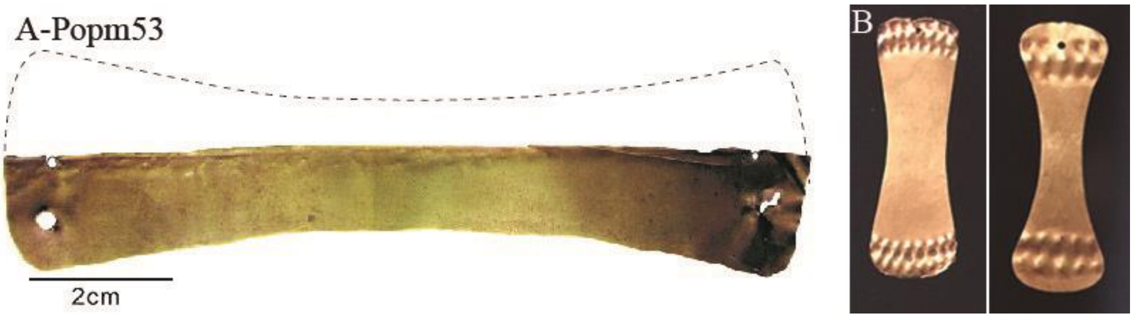


Figure 154: A- Pendant popm53, B- similar pendants from NWA (unknown precedence), but with only one suspension perforation (B- Images after Goretti, 2012, p. 162).

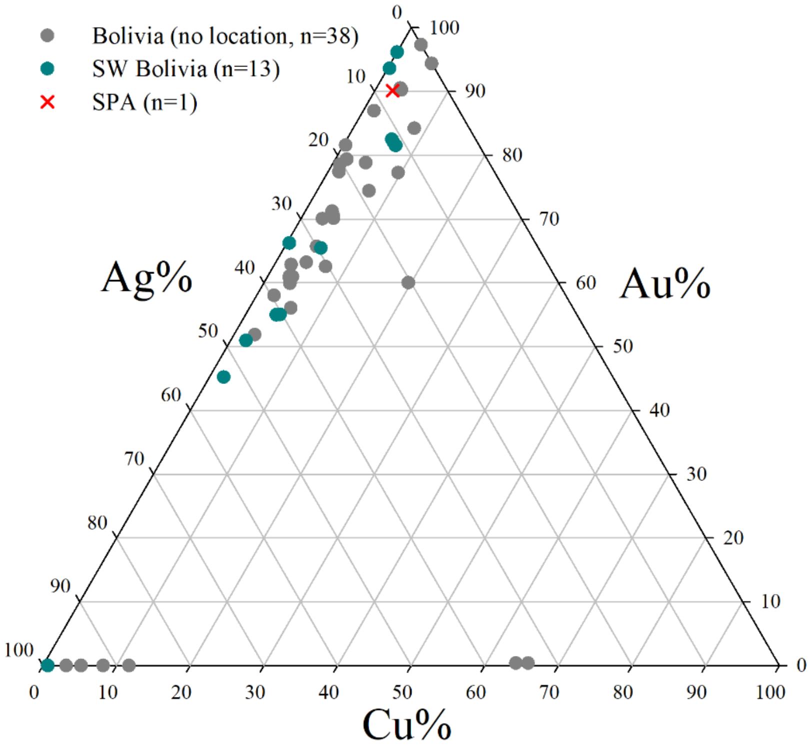


Figure 155: Au-Ag-Cu ternary diagram comparing SW Bolivia with popm53 from SPA.

7.4 Distribution of foreign technologies by sites

In terms of distribution, Larache concentrates most number of Tiwanaku objects, representing 35% of its gold and silver items, whereas 2% is from NWA (Figure 156). The high frequency of bells in central *Altiplano*, the presence of wire-rings in the site of Tiwanaku, together with the highly pure composition of some gold items, relate this technology to the Titicaca Basin.

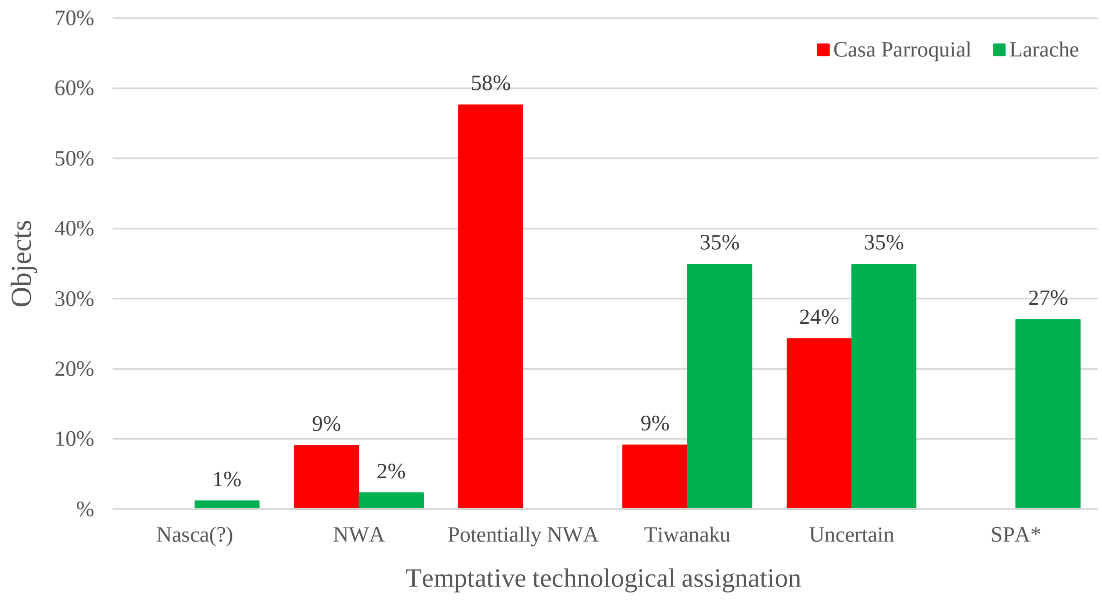


Figure 156: Bar graph showing the percentages of objects that were probably made by different technologies. (*) Indicates objects that may have been made locally, see chapter 8. The Nasca object is the only item with high-copper levels in Larache, still its assignation is tentative.

In Casa Parroquial ("CP"), on the other hand, Tiwanaku and NWA objects are represented in the same proportion with 9% (3 objects each; Figure 156). However, given the iconography in *kero* popm140, Tiwanaku technology in this case may derive from Cochabamba Valley rather than from the Titicaca Basin.

Notwithstanding the limited number of objects that are convincingly from NWA, there is 58% of the assemblage that shares composition (Figure 157), manufacturing traits and designs with other objects reported in NWA, in particular the Humahuaca Ravine. Unfortunately, given the simplicity of these items, their assignation is not definite and further evidence is needed to confirm this link (e.g. trace elements). Nevertheless, and considering the above, it is proposed here that the majority of CP gold artefacts were most likely made in NWA and imported to SPA, relating this cemetery to NWA.

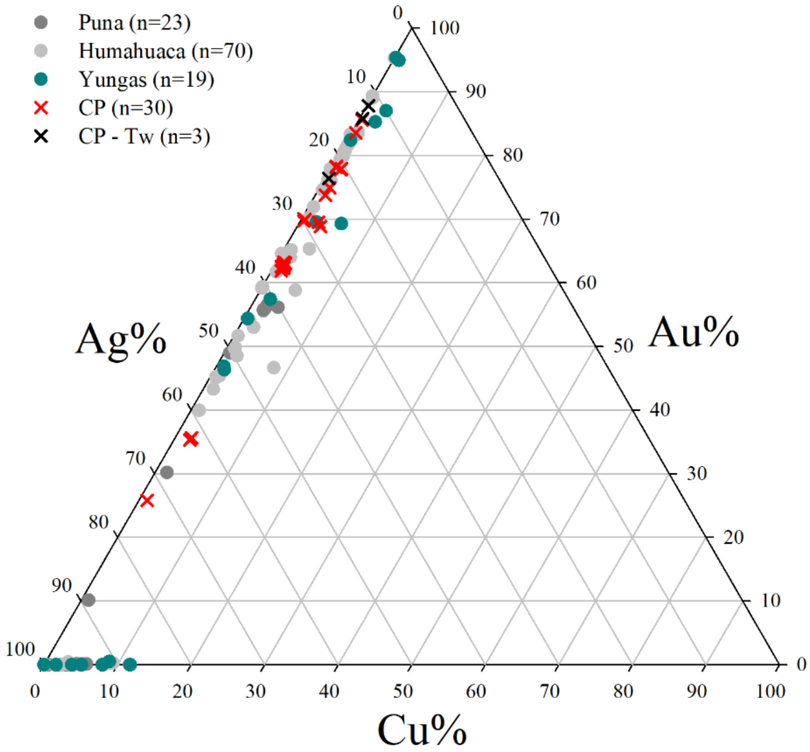


Figure 157: Au-Ag-Cu ternary diagram comparing NWA with Casa Parroquial (CP). Objects of Tiwanaku origins are plotted in black.

One pendant from Quitor-5 is proposed as Tiwanaku, still its assignation is less certain. In the other cemeteries, such as Coyo-3, Quitor-1 and Sequitor Alambrado there is no diagnostic evidence to relate more directly their grave goods to specific areas. Still from items of unknown cemeteries, there are three objects probably coming from Tiwanaku, southern *Altiplano* and NWA (one each).

It is noteworthy then, that regarding precious metal metallurgy - and judging by the objects frequency -, Larache in particular shows a closer relation to Tiwanaku metallurgy, whereas CP is more NWA in its technology. Still in both cemeteries, a few Tiwanaku or NWA are present, indicating that the gold offerings gathered in the same cemetery are coming from different areas, not only from a single place. Considering that Larache has earlier dates than CP, it is possible that the different technologies reflect changes in the social dynamics or mobility networks during the Middle Period between these particular *ayllus*; indicating connections with the central *Altiplano* during the Quitor phase (AD 400-700), that shifted towards NWA and Cochabamba Valleys during the Coyo phase (AD 700-1000).

7.5 Final summary

In this chapter elemental composition and manufacturing techniques of gold and silver objects from the SCA were presented and discussed. Their comparison with the assemblage from SPA has revealed key information about gold objects deposited in SPA, challenging previous assumptions regarding the origins of these artefacts. It was demonstrated that even though some grave goods were made with a technology associated to Tiwanaku - as previously granted - objects may come either from the Titicaca Basin or the Cochabamba valley. Further, gold objects are also entering SPA from neighbouring areas such as NWA and the southern *Altiplano*, associations not previously seen in gold or silver objects.

Elemental composition of major elements overlap between SPA-Tiwanaku and SPA-NWA, suggesting that similar sources and alloy practices were used and developed (e.g. gold-silver and silver-copper alloys). It is proposed here that some compositions are distinctive for each region, such as gold with low-copper in NWA and relatively pure gold in Lake Titicaca Basin (although an important group overlap between NWA and Tiwanaku). Still, these proposals would need further verification; comparing trace elements between the assemblages of these areas would be appropriate to test this assumptions.

In terms of typologies and manufacturing traits, *keros*, portrait-vessels, bells and wire-rings are the main Tiwanaku categories present in SPA; whereas headdresses with appendices, discs perforated by rotation, Maltese crosses and *llama*-shaped pendants would represent a tradition from NWA. In general, diagnostic objects from NWA are not frequent in SPA, but there is a large number of simple and plain pendants that are more difficult to relate to other areas, which are very similar in manufacture and appearance to objects from NWA. It is possible then, that a great proportion of these plain items were produced and imported from NWA.

Finally, based on the frequency of Tiwanaku, NWA and southern *Altiplano* objects, Larache appears strongly related to a Tiwanaku technology; whereas Casa Parroquial would relate to a NWA technology, particularly from the Humahuaca Ravine.

Chapter 8. Discussion Part III: Precious metalwork in SPA

The results presented in chapters 5-7 generated abundant information about the production of gold and, to a lesser extent, silver in SPA during the Middle Period. In this chapter, I will use all the information and discuss the major contributions of this research, which would help to address some of the questions stated in the introduction, covering in part some of the research gaps.

Sections 8.1 and 8.2 are directly related to the characteristics of the SPA assemblage. The data suggest that 8.1) the majority of the assemblage found in SPA is composed of imported items, made in the Bolivian *Altiplano* and NWA; and 8.2) it identifies a local metalwork, divided in two different activities: 8.2.1) the local modification of imported items by non-specialists and 8.2.2) the local production of a specific commission. This local metalwork produced objects especially made for the burial (section 8.2.3).

Sections 8.3 and 8.4 deal with more regional matters. The thorough analysis of the assemblage has provided a series of features that allows to infer some aspects of the organisation of gold production in the SCA. In this regard, I argue that 8.3) objects produced with a Tiwanaku technology were most likely produced in workshops were various specialists were practicing together; whereas objects made in NWA, the southern *Altiplano* and SPA, are most likely the product of independent specialists, of variable skill levels, working alone or in small groups. In terms of circulation, 8.4) gold moved in the same spheres as other materials, such as bronze alloys or pottery; and it is possible that the variability seen in SPA reflects in part the different mobility systems in place during the MP.

8.1 Imported gold and silver objects

One of the main aims of this research was to characterise the gold and silver assemblage of SPA, in the hope of identifying technological styles that would support a Tiwanaku origin or maybe a local production. The evidence gathered in chapters 5-7 suggests that most of the gold objects found in SPA, and to a lesser extent those made of silver, comprise a mix of items presumably acquired by trade or exchange. Contrary to received wisdom (except for Stovel, 2001; Torres-Rouff et al., 2015), these would have come not only from the Central *Altiplano*, but also from additional areas, and mainly as finished objects.

The reasons to support this claim are various: Firstly, the variability of designs, manufacturing techniques, work quality, chemical compositions and types of artefacts seen in the seven cemeteries considered here strongly suggest that these objects were made by multiple producers (including individual craftsmen or groups of artisans), with their own techniques and gold sources, and different skill and specialisation levels. Such characteristics are in stark contrast with those identified in local crafts such as pottery (Stovel, 2002, 2013, 2005; Tarragó, 1976, 1989), basketry (Núñez, 1991), snuffing wooden trays (Horta, 2014), copper beads (Horta & Faundes, in Press), textiles and headdresses (Oakland, 1992, 1994) which are very standardised and homogenous in their designs and technological style (Salazar et al., 2014).

Secondly, up to date there is no direct evidence of silver or goldwork production in SPA that would support the practice of those many artisans; i.e. no technical ceramics, native gold, silver minerals or any production debris related to noble metals have been identified in burials or the few settlements excavated, which might be used to support the proposition of a local production (Cifuentes, 2014; Cifuentes et al., 2018; Salazar et al., 2014). The lack of production evidence may be affected by a recovery issue, since goldwork usually leaves scarce production evidence and tools used that can easily go unrecognised (Armbruster et al., 2004; Perea, 2010). Still, the presence of copper prills, slags, small copper ingots and technical ceramics recovered in Solor-3, Solcor-3, Sequitor Alambrado, Coyo and Beter has revealed a local small-scale copper production in SPA of cast awls, chisels, T-axes and mazes, indicating that the knowledge and means to work metals were available at SPA (Cifuentes, 2014; Cifuentes et al., 2018; Maldonado et al., 2013; Salazar et al., 2011, 2014).

Thirdly, specific designs, decoration, manufacturing techniques and compositions found in the SPA assemblage were also identified in other areas with early evidence of gold and silver use (e.g. NWA), and where production is well attested (see chapter 2:2.2). For instance, *keros*, portrait-vessels, wire-rings and bells are considered objects of Tiwanaku style, representing 25% of the 142 objects analysed (Bennett, 1934; Flores et al., 1998; Horta, 2014; Janusek, 2003; Lechtman, 2003b; Llagostera et al., 1988; Sagárnaga, 2007). This group would include items from the Titicaca basin, such as the conical bells, which are more abundant there (Férnandez, 2016), and other centres such as Cochabamba, as suggested by the avian design in *kero* popm140 (Posnansky, 1957).

The technological links with NW Argentina are inevitably more problematic given the simplicity of the objects produced. Still, composition with low copper levels, particular designs and techniques that are characteristic of that area (e.g. rotatory perforations) would support this connection, tentatively assigned to 37 objects or 27% of the studied assemblage (Angiorama, 2004; Goretti, 2012; Gudemos, 2013; Ventura & Scambato, 2013). Yet, this connection would need further confirmation, using trace elements for instance. From the southern *Altiplano* there is only one possible item (1%), whereas the four *tumbaga* artefacts may derive from Peru, however this link is by no means confirmed (6%). Based on the above then, there is little doubt that the majority of SPA gold and silver assemblage (~60%) includes objects of different technological traditions that arrived at SPA as traded objects or with people moving to SPA.

8.2 The local metalwork

Within the assemblage, some objects stand out because of their fresh manufacturing marks (35%), suggesting that they were made shortly before their burial. I argue here that these items are evidence of small-scale local metalwork. When compared, these artefacts can be grouped in two types of metalwork. The first group includes 27 (19%) imported objects that were *intentionally modified* (see chapter 6:6.3.6); whereas the second group encompasses the 23 (16%) coarsely-made ornaments from burials B.356, 358 and 359, whose production sequence and wear marks suggests that they were *locally made*, i.e., shaped from an ingot.

8.2.1 Local modifications

In the first case, modifications were made using basic mechanical techniques such as cutting and perforating. The presence of unusual and coarse technical solutions, such as folding and hammering in headbands popm17-18, would point to a preference for "cold" or mechanical manufacturing techniques, as opposed to melting and casting to make new ornaments. For that task, basic knowledge of the mechanical properties of gold and how to operate chisels, burins and punches would be necessary.

Indications supporting the idea of the local origin of these modifications are a) the modification were applied to all types of objects, both finely and coarsely made, including objects from NWA and Tiwanaku, suggesting that local individuals modified whatever was arriving; b) the fact that most modified ornaments are deposited in groups showing identical modification marks; c) the ubiquity of these modified objects in most cemeteries included here (5 out of 7); and d) the local availability of the tools necessary to modify these artefacts (e.g. chisels and burins; Cifuentes et al., 2018)

In this case perhaps, it was not essential to be a metalsmith to cut these items; it is possible that this type of "cut-and-punch" work was made by non-specialists; either people with no crafting experience or artisans of other crafts, but with little or no experience in precious metals as material. I lean towards the second however (although both options are not mutually exclusive), because even if the techniques employed in those cases are described as "coarse" compared to other objects, I would argue that the presence of guide marks, proportioned forms and some relatively complex designs (e.g. popm86, popm125) produced perfectly acceptable results, indicating planning, good aesthetic perception and experience in "making things".

It is possible then that these modifications are evidence of the multi-crafting activities of SPA artisans, as proposed by DeMarrais for this type of corporative and heterarchical societies (2013), where individuals engaged in a range of crafts, acquiring different and diverse skills (see also Spielmann, 1998). This means that craftspeople in SPA were able to work different materials and produce a range of different goods, similar to what is observed archaeologically in the Calchaquí Valley, Argentina (DeMarrais, 2013) or in other living societies from North America (Spielmann, 1998). In SPA, the presence of toolkits to produce different crafts (e.g. beads, weaving, woodwork, smelting) found in association to the same individuals in cemeteries such as Solcor, Coyo and Quitor, would support the idea of multi-crafting activities (Horta & Faundes, in Press; Salazar et al., 2014). Especially in Quitor, the considerable number of chisels, burins, punches, weaving kits, implements to make mineral beads, brushes and pigment cakes amongst others, would point to Quitor's craftsmen as the probable candidates to modify imported gold and silver artefacts. It is noteworthy that local modifications of imported objects are also found in other supports. For instance, Horta (2012, p. 18) argues that it was a common practice in SPA to modify wooden trays of Tiwanaku style by inlaying mineral beads in their borders. It would be interesting to look for more evidence of modifications in other materials, and explore whether modifications were a cross-material tradition in SPA.

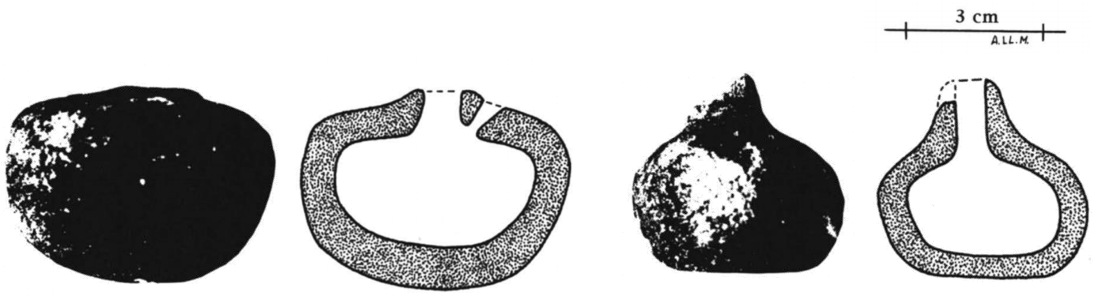
The possible reasons of these modifications will be further discussed in chapter 9; however, it is worth advancing here that, from an economic perspective the modification, re-use and cutting of finished objects may reveal a shortage of raw material or finished objects (Gosselain, 2000). As well, a local modification may give more value or re-signify the meaning of these objects (Helms, 1993; Horta, 2012; Spielmann, 1998, 2002), adapting them to local needs which, I will claim, are closely related to the mortuary ritual and the materialisation of social relationships (see chapter 10).

8.2.2 Local production

In the second group, the manufacturing features seen in the coarsely-made artefacts of burials 356, 358 and 359 (set 13, see chapter 6:6.6.2) would reflect the work of a small group of goldsmiths who produced three sets of ornaments. Given the specific compositions and the manufacturing features, the artisans would have been involved in different stages of production, from melting to finishing treatments, including forging and shaping; as well as the modifications seen in objects from burial 358. The similarity of ornaments between sets, the fresh manufacturing marks and the absence of traces of use, would point to a particular commission for the funerary ritual.

In this is the case, artisans would have required a specific place to work – such as a house or workshop –, probably located in SPA. Their work, including melting and forging gold sheets, would denote a more complex skill-set, compared to the individuals modifying imported objects, which may reveal the existence of local metalwork specialists. The possibility that these items were acquired by trade, however, but used only and especially for the burial, cannot be ruled out conclusively.

Finding direct evidence in the form of tools or metallurgical remains with traces of gold production would be decisive to prove this point; but there is no evidence of this type in SPA heretofore. Still, in Coyo-3 there are two ceramics with compelling features (Figure 158): small size, thick walls and closed shapes, very similar to crucibles used for melting in Europe, some of them interpreted as jeweller's implements given the small volume of metal produced (see examples in Bayley & Rehren, 2007; Eniosova & Rehren, 2012; Tylecote, 1982). These ceramics have not been analysed yet, thus future study should assess their use; for now, their involvement in gold or silver melting processes remains uncertain. Still, given the evidence for copper metallurgy in Coyo, Solor, Solcor and Sequitor, artisans from these *ayllus* would be potential candidates for this type of local work (Cifuentes, 2014; Cifuentes et al., 2018; Salazar et al., 2014): craftsmen familiar with liquid metalwork, but not necessarily so with more delicate finishing techniques.



Burial 9, Nº 13248, pottery type 16 Burial 14, Nº 13369, pottery type 17

Figure 158: Technical ceramics from Coyo-3?
Note the small size and close shape (modified from Costa-Junqueira & Llagostera, 1994, fig. 6).

Lastly and regarding the gold used to locally make the ornaments from Larache (set 13), it is possible that the starting material consisted of some imported artefacts that were melted. A potential indication of this is given by the seven bells from B.Body-2 (also from Larache) of Tiwanaku style, showing relatively high skill level and with evidence of use, which have a composition identical to the ornaments from B.359 (Figure 112:C and Figure 113). The elemental similitude between both bundles may be a coincidence, but it could also suggest that objects that arrived together have been locally recycled or re-melted (see chapter 6:6.6.2).

Building on the arguments above, I propose that most gold and silver objects were arriving at SPA as complete ornaments from different areas of the SCA, mainly the Bolivian *Altiplano* and NWA. However, often these were modified locally, probably by local artisans using mechanical or cold techniques, regardless of the artefacts' quality or origins. The coarsely-made ornaments from burials 356, 358 and 359 would also suggest the existence of a local small-scale production, involving melting and hammering gold, which still would need further evidence to be confirmed.

8.2.3 A local metalwork for the mortuary ritual

The local tradition identified above, recognisable by their fresh manufacturing marks, also indicates that part of the assemblage was especially created and modified for the burial. Objects acquired during the life of the individuals, used as ornaments on textiles or the body, as well as in drinking rituals or psychotropic consumption, are expected to present evidence of wear or usage marks such as damaged or torn perforations, repairs and worn edges and surfaces. Generally, a regular manipulation or use would delete and erode tool marks from the surface, as well as around the edges in an inconsistent manner (Perea & García-Vuelta, 2012). Conversely, newly made objects with little or no use would present fresh and sharp features and manufacture marks. It is assumed here that unused grave goods would have been made shortly before or especially for the burial (Martinón-Torres & Uribe, 2015; Perea et al., 2013, 2016). Given the softness and malleability of gold, this seems a reasonable assumption. In SPA, a mix of used and newly made objects are present as grave goods. In particular, most part of the assemblage (53%) shows wear or usage marks, indicating that they were used in life; while 35% are the locally modified and produced items described in the previous section, which were especially made as grave goods. The remaining 12% was unclassified.

It is possible then, that the local goldwork was stimulated by the need of using these metals in the mortuary ritual. The relatively coarse quality of the local metalwork may reflect the relatively low demand of these objects (used by a few individuals only), which would have employed the expertise of local artisans in particular situations or for specific commissions (who were not necessarily specialised metallurgists). Given that the raw material was limited, they would have utilised what was available: i.e., foreign finished ornaments. This model would be very similar to what Spielmann (1998, 2002) and DeMarrais (2013) define as "ritual mode production", but on a very modest scale. These authors propose that in heterarchical societies, craft production can be developed to "*fulfil ritual obligations and create and sustain social relations*" (Spielmann, 2002, p. 197). In those cases, particular artisans would create a moderate number of symbolic objects that would be used in ceremonies or as social markers (DeMarrais, 2013; Spielmann, 1998, 2002).

Given the characteristics of SPA local goldwork, it would be possible to interpret the precious metalwork as part of a ritual production. The ritual importance of gold and silver can be deduced from their active role in the mortuary ritual, both as objects present in the ritual, as well as objects especially made (or modified) for it; this symbolism could be rooted in their aesthetics qualities, their scarcity as raw material and their own histories, i.e., as objects that are moving from different areas (González, 2004b; Lechtman, 1993; Nielsen, 2007; Spielmann, 2002). Similarly, another local ritual production may be the production of wooden snuffing paraphernalia (Horta, 2014), also considered highly symbolic (Llagostera, 2006a; Llagostera et al., 1988; Torres, 1998). The use of these locally modified and produced gold and silver objects is discussed in more detail in the next chapter. Still, the presence of pendants modified in SPA with evidence of wear such as popm36 (see section 6.3.6) indicates that not all items were necessarily used for the funerary ritual. Unfortunately, this type of objects is difficult to identify and they can be easily missed out, and as such they were probably more frequent than estimated here.

8.3 Goldwork in the SCA: a glimpse of the social organisation of production

The careful analysis of the objects, identifying a series of technical attributes within the assemblage, showing different degrees of standardisation, skill and labour investment along the *chaîne opératoire*; together with the elemental composition and designs, has allowed to explore to some extent the organisation of gold production in the SCA during the Middle Period (Costin, 1991, 2005; Costin & Hagstrum, 1995).

As shown in previous chapters, the SPA assemblage is relatively small and heterogeneous, but within this variability it is possible to identify different ways in which production was socially organised, including objects made by a single artisans or groups of artisans (see chapter 6:6.6.4.1). Interestingly, the quality of the work, the objects made and the possible ways in which knowledge was transmitted would reflect political and social aspects of the society that produced them. Overall, I propose that two broad models can be inferred from the SPA assemblage, which would respectively represent the social organisation of production in a) Tiwanaku and b) the communities from the *Circumpuna*, including SPA.

In his study of Tiwanaku craft production in the sites of Tiwanaku and Lukurmata, Janusek (1999) identifies urban specialists (potters and panpipe makers) organised in domestic compounds that include several households, in some cases forming real neighbourhoods of potters or panpipe makers. These specialists were semi-autonomous groups, i.e., answering to local authorities, rather than to an elite or a central authority. The analyses on pottery and panpipes production identified idiosyncratic formal and technological attributes that maintained the group identity of these compounds and differentiate them from other specialists[19], still producing objects of clear Tiwanaku style (Janusek, 1999). For Janusek, craft specialisation was an active and fundamental part of these groups' social identity. Referred to as "embedded production" (Janusek, 1999) this

[19] For instance, Janusek recognises the selection of particular iconographic figures of the Tiwanaku repertoire, such as the camelid, which were more frequent in the workshop of Ch'iji Jawra in the Tiwanaku urban centre, as well as a particular way of depicting it. Still, the production falls under a classic Tiwanaku style.

type of organisation would represent something in between an independent and attached form of production, as defined by Costin (1991; Costin & Hagstrum, 1995). Nonetheless, Janusek (1999, 2003) emphasises that sumptuary items such as ceramic *keros* may have been produced by attached specialists given their high standardisation, extraordinary craftsmanship and complex iconography, albeit these type of workshops have not been found so far.

The organisation identified in Tiwanaku would correspond with the production of Tiwanaku style objects found in SPA. In the case of metalwork, there is currently no evidence of production sites or workshops in Tiwanaku sites. However, if gold and silver artefacts were made either by embedded or attached specialists, we could assume at least that they were organised in similar household compounds. As seen in the embedded organisation, they would form real communities of practice, where knowledge was continually and constantly shared in the regular practice (Wendrich, 2012a, 2012b). Considering that most elements were made following a Tiwanaku style, a relatively formal teaching of "conscious" or "formal" attributes such as designs and technological sequences would be expected (Costin, 2005; Costin & Hagstrum, 1995; Martinón-Torres & Uribe, 2015; Miller, 2012; Whittaker, 1987). Still, as observed by Janusek, there would be some room for individual or group differentiation that would identify different compounds or workshops (1999).

The production characteristics of the conic bells, wire-rings and goblets found in SPA would be consistent with the work of embedded or attached specialists in Tiwanaku sites, making gold and silver items. The relatively standardised shapes, the use of the same technological sequences, the good quality of the work, the use of complex techniques (e.g. raising), and the identification of more than one artisan involved in their production (e.g. different "hands" seen in goblets and wire-rings, and the variety of bells), would reveal the work of groups of specialists working together probably for generations, practicing with relative regularity, sharing tools and facilities. Potentially, over time, such organisation would derive in the highly specialised communities or towns of *plateros* (metalworkers of silver, gold and copper) managed by the Inkas and described by the Europeans in the 16th century (Benzoni, 2017 [1572]; Cieza de León, 2005 [1550]; Cobo, 1892 [1653]; de la Vega, 1609 [1560]; de las Casas, 1892 [1553]).

In the *Circumpuna* there is more information about metal production. In NWA, from AD 400 onwards[20], massive cast bronze objects start to appear – discs, axes and

[20] AD 400-900: Final Formative in Argentina or Middle Period in Chile

bells – which indicate the presence of specialised metalworkers using complex techniques (see chapter 2; González, 2004a). However, crucibles with evidence of gold and silver melting are reported in the large metallurgical centres and workshops, such as Rincón Chico (Yocavil Valley), Potrero de Payogasta (Calchaquí Valley) or the Central Plaza in Los Amarillos (Humahuaca Ravine, Figure 117). All these centres have late dates, from AD 900 onwards, and according to González (2003) they were first controlled by local elites and then by the Inkas (Angiorama, 2004; Angiorama et al., 1999; González, 2003).

However, gold ornaments are frequent in NWA since the Formative Period (1000 BC-AD 400), decreasing in frequency towards the Middle (AD 400-900) and later periods[21] (AD 900-1450; González, 2003). Although González (2003) claims that during the Intermediate Period metallurgy was controlled by local elites, Nielsen (2007, 2013) argues that overall mining and metallurgy was not conclusively controlled by the leaders, especially given the ubiquity of metallurgical evidence in domestic contexts, such as domestic unit-400 in Los Amarillos (Humahuaca) with evidence of bronze production (Angiorama, 2007), or the site of Borgatta (Calchaquí valley), where crucibles were found in a few specific households (DeMarrais, 2013). Similarly, in Lipez and Uyuni (southern *Altiplano*) there is evidence of independent specialists smelting copper and silver during the Middle Period (e.g. Pulacayo-50; Cruz, 2009; Lechtman et al., 2010; Nielsen, 2013), which is supported by the references of Lozano Machuca who in 1581 reports that in "*Lipez district, in the houses and farms of the Indians there are furnaces to smelt and refine silver and several huairas on the hills,* ***and all [Indians] work beneficiating and smelting silver*** *[...]"* (my translation and emphasis; Casassas, 1992, p. 31). In SPA, funerary evidence from the Middle Period suggests that certain individuals were involved in metal production on a small-scale, in at least five *ayllus*: Coyo, Solcor, Solor, Sequitor and Beter (Cifuentes, 2014; Cifuentes et al., 2018). Excepting for the reference of Lozano Machuca, from the information above is also inferred that not everybody was engaged in metallurgy, reasons why these artisans may be considered specialists (Costin, 2005; Kuijpers, 2017).

It is likely then that before AD 900 in these corporate (Nielsen, 2006b, 2007), autonomous (Castro et al., 2016) and heterarchical (Crumley, 1995, 2007; DeMarrais, 2013) societies from the *Circumpuna*, gold and silverwork was practiced by independent specialists, most likely engaged in multi-crafting, working different materials and

[21] According to González (2003), the small number of gold and silver artefacts in NWA may represent a limited use of these metals, or it may reflect years of looting, since the Europeans arrived in the area in the 15th century – or a combination of both.

participating in a range of different activities and tasks, either in an opportunistic or communally regulated way (e.g. calendric activities; Grebe, 1990, p. 78; Guaman Poma de Ayala, 2009 [1615], p. 179). Production would be intermittent and household based, yet workshops may exist to share tools, installations and knowledge. In these contexts, craftspeople were relatively autonomous; they would acquire diverse skills with different levels of expertise (DeMarrais, 2013), depending on the frequency and intensity of their practice (Kuijpers, 2017, 2018). The objects produced would be varied and diverse, of different quality, albeit they would follow a general style. This type of artisan is similar to the independent specialist defined by Costin (1991), but DeMarrais (2013) includes in this type of production highly valuable items, besides utilitarian objects. In SPA, evidence of this type of independent specialisation is seen in local crafts such as snuffing trays, mineral beads and pottery. Although these artefacts follow a characteristic local style, published studies highlight technological differences that indicate the work of several individuals of different *ayllus* aiming for a specific final design (Carrión, 2014, 2015; Salazar et al., 2014; Stovel, 2002, 2005).

The characteristics of the gold items from NWA, the southern *Altiplano* and those locally made in SPA (not the items modified, which could be generated by non-specialists), would support a metal production organised in an independent way. As seen in chapter 7, objects from these areas present different qualities, there is almost no standardisation – except for objects made in pairs –, however there are ornaments that are clearly following particular designs, such as the headdresses of four appendices, the *llamas*, or the oval discs from NWA, or the bow-tie shape pendants from southern *Altiplano*. Overall, this type of production would suggest the work of individual and independent artisans or small groups of metalworkers making ornaments, in contrast with the large compounds expected in Tiwanaku. The different qualities would reflect different skill levels, probably a result of the different intensity of the practice. If the categories proposed by Kuijpers (2017) are accepted, the items seen in the *Circumpuna* would range between high-quality items probably produced by master crafters (Figure 136:popm189, Figure 140:popm185) and unrefined ornaments, probably produced by amateurs (Appendix Nº5: 1(1,10); Figure 139:popm181). In particular, gold objects from NWA show better quality than those locally produced in SPA, probably revealing the experience of a longer-term metallurgical technological tradition developed in NWA (González, 2004a), compared to a young and small-scale metallurgical production in SPA, only identified from the MP heretofore (Cifuentes et al., 2018).

Summing up, given that the SPA assemblage encompasses objects made by Tiwanaku, NWA, southern *Altiplano* and a local technology, the results of this study are useful not only to characterise the SPA assemblage, but also to explore how artisans organised to make these items in different areas of the SCA. The sample is small and therefore preliminary, but in the case of Tiwanaku style objects an embedded and perhaps an attached production would better explain their form of production, whereas in the *Circumpuna*, including SPA, NWA and southern *Altiplano*, gold and silver ornaments would be produced by independent specialists with different skill levels. Another expression of the independence of craft production in these communities, would be the modifications potentially made by non-specialists, on gold and silver items arriving at SPA.

8.4 Circulation of gold and silver in the SCA

How did circulation of gold and silver compare to that of copper and other materials? And what can this information say about the relationship between SPA and other areas of the SCA? Based on the styles and technologies identified in SPA, it is proposed that objects were potentially imported from four areas: those from Tiwanaku may have been produced in the 1) Titicaca Basin or 2) Cochabamba Valley (given the iconography of *kero* popm140); 3) NWA and 4) the southern *Altiplano* (Figure 159).

Compared to copper-based objects, it appears that gold and silver items were circulating in the same areas, except for Cochabamba. The analyses of 50 copper-based metals deposited in SPA indicate that 45% of artefacts are using alloys characteristic of the Titicaca Basin, such as copper-arsenic-nickel and copper-arsenic-nickel-tin; whereas 30% are made of copper-tin, a bronze produced either in the Titicaca Basin or in different areas of NWA (Cifuentes, 2014; Cifuentes et al., 2018; Lechtman, 2003b; Lechtman & Macfarlane, 2005, 2006; Maldonado et al., 2010, 2013, 2014; Salazar et al., 2011, 2014). Although there is no certainty where in the Titicaca basin these bronzes were made, metallurgical evidence in SPA revealed the production of unalloyed copper artefacts only, and no tin or copper-arsenic-nickel was detected either in prills or slag, suggesting that bronze items are arriving as finished product to SPA (Cifuentes et al., 2018). Thus, 75% of 50 copper-based metals studied would be foreign, and probably coming from Tiwanaku. Interestingly, in NWA most tin-bronze was produced by Aguada, in the southern valleys of Catamarca. Still, the typical tin-bronze artefacts of Aguada style do not appear in SPA, suggesting that - if made in NWA - tin-bronze was probably coming from areas within the *Circumpuna*, such as the *puna* or Humahuaca Ravine (Cifuentes et al., 2018). In fact, our results regarding gold circulation can be used to revisit the proposal about bronze circulation, and to explore the possibility that NWA was more relevant in the production of tin-bronze than expected. Lastly, other mining and metallurgical sites from the period are also found in the southern *Altiplano* of Lipez (Cruz, 2009; Lechtman et al., 2010).

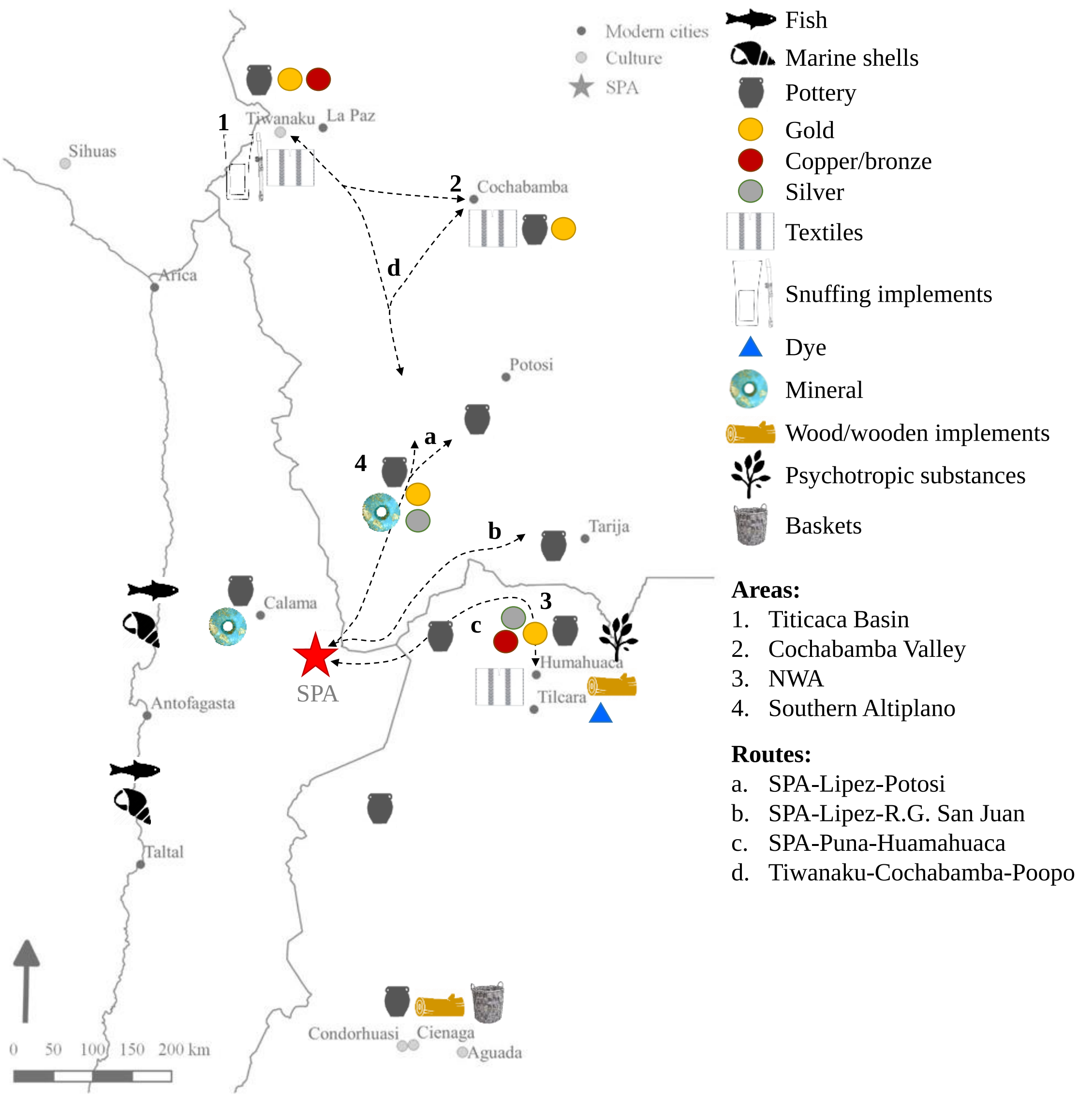


Figure 159: Map showing the provenance of non-local goods and raw materials found in SPA, during the Middle Period.
1-4: areas mentioned in this section. Trade and mobility routes: a-c- connecting SPA, NWA and southern Altiplano, d- connecting Tiwanaku, Cochabamba and Lake Poopo basin (After Carrión, 2015; Llagostera, 1995; Michel-López, 2008; Nielsen, 2013; Niemeyer et al., 2013; Niemeyer & Agüero, 2015; Stovel, 2008; Tarragó, 1989; Uribe & Agüero, 2001).

As mentioned in chapter 2, metals are not the only materials imported from those four areas into SPA (Figure 159). From the **Titicaca Basin**, there is Tiwanaku style pottery, which represents 4% of the non-local ceramics (14 out of 350; Stovel, 2002, 2008; Tarragó, 1989); textiles, present in 58% of the 57 burials in Coyo-Oriental

(Oakland, 1992, 1994); and snuffing implements, representing 25% (151 out of 610; Horta, 2012, 2014; Llagostera, 1995; Llagostera et al., 1988). Tiwanaku variants from **Cochabamba Valley** are seen in ceramics (2%) and textiles (Agüero, 2003; Stovel, 2002, 2008; Uribe & Agüero, 2001). The identification of a local San Pedro textile style, which shares technical attributes with textiles from Cochabamba, has led Uribe and Agüero (2001) to propose that most of the Tiwanaku material coming from the *Altiplano* was introduced to SPA via Cochabamba. Objects made in different areas of **NWA** are present as well, such as pottery from Humahuaca (Isla and Hornillos styles, 6%) or from the boundary between Bolivia and NWA (Vaquerías and Tarija styles, 5%; Stovel, 2002, 2008; Tarragó, 1989) and textiles (Agüero, 2003). Raw materials were also imported from NWA and the *yungas* such as red and blue dyes for textiles, wood and psychoactive products (Niemeyer, 2013; Niemeyer et al., 2013; Niemeyer & Agüero, 2015; Salazar et al., 2014). From the **southern *Altiplano***, Hurquilla and Yura pottery (3%) has been identified (Stovel, 2002, 2008; Tarragó, 1989), but it is likely that minerals, rocks and even metals were imported as well (Nielsen, 2013). Against this background, noble metals – especially gold – coincide with a range of other materials, potentially constituting just one more item exchanged amongst others (Figure 159).

But what were the channels and means by which gold and silver objects arrived at SPA? Studies on Andean mobility and exchange systems have revealed a complex and dynamic scenario where people, goods and ideas moved in varied ways (Nielsen, 2006a, 2013). For our purposes, considering the life-histories of certain items may narrow down some options.

A first option is that gold objects moved as goods in specialised caravans between SPA, NWA, southern *Altiplano* and the Titicaca Basin (Nielsen, 2006a, 2013). Nielsen (2013) identifies three corridors used to mobilise caravans and people that connected SPA with different areas of the Argentinean *puna* and NWA valleys; north and southern Lipez, Rio Grande de San Juan (border with Bolivia) and Potosi Valley (Figure 159:a-c). Based on the archaeological evidence found in these corridors, Nielsen (2013) argues that the circulation of Tiwanaku items was mediated by the several intermediate communities that lived in south Lipez, Potosi Valley and Lake Poopo basin; i.e., it was not direct exchange between SPA and Tiwanaku. Attesting this, in Potosi Valley (Pulacayo site) five local individuals dated between 674-874 Cal AD were buried with SPA and Tiwanaku grave goods, at a site that also has evidence of copper and silver metallurgy (Cruz, 2009; Lechtman et al., 2010). But towards the north, in the Lake Poopo basin, trade was especially connected to the Titicaca region and Cochabamba (Michel-López, 2008), without evidence of SPA or southern materials (Figure 159:d).

Evidence that these caravans were transporting metals is given by a silver ring found in a campsite and gold sheets and trimmings deposited in roadside shrines (Nielsen, 2006, 2013). It is possible then, that Tiwanaku gold and silver objects arrived at SPA by specialised caravans acting as intermediaries between SPA and either the Titicaca Basin or Cochabamba Valley. This is particularly possible for the goblets from Casa Parroquial, considering that the three of them have different designs and compositions which may reflect items that were mixed during travel, obtained from different producers, or from different caravans. The case of Tiwanaku style objects from Larache is different though. Strontium isotope signatures indicate that male 358 (bearing goblets, axes and headdresses) was probably born in the Titicaca Basin (Torres-Rouff et al., 2015). Considering that the goblets were most likely made together, as well as the wire-rings and conic-bells present in Larache, it is possible that some objects travelled from the Bolivian *Altiplano* with their owners, subsequently being used in ceremonies or as ornaments, and then buried together.

In the *Circumpuna*, besides specialised caravans, Nielsen also outlines other ways in which objects can circulate, where exchanges can occur face-to-face. In the *embedded traffic* model, people from different parts of the *Circumpuna* seasonally gather or coincide in specific ecological niches to exploit their resources (Nielsen, 2013). These task camps create the perfect situation where objects are transferred. Other ways are *interethnic exchange* such as marriage, political alliances or friendship/family visits (Martínez, 1998; Nielsen, 2013). In the case of SPA, it is possible that intentionally fragmented ornaments are result of these face-to-face exchanges. As discussed in the next chapter, fragmented objects can be used to materialise social relationships, representing links between two or more people or communities (Chapman, 2015; Chapman & Gaydarska, 2009); in such contexts, face-to-face transactions would be more appropriate. In particular, it is likely that items from NWA were acquired in embedded traffic or interethnic exchange, and the presence of SPA populations in areas of the *puna* or in Rio Grande de San Juan (Figure 2:d), where mining and metallurgy was reported, would support this view (Nielsen, 2006a).

All the mobility practices presented above may generate a *chain of exchanges*, whereby objects can travel long distances by changing hands several times (Nielsen, 2006). The presence of copper-rich gold ornaments in SPA – not found in NWA or

Bolivia so far – may reflect this type of chained movement. The best example is popm27 (with 48.7%Cu), a piece of a disc that shows evidence of use, as well as two modifications made at different moments, suggesting a long life-history which probably involved more than one owner. Similarly, fragmented headdresses popm87 and popm84/86, probably made in NWA, present more than one modification suggesting again a transfer between different people.

The diversity seen in the assemblage from SPA is thus the likely result of objects coming from different places, but also acquired in different ways; trajectories that were recorded in the objects themselves, through changes underwent in their life-histories: wear, curation, exchange, modifications, repairs, etc. If we assume that caravans were transporting materials and goods especially made for exchange, new objects may have been introduced by caravans, including items from the Titicaca Basin or Cochabamba Valley. Still, new, used and already modified ornaments could also be acquired in face-to-face situations, materialising the social integration with more distant communities. The latter hypothesis is ideally suited to explain the movement of objects from NWA and southern *Altiplano*. Certainly, all these mechanisms were in place at the same time, as evidenced in Casa Parroquial, where gold objects from Cochabamba and NWA appear in the same cemetery. Still, it is important to remember that in every act of acquisition, either an exchange or gift, what really mattered in the Andes was the social and religious dimensions behind them (Martínez, 1998), which may be especially relevant in the case of gold and silver, given their symbolism.

It is noteworthy though, that this dynamic mobility system where control over the exchanged objects appear rather complicated, noble metals still appear concentrated in two cemeteries: Larache and Casa Parroquial. Possibly, the differential access seen in the archaeological record may be dictated by cultural norms of use, rather than a control of their production or circulation, as proposed by Nielsen (2007). In the next chapter I will study the characteristics of noble metal bearers and explore further this matter.

PART IV

Results: Consumption

Chapter 9. Consumption of gold and silver in SPA

This chapter focuses in the consumption patterns of gold and silver, i.e. by whom and how these objects were used. The *who* is determined first, at a cemetery level analysing the amount and distribution of noble metals in SPA; and second, by looking at specific aspects of the individuals buried with gold and silver, such as types of burials (single/multiple), sex, age, cranial vault modification, strontium isotopes and the amount of other grave goods. The evidence suggests that the amount of gold and silver grave goods would be related in first place to the *ayllu* of the individuals, and to a lesser extent to other personal characteristics. Specifically, individuals from Larache and Condeduque had privileged access to gold, whereas people from Condeduque, Coyo and Quitor accessed silver. I propose that these features are based on the rank and specific activities of these particular *ayllus*.

The *how* focuses on understanding what objects were made of noble metals. The use of gold and silver in a) ritual and leadership emblems, b) funerary ornaments and c) fragments and small gold pendants, are argued to reveal respectively different levels of meaning and symbolism: to represent the diverse roles of the Andean leaders, as objects of local affiliation and as connectors with other areas or distant communities.

Section 9.1 focuses on who is using gold and silver in SPA. The first part explores the amount and distribution of noble metals (9.1.1), and the second part (9.1.2) considers specific information of the individuals buried with metals. In section 9.2, how objects were used is presented, starting with the ritual and leadership emblems (9.2.1), funerary ornaments (9.2.2) and parts and fragments (9.2.3). Finally, in Chapter 10 the main findings of this chapter are discussed and interpreted.

Before I continue, it is important to keep in mind that in this chapter the original information from the excavations is used, which considers all objects originally registered in the fieldwork diaries by Gustavo Le Paige. It includes objects currently found in the museum and also “ghost” items; i.e., artefacts that did not survive excavation, are lost or decontextualised, but whose descriptions are found in the excavation reports (see full list in Appendix Nº3: 11). In nine *ayllus*, 16 cemeteries with Middle Period dates were identified, containing 694 metallic objects, of which 48% were noble metals (n=335): 177 made of gold (53% of 335) and 158 made of silver (47%, of 335; Table 36). They include objects made of these precious metals such as pendants, attachments, conical and folded bells, headbands, beads, rings, bracelets, headdresses, goblets, axes, jugs, and sheets; as well as snuffing implements decorated with gold such as tablets, tubes, mortars and spatulas (Table 37). The classification as gold or silver though raises some issues. As previously shown, analysed compositions include a range of gold-silver alloys with up to 73% silver, which are considered here silver-rich gold alloys. In the excavation diaries, 8 out 10 objects with over 60% silver appeared described as silver, and two as gold. It seems then that silver objects were classified by their colour, which changes over 60% silver, and their corrosion state. Therefore, it is possible that some artefacts classified as silver in the reports or the museum correspond to our high-silver gold alloys.

Ayllu or Archaeological district	**Cemetery**	**Total funerary units**	**MNI**	**Nº of funerary units with: Metals (all)**	**Gold**	**Silver**	**Gold & silver**	***Total (Au+Ag)***	**Isolated finds**	**Nº of objects made of: Metal (all)**	**Gold**	**Silver**	***Total (Au+Ag)***
Condedque	1- Casa Parroquial	22	22	14	4	4	6	*14*	-	52	35	14	*49*
	2- Tchilimoya	56	69	5	-	1	-	*1*	-	98	-	90	*90*
Catarpe	3- Catarpe-2	320	320	5	-	1	-	*1*	-	6	-	1	*1*
Coyo	4- Coyo oriental	315	442	20	1	5	-	*6*	-	38	1	7	*8*
	5- Coyo-3 (occidental)	51	80	7	1	4	-	*5*	-	20	1	14	*15*
Larache	6- Larache [1]	108	108	17	11	1	-	*12*	5	152	114	5	*119*
Quitor	7- Quitor-1	94	103	10	2	5	-	*7*	-	21	2	14	*16*
	8- Quitor-2	174	257	8	-	1	-	*1*	-	18	-	10	*10*
	9- Quitor-5	218	462	22	4	-	-	*4*	-	60	5	-	*5*
	10- Quitor-6	76	479	46	4	-	-	*4*	-	69	4	-	*4*
	11- Quitor-9	17	23	1	-	1	-	*1*	-	3	-	2	*2*
Sequitor	12- Sequitor Alambrado[2]	409	500	25	6	-	-	*6*	2	43	8	-	*8*
Solcor	13- Solcor Plaza	88	125	3	1	-	-	*1*	-	4	1	-	*1*
	14- Solcor-3	93	153	18	1	-	-	*1*	-	53	1	-	*1*
Solor	15- Solor-3	113	319	20	2	-	-	*2*	-	54	4	-	*4*
Yaye	16- Yaye-1	51	56	3	1	1	-	*2*	-	3	1	1	*2*
	Total	**2205**	**3518**	**224**	**38**	**24**	**6**	***68***	**7**	**694**	**177**	**158**	***335***
	Of gold & silver total %				***56***	***35***	***9***	***100***			***53***	***47***	***100***
	Of all metals total %			***100***	***17***	***11***	***3***	***30***		***100***	***26***	***23***	***48***

1: It includes Larache Callejón and Rescate. 2: In includes Sequitor Alambrado Acequia, Oriental and Occidental.

Table 36: Total metallic objects reported in 16 SPA cemeteries.
MNI: minimum number of individuals identified per funerary unit.

Objects	Gold	Silver	*Total (Au+Ag)*	Copper	Not specified	*Total*
Pendant/attachment	36	3	*39*	5	1	*45*
Bead	26	-	*26*	-	-	*26*
Bell	23	9	*32*	59	-	*91*
Ring	16	5	*21*	44	3	*68*
Headband	15	8	*23*	1	4	*28*
Headdress	10	-	*10*	5	-	*15*
Disc	9	30	*39*	9	2	*50*
Sheet[2]	9	4	*13*	15	6	*34*
Tablet[1]	8	-	*8*	-	-	*8*
Fragment	6	5	*11*	1	1	*13*
Goblet	6	1	*7*	-	-	*7*
bracelet	4	4	*8*	34	2	*44*
Tube[1]	4	-	*4*	1	-	*5*
Axe	2	-	*2*	41	1	*44*
Mortar[1]	2	-	*2*	-	-	*2*
Spatula[1]	1	-	*1*	-	-	*1*
Ornament[2]	-	88	*88*	8	3	*99*
Jug	-	1	*1*	-	-	*1*
Chisel	-	-	-	56	1	*57*
Mace	-	-	-	15	-	*15*
Slag	-	-	-	8	-	*8*
Molten Cu	-	-	-	3	-	*3*
Tweezers	-	-	-	3	-	*3*
Burin	-	-	-	2	-	*2*
Earrings	-	-	-	2	-	*2*
Tupu	-	-	-	2	1	*3*
Arrow	-	-	-	1	-	*1*
Brassard	-	-	-	1	-	*1*
Figurine	-	-	-	1	1	*2*
Knife	-	-	-	1	-	*1*
Knife-axe	-	-	-	1	-	*1*
Needle	-	-	-	1	-	*1*
Object[2]	-	-	-	3	-	*3*
Spindle whorl	-	-	-	1	-	*1*
Spoon[1]	-	-	-	1	-	*1*
Bar	-	-	-	-	7	*7*
Pestle[1]	-	-	-	-	1	*1*
Total	**177**	**158**	***335***	**325**	**34**	***694***
Out of 694 %	**26**	**23**	***48***	**47**	**5**	***100***
Out of 335 %	**53**	**47**	***100***			

1: Objects made of wood and decorated with gold. 2: Objects with no specific description

Table 37: Metal objects reported in SPA.
Copper and not specified metals are reported for comparative purposes. "Not specified" metals include artefacts described as "metal" or other metals such as zinc, tin, antimony or lead, but that have not being analysed.

9.1 Who is using gold and silver in SPA?

I will explore here the amount and distribution of gold and silver in SPA, as well as the characteristics of the people buried with these metals. Overall, only a few individuals are buried with noble metals in SPA. Although most are young adult men, there are also mature females and infants with several precious metal objects as grave goods. The number and dispersal of gold and silver reveals a structure mainly based on the community, i.e., access to gold seems to be mediated by the *ayllu* to which they belong, rather than the personal characteristics of the individuals.

9.1.1 Amount and distribution of noble metals in SPA

9.1.1.1 Amount of gold and silver consumed

Overall, the amount of gold and silver objects consumed in 16 cemeteries at SPA is almost half of the total metals registered. Of 694 metal objects identified, 48% were precious metals (n=335). Gold represents 26% with 177 artefacts, and silver 23% with 158 (Table 36-37). At first, silver appears slightly less frequent than gold, however, this difference is small and it is likely unrealistic for two reasons. First, silver corrodes much more easily in poor deposition conditions (e.g. moisture); therefore, smaller items such as those recorded here may have disappeared over time. Second, there are 20 objects (20/694, 3%) described in the reports as made of tin, zinc or antimony (bars, sheets, headbands; and only one ring, pendant, chisel and axe). The pXRF analysis on one of them detected 100% silver, suggesting the presence of silver in corroded state (the light elements were not detected by the instrument). If the 20 items were in fact made of silver, its number would result in 176 items, the same amount of gold items reported, showing virtually no difference between both.

The remaining metals are copper or copper-alloys with 325 artefacts (47%) and unidentified metals with 34 artefacts (5%, including the 20 items above). Despite the fact that gold and silver together are almost the same proportions as copper objects, the volume of metals is completely different. The total weight of gold, silver and copper objects from SPA is not available, but for illustrative purposes, there are 169 noble metal items in SPA weighing ~3kg[22] that represent 50% of the total gold and silver artefacts; whereas made of copper and bronze, there are 41 axes and 56 chisels. Extrapolating data

[22] Data obtained from publications and my own data collection.

from Chile Central (Plaza, 2010), axes can weigh on average 200gr and chisels 13gr, which result in 9kg, representing just 30% of the copper-based objects.

This difference in bulk weight reflects the contrast between the amounts of noble metals and copper consumed in SPA, which probably relates to the access to raw materials, manufacturing techniques used and type of objects made: relatively small and light objects were produced in gold and silver and exchanged in occasional contacts; compared to solid copper axes, maces, tools and ornaments, which are exchanged and also locally made (Cifuentes, 2014; Lechtman, 2003b; Lechtman & Macfarlane, 2006; Macfarlane & Lechtman, 2016; Salazar et al., 2011, 2014). From the same period, the San Sebastian Treasure in Cochabamba (Bolivia), which is one person's apparel, weighed 1.8kg (Money, 1991); two hoards like this would probably make up the full weight of all the precious metal deposited in SPA in 600 years.

Therefore, the total volume of gold and silver consumed in SPA is relatively small for a span of 600 years. As proposed in previous chapters, the objects were most likely introduced in discrete and intermittent events. It is difficult to estimate the number of acquisition events, but as discussed in previous sections, the identification of specific batches grouping two or more objects indicates that the number of events would be much lower than the number of objects actually identified (see chapter 7).

9.1.1.2 Inter- and intra-cemetery distribution of gold and silver

The first thing noted when analysing the distribution of the metals in SPA is the differential access to gold and silver, both at inter- and intra-cemetery level. Chiefly, not all cemeteries contain precious metals, gold and silver grave goods belong to a relative small number of individuals per cemetery, and the amount of noble metal objects per individual is usually small. Still there are compelling exceptions of individuals with relative large apparels that stand out of the general pattern.

Of approximately 44 "large" cemeteries (with more than 10 individuals), 16 had individuals buried with noble metals, representing 36% of the cemeteries (Bravo & Llagostera, 1986; Costa-Junqueira & Llagostera, 1994; Hubbe et al., 2011; Le Paige, 1964; Llagostera et al., 1988; Téllez & Murphy, 2007). In these cemeteries, individuals with gold ans silver are distributed in 68 burials, 3% of 2,205 burials in total (Table 36).

Within the cemeteries, the amount of burials with noble metals is also relatively low. In more than half of the cemeteries (9/16, 56%) burials with precious metals represent less than 2% (Figure 160:A) with 1-4 funerary units (Figure 160:B); whereas in

31% of the cemeteries (5/16), gold and silver bearers represent 4-10%, with 5-7 funerary units. Two exceptions are Casa Parroquial and Larache with 12-14 units that represent 63.6% and 11% of the total burials, respectively.

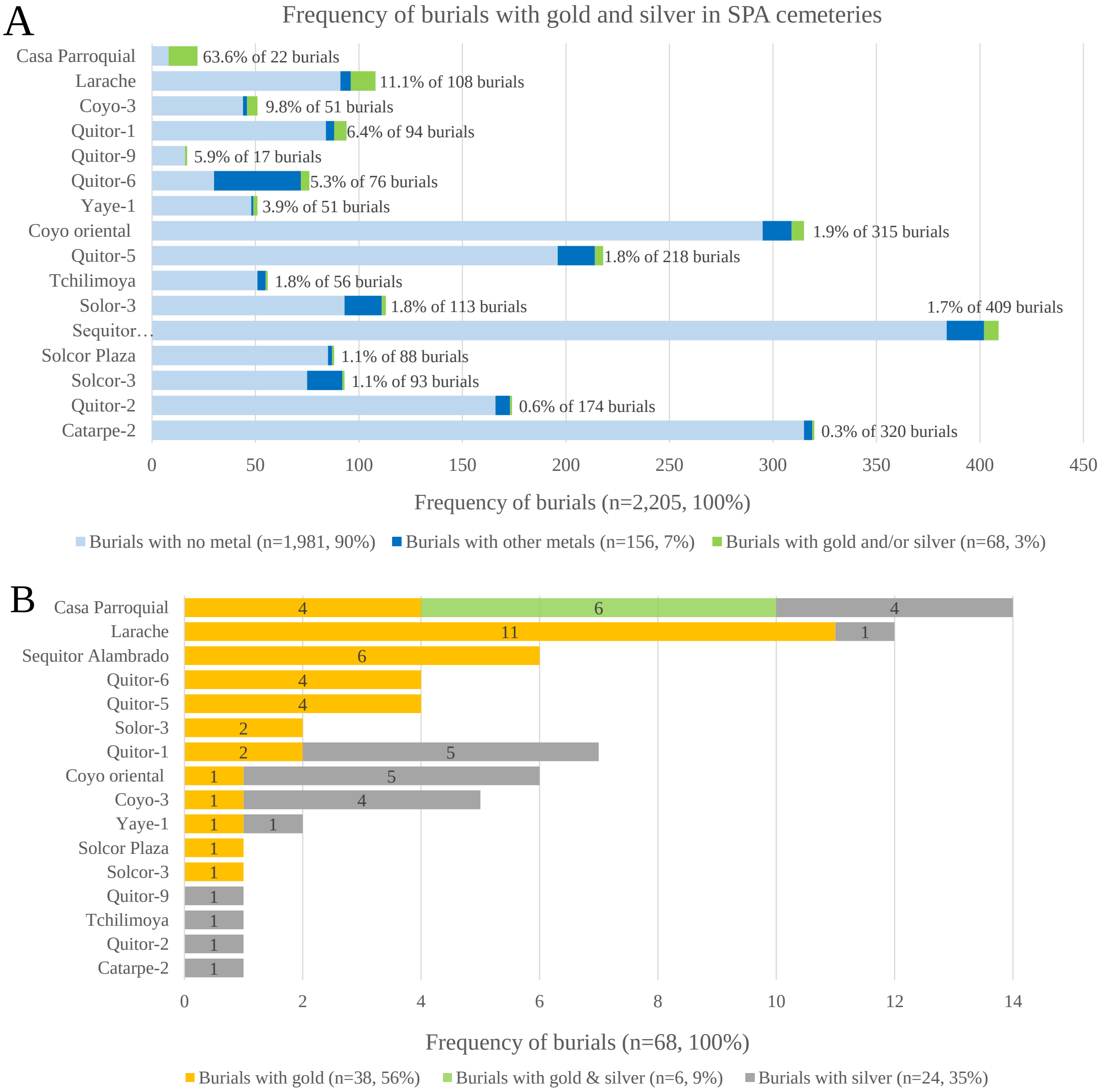


Figure 160: Bar graph showing the frequency of burials with gold and silver compared to (A) all burials in each cemetery and (B) differentiating between those with gold or silver grave goods.

A relevant difference is observed in the amount of gold and silver objects per burial, which can be grouped in two: 1) individuals with 1-4 grave goods, and 2) individuals with five and more. As presented in Table 38:A, 78% of the individuals in SPA (n=53) were buried with four or less metal grave goods, most of them having only one item (59%). In total they comprise 22% of the noble metal objects (75/335). Group 1 includes people from most cemeteries, 14 out of 16 (Table 38:B), and would represent the majority of the precious metal bearers in SPA.

This pattern contrasts with 22% of individuals (n=15) that have five or more grave goods, equating to 77% of the precious metals (258/335). The number of grave goods in these burials is particular for each person, with no discernible pattern. People from six cemeteries are part of this group, most of them from Larache (n=8) and Casa Parroquial (n=3; Table 38:B). The remaining individuals are from Coyo-3, Quitor-1, Quitor-2 and Tchilimoya[23]. Larache and Casa Parroquial have mainly gold grave goods, the last four sites have only silver grave goods. Furthermore, in Quitor-2 and Tchilimoya, these "rich" individuals were the only ones with noble metals in their cemetery, whereas in Quitor-1 and Coyo-3 they were 1/5 and 1/4, respectively. Group 2 are individuals that are escaping the general pattern represented by group 1.

Consequently, relatively few people were buried with precious metals in SPA, and in most cases they have 1-4 items (group-1). Still, there is a small group that stands out for their numerous offerings (group-2). In the following sections, different aspects of these individuals will be explored to understand who were they and whether they are different from the rest of the population.

A-	Nº burials with:				
Nº grave goods	Gold	Silver	Gold & silver	Total	%
1	25	15		40	59
2	3	2	1	6	9
3	2	1	1	4	6
4	1	1	1	3	4
Total	*31*	*19*	*3*	*53*	*78*
5		1		1	1
6			1	1	1
8	1	1	1	3	4
9	1			1	1
10		1		1	1
11		1		1	1
13	1			1	1
14			1	1	1
16	1			1	1
18	2			2	3
22	1			1	1
90		1		1	1
Total	*7*	*5*	*3*	*15*	*22*
General total	**69**	**43**	**9**	**68**	**100**

B-	Nº of burials with:		
Cemetery/ Nº grave goods	1-4	≥5	Total
Casa Parroquial	11	3	14
Larache	4	8	12
Quitor-1	5	1	6
Coyo oriental	6		6
Sequitor Alambrado	6		6
Coyo-3	4	1	5
Quitor-5	5		5
Quitor-6	4		4
Solor-3	2		2
Yaye-1	2		2
Quitor-2		1	1
Tchilimoya		1	1
Catarpe-2	1		1
Quitor-9	1		1
Solcor Plaza	1		1
Solcor-3	1		1
Total	**53**	**15**	**68**

Table 38: A- Number of burials with different amounts of gold and silver grave goods. B- Burials with different number of grave goods in each cemetery.

9.1.1.3 *Spatial and chronological distribution*

Figure 161 shows the different spatial distribution of the gold and silver artefacts in SPA. Larache and Casa Parroquial, the cemeteries with most gold, are part of the central *ayllus* of Larache and Condeduque, a privileged location just on the delta of the river, with the best access to water (Castro et al., 2016; Llagostera & Costa-Junqueira,

[23] In Tchilimoya, burial 4866 contained "90 ornaments". However, I was not able to see this material to confirm whether they are complete items or a few fragmented objects.

1999). Still, a few gold items appear in Sequitor, Quitor, Solcor, Yaye and Coyo. Contrarily, silver is more frequent in the peripheral *ayllu*s of Quitor and Coyo, as well as Condeduque (Casa Parroquial and Tchilimoya; Table 36). Only a few silver objects are reported in Yaye and Larache. The distribution of silver, however, may not be reflecting a real picture, because it is likely that many objects were destroyed by poor deposition conditions. This is especially possible for the negative evidence observed in the central *ayllus*, areas that are commonly flooded and artificially irrigated promoting silver corrosion. Still, the available data indicates that while people from the central *ayllus* were buried preferably with gold, silver was used mainly in peripheral communities (see futher discussion in section 10.1). This distribution, however, seems to be diachronic, more than synchronic in time.

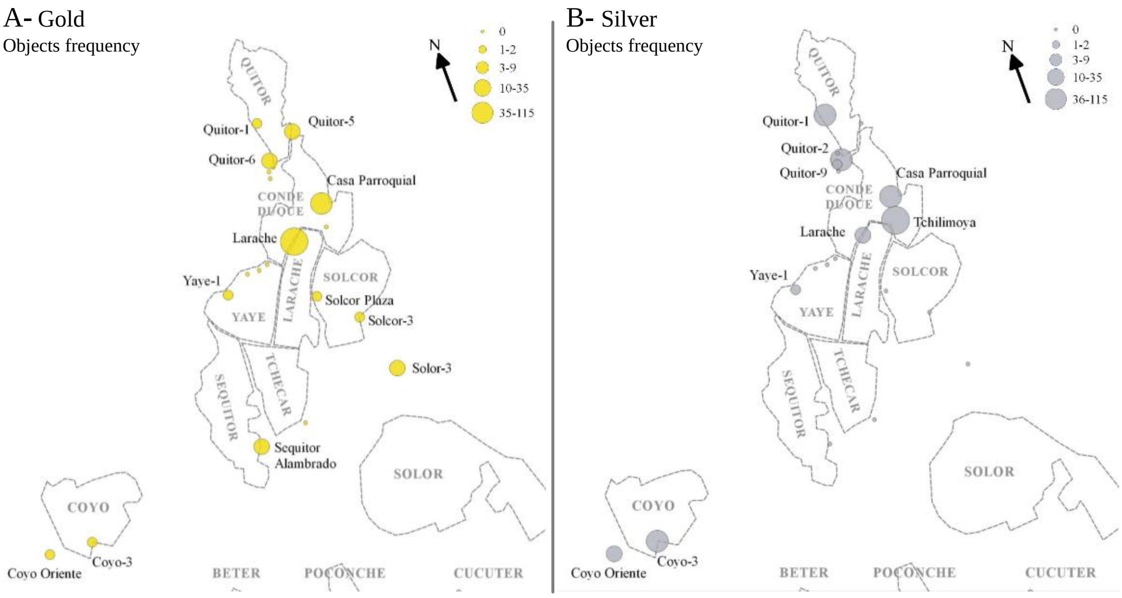


Figure 161: Spatial distribution of gold (A) and silver (B) grave goods in SPA.

Chronologically, both metals were consumed across the period, but showing different intensity in time. The distribution is relative and very general given that only four burials with gold or silver have been dated so far (Figure 162). The information used here belongs to those cemeteries with metals that have been dated heretofore, allowing to observe only general trends.

Cemeteries with more gold items are usually early sites, dated within the Quitor Phase (AD 400-700): Larache (n=115), Sequitor Alambrado (n=8), Quitor-5 (n=5), Solor-3 (n=4). The frequency of gold items decreases towards the Coyo Phase (AD 700-1000), when most cemeteries have only one item, except Casa Parroquial. Dated burials with gold in Sequitor Alambrado 428-604 Cal AD, Solcor-3 669-961 Cal AD (n=1) and Casa Parroquial 777-1017 Cal AD, support this trend. Silver on the contrary, is more frequent in cemeteries of the Coyo Phase: Quitor-1 (n=15), Casa Parroquial and Coyo-3 (n=14 each), Coyo Oriente (n=7, with a date of 610-868 Cal AD associated with silver discs), Quitor-9 (n=2), Yaye-1 and Catarpe-2 (n=1 each). Larache and Quitor-2 are the only early cemeteries with silver (still, burial 4866 from Tchilimoya with 90 silver ornaments is not dated).

Consequently and based on chronology, the consumption of gold and silver items changed over time. Gold was more frequent at the beginning of the Middle Period, decreasing its consumption towards AD 1000. Silver shows the opposite trend, it seems less common at the beginning, but is more frequent from *ca.* AD 700 onwards. The difference would indicate a shift in the patterns of circulation and consumption, with gold being scarce, or less accessible at the end of the Middle Period compared to silver. This trend is also observed in the assemblages of Larache and Casa Parroquial. The former has more gold items, few silver ornaments, and the gold is more pure (see Chapter 5:5.4); whereas in Casa Parroquial gold items are fewer, there are more silver ornaments and the gold has higher silver-levels compared to Larache. Finally, it is noteworthy that despite the changes in time, gold was always more frequent in the central *ayllus* of Larache and Condeduqe.

9.1.1.4 Summary

To sum up, the distribution above gives a scattered picture, where gold and silver appear in some cemeteries (16/44), although they include almost all the *ayllus* (9/13, 69%). In most cemeteries, gold and silver artefacts were deposited with a few individuals, and usually in small numbers (1-4 objects, group-1). There are a few exceptions were individuals have over five noble metal grave goods (group-2). With gold items, these individuals are only found in Larache and Casa Parroquial; with silver, they occur in Tchilimoya, Quitor-1, Quitor-2 and Coyo-3. The spatial distribution indicates that gold was concentrated in the central *ayllus* (Larache and Condeduque), whereas silver was principally used in peripheral communities (Quitor and Coyo), as well as in Condeduque. Still this difference may be explained by chronological factors: the cemeteries with more gold items have early dates from the Quitor Phase (AD 400-700), whereas cemeteries with more silver artefacts belong to the Coyo Phase (AD 700-1000). Overall, throughout the whole Middle Period the central *ayllus* accumulated most gold items.

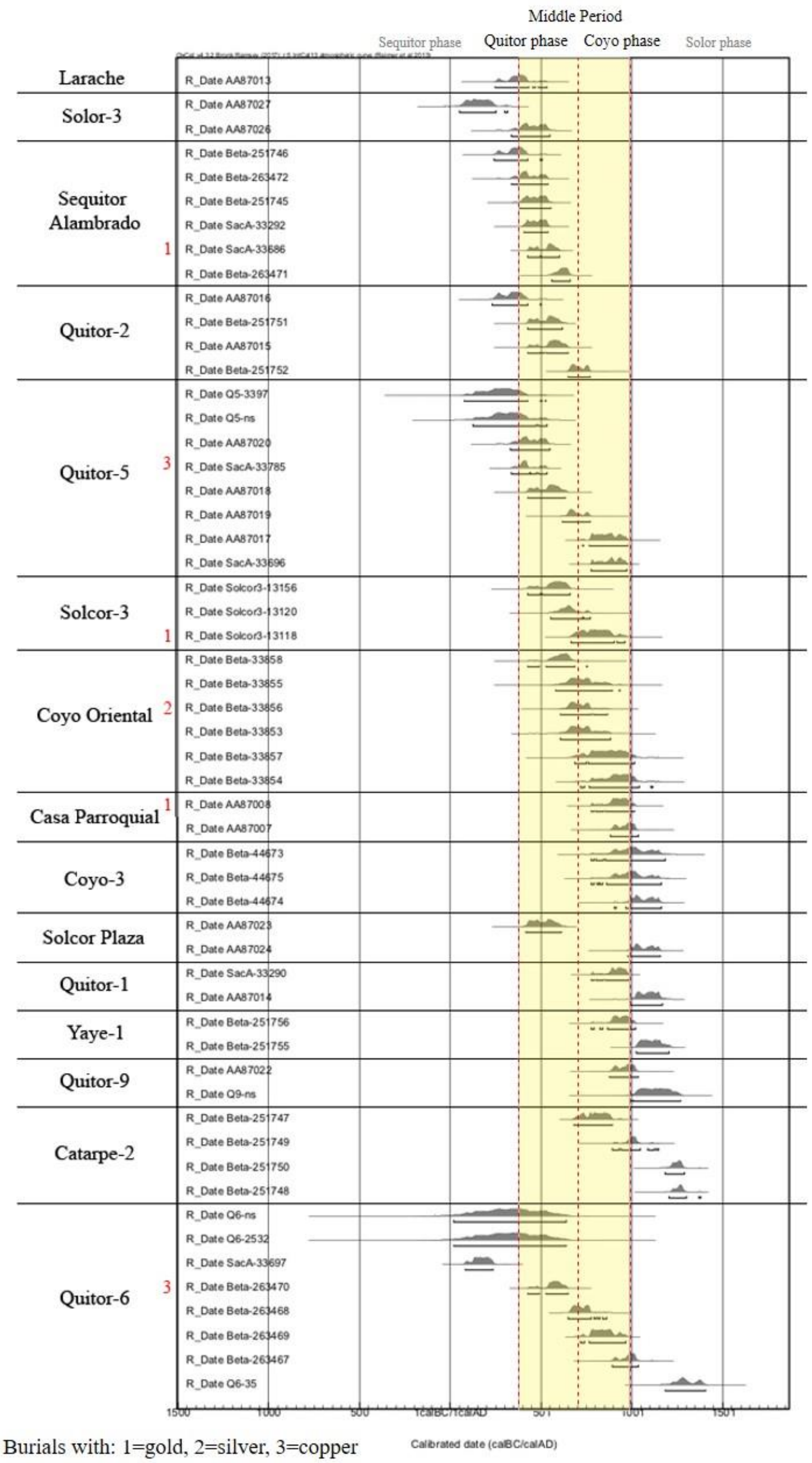


Figure 162: Re-calibrated radiocarbon dates of 16 cemeteries using the programme OxCal version 4.3, date: 05/2018
(After Berenguer et al., 1986; Costa-Junqueira, 1988; Costa-Junqueira et al., 2008; Costa-Junqueira & Llagostera, 1994; Hubbe et al., 2011; Llagostera, 2006a; Llagostera et al., 1988; Oakland, 1992; Richardin et al., 2015; Stovel, 2013; Torres-Rouff, 2002). Full dates in Appendix Nº2: 26. Numbers in red indicate the burials with metals.

9.1.2 Who is buried with gold and silver?

9.1.2.1 Type of burial

In SPA, both single and multiple graves were used as funerary units, in a proportion of 70/30 approx. (Table 39:A). The same proportion is observed in the 68 burials with noble metals. It seems then the use of metals followed a normal pattern, where most individuals were buried in single burials. At the same time, single individuals gathered most part of the metallic objects with 84% of the total, compared to 16% associated with individuals from multiple burials. The same trend is seen in groups 1 and 2, showing no major differences in their distribution (Table 39:B).

In total, it is estimated that around 73 individuals were buried with precious metals. The 18 multiple burials contain 142 people; in nine cases metals and individuals were directly associated, recognising 13 people. In the other nine burials, metals were not associated to a specific individual. Therefore, the maximum number of individuals with metals was calculated assuming that one object = one person of the burial, resulting in 10 possible individuals with metals. This is 23 individuals from the multiple burials, plus 50 from the single burials, giving a maximum of 73 noble metal bearers in SPA. From now on, when I refer to "burials" it will consider 68 funerary units, while "individuals" will consider 73 people as total.

A-			Nº burials with precious metals:					
Burial type	Average of 10 cemeteries	%	All	%	Group 1	%	Group 2	%
Single burial	799	73	50	74	38	72	12	80
Multiple burial	300	27	18	26	15	28	3	20
Total	**799**		**68**		**53**		**15**	

B-	Nº of objects made of:											
	All individuals				Group 1				Group 2			
Burial type	Gold	Silver	*Total*	*%*	Gold	Silver	*Total*	*%*	Gold	Silver	*Total*	*%*
Single burial	143	138	*281*	*84*	35	22	*57*	*76*	108	116	*224*	*87*
Multiple burial	32	20	*52*	*16*	10	8	*18*	*24*	22	12	*34*	*13*
Total	**175**	**158**	***333***		**45**	**30**	***75***		**130**	**128**	***258***	

* Two isolated finds from Sequitor Alambrado are excluded here.

Table 39: Single vs multiple burials.
A- Number of burials and B- Number of gold and silver grave goods in each type of burial.

9.1.2.2 Sex

Unfortunately, detailed information about the sex of the individuals bearing metals in SPA is scarce and incomplete. Sex was assigned to 28 individuals (38%), who gathered 44% of the gold and silver offerings (146/335), allowing only preliminary observations for now. Sex designations based on the material culture (grave goods/offerings) were excluded, using only those based on biological traits.

Of the 28 sexed individuals, 39% were female (n=11) and 61% were male (n=17), suggesting that there are more male buried with noble metals than female (Table 40:A). As for the amount of artefacts, there is no major difference between the number of grave goods buried with male or females. The 11 females identified were buried with 65 items in total, resulting in a mean of six items (Table 40:A-B), while the 17 males gathered 81 offerings, resulting in five items per male. When observed by groups, females and males have on average one noble metal grave good in group-1, whereas in group-2 females had in average 14 items and males 13. Evidently, between groups there is a great difference: one against 13-14 grave goods.

A-	Nº of individuals and average of objects per individual:								
Sex	All	%	Obj. average	Group 1	%	Obj. average	Group 2	%	Obj. average
Female	11	39	6	7	37	1	4	44	14
Male	17	61	5	12	63	1	5	56	13
Total	**28**			**19**			**9**		
out of 73 %	**38**			**26**			**12**		

B-	Nº of objects made of:											
	All				Group 1				Group 2			
Sex	Gold	Silver	*Total*	*%*	Gold	Silver	*Total*	*%*	Gold	Silver	*Total*	*%*
Female	49	16	*65*	*45*	2	8	*10*	*37*	47	8	*55*	*46*
Male	55	26	*81*	*55*	8	9	*17*	*63*	48	16	*64*	*54*
Total	**104**	**42**	***146***		**10**	**17**	***27***		**95**	**24**	***119***	

C- Object		Total nº objects	Females	*%*	Males	*%*
Pendant/Attachments		39	11	*28*	**28**	***72***
Bead		26	11	*42*	**15**	***58***
Headband		18	**11**	***61***	7	*39*
Ring		15	**14**	***93***	1	*7*
Bells	Conical	9	**9**	***100***	-	-
	Folded	5	-	-	**5**	***100***
Headdress		7	-	-	**7**	***100***
Goblet		7	-	-	**7**	***100***
Bracelet		6	**6**	***100***	-	-
Tube		4	-	-	**4**	***100***
Axe		2	-	-	**2**	***100***
Jug		1	**1**	***100***	-	-
Tablet		1	-	-	**1**	***100***
Undetermined		6	2	-	4	-
Total		**146**	**63**		**81**	
Out of 335 %		**44**	**19**		**24**	

Table 40: Sex of the metal bearers.
A- Number of female and male individuals and average of items per individual. B- Number of gold and silver grave goods in female and male burials. C- Types of gold and silver objects associated with females and males (four unclear objects are excluded).

It seems then, there are more males buried with precious metals than females. In contrast, the number of grave goods per burial does not appear to be strongly affected by sex; i.e., once they are buried with metals, both males and females could have a few or many artefacts. If this tendency is corroborated, it may show that females, when buried with metals, could have the same or more number of items as males. With the available information, this pattern applies for gold items only, because the frequency of silver artefacts is lower in female burials (16 vs 26 objects). This find challenges traditional associations between silver and women in the Andes, associations that would need further research in pre-Inka periods (González, 2004c; Iwasaki, 1984; Lechtman, 1991a).

When sex and types of objects are compared, six categories appear in association with males only: axes, goblets, headdresses, tubes, tablets and folded-bells; while bracelets, conical-bells and the miniature jug are associated with females. Beads and pendants are used by both, but their frequency is higher in male burials; whereas rings and headbands are more frequent with females (Table 40:C).

9.1.2.3 Age

Overall, 84% of the individuals are identified generally as adults or infants (n=61), however more specific age ranges are given for 13 individuals only (18%), classified as young adults (18-35yr), mature adults (35-50 and 50-60yr) and elderly (60+). Infants include new-borns, babies and small children.

Table 41:A shows that most people buried with gold or silver in SPA are adults (75%), gathering the 84% of the grave goods. Only 6 infants were reported, representing 8% of the individuals (all single burials) and containing 10% of the precious metal offerings. The percentage of infants in group-1 is low, representing 4% (n=2), having one metallic grave good each; in contrast to group-2 where infants are 27% (n=4) and were buried with 28 gold and 3 silver grave goods.

A-	Nº individuals:									Nº objects made of:					
Age	Gold	Gold & silver	Silver	*Total*	*%*	Group 1	*%*	Group 2	*%*	Gold	*%*	Silver	*%*	*Total*	*%*
Adult	28	4	23	*55*	*75*	44	*96*	11	*73*	125	*81*	155	*97*	*280*	*84*
Infant	3	3	0	*6*	*8*	2	*4*	4	*27*	29	*19*	4	*3*	*33*	*10*
Total	**31**	**7**	**23**	***61***	***84***	**46**		**15**		**154**		**159**		***313***	***93***

B-	Female						Male					
Age range	Nº individuals[1]	Nº Au obj	Nº Ag obj	*Total*	*%*	Nº Cu obj	Nº individuals	Nº Au obj	Nº Ag obj	*Total*	*%*	Nº Cu obj
18-35	2 (4)	2	1	*3*	*1*	17	6 (5)	21	3	*24*	*7*	26
35-50	3 (2)	29	1	*30*	*9*	3	0 (2)	-	-	-	-	3
50-60	0 (1)	-	-	-	-	13	-	-	-	-	-	-
70	1 (0)	18	-	*18*	*5*	-	-	-	-	-	-	-
Total	**6 (7)**	**49**	**2**	**51**	**15**	**33**	**6 (7)**	**21**	**3**	**24**	**7**	**29**

1: The number of additional individuals with copper are given between parenthesis ( ).

Table 41: Age of the metal bearers.
A- Number of adults and infants buried with gold or silver, and amount of grave goods associated. B- Detail of some individuals with more precise age-ranges.

The ages of six female and males were given in more detail, showing interesting patterns (Table 41:B). All males are young adults between 18-35yr, bearing 7% of the noble metals grave goods (n=24); whereas females exhibited a wider age range, including mature adults (35-50yr) and elderly (~70yr). Older females (35+) contain important number of gold grave goods with 48 items (14%), compared to young females (18-35yr) with 3 objects (1%). When copper objects were included as comparison, the pattern for males stayed the same, with only two mature individuals (Table 41:B); but for females, copper appears primarily associated with young adults (17 copper objects), and secondly to mature adults (3 objects). Apparently, metals in general are associated with young adult males (18-35yr); whereas in females, the use of metals is more spread, including females of different age ranges. Gold in particular is more abundant in mature females (35+), compared to young adult females who contain more copper. Silver is reported in few cases only, both in young adults and one mature adult.

The distribution of types between adults and infants, indicates that adults used all the categories used by infants. In fact, 11 types (axes, beads, bracelets, goblets, jug, snuffing implements, and rings) are only present with adults; whereas headbands, discs, sheets, headdresses, conical-bells, pendants and fragments are associated with adults and infants.

9.1.2.4 Cranial vault modification and strontium isotopes signature

Both cranial vault modification and strontium isotopes have been used to identify foreigners in SPA, i.e., individuals that were born somewhere else, but died and were buried in SPA (Cocilovo et al., 2011; Costa-Junqueira et al., 2008; Costa-Junqueira & Llagostera, 1994; Knudson, 2007; Knudson & Torres-Rouff, 2014; Llagostera, 2004, 2006a; Llagostera et al., 1988; Salazar et al., 2014; Torres-Rouff et al., 2013; 2015). Cranial vault modification is considered in SPA and the Andes a means of expressing ethnicity, identity and social relationships (Cocilovo et al., 2011; Torres-Rouff, 2002). Because it needs to be performed during infancy, it is assumed that different modification types would indicate the community of origins of their carriers (Torres-Rouff, 2002). In SPA, the local variant includes the tabular erect, however, most people did not modify their head (Cocilovo et al., 2011; Costa-Junqueira & Llagostera, 1994, 2014; Llagostera, 2004, 2006a; Llagostera et al., 1988). In the Titicaca basin the most common is the annular type; and the tabular oblique type is consider a “foreign” form, found elsewhere such as in Moquegua, a Tiwanaku colony in the Peruvian south-coast (Torres-Rouff, 2002) or NWA (Cocilovo et al., 2011).

Nine individuals associated to precious metals (12%) have cranial deformation (Costa-Junqueira et al., 2008; Le Paige, 1961; Torres-Rouff, 2002). They gather 33% of the 177 gold objects (n=58), and 2% of the 158 silver items (n=3; Table 42:A). The types of deformation include the local tabular erect variant for five individuals (one female, two males and two undetermined sex) with 41 gold items in total, and one foreign variant: female 359 with tabular oblique form and 16 gold items. The individuals in group-1 (1-4 items) include local (n=3) and unidentified (n=3) types, while group-2 includes the one foreign and two local variant (all from Larache). An important number of gold grave goods (n=16, 9%) belong to a female with foreign modification type. This female and three individuals with local types are from Larache (B.356, B.359, B.1714 and Body1), whereas two males with local type are from Solcor-3 (B.107) and Coyo Oriente (B.4111). The not-specified types are from Casa Parroquial (B.1) and Coyo-3 (B.6 and B.33).

A- Type	Origins	Nº individuals	Nº gold objects	Nº silver objects	Cemetery
Tabular Erect	San Pedro	5	41	-	Larache (3), Solcor-3 (1), Coyo Oriental (1)
Tabular Oblique	Foreign	1	16	-	Larache
Not specified	-	3	1	3	Casa Parroquial (1), Coyo-3 (2)
	Total	**9/73**	**58/177**	**3/158**	
	%	**12**	**33**	**2**	

B-	Nº individuals with:							Nº objects made of:			
$^{87}Sr/^{86}Sr$ signature	Gold	Gold & silver	Silver	*Total*	*%*	Group 1	Group 2	Gold	Silver	*Total*	*%*
SPA	4	4	4	*12*	*16*	9	3	34	9	*43*	*13*
Foreign	1	-	1	*2*	*3*	2	-	1	1	*2*	*1*
Titicaca basin/ NWA	2	-	-	*2*	*3*	1	1	20	-	*20*	*6*
Total	**7**	**4**	**5**	***16***	***22***	**12**	**4**	**55**	**10**	***65***	***19***

Table 42: Cranial modification and strontium isotopes.
A- Type of cranial vault modification in nine individuals associated to gold and silver grave goods. B- Strontium signature of 16 individuals from SPA and the amount of grave goods per possible origin.

Strontium signatures from human tooth enamel were also considered here, indicating the region in which individuals lived the first years of their lives (Knudson & Torres-Rouff, 2014; Torres-Rouff et al., 2015). Of 16 individuals, 12 (16%) showed local $^{87}Sr/^{86}Sr$ signatures, indicating that were born and died in SPA. They carried in total 34 (19%) gold and 9 (6%) silver artefacts (Table 42:B). Four people with foreign signatures were identified (5%): two individuals grown most likely in the Titicaca basin with 18 and two gold objects, respectively; and two “foreign” individuals (the signatures are not identified yet, but are not local) with a gold and a silver object. The $^{87}Sr/^{86}Sr$ values indicate that local and foreign people were buried with gold grave goods; and both –local and foreigners- could have 1-4 (group-1) or more gold items (group-2). Without metals, 10 people in total from Quitor-5, Solcor Plaza, Solcor-3 and Solor-3 present isotopic values within the Titicaca or NWA region, which is interesting because these are the same cemeteries that contain gold objects in small amounts (Figure 161:A).

It is noteworthy that in Larache male 358 (18 gold items) had local cranial modification type, but a $^{87}Sr/^{86}Sr$ signature from the Titicaca Basin, whereas female 359 (16 gold items) had a foreign modification type and local $^{87}Sr/^{86}Sr$ signature. The combination of local/foreign $^{87}Sr/^{86}Sr$ values and cranial deformation types, may reveal people from other ethnic groups (e.g. from the Peruvian coast or NWA) that were born or grew up in SPA, and San Pedrinos that were born abroad, but went back to SPA in their later years. These movements are consistent with ethnohistorical records that recognise this type of situations in the Andean communities of the Colonial Period (Martínez, 1998). Both cranial vault modification and strontium isotopes indicate the presence of a few people related to or from the central *Altiplano* or NWA in SPA.

9.1.2.5 Funerary offerings

Unfortunately, the amount and type of funerary offerings between cemeteries cannot be directly compared, because of differences in size, number of burials and post-depositional conditions. Whereas Larache and Casa Parroquial are located in areas prone to flood, where the organic material did not survive, the cemeteries from Quitor, Coyo and the other *ayllus* are located in dry areas showing an extraordinary preservation of the whole funerary furnishings. Still, the former sites contained pottery, lithics and mineral implements.

Based on their offerings, both Larache and Casa Parroquial already appear as “atypical” within SPA (Castro et al., 2016; Stovel, 2001; Torres-Rouff et al., 2015). According to Le Paige (1961), during the excavation of Larache, only items directly associated to the bodies were described as their grave goods (e.g. gold objects), because several contexts were disturbed. Most pottery and other materials found were recorded but were not directly associated to a particular individual. This means that the gold bearers with only few additional grave goods recorded may reflect a skewed picture. In any case, Larache as a cemetery shows a different pattern compared to other sites, because of its relatively a) high frequency of *Rojo Pulido* pottery (burnished red), and b) the large amount of noble metals (Castro et al., 2016; Torres-Rouff et al., 2015). Similarly, the funerary pattern of Casa Parroquial is also considered different, based on the low frequency of local funerary pottery styles (i.e. black pottery) compared to other cemeteries of the period (Téllez & Murphy, 2007).

Having said this, I will look here only at a general trends based on the amount of total grave goods and the presence/absence of specific artefacts. Essentially, the amount of total grave goods is very varied in individuals with noble metals, ranging from 2 to 100 items. Figure 163 shows that there is no relation between the total size of the funerary bundle and the amount of gold or silver objects in them; i.e., single burials with more grave goods do not necessarily have more gold or silver, compared to individuals with fewer offerings (Figure 163:B). Multiple burials are similar, although they comprise the grave goods of a group of people (Figure 163:C). Indeed, as previously mentioned, most burials have one gold or silver item only, irrespective of the other grave goods. People with rich burials from Larache and Casa Parroquial, show a similar trend; i.e., in Casa Parroquial most inorganic grave goods appear in graves with 1-2 gold/silver artefacts, whereas in Larache reports identified people with gold having from none to 10 other grave goods (Figure 163:A).

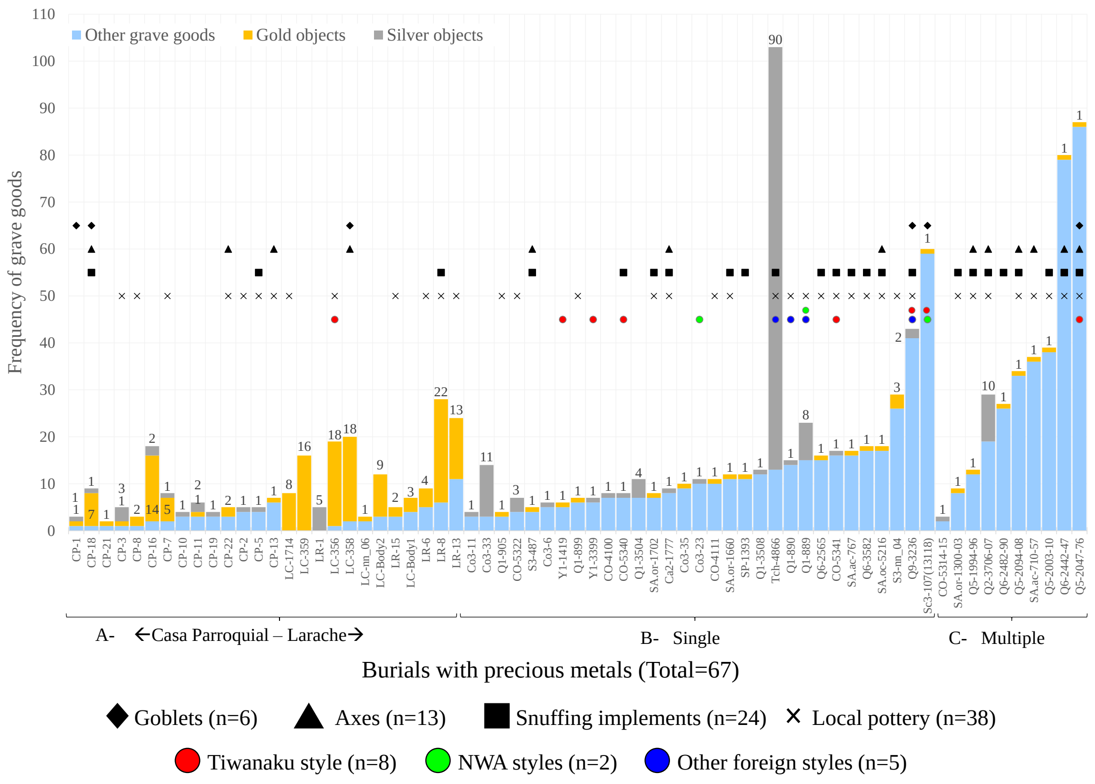


Figure 163: Bar graph showing the amount of grave goods in 67 burials from SPA, indicating the number of gold and silver items.
Burials are separated in three: A) Casa Parroquial and Larache, b) single burials and c) multiple burials. The figure on top of the bars is the number of gold and silver objects. The symbols represent the presence of other grave goods in that burial. Foreign artefacts (circles) include pottery, textiles and snuffing implements.

Due to time constraints, it was not possible to analyse in detail the relation between the grave goods in these burials, between burials with or without noble metals, nor the quality of the grave goods. Still, specific categories were selected to compare their association between noble metals bearers, considering the presence/absence of these other offerings and the amount of gold or silver grave goods. These include local pottery (different types), goblets, axes, snuffing implements and foreign objects (such as pottery, snuffing implements and textiles). Overall, no pattern was identified, indicating that a) the presence of these items (and the activities that they represent) was not associated to the amount of gold or silver deposited in the burials, and b) that noble metals typically appear in burials with local funerary patterns, except for the less typical contexts of Larache and Casa Parroquial (Llagostera, 2006b; Salazar et al., 2014; Stovel, 2001; Uribe & Agüero, 2001).

Different types of local pottery were found with 38 individuals (52%), half of the noble metal bearers, showing no particular trend. Local pottery was used both in individuals of group-2 from Larache, Quitor-1, Quitor-2 and Tchilimoya; as well as individuals with 1-4 gold/silver artefacts from group-1 (Appendix Nº3: 13). Similarly, 24 individuals (33%) are associated with snuffing implements; and only four of them have more than one gold/silver artefact (CP B.18, Larache B.8, Tchilimoya B.4866 and Quitor-2 B.3706-07; Appendix Nº3: 15). While 13 burials (18%) contain axes of different materials, and only three of them have 8-18 gold/silver grave goods (CP B.18, Larache B.358 and Quitor-2 B.3706-07; Appendix Nº3: 16). Goblets appear in six burials (8%, Appendix Nº3: 17): two single burials have large amounts of grave goods, but only 1-2 gold/silver items (Quitor-9 B.3236, Solcor-3 B.107); whereas in other two, gold items predominate (CP B.18, Larache B.358). It is likely that goblets were used by important people, reflected in their recurrent association to a) large amounts of additional grave goods or b) additional gold/silver items. Still, the use of ceremonial goblets is not correlated with a higher amount of gold/silver grave goods.

Foreign items of Tiwanaku style appear in eight burials (12%) with variable amounts of grave goods, but with a single gold or silver item (Quitor-5, Quitor-9, Coyo Oriente, Yaye-1). The only exception is female B.356 from Larache, with 18 gold artefacts and a vessel of Tiwanaku style from Cochabamba (Stovel, 2001). Styles from NWA appear in two burials (3%) with more than 10 grave goods: female B.889 from Quitor-1 with Isla pottery (from Humahuaca ravine) and eight silver funerary ornaments (Stovel, 2001); and female B.13363 from Coyo-3 with Aguada pottery and a silver miniature jug (Llagostera, 1995). Other foreign items include Huruquilla style pottery (from Southern *Altiplano*) in Tchilimoya B.4866 (Tarragó, 1989), and other foreign undetermined styles in Quitor-1 B.889, B.890, Quitor-9 B.3236 and Solcor-3 B.107. In four of these five cases (7%) the metal present was silver in amounts of 1-2, 8 and 90 artefacts; whereas a gold tube was found in Solcor-3. Still, most burials with foreign items have one gold/silver item, except for three burials, suggesting that the access to foreign items did not necessarily influence the amount of noble metals acquired (Appendix Nº3: 14).

9.1.2.6 Summary

Table 43 summarises the main characteristics of individuals buried with gold and silver explored above. Based on the groups proposed, group-1 represents the majority of the individuals associated with precious metals in SPA; whereas group-2 is slightly different and includes individuals that can be further divided in two: 2a) individuals with gold and 2b) individuals with silver. Overall, there is a difference between the users of gold and silver in terms of the type of burial, sex, age and origins, favouring young adult males and to a lesser extent mature females and infants. Nonetheless, it seems that still the biggest difference relates to cemetery, i.e., people with preferential access to gold are from the *ayllus* of Larache or Condeduque, whereas silver is more frequent in Coyo, Quitor and Condeduque, in spite of their personal characteristics. Thus, it seems more likely that people could obtain gold if they were from Larache or Condeduque, compared to other *ayllus*, regardless of sex or the amount of other grave goods. The weight of metal recorded so far is a good indication of this fact: Larache has 1,830grs, Casa Parroquial 935grs and the other sites together have 198grs (notwithstanding there are several lost objects not included in this figure).

Yet, age may suggest some differentiation, with noble metals being used primarily by young adult males and mature females. In Larache, females, males and infants used gold in similar way, although the type of objects were different: while males are associated with goblets, axes and headdresses, females have bracelets and conic-bells. Still, individuals from other *ayllus* (13 people in total), such as Sequitor, Solcor, Solor, Yaye and Catarpe, buried with 1-4 gold or silver objects, indicate that the circulation was not exclusively of the four *ayllus* mentioned above, although the frequency of objects is much low in comparison, with 17 items in total. The sex and gender of these individuals is not known, and regarding offerings, five of these burials had axes, seven were associated to snuffing implements and three had only pottery or gourd containers, showing no evident patterns regarding the activities of these noble metal bearers.

	Group 1	Group 2a - Gold	Group 2b -Silver
Nº noble metal grave goods	1-4	>5	>5
Total nº of gold/silver objects	45/30	130/9	0/119
Nº burials	53 (73%)	11 (15%)	4 (6%)
Sex	male[1]	female, male	female, male
Age	young adult	young adults, mature adults[2], infants	adults
Type of burials	single	single	single
Cranial vault modification & Strontium signature	local and foreigners	local and foreigners	no information
Amount of other grave goods	2 to 60, average:12	0 to 10, average:2	3 to 20, average: 13
Cemeteries	All except Quitor-2 and Tchilimoya (14 out of 16)	Larache, Casa Parroquial	Coyo-3, Quitor-1, Quitor-2, Tchilimoya
Ayllu	9: Larache, Condeduque, Quitor, Coyo, Sequitor, Yaye, Catarpe, Solcor, Solor	2: Larache, Condeduque	3: Coyo, Quitor, Condeduque
Observations:	*[1]Females are present in low number, but have the same nº of metallic grave goods than males*	*[2]Most gold is associated to mature females (35+)*	

Table 43: Table summarising the most common associations between individuals and noble metal grave goods.

9.2 How were gold and silver objects used in SPA?

Overall, gold and silver artefacts in SPA have been classified as personal ornaments, ritual objects and political emblems (Cifuentes et al., 2018) used to communicate and reinforce ideological, social, religious and political messages (DeMarrais et al., 1996; Lechtman, 1991a, 1993; Salazar et al., 2014). The analyses of the manufacturing techniques, use-wear variations, type of the objects produced and contexts of deposition performed in this investigation have provided additional detail on how these objects were used, identifying new features and expanding our understanding of classic objects.

Below, I explore how religious and leadership emblems were employed, identifying objects ritually killed and proposing that two personal ornaments may represent a ritual apparel (9.2.1). In section (9.2.2), I propose a new category of *funerary objects*, i.e., artefacts especially made for the mortuary ritual, an activity that is proposed here to have been an intrinsic part of a local funerary tradition. And finally (9.2.3), I discuss the use of incomplete or fragmented ornaments as *deliberate fragmentation* revealing inter- and intra-community links. These finds confirm that noble metals symbolised political and ritual leadership, while they were also means to materialise and maintain connections within the local community, the ancestors and long-distance relationships within the region.

9.2.1 Ritual and leadership emblems

Amongst the grave goods found in SPA, there are 25 objects that can be considered emblems of political and religious leadership. In the Andean structure, the obligations of the chiefs or leaders included the exercise of justice, administration of local and foreign resources (e.g. redistribution), organisation of communal labour, and compliance with strict ritual protocols (Martínez, 1998; Nielsen, 2006b, 2007; Platt, 1987). In SPA, axes, maces, and brassards are considered leadership emblems (Castro et al., 2016; Llagostera et al., 1988; Nielsen, 2006b; Salazar et al., 2014), while the *keros*, portrait-vessels and psychotropic implements, are related to the ritual and ceremonial spheres (Cummins, 2004; Janusek, 2003; Llagostera et al., 1988; Torres, 1984; Torres et al., 1991).

9.2.1.1 Precious metals in the political sphere

Axes in SPA are primarily associated with males (Cifuentes, 2014; Llagostera et al., 1988). They are made in different materials such as stone, copper or copper-alloys and gold. Although there are nearly 41 copper-based axes in SPA, only two are made of gold (2/44, 5%) and possibly one is made of silver (described as tin in the excavation report). One axe belongs to male B.18 from Casa Parroquial and two to male B.358 from Larache (made of gold and possibly silver). Overall, there are no use-wear studies on the axes, but it seems that most of them were not used (Ariadna Cifuentes, *pers. comm.* 2018), as observed in axe popm126 from Larache, supporting their role as emblems and not tools. Both gold axes are the only decorated axes in SPA: with (corroded) silver bands in Larache and a checkered design in Casa Parroquial, enhancing their unique characteristics (Figure 164).

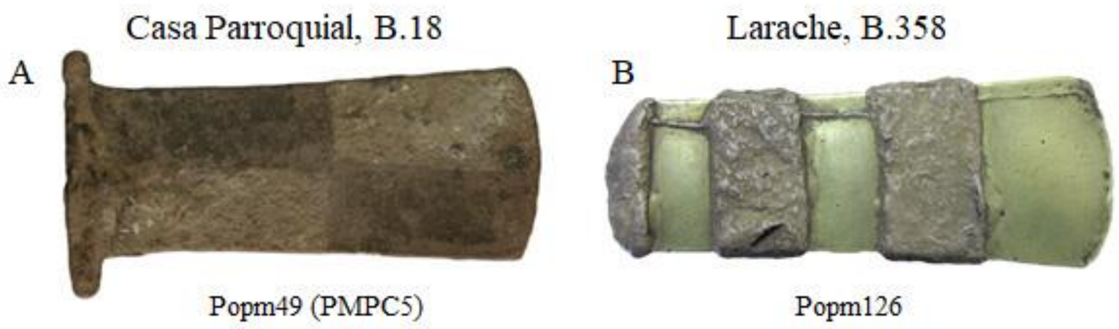


Figure 164: Axes from (A) Casa Parroquial and (B) Larache.
Note the decoration of both artefacts (images are not to the same scale). Unfortunately, popm49 was not accessible for this research (elemental analysis in Salazar et al., 2011).

The small number of these items may relate to an access or availability issue, however, it is very possible that these were unique items that were kept and transmitted through generations, being used only in specific situations and by the leader in charge (Nielsen, 2007; Platt, 1987). Espinoza gives an example of the use of highly symbolic objects, when talking about a vest overlaid with gold, silver and shell given by the Inka to an interethnic *curaca*, to recognise the *curaca's* authority*: "The powerful leader […] wore this important insignia only once because, according to custom, it must be kept in perfect condition for many generations in order to be transferred from one successor to another"* (my translation of Espinoza 1981:203; Nielsen, 2006b, p. 139). The presence of axe handles without the stone or metal[24] blades in the burials, would support the idea

[24] They are recognised by the rims of copper mineralisation at the perforation where the axe was fitted.

that these items where inherited and not always buried (some axes were symbolically replaced with bone, wood or ceramic blades).

9.2.1.2 Precious metals in the ritual sphere

The ritual objects comprise seven goblets, 15 snuffing implements and I have also included here a headband and a disc (see justification below). There are at least 20 *keros* and portrait-vessels in SPA made of pottery, wood, gold and silver. Gold specimens are associated with male individuals in B.358 in Larache (n=3); B.1 (n=1) and B.18 (n=2) in Casa Parroquial; only one silver *kero* is reported in Quitor-9 (B.3236-37, undetermined sex). The six metallic goblets analysed are Tiwanaku style – as discussed in previous sections –, with smooth and worn surfaces, suggesting that they were manipulated and used. These items were fundamental in feasting where the *chicha* – used as social integrator – was redistributed by the leaders (Cummins, 2004; Janusek, 2003; Martínez, 1995; Nielsen, 2006b, 2007). In Larache and Casa Parroquial, males B.358 and B.18 were associated with *keros*/portrait-vessels and axes, which corroborates the figure of a leader in charge of the political or ceremonial spheres.

Figure 165: Ritually killed keros from Casa Parroquial

The importance and powerful nature of these items is also reflected in the fact that the two *keros* from Casa Parroquial (B.18) were "ritually killed" or intentionally flattened (Figure 165). For Chapman (2015), the ritualised destruction of objects in traditional societies is a deliberate act oriented to de-animate the artefacts prior to deposition, given that they are considered animate and powerful entities (2015, p. 32). In this case, the ritual killing would symbolise the end of the life of the object, which would not be able to perform again (Brück, 2006). In SPA, no other "killed" *keros* have been reported, however the practice of intentional breakage or destruction is observed in the arches buried across cemeteries, which - according to Le Paige excavation reports - were broken in half. Breaking the arches was probably a way of ritually kill these hunting weapons.

The snuffing implements include eight tablets, four tubes, two mortars and a spatula inlayed with gold or wrapped with gold sheets. The presence of snuffing implements in SPA is relatively common and they relate to the ritual and shamanic sphere, oriented to reach altered states of consciousness (Llagostera, 2006a; Llagostera et al., 1988; Núñez, 1991; Torres, 1998; Torres et al., 1991). These implements are mainly associated with males, and to a lesser extent with females. It is compelling though, that in Solcor-3 the only two females with snuffing implements were mature adults between 45-50yrs (Llagostera et al., 1988), similar to female gold bearers. In the cases with gold, the four tubes appear in male burials, but the tablets, mortars and spatula do not have associated information about the individuals' sex.

Figure 166: Tablets with gold inlays (white arrows).
A- San Pedro style from Sequitor Alambrado and B- Tiwanaku style from Quitor-6. Note the tiny size of the inclusions and gold foil used.

In tablets and mortars, gold decoration is very subtle and comprises tiny inclusions or small gold foils under the mineral beads, only visible from very close distance (Figure 166). The tubes are more noticeable, given that they wrapped the tips and/or the body. Still, given the type of decoration, the use of gold in tablets and mortars does not suggest ostentation. In fact, it looks like a very intimate detail in some ways may be explained by Lechtman's theory of essences (Lechtman, 1984, 1993). In this case, the tiny amounts of gold would be enough to impregnate the tablet with its essence, revealing the value and significance of gold in these ritual practices. Regarding the styles of the tablets and tubes, both Tiwanaku and San Pedro Styles are recognised (Horta, 2014; Llagostera, 2006a; Torres, 2001), suggesting that gold was used in local and *altiplanic* implements during the Middle Period (Figure 166).

Finally, there are two ornaments that may be part of a ritual costume, although their assignation is more hypothetical. These are a headband (91.1.20) and a disc (91.1.21) associated with female B.13 from Larache (Figure 167). The shape of the headband and its combination with a pectoral disc is very similar to the attire seen in a stone figure from NWA, which would represent "the sacrificer" (or *el sacrificador*). The origin of the sculpture is not clear, but it is believed to belong to the Middle Period (AD 500-900; Goretti, 2012, pp. 51–55). It is not proposed here that the female in Larache was the equivalent of the sacrifice; however, it is possible that these ornaments were worn to perform in ceremonies and rituals, instead of being personal ornaments of daily use.

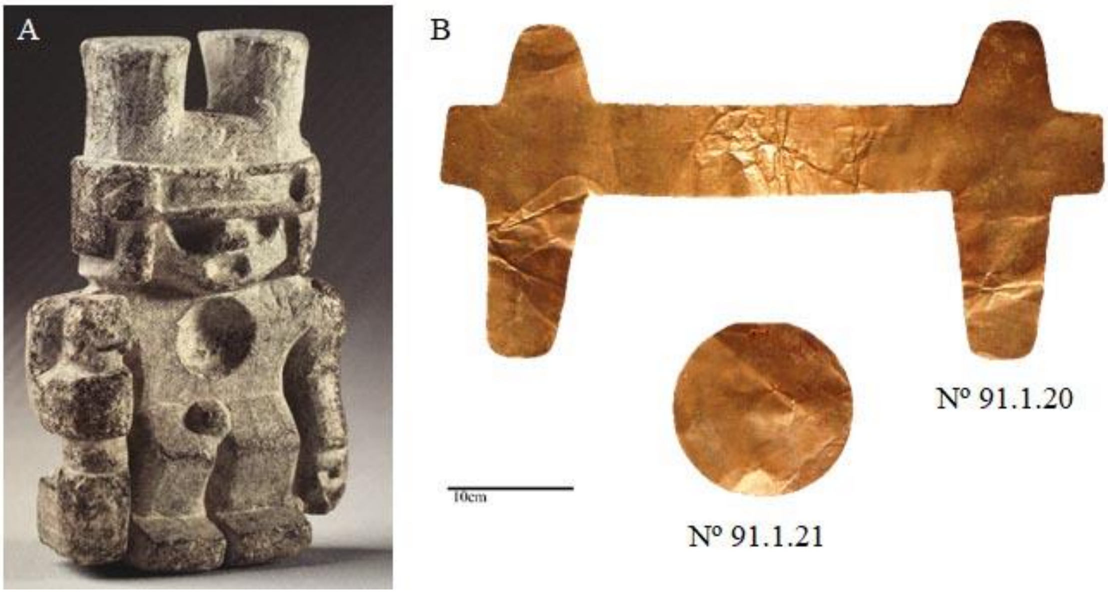


Figure 167: Ritual apparel.
A- Stone figure of "The Sacrificer", note the headband and the pectoral (after Goretti 2012, p51). B- Possible ritual apparel from Larache (Rescate), B.13 (images courtesy of Ana María Barón 2016). Note the similitude between both.

9.2.2 Funerary ornaments

As discussed in chapter 8, within the personal ornaments, a group of items shows specific features that suggest that they were especially made for the mortuary ritual. These comprise 39 gold and silver objects with fresh perforations and cutting marks, showing little or no evidence of wear, suggesting that they were made or modified and buried shortly after. The artefacts include both long and short headbands, sheets, pendant and attachments (discs or quadrangular), all being placed on the upper body within the funerary bundle (Figure 168). The headbands and sheets covered the front head, eyes, mouth or face; the pendants and attachments covered the chest. Some of them were placed in direct contact with the body, others were located outside the shroud at eyes, mouth or face levels (Le Paige, 1961, 1964). A further 21 similar objects made of gold, silver, copper and unidentified metals were used in the same way. Still, a few analysed bands were smooth and worn indicating that some items were used in life as headbands or pendants, before being placed on the eyes and mouth for the burial.

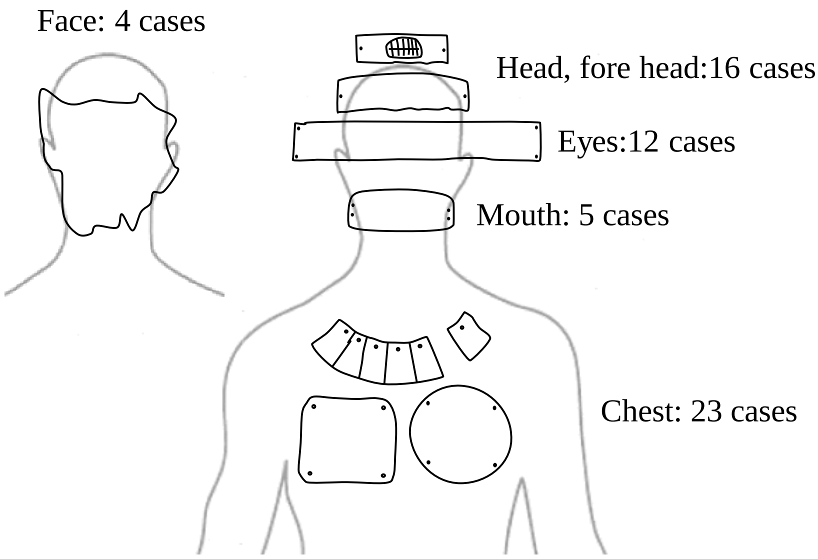


Figure 168: Diagram showing the position reported of the funerary ornaments and their frequency.

Commonly, these items are classified as personal ornaments, but the lack of use in most of them and their location in the body (on the eyes or mouth), point towards a local ritual production of *funerary ornaments* to be displayed in a specific way (DeMarrais, 2013; Spielmann, 1998, 2002). Nevertheless, there is a clear overlap between personal ornaments used in life and funerary ornaments. In SPA and the Andes in general, people were often buried with their belongings (Berenguer, 2006; Bibar, 1966 [1558], p.14; Cieza de León, 2005 [1553], p.257), and in this case, some personal ornaments were used as funerary ornaments covering specific areas as well. It is noteworthy though, that gold and other metals in SPA alludes to a ritual that would require specific objects to cover particular parts of the human body.

More obvious personal ornaments, in contrast, are pendants, attachments, bells, rings, bracelets, headbands, headdresses and beads that were made and used in life, showing evidence of wear. And yet also some of these items have fresh marks suggesting that they were also cut and modified for the burial, such as two rings (popm96-97), a headdress (popm86), a bracelet (popm108) and two small sheets (popm8,11), adding up to 65 with the funerary objects above (though this number may be higher given that the 90 offerings from Tchilimoya are excluded due to the amounts or ornaments are unclear, and there are other eight ornaments of imprecise use).

The funerary ornaments appear in 10 cemeteries and are associated with 27 individuals from single (n=20) and multiple burials (n=7); including females (n=2), males (n=3), infants (n=4), and undetermined individuals (n=18). Most people have 1-2 items covering the eyes or mouth (23/27, 85%); four individuals (15%) from Larache and Casa Parroquial have 5-11 funerary ornaments. From Larache they include the three "coarse" sets from B.356, B.358 and B.359, which are of particular interest because of their similarity, suggesting that they were made following a specific pattern: three bands to cover head, front head and eyes, a disc and a quadrangular attachment each, to cover the chest of two females and a male. Moreover, in previous sections it was proposed that these items from Larache were locally made, and their use in a local mortuary tradition would support this idea.

Covering the upper body, especially the face or head, with metal sheets appears to be a local tradition not seen in burials from Tiwanaku, where individuals were buried with their personal ornaments in their correct positions (note that they also used pectorals and headbands, but reports do not mention any objects covering the eyes, mouth or face in general; Korpisaari, 2006; Stovel, 2001); nor NWA, where the use of stone or metal masks was more extended (Goretti, 2012; Tarragó, 2006). However, similar practices are identified in Peru by Joseph de Acosta, who writes in 1590: *"[…] They […] use to place silver on their mouths, on their hands, on their breasts, and to dress them with new […] clothes folded under the shroud"* (Acosta, 1894 [1590], p. 27). In Moche burials, metals were used to cover bodies and coffins, reason why Lechtman proposes that metals may have had a protective role (2014, p. 375). However, to discuss the meaning of this practice is beyond the scope of this study, and what is clear is that these objects were important and significant, since their participation in the mortuary ritual encouraged the development of a local technology oriented to make (e.g. the three sets from Larache) and modify imported items for that specific use.

Copper mineral plaques covering the mouth, eyes and in the ears of at least seven people in Quitor-5 and Quitor-6 (Horta & Faundes, in Press) and textile bags covering the head of individuals in Quitor-2 and Quitor-6 (Agüero, 2003) would suggest that a similar practice was used by non-metal bearers; however, future research should determine which and to what extent other materials were used in the same way and whether they were especially made for the burial.

9.2.3 Parts and fragments

Another characteristic seen in SPA is the use of incomplete personal and funerary ornaments, proposed here as evidence of intentional fragmentation. Deliberate fragmentation has been extensively studied in heterarchical or middle range societies in Europe and Eurasia (Brück, 2006; Chapman, 2010, 2015; Chapman & Gaydarska, 2009). These approaches are based on the idea that people have "fractal personhoods", i.e., a person's identity is constructed in connection with other people, places and things, being a sum of multiple enchained parts (Chapman & Gaydarska, 2009). In this context, objects and fragments of objects are active entities that materialise these links, at the same time that become part of who the person is (Brück, 2006; Chapman, 2015). Fragments in particular, have the advantage and capacity to stand "*for the complete object in one place [and] presence the persons and places of the object's origins and later biography in other places*" (Chapman, 2015, p. 26). Moreover, fragments can relate or enchain different people, places and things at the same time, establishing a dynamic relationship among them (Brück, 2006; Chapman, 2015).

When the fragments or parts are re-fitted, depending on where they appear, they may reveal "enchained" relations among people from the same community, or different communities; as well as relations between the dead and the living (Brück, 2006; Chapman & Gaydarska, 2009). However, orphan fragments are also common. According to Chapman and Gaydarska (2009) orphan fragments of exotic materials, especially in burials, would reveal long-distance relationships, probably generated by face-to-face contacts or exchanges with other communities.

In SPA there are two sets of objects that were divided in several parts and deposited in different burials (n=23) and 13 modified items that appear as orphan fragments. The sets identified in SPA are part of the funerary ornaments described above, and were divided in several parts, some of them showing different biographies. Orphan fragments are mostly small pendants and attachments of random shapes, together with three headdresses. Clearly, all of them are parts of single objects that were cut, which differs from the funerary ornaments that were cut to obtain specific shapes, e.g. elongated bands.

9.2.3.1 The sets: enchained relations with the ancestors and within the community

The first example is from Larache and includes six rectangular pendants (popm119-124) associated with an adult male in burial 358, and a rectangular pendant (popm36) in burial 1714 (Figure 169). Pendants popm119-124 present remarkably fresh cutting marks indicating that they were made just before were buried. In fact, it was possible to fit all the pendants together, except the last link, suggesting that one part at least is missing. Contrarily, pendant popm36 was heavily used, showing worn surfaces and edges, an indication of a relatively long life. Still, when these seven pendants are compared, they show identical shapes, manufacturing traits and chemical composition. It is very likely then, that popm36 is one of the missing links in popm119-124. This means that once the pendants were cut, one link was separated from the main group; then the group was buried with the male 358 and the remaining link was kept and used for certain amount of time, and finally buried with individual 1714.

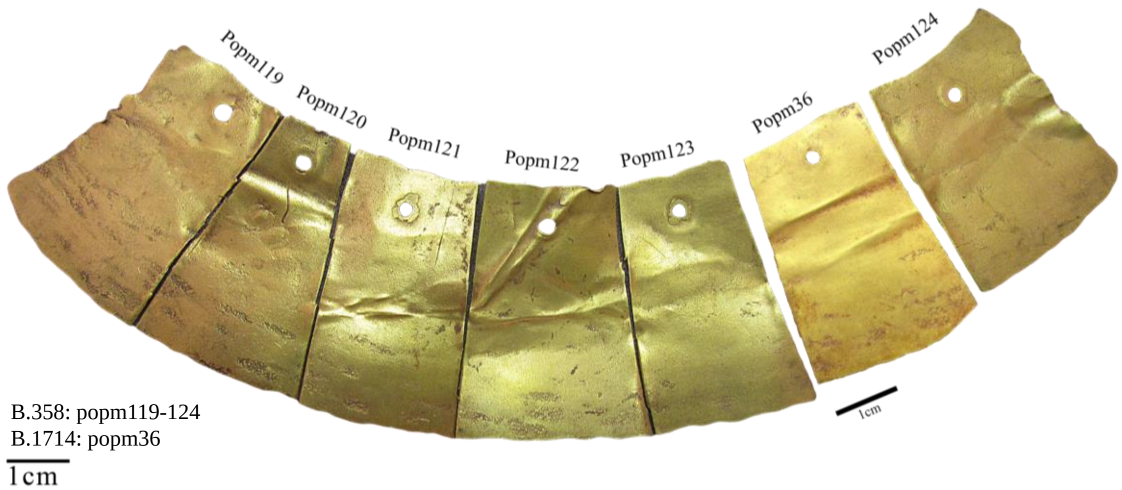


Figure 169: Set from Larache. Note the similitude between the pendants.

The second case is from Casa Parroquial and includes a set of 16 grave goods with identical composition and two styles of manufacturing techniques. I proposed in previous chapters that these items arrived as a group at SPA, and a part of it (one or more items) were locally modified. Thus, the assemblage can be grouped in two: three headdresses as the original objects and 13 newly made pendants and attachments, all deposited in three separate burials (Figure 170). The distribution of these objects is complex: the original objects appear in B.11 and B.16, connecting an adult male and two new-borns, whereas parts of the newly made pendants are distributed in B.16 and B.18, the same new-borns with a different male (see also Figure 111 and 116).

These examples reveal that objects can be made and separated, showing different and complex life-histories telling different stories about their owners. The retention of a part (popm36) in Larache could materialise ongoing relationships between the living and the dead (Brück, 2006), which is very consistent with Andean traditions whereby ancestor worship was (and still is) central (Acosta, 1894 [1590]; Nielsen, 2006b; Platt, 1987). This link could represent a direct connection between male 358 and individual 1714, and also a way of connecting different stages of people's lifecycles (life and death) in the community (Brück, 2006). Moreover, this example provides a relative chronology where B.358 was deposited before B.1714; it warns us that objects may not be recognisable as "modified objects" by us after pronged periods of use. It is likely then, that the actual number of locally modified items was larger than it is identified here.

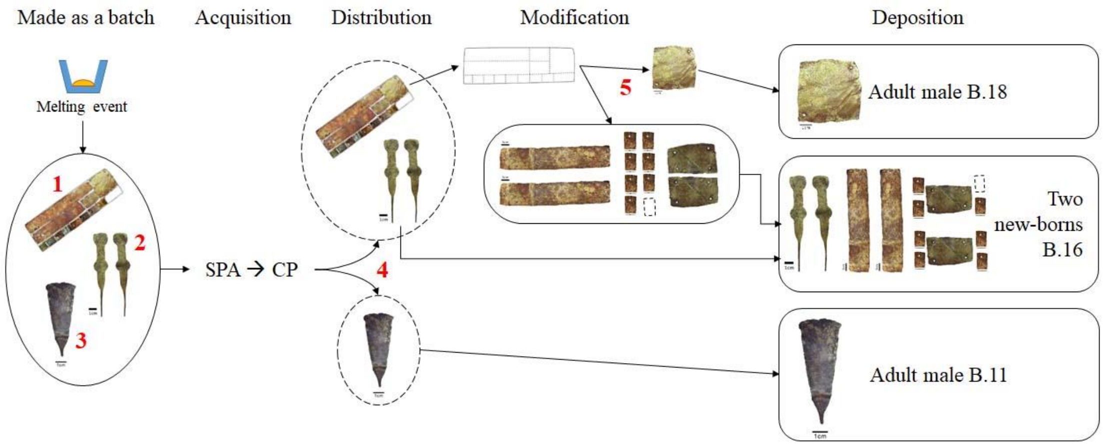


Figure 170: Diagram of 16 grave goods from Casa Parroquial.
1: hypothetical original object, 2-3: original items, 4: possible distribution within the community, 5: distribution of locally modified pendants for the burial.

In Casa Parroquial, at least two different situations can be identified. First, it appears that when the objects arrived in SPA, they were distributed within the community probably to two people (Figure 170:4; I assume that the new-borns were not able to use any of these ornaments in life, consequently they belonged to someone else, probably to a relative). Second, when the items were locally modified, one piece was separated from the rest and deposited in B.18 (Figure 170:5). The fresh marks in pendants and attachments indicates that they were buried shortly after their modification, suggesting some contemporaneity between burials (although the possibility that parts were separated and not used until the burial cannot be ruled out). In this case, the cut parts could materialise in death the links amog three people from the same community: a male and two new-borns; and at the same time, the original objects – as parts of the same production event – may link people from Casa Parroquial to the person, place or community where these objects were made (Chapman & Gaydarska, 2009).

The examples above are evidence of the complex and intricate relationships that this type of study – combining analytical, technological and contextual data – can unveil about ancient people. Future DNA studies in these cases would be fundamental to better understand the dynamics of circulation of these artefacts within the community.

9.2.3.2 Orphan fragments: regional enchained relations

There are 13 gold orphan fragments, for which we do not know where the other parts are (Figure 171). Most of them present fresh cutting marks, suggesting that they were cut shortly before being buried. Based on the examples above, it is clear that parts of gold objects are charged with meaning, revealing links between people beyond death. For orphan fragments, the links are more difficult to identify. One option is that the missing parts are somewhere in SPA, revealing connections inter- or intra-community.

However, if it is considered that these are a) foreign objects, b) that gold was a relatively exotic, symbolic and scarce metal, c) that most items are small and do not suggest necessarily great ostentation, d) but their presence in the mortuary ritual highlights their meaning and significance (Berenguer, 1994), e) that trade routes and the movement of people were very dynamic in this period, and f) similar small objects are reported in burials across the region (Stovel, 2001), such as in Humahuaca; it is reasonable to propose that these fragments could materialise relationships among people from SPA and people from other areas, or alternatively between people from the same SPA community living in different regions (Casassas, 1992; Martínez, 1998; Stovel, 2008).

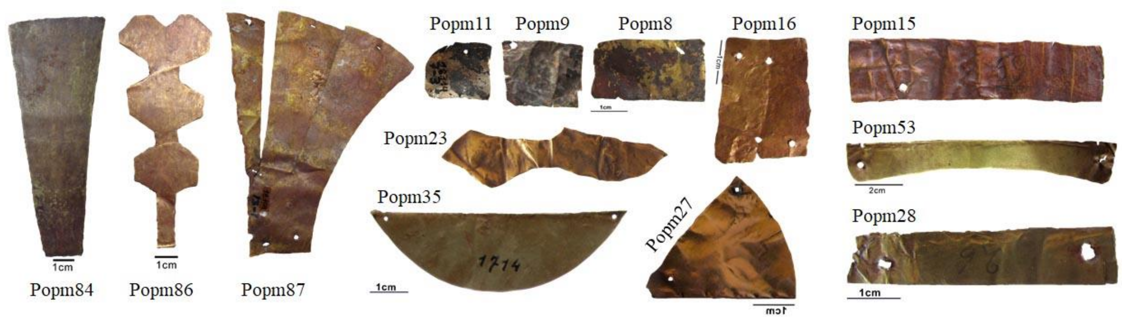


Figure 171: Orphan fragments from SPA burials

Within this context, the use of these artefacts would go beyond mere ostentation; they would serve as identity objects, expressing ongoing connections between the user and other person or community. The fact that the original shape of some objects is still recognisable may be intentional then, in order to make more evident these links (e.g.

headdress popm87). Based on their composition and technology, possible areas of contact are NWA for popm84/86/87 and popm35, whereas popm53 may reveal connections with the Southern *Altiplano* of Lipez (Figure 171). Regarding strontium isotopes, only two individuals with orphan fragments have been analysed so far, both from Casa Parroquial: individual 7 with a SPA signature (popm8-9,11), and individual 22 from the Titicaca Basin (popm84,86).

It is interesting to note that the shapes and cutting techniques in pendants popm27 and popm35 suggest that they were cut in more than one piece (Figure 106), which would mean that the enchainment is probably including several people at the same time, widening the network that these objects may represent. Similarly, Stovel (2001) reports orphan fragments of Tiwanaku and Isla pottery (NWA) that were re-used or repaired and deposited as grave goods in SPA. Against this background, fragmentation would make a key study field in future research, to then match these data with genetics or mobility systems, amongst others.

9.2.4 Summary

In this section, I have discussed how some objects were used, to better understand the role of gold in SPA. First, gold and silver was utilised in highly symbolic items such as *keros*, portrait-vessels and axes, used to display leadership roles. These leadership emblems (made in gold or silver) appear only in Larache and Casa Parroquial associated with males, except for the silver *kero* in Quitor-9. Remarkably, leadership emblems combine Tiwanaku and local categories, i.e., while *keros* and portrait-vessels have Tiwanaku style and are relatively rare in SPA (only 20 references were found), the axes represent a local symbol of leadeship and are relatively abundant in other materials since previous periods (e.g. stone and copper; Cifuentes, 2014; Llagostera, 2004; Salazar et al., 2011, 2014). Yet, the decoration of the gold axes is unique, not seen in other axes.

Second, it is proposed that a series of objects usually characterised as personal ornaments, are in fact objects or ornaments especially made for funerary purposes. These items would reveal a local mortuary ritual that utilised metallic sheets (e.g. headbands, bands, pendants and attachments) to cover the front head, eyes, mouth and chest. Based on the different use-wear seen in the objects, both newly made and worn ornaments were accepted. These features are not described for Tiwanaku (Stovel, 2001), nor NWA burials, although in the latter they used metal and stone masks (Goretti, 2012; Tarragó, 2006).

Third, it is proposed here that the use of parts and fragments of gold artefacts can be interpreted as evidence of enchained relations between the living and the ancestors (e.g. Larache), between people from SPA (e.g. Casa Parroquial), as well as connections with people from other communities far from SPA (e.g. orphan fragments). Gold in this case would be active in materialising social relations and constructing identity. The fragments in these cases, would help to reveal the existence of these links that can be extended to the complete objects as well, as it will discuss in the next section.

Chapter 10. Discussion Part IV: Use and symbolism of precious metals in SPA

The main characteristic that stands out about the consumption of gold and silver in SPA is the differential access to these metals and their distribution among and within the San Pedro communities. This difference has been already noted (Cifuentes, 2014; Cifuentes et al., 2018; Salazar et al., 2014; Tamblay, 2004; Téllez & Murphy, 2007) and it has been interpreted by Salazar and colleagues (2014) as evidence of social differentiation within and between the *ayllus,* expressed in three levels: high-rank leaders with gold and silver in central *ayllus,* low-rank leaders with a few or no gold and silver, but with copper in peripheral *ayllus*; and the rest of the population without metals. Assuming that all precious metals were imported from the central *Altiplano,* authors have considered these metals as "*an explicit material expression of affiliation of these [local] leaders to the Tiwanaku state"* (Salazar et al., 2014, p. 146). This research, however, has generated new information: it has identified gold objects that are coming from other areas, and funerary ornaments especially made for a local mortuary ritual, as well as a series of small, plain and fragmented artefacts, complicating the picture and inviting us to re-think the meaning and use of noble metals in this period. Ultimately, gold and silver would represent local and regional affiliations, not only with the Tiwanaku polity.

In the Andes, gold and silver was used to communicate political, religious and social power (González, 2004a, 2004b; Lechtman, 1993), materialising ideological aspects in symbolic objects (DeMarrais et al., 1996). Still, considering that SPA during the Middle Period is part of a dynamic and wide inter-cultural system where non-local artefacts and raw materials were continuously circulating (see chapter 2:2.3), it seems appropriate to introduce Axel Nielsen's (2006b, 2007) and Emily Stovel's (2008) approaches regarding of the meaning of foreign objects in these corporate Andean societies.

Based on his archaeological and ethno-archaeological research in the *puna*, Nielsen argues that the role of foreign and exotic items in the South Central Andes was varied and it goes beyond their use as "elite" objects. These items actively participated in the construction of gender or social identities (e.g. a herder needs bronze bells for his *llamas*); they were also utilised as corporate emblems of leadership, although not to enhance the person itself, but to highlight the leadership role played for a person at a specific moment (Nielsen, 2007, p. 393). Nielsen emphasises two points to consider when looking at foreign artefacts: a) the low frequency of some goods could reflect rules that restrict their use to specific people or situations, rather than being of limited offer; and b) the value of these artefacts is not necessarily based on their scarcity or rarity, but in their "*ability to signify multi-ethnic and multi-ecological integration*" (my translation; Nielsen, 2007, p. 407), which was vital for the communities of the region. Similarly, Stovel (2008) claims that during the Middle Period, foreign pottery in SPA reflected long-distance social relationships between SPA and people from other areas such as Tiwanaku, Lipez, Chichas, Tarapaca and NWA (Figure 159).

Considering the above, I propose that precious metals in the SPA society represent at the same time multiple meanings that operated at different levels and that were intentionally expressed in the funerary ritual (Berenguer, 1994): they reflected the rank of certain *ayllus* (10.1 and 10.2), they reinforced local identity (10.3), and they also materialised the extent of certain people's social networks (10.4).

To finish this chapter, I present some general thoughts about research on gold and silver from the archaeologist's perspective in section 10.5.

10.1 Gold for the leaders

Gold concentrates in two cemeteries: Larache and Casa Parroquial. The people buried in these sites not only used more gold, but also the objects made of gold are of two types: highly symbolical emblems related to the leaders' political (axes) and ceremonial (goblets) roles, and funerary ornaments of local tradition. Most certainly, this distribution is not random and exposes important aspects of the political structure of SPA during the Middle Period, which is consistent with ethnohistorical sources.

Ethnohistorical records reveal that Andean societies were organised in levels, each one with their own leaders (Martínez, 1998; Platt, 1987). This is, the minor *ayllus* grouped in major *ayllus*, then in "halves" and finally in ethnic groups or confederations (Janusek, 1999; Nielsen, 2006b; Platt, 1987). There was a specific leader at each level: the *jilaqata* for minor *ayllus*, the *malka* for major *ayllus* and the *capac malku* for the ethnic group. They were primarily males, and usually they were assisted by a "second person", in a sort of dual administration (Nielsen, 2006b, p. 126). Interestingly, the leaders at minor *ayllu* levels were selected by taking turns, i.e., power rotated between different families; whereas at major *ayllu* level and higher, leaders were provided by and selected from one or two specific families or "main houses" within that faction (*casas principales*). The rank of these families was directly related to the rank, power and territory of their ancestors, either real or mythical (Nielsen, 2006b; Platt, 1987).

Based on the above, and considering the risks of using ethnographic parallels, it is possible then that people from Larache and Condeduque represent the early expression of this type of organisation, where the minor *ayllus* of SPA joined in a major *ayllu* (Castro et al., 2016; Salazar et al., 2014). In this case, people buried in Larache and Casa Parroquial would represent the main houses from where the leaders (e.g. *malka*) were selected. Considering the importance of the dualism in the Andes, the identification of two potential main houses does not look random either. The dualism is reflected in that indigenous towns, leaders and other aspects in life are usually divided into two parts, organised as counterparts that are opposites but at the same time they complement each other. The most common example of this duality are the attributes of masculinity/sun/gold and femininity/moon/silver, as their opposing pair in the Inka worldview (Korpisaari, 2006, pp. 57, 81). In SPA, the rank of these two communities would be materialised in:

1) The use of gold *keros*, portrait-vessels and axes to express leadership and perform rituals and ceremonies, compared to ceramic and wooden goblets, or stone and copper-based axes used by the leaders of minor *ayllus (e.g. jilaqata)*
2) The extended use of gold by several members of the lineage, including females of different ages and infants
3) The circulation of gold within the community, seen in fragments of a same object distributed in different burials
4) Their central location within SPA, administering the best farmlands at the delta of the San Pedro and Vilama rivers (Castro et al., 2016; Llagostera & Costa-Junqueira, 1999; Salazar et al., 2014)

The higher rank of these two families may be rooted in ancestor worship and kinship (Nielsen, 2006b, 2007). We cannot really know who they worshipped as their ancestors, but there is compelling biological and technological evidence that links them with Tiwanaku or communities under Tiwanaku influence. For instance, biodistance analyses on teeth shows that people from Casa Parroquial and Tiwanaku shared recent common ancestry, compared to people from Coyo who show completely different biological roots (Sutter, 2009). Similarly, strontium isotope analysis detected in Casa Parroquial four people that were born in the central *Altiplano*: two from the Titicaca basin and two from the Poopo basin (Knudson & Torres-Rouff, 2014).

In Larache, strontium isotopes identified four people possibly from the Titicaca basin, one from Cochabamba and one from the Poopo Lake basin[25] (Knudson & Torres-Rouff, 2014; Torres-Rouff et al., 2015). Both Casa Parroquial and Larache were the cemeteries with most isotopic variability, indicating a greater movement of people from different areas compared to Coyo-3, Coyo oriental, Quitor-5 and Tchecar T.S. (Knudson & Torres-Rouff, 2014). The ethnic diversity seen in these *ayllus* is consistent with documentary, which highlight that the *ayllus* and their leaders, in order to ensure and better administer the resources, constantly looked to expand their social and exchange networks (Casassas, 1992; Nielsen, 2006b, 2007; Platt, 1987).

The characteristics of individuals B.356, B.359 and B.358 with the richest burials in Larache are also very suggestive. The Sr isotope signature of male B.358 indicates that this person was born in the Titicaca Basin but his local cranial deformation type would suggest that he was ethnically from SPA. As Martínez (1998) reports, during the colony (1600) it was common that people from Atacama went to live in other regions, where they learnt different tasks. Maybe during his staying in the central *Altiplano*, male 358 was introduced to administrative and ritual roles that gave him authority in SPA, given his association with *keros*, portrait-vessels and axes. Female B.359 on the other hand, with Tiwanaku style gold objects, was born in SPA but had a foreign form of cranial modification typically found in Tiwanaku colonies (e.g. Moquegua), most likely to state her affiliation to Tiwanaku.

In this context, the affiliation with the central *Altiplano* or other Tiwanaku centres (e.g. Cochabamba) were also materialised by using objects of Tiwanaku technological style and iconography such as gold *keros*, portrait-vessels, conic-bells, wire-rings and headdresses (Berenguer, 1998; Berenguer & Dauelsberg, 1989; Tarragó, 1989; Uribe & Agüero, 2001). Yet, Tiwanaku gold objects were combined with gold artefacts from NWA, especially in Casa Parroquial, revealing the complexity and the extent of their networks. Regarding pottery, a few vessels of Tiwanaku, Cochabamba, NWA or southern *Altiplano* styles are present, however they are not exclusive of these sites (Barón, 2004; Le Paige, 1961, 1964; Stovel, 2008; Tarragó, 1989). There is every reason to propose then, that in Larache and Casa Parroquial the connection with the Tiwanaku sphere at biological level, less apparent in other cemeteries, and technologically, is evidence of an extended social network integrated to the *altiplanic* tradition and presumably based on

[25] From the Titicaca Basin B.358, 360, 390, LAR-S/N(10753); from Lake Poopo Basin B.117; from Cochabamba B.221. After Knudson and Torres-Rouff 2014 and Torres-Rouff et al. 2015.

ancestry and kinship, which probably legitimised the rank to these *ayllus* to become the "main houses" from where high levels of leaders were chosen.

In this case, gold was used to show rank, leadership and affiliation with Tiwanaku, showing the importance and great symbolism of this metal to communicate political and religious messages, which is not casual in SPA (DeMarrais et al., 1996; González, 2004a; Lechtman, 1993). The gold offerings in Tulán-54, an important and unique ceremonial site from the Formative Period located at the south of the oasis (some 100km from SPA, Figure 117 and Figure 145:G), are clear evidence that the meaning of gold and its use in highly significant rituals is well rooted in the *San Pedro* culture, dating as early as 3000-2700 BC (Núñez et al., 2017).

Considering the dates, the influence of these *ayllus* would seem to show a diachronic shift: first Larache (250-534 Cal AD) and afterwards Condeduque (777-1017 Cal AD). Indeed, the contact with the Tiwanaku sphere was probably more direct during the Quitor Phase (AD 400-700), based on the gold objects from Larache, with strong Tiwanaku styles; and it changed during the Coyo Phase (AD 700-1000), being mediated by Tiwanaku centres such as Cochabamba, as supported by the presence of people, pottery, textiles and gold items with Cochabamba style, such as *kero* popm140 (see also Knudson & Torres-Rouff, 2014, p. 201; Stovel, 2008; Torres-Rouff, 2002; Uribe & Agüero, 2001). The ritual killing of the *keros* in Casa Parroquial can probably be related to the end of the Coyo phase and Middle Period, with the disappearance of Tiwanaku in the *altiplano* and the disintegration of the long-distance trade routes, in favour of shorter routes (Castro et al., 2016; Nielsen, 2013), producing the rearrangement of the local political system and modifying previous rank structures based on the contact with the *Altiplano*.

10.2 Silver for the miners and artisans

Silver on the other hand shows a different distribution, appearing in Condeduque, Coyo and Quitor. Its presence in Condeduque (Casa Parroquial and Tchilimoya) may be explained by the rank of that *ayllu* and their extended networks, as proposed above. Still, the relative high frequency of silver in Quitor and Coyo (n=47) is not clear and it may reflect something different. If silver had been used by the leaders of the minor *ayllus* in general, I would expect several *ayllus* to have some silver, but this is not the case. Only one ring is found in Yaye-1 and even if the objects potentially made of silver but not confirmed are considered (Figure 172), they would only be two and three artefacts from Sequitor Alambrado and Solor-3, respectively, still maintaining the same general pattern.

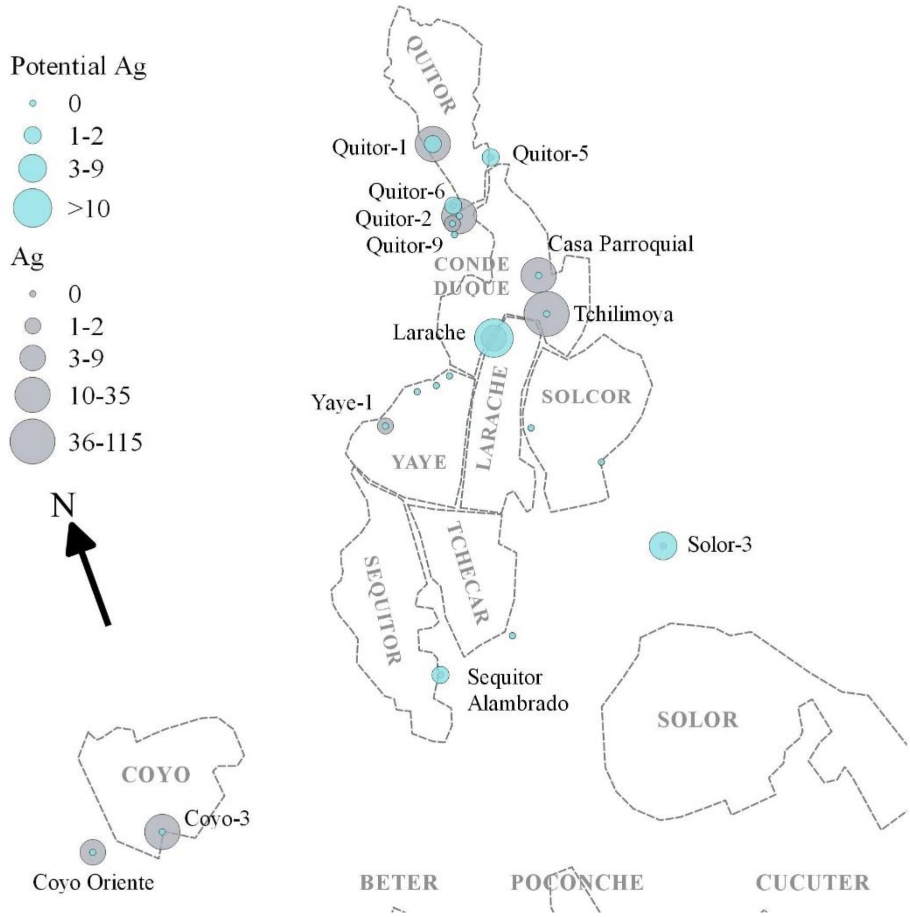


Figure 172: Spatial distribution of silver objects (grey) and potential silver objects or objects described as "white metals" (blue) in the cemeteries of SPA

An alternative explanation is that, compared to the other *ayllus*, Coyo and Quitor maintained close ties with communities from other places were silver was obtained and/or produced, such as Lipez or Uyuni in the Southern *Altiplano* (Casassas, 1992; Lechtman et al., 2010; Stovel, 2008). However, pottery from those areas appear in several cemeteries from SPA, not exclusively in Coyo and Quitor (Costa-Junqueira & Llagostera, 1994; Tarragó, 1989).

A third possible explanation is that the use of silver was reinforcing social identities based on activities or roles (Costin, 1998; Nielsen, 2006b; Salazar et al., 2014). The presence/absence of specific grave goods has shown different economic specialisation at *ayllu* level, making it possible to recognise particular occupations (Knudson & Torres-Rouff, 2014; Salazar et al., 2014; Stovel, 2008), similar to what Spielmann denominates community specialisation (1998). Coyo has been proposed as the *ayllu* of the miners and potential metalworkers, because of the large number of mining stone hammers and copper metallurgical debris (Cifuentes, 2014; Figueroa et al., 2013;

Salazar et al., 2014); whereas Quitor could be identified as the *ayllu* of the artisans, given the high frequency of copper chisels, brushes, bead-making kits and weaving implements (Bravo & Llagostera, 1986; Horta & Faundes, in Press).

Perhaps, the access to silver was somehow restricted or preferred by the *ayllu* of miners and artisans, as recognition of the ability and craft of specific people, which probably gave a special rank or identity to these communities. Another possibility is that people from these *ayllus* were in closer contact with metals, compared to other communities, and using silver was a way to recognise that link. For example, miners from Coyo would have known about silver (and copper) extraction, its minerals and their transforming process and melting; while Quitor artisans are the most likely candidates to have modified gold and silver ornaments that arrived at SPA (See chapter 8). Still, the presence of two *ayllus* concentrating gold and other two concentrating silver, sound very compelling considering the importance of the dualism in the Andes, as mentioned in the previous section (although Larache and Condeduque functioned at different times; Korpisaari, 2006). Nonetheless, this is a proposal that would need further study. Because of time constraints and the lack of detailed information about the quality and characteristics of the grave goods, it was not possible to analyse the contexts of these cemeteries in more detail to explore this thesis. It has to be remembered as well, that the absence of silver in other cemeteries may result from post-depositional effects rather than a restricted or socially ruled use.

10.3 Gold and silver in the mortuary local tradition

One of the main contributions of this study is the identification of a local ritual production, based on adapting imported artefacts for the mortuary ritual (DeMarrais, 2013). Headbands, pendants and attachments placed on the eyes, mouth and chest were spread across 10 cemeteries of SPA, including 27 individuals from the main families, individuals with many silver grave goods from Quitor-1, Quitor-2, Tchilimoya and Coyo-3; and people with a few gold or silver grave goods (group 1 and 2, see previous sections).

The use of gold and silver in these contexts would be deeply significant, because they not only bear the symbolism of the material itself, but also the life-histories behind each item including its origins, its transport, its use (or not) and its physical change in local hands, all potentially adding more meaning and value (Gosden & Marshall, 1999; Helms, 1993; Horta, 2012; Joyce & Gillespie, 2015; Kopytoff, 1986; Spielmann, 1998). Furthermore, their use across SPA would point to a practice that connected the different *ayllus* at major level, most likely reinforcing the local membership of noble metal bearers within the community through the ancestors worship (Nielsen, 2006b, 2007; Platt, 1987).

Larache and Casa Parroquial are interesting cases because in both cemeteries the mortuary ritual would combine foreign artefacts related to Tiwanaku (e.g. *keros*) and local objects such as axes and funerary ornaments. This combination is clearly intentional, and it was probably necessary to validate the role and rank of these families, materialising at the same time their local affiliation and their participation within the Tiwanaku sphere (Berenguer, 1994; DeMarrais et al., 1996; Salazar et al., 2014).

It is possible as well that the mortuary ritual intended to homogenise metal bearers in death, beyond sex and age. For instance, burials B.358, B.356 and B.359 from Larache carried very similar funerary bundles with three headbands and two pectorals; compared to their personal and ritual objects that were differentiating the individuals: B.358 was a male with goblets, axes and headdresses; B.359 was a mature female with two bells and wire-rings, plus bracelets and band-rings; and B.356 was an old female with five bells, four wire-rings, and bracelets. Similarly, plates and bands were used in infants from Casa Parroquial, Larache and Yaye-1.

This practice was also an opportunity for the living to connect with the ancestors. In several regions of the *altiplano*, the bodies of the ancestors were dug up to participate in different ceremonies (Acosta, 1894 [1590]; Cieza de León, 2005 [1553]), but this was not the case in SPA. Most burials excavated were intact or affected by modern actions (e.g. looted), which is consistent with the description of Gerónimo de Bibar, who visited SPA in 1558 and wrote: *"[...] this is their burial and grave, and there they have their great-grandparents, grandparents, parents and all their generation. They are buried with all their clothes, jewels and weapons that, being alive, they possessed, **and no one touches them**"* (my translation and emphasis; Bibar, 1966 [1558], p.14). In this context, to keep a part of the funerary bundle, such as a pendant of B.358 by individual 1714, would be highly significant, representing not only a direct link between the dead and the living community (Brück, 2006; Chapman & Gaydarska, 2009), but also a way for the ancestors to continue participating in the affairs of the livings (Nielsen, 2007, p. 404).

10.4 Gold and silver as social connectors

In this section, I want to turn to a group of simple and plain objects, which are usually not discussed in the literature because of their less spectacular appearance (Figure 171 and 173). Basically, these are about 24 artefacts with compositions and manufacturing techniques that agree with those reported in NWA and Bolivian artefacts, supporting their foreign origins. Most of them appear as solitary ornaments within local funerary sets, presumably acquired in a single occasion; yet their use as grave goods reveals their social significance. Some of them are fragments of ornaments that were intentionally cut into two or more pieces, preserving part of their original shapes (Figure 171). I propose that looking at these fragments we can interpret the use and potential meaning of these modest gold items.

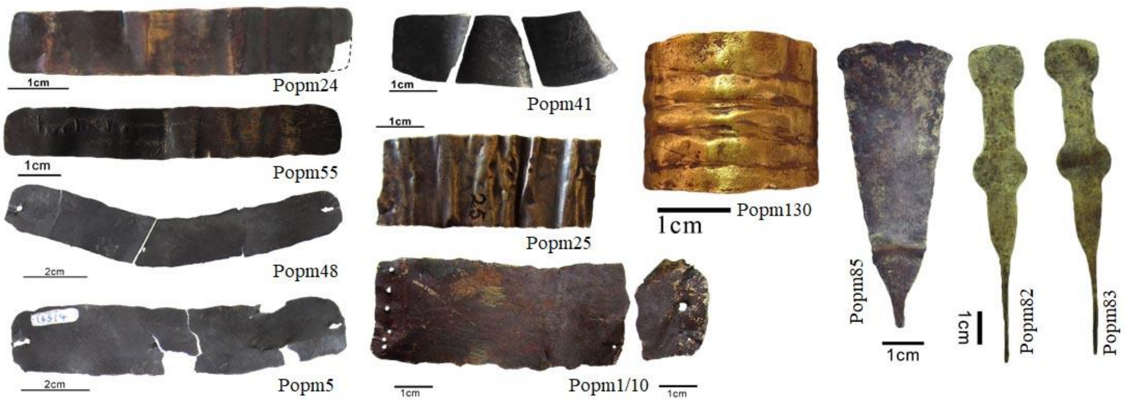


Figure 173: Small and ordinary pendants, attachments, rings and headdresses from SPA cemeteries.

In her insightful study of non-local pottery, Stovel (2008) portrays SPA in the Middle Period as part of a dynamic and integrated cultural system, composed of multiple communities from the *Circumpuna* with tight and long-term relationships. Social networks in this case, have not only economic functions; i.e., "*[...] while goods are exchanged, this exchange* ***serves to solidify social relations****, rather than social ties serving the acquisition of key subsistence goods*" (my emphasis; Stovel, 2008, p. 996). In this context, ceramics styles would operate "*as metaphors for place and family relationships*", and non-local styles present in SPA burials would express these connections (Stovel, 2008, p. 996). Similarly, Nielsen argues that foreign or exotic objects or raw materials in the Andes were the perfect means to represent this multi-ethnic integration (2007). Complementing the above, Chapman and colleagues' consider deliberate fragmentation as a social practice oriented to create and maintain social relationships, while fragments themselves would materialise those links (Brück, 2006; Chapman, 2015; Chapman & Gaydarska, 2009).

Building on the arguments above, I propose these gold fragments are the material evidence of ongoing social links and kinship relationships within and between the SPA society and other communities of the *Circumpuna*, as the "metaphors of place and relationships", proposed by Stovel (2008). Thus, these relatively simple metal objects would also reveal their social significance: building and maintaining social networks as proposed by DeMarrais (2013, p. 349). In this context, it is possible that the act of modification was ritually important, marking a specific moment in the life of two or more people or communities; and at the same time, it represented different stages in the social life of the ornament in question (Sáenz-Samper & Martinón-Torres, 2017).

Given that the contexts of use are the same, a similar role may be extended to the group of small ordinary metallic objects such as pendants, attachments, rings or headdresses that were used as personal or funerary ornaments (Figure 173). I thus suggest that not all gold items should be interpreted as symbols of political or religious power, nor to represent hierarchical relationships, especially if some of these objects are relatively small, plain, and simple in appearance, and are only one artefact within a larger group of grave goods; instead I argue that these objects have a different purpose: they circulated and were used to communicate and represent – both in life and death – their users' social relationships, the extended networks in which they participated.

Based on the composition of some objects, is possible that relationships were established with areas where metals were exploited or produced. Ethnohistorical sources from the Colonial Period (AD 1600-1700) identify a great number of *Atacamas* from SPA in Lipez, an area known for their metallurgical production. In particular, these *Atacamas* were from the *ayllu* of Solcor, which yielded four gold artefacts (two rings, a sheet and a tube). *Atacamas* were also reported in the San Juan River in the puna, Jujuy *("Gobernación de Tucumán")*, and Chichas territory (south Bolivia, "*Corregimiento de Chichas"*), where they accessed to the many gold and silver placers and mines of those regions (Angiorama & Becerra, 2012, 2014; Casassas, 1992; Martínez, 1998; Nielsen, 2013). Based on the Middle Period pottery found in SPA, archaeology also support links with those areas (the puna and Humahuaca in Argentina; Tarija, Lipez, Potosi and Uyuni in Bolivia; Stovel, 2008); as well as SPA pottery has been found in sites of the *puna* such as Tebenquiche and Calahoyo (Castro et al., 2016). Possibly, the relationships materialised linked SPA families participating of similar activities in distant areas, or represent multi-ethnic relationships with locals from those places.

I am not claiming, however, that the ability to represent social networks would be exclusive to this type of ornaments. Similar connections are clearly seen in more spectacular objects, such as those of Tiwanaku style, since is widely accepted that Tiwanaku style artefacts were actively used to represent affiliation with the Tiwanaku sphere (Berenguer, 1998, 2000; Janusek, 2003; Korpisaari, 2006; Korpisaari et al., 2011, 2012; Salazar et al., 2014; Uribe & Agüero, 2001, 2004). In fact, it is possible to propose gold as an element that integrates SPA at regional level, both with the *Circumpuna* and the Central *Altiplano.* However, this approach allow us to include and better understand a series of ordinary objects that are hardly considered in publications, and it would explain – in part at least – their relevance evidenced in their inclusion in the mortuary ritual.

10.5 Studying gold and silver. Etic or emic classification?

A final issue that has emerged during this research is whether the classification used by us as researchers, our etic categories that tend to separate gold and silver (and copper) artefacts as materials, matches the emic categories of the Andean people, i.e., does this dichotomy have an actual meaning for the Andean societies of the SCA in this particular period?

The significance and symbolism related to gold and silver in the Americas, and specifically their dichotomy and association to the sun/moon, male/female, is based mainly on the Inka worldview (Duviols, 1983; Iwasaki, 1984; Lechtman, 1993, 2007). Although it is proposed that the symbolism of noble metals is deeply rooted in the Andes (González, 2003; Lechtman, 2014), authors such as Shimada and colleagues (2000) emphasise that the significance of noble metals may be more complex and it may differ in time and between societies.

In the study of the SPA assemblage and considering the chemical analyses, the gold-silver dichotomy is not clear. The range of compositions shows an almost seamless gradation comprising objects made of very pure gold with 3%Ag to gold with 75%Ag (with very low copper), including pure silver and silver with small amounts of copper (Figure 25-26). In terms of colours, objects varied from golden yellow to greenish yellow and whitish, making difficult to find a specific point in the colour scale that would allow a clear cut perceptive separation of gold from silver objects. Considering that most items in SPA were imported, this distribution suggests that there was no particular preference or selection of objects of specific colours (or compositions). In fact, the distribution, which is more concentrated within the ranges of native gold, would suggest that a) people in SPA acquired whatever was available, and b) artisans producing these items were mainly using native metal; when they produced alloys, silver was added in poorly controlled amounts, perhaps resulting from indiscriminate recycling.

This seamless colour gradation in gold alloys is also present in Sican and Muisca metalwork. In these cases scholars propose that the colour variety was intended. Shimada claims that given the expertise of Sican metallurgists, they were perfectly capable of producing specific and uniform colours, but they still used a varied palette to produce specific types of objects (Shimada et al., 2000; Shimada & Griffin, 2005). Similarly, Uribe and Martinón-Torres (2012) argue that in Colombia, Muisca goldsmiths produced multi-coloured assemblages, gradually adding copper to gold, although in the Muisca case compositions did not match typology. In the SCA, however, there is not enough evidence to propose that artisans were able to produce, or indeed wanted, specific colours within the gold-silver range.

Having said this, an intentional selection may be behind the occurrence of objects with high copper levels - producing reddish colours - which are only rarely present in SPA. However, *tumbagas* (Au-Ag-Cu alloys) are rare in NWA and Bolivia in general, and hence their scarcity in SPA would reveal a regional trend rather than a conscious selection of the *San Pedrinos*. The scarcity of copper-rich noble metal alloys is interesting given the complex copper metallurgy of the period. It is possible then, that the limited use of *tumbagas* may be intentional, in the sense that artisans (from Tiwanaku or NWA) are not mixing copper and noble metals, even if they have both materials available. Although the reason may be dictated by mechanical constraints (e.g. copper-rich objects would be more difficult to hammer), metalworkers did produce hammered ornaments in bronze (e.g. Cifuentes et al., 2018 report a headdress and a bracelet made with a ternary bronze Cu-Ni-As), therefore the know-how existed. Another option is that copper and goldwork were practiced by different craftsmen, as two distinct crafts that served different functional and cultural arenas and derived in separate technological traditions. However, ethnohistorical sources indicate that silversmiths also produced and repaired copper artefacts (Cieza de León, 2005 [1550]; Cobo, 1892 [1653]; de la Vega, 1609 [1560]; de las Casas, 1892 [1553]). Alternatively, the use (or not) of certain alloys may have a more transcendental significance. For instance, in Colombia, Falchetti (2003) argues that alloying gold and copper would have deep meanings, representing the combination of opposites closely related to ideas of fertility and life-cycles. Perhaps in the SCA conceptions were different and did not promote nor prefer the gold-copper combination.

Given the variety of compositions and colours, it was opted in this thesis to classify as "silver", those objects made of pure silver or silver-copper, and the rest were considered "gold" including all gold-silver(-copper) alloys (chapter 5). However, it was not possible to apply the same classification when consumption was studied (chapter 9), because the objects in the reports were already classified. In that case, it was noted that colour and corrosion was utilised to differentiate metals: white-grey metals were described as silver (usually >60%Ag), while yellow metals as gold. Based on that classification, it was observed gold and silver in SPA were used in a similar way. For instance, funerary ornaments were made in all metals: gold, silver and copper. In fact, Le Paige noted in his excavation reports that silver or corroded white-metals replaced gold items in some burials. Beads and headdresses were the only typological categories (out of 15) found exclusively in gold, together with the decorations of wooden items.

However, there are indications that both metals were perceived as different. For instance, gold and silver items were unevenly distributed within SPA (central vs peripheral *ayllus*), revealing differences between both metals (see chapter 9). Other difference emerges when consider their geology and extraction processes; silver ore smelting occurred as early as 40 BC in the Titicaca Basin (Schultze et al., 2009), a complex process compared to the melting of native gold. The different perceptions were also materialised in their language as reported by Petersen (1970): in Quechua and Aymara they had names for gold (*kori/choke*), silver (*collqui/colque*), refined silver (*yuraj kollke*), red-yellow metal (*ante*), red metal (*pucca anta*) or pure copper (*anta*).

The association male/gold and female/silver, is not evident in SPA either. As seen in chapter 9, both females and males were associated to gold, whereas silver was more frequent in males. The main difference is seen when combining sex and age: gold (and metals in general) tend to appear preferentially with mature females (+35yrs) or with young adult males (18-30yrs).

From an analytical perspective, it is noteworthy that most compositional data of gold objects recovered from publications showed silver levels up to 50% (e.g. Figure 118). This distribution most likely represents an arbitrary classification of what is classified as "gold" objects by present researchers, and it may obscure the overall range of alloys produced in antiquity. In fact, during the systematisation of our data, out of 10 objects with silver levels above 60%, eight had been classified in excavation reports as silver items and two as gold, revealing how arbitrary classifications can be.

All things considered, the picture is not clear. As stated by Shimada and colleagues (2000), the dichotomy gold/silver is not straight forward and further research is needed to explain the symbolism of these variety of colours (or compositions) in a particular society, at a specific time. In this case, our traditional split between gold and silver when classifying and storing these items has facilitated the observation of patterns in their distribution, but at the same time it is recognised that such dualistic categorisation may not do justice to the contextual cultural complexity and technological variability of Andean metalwork.

PART V

Conclusions

Chapter 11. Conclusions and future work

11.1 Conclusions

The prehistory of San Pedro de Atacama has been the subject of considerable research, especially during the Middle Period, period when the influence of the Tiwanaku State in the SCA is notable. Systematic investigation has focused on bioarchaeological remains, snuffing implements, textiles, pottery, mineral beads and copper-based metallurgy. This evidence has been key in clarifying the autonomy of SPA and the relatively indirect nature of its relationship with Tiwanaku and other communities of the SCA. However, before this doctoral research, gold and silver remained only poorly studied, assumed to be a Tiwanaku technology, and taken as a proxy to identify an emerging elite within SPA (Salazar et al., 2014; Tamblay, 2004).

The primary aims of this thesis were to provide the first technological characterisation of the gold objects deposited in SPA (and, as far as possible, silver objects), during the Middle Period AD 400-1000; as well as to explore how these objects were used and consumed. As a backbone, I reconstructed their *chaînes opératoires*, considering in particular their production, life-history and consumption patterns, which revealed significant information regarding human behaviour and social relationships, both at local (SPA) and regional level (SCA).

The research was organised in four main parts: the first three related to the production of the items, and the fourth focused on their consumption and use.

11.1.1 About production

Elemental data obtained by pXRF, SEM-EDS and PIXE identified a wide range of gold-silver alloys, including element concentrations consistent with unalloyed native gold, artificial gold-silver alloys with addition of silver, and gold-copper alloys. The lack of gold deposits near SPA, and the comparison with published geological data from the SCA, support the proposition that raw materials were most likely obtained from placer deposits concentrated in two areas: the Argentinean *puna* and the mountain-range adjacent to the Titicaca Basin. Still, the large amount of primary gold deposits located east and west of SPA could also be potential sources of this metal. Furthermore, the chemical analyses revealed different alloy practices, including melting unalloyed gold, alloying gold-silver or gold-copper; examination of the results also exposed various "chemical clusters", as potential evidence of individual production events.

Micro- and macroscopic analyses were applied to reconstruct the manufacturing techniques employed in the creation of these artefacts, resulting in a rich corpus of data that should remain as a reference for future work. Based on the quality of the techniques identified, objects were broadly grouped in finely-made and coarsely-made items. Additionally, it was possible to identify objects with relatively long life-histories of intensive use and later modifications or repairs; these stood in contrast with other objects with fresh manufacture evidence. Specific attributes of execution were recognised, identifying sets of artefacts made by individual craftsmen. Manufacturing information was compared and matched with the chemical clusters and this allowed the identification of several batches or sets of objects made and acquired together. Altogether, this evidence highlights the diversity of materials and technical practices documented in SPA, revealing the work of multiple producers with different specialisation and skill levels. I proposed that the assemblage was primarily composed of artefacts imported to SPA as finished objects.

The comparison of the elemental and technological information with that of objects from Peru, Bolivia, NWA and northern Chile, made it possible to propose the potential origins of SPA objects. The integration of published and new data led to the identification a series of technological markers that were combined with morphological and stylistic information to enable a systematic comparison. Overall, two principal groups were detected in the SPA collection: objects made following a Tiwanaku technological tradition (25% of the assemblage), including items probably made in the Titicaca Basin and Cochabamba Valley; objects made following a NWA tradition (27%), probably from Humahuaca; and an item probably from the southern *Altiplano* (1%). The remaining 47% included objects proposed as a local production (16%, see below) and undiagnostic items (31%).

Five key discussion points emerged from the data.

Firstly, it was possible to characterise for the first time the SPA assemblage as a heterogeneous group with multiple compositions, manufacturing techniques, shapes and designs. Based on comparative data, it was established that most part of the objects (at least 53%) were imported as finished items from areas such as the Titicaca Basin, Cochabamba Valley and NWA. These findings agree in part with previous assumptions that objects from SPA were non-local; however, traditional research only contemplated possible Tiwanaku origins, whereas this thesis demonstrates that the circulation of gold during the MP support interactions between SPA and other areas of the *Circumpuna*, such as NWA and the southern *Altiplano* and not only with the Tiwanaku State, revealing that noble metals were part of much more complex material and cultural networks.

Secondly, of great relevance was the identification of local metalwork, manifest in two key strands of evidence: a) objects that were locally made and would have required the involvement of local specialists (16%); and b) imported objects that were modified locally (19%). For the latter group, given the relative simplicity of the techniques employed (cutting and perforating), this type of metalwork would not necessarily require nor support the work of specialist metalworkers. Hence, the possibility was raised that non-specialist metal craftsmen simply re-used imported items when needed, regarding the quality of the items (e.g. high and low quality) or their possible origins (e.g. Tiwanaku or NWA).

Thirdly, it was possible to recognise that the local production and modification activities were largely oriented to the production of funerary objects aiming to express local membership during the mortuary ritual. The identification of these *funerary ornaments* as a distinct category improves the current classification of metal items, and points to the reasons why objects were produced in SPA in the first place. The association between a local metalwork and the mortuary ritual is highly significant, as it indicates that the ritual use of noble metals in SPA was of enough significance to stimulate the local production of metalwork by both specialists and non-specialists.

Fourthly, this research provided useful information regarding the organisation of goldwork production in the broader region, by outlining at least two possible ways in which metalworkers were organised in the SCA. On the one hand, Tiwanaku style objects display traits that are consistent with the models of embedded or attached production identified in Tiwanaku urban centres (Costin, 1991; Janusek, 1999). On the other hand, the technological features of the items made in NWA and SPA are consistent with the work of independent specialists, working alone or in small groups at a household level. These proposals are preliminary but consistent with the data available, and it is hoped that they will guide future research on the topic.

And fifthly, in terms of the circulation of these objects, the results obtained here indicated that gold was circulating in the same spheres as other materials of the period such as bronze, textiles, and pottery and snuffing implements. At the same time, its internal variety and diversity could at least in part reflect the different ways in which objects circulated in the Andes, including items moved by specialised caravans, people travelling with their own objects, items exchanged in seasonal gathering or meetings, or objects that travelled long distances by changing hands several times.

11.1.2 About consumption

The last part of this thesis focused on *by whom* and *how* noble metals were consumed in SPA. To assess who was using gold and silver, published data was collected systematically, and trends were explored. In general, it was observed that gold and silver were preferentially consumed in certain cemeteries of the period, and associated to a few individuals only. The spatial distribution showed that most individuals buried with gold belong to the central *ayllus* of Larache and Condeduqe; whereas silver was more frequent in peripheral *ayllus* of Coyo and Quitor. Chronologically, cemeteries with more gold items were dated within the Quitor phase (AD 400-700), while cemeteries with more silver items are dated within the Coyo phase (AD 700-1000). The individual profile of the noble metal bearers was explored, based on characteristics such sex, age, type of burial, cranial modification, strontium isotopes and amount of grave goods. Although it was observed that the distribution favoured young adult males and to a lesser extent mature females and infants, the most notable differences were those noted at the cemetery level: people with preferential access to gold are from Larache or Condeduque, whereas individuals with most silver are from Coyo, Quitor or Condeduque, irrespective of their personal characteristics.

Regarding how gold and silver were used, it was observed that most noble metal items of recognisable typology or style were highly symbolic, including ceremonial objects such as *keros*, portrait-vessels and snuffing implements; leadership emblems such as axes, and funerary ornaments. It was noted that these symbolic items combined both Tiwanaku style objects (goblets and snuffing implements), and local categories (axes and funerary ornaments). Somewhat less spectacular but revealed as equally important and informative were the fragments of artefacts, which were interpreted as mechanisms used to materialise social relations and construct identities, in line with other studies of fragmentation in archaeology (Chapman & Gaydarska, 2009).

Bringing all this information together, it was concluded that noble metals, gold in particular, embodied multiple levels of meaning: they were used in some cases to a) express and legitimise the rank of particular *ayllus*, but also b) they were employed by “common” people to materialise long-distance social relationships.

Regarding the first dimension of gold use, considering the spatial distribution of gold and silver, and the difficulty of controlling traffic and the circulation of these objects (Nielsen, 2013), it was argued that the patterns in the spatial distribution of noble metals in SPA would reflect a culturally regulated consumption of noble metals (Nielsen, 2007), based on the *ayllus* rank, roles or community specialisation. According to this proposition, Larache and Casa Parroquial (with more gold), would represent early examples of the main houses or families recognised in ethnohistorical documents (Nielsen, 2006b; Platt, 1987), from where leaders were chosen to administer the *ayllus* at a major level.

Before this research, it was thought that people from these communities used gold items to demonstrate affiliation with the Tiwanaku sphere, and in so doing legitimising their administrative role (Salazar et al., 2014; Tamblay, 2004). However, this investigation has demonstrated that the use of gold entailed wider social and political networks, not only with Tiwanaku, but also with polities from NWA or Cochabamba. Moreover, it also revealed that gold was used and adapted when necessary to represent local membership through the funerary ornaments and axes. All in all, gold in SPA was used idyosincratically to express multiple levels of affiliation that were displayed in the mortuary ritual, and which were presumably necessary to legitimise the rank of those communities.

In the case of Coyo and Quitor, on the other hand, the use of silver was probably related to their specialisation as communities (miners/metallurgists and artisans, respectively). It is likely that these activities provided certain rank or particular roles within SPA that were recognised in funerary rituals that involved burials with silver items.

As regards the second dimension of gold use, given the presence of individuals buried with just one or two relatively simple and small gold items, often including pieces that were deliberate fragmented, is was proposed that gold not always was used to express rank or hierarchical relationships. It was argued that these kinds of artefacts circulated and were used to communicate and represent – both in life and death – their users' social relationships, the extended networks in which they participated. Their use could therefore have been significant on a more personal of level, as a material memory of relationships established with people or communities, presumably from areas where these metals were exploited or produced.

11.2 Methodological contributions

From an archaeometallurgical perspective, this thesis constitutes the first systematic study of precious metalworking technology in SPA, but its approach and methodological protocols will hopefully be of use for further studies in the region and elsewhere. While the informative potential of applying archaeometric techniques to metalwork is well-known, the work presented here may be notable in that it avoided skewing the research focus – and hence the archaeological narrative – to the more spectacular and recognisable objects. In particular, I stress the promising results obtained by applying a rigorous technological perspective to study a group of seemingly plain and straightforward objects that did not appear stylistically or typologically rich, and would in most cases be dismissed as "small pendants". The combination of elemental, microscopic and macroscopic analyses, focused not only on reconstructing their production, but also their life-histories and consumption patterns, provided a wealth of information that could never be obtained using traditional methods alone. We now have information about value systems, ritual behaviour and social relationships within SPA people, and between them and other communities, that would have remained unknown.

A key factor in the success of this approach was the combination of different analytical techniques, establishing protocols to study the composition and technology of these objects. The pXRFs used were calibrated specifically for the study of the major elements of these objects, and the data obtained was crossed-checked with PIXE and SEM-EDS analyses. PIXE was used to explore major, minor and trace elements, even though it is acknowledged that trace element analyses could benefit from further confirmation because - and due to time constraints -, analytical conditions were not ideal. SEM-EDS was useful to observe the artefacts in cross-section and obtain additional information about crystallography and the presence and distribution of impurities, as well as copper and silver behaviour. In particular, SEM provided valuable information regarding corrosion and surface phenomena that may inform debates about the extent to which surface depletion may result from intentional treatment or post-depositional weathering. Owing to space and time constraints, these results were not fully presented in this thesis, but they will be treated in a future publication.

A careful characterisation of the objects from SPA, and the systematisation of published and original data from neighbouring areas has made it possible to characterise technological traditions for the goldwork of Tiwanaku, NWA and SPA, in a way that they will serve as a basis and reference for future work. Additionally, an in line with recent work in archaeological materials science, the resolution of the data recovered has made it possible to identify the work of individual artisans and also the recognition of different craftsmen working in parallel. Macroscopic analyses in this case were fundamental in detecting technological attributes that were then matched with compositional and contextual data. Researchers are encouraged to record and publish technological and use-wear details to facilitate comparisons between regions, in order to identify practices such as modification or deliberate fragmentation. The use of a relatively basic digital microscope was of great help in this process.

The study of deliberate fragmentation and local modifications has appeared as novel and key subject to consider in future research. As proposed for other material categories elsewhere, deliberate fragmentation of metalwork may be more common than expected and it would allow us to explore further links between people from the same cemeteries, or – if we are fortunate – with other communities; to extract social information from remains that are not usually considered, and to explore the significance of materials in different contexts. It is noteworthy that the recent discovery of a Inka shrine in central Peru with various gold sheets that were deliberated cut, perforated and deposited, together with complete and fragmented copper mineral beads (Lau, 2018), indicates that using fragments and deliberate fragmentation may be a Andean phenomenon that would deserve some thought.

11.3 Future work

The investigation of the gold and silver objects from SPA has provided crucial information to understand their production, consumption and circulation during the Middle Period, as well as their use and value in context. Still, this work is a first step and there are many topics that could and should be further investigated.

A key item in the agenda for future research on gold technology in the SCA is to increase the sample of analysed objects outside SPA, including elemental and technological analyses to define and refine the technological traditions proposed in this thesis (especially for Bolivian material). Composition is fundamental to explore raw materials, alloys practices and identify patterns that can relate – to some extent – to geological sources or areas. Using trace elements to confirm potential batches and clarify connections between assemblages would be ideal. It is important that these analyses cover small items and record manufacture techniques, to explore matters such as modifications, fragmentation, and skill. Overall, it is stimulating that this apparently simple sheet-metal technology observed in detail and compared within a wider context, can provide valuable social information.

Interestingly, a series of technological connections were recognised in this work, linking particular individuals in the cemeteries. Genetic studies would be extremely illuminating in exploring the ties between these people. Suggested candidates would be burials B.356, 358, 359, 1714, Body-1, Body-2 from Larache; or B.11, 16, 18 from Casa Parroquial. Identifying family ties between these people would provide a better understanding of how gold circulated within SPA communities.

A subject that was only partially covered in this thesis is the study of the grave goods associated with noble metal bearers, as well as the comparison between the type, amount and quality of the grave goods between individuals with and without precious metals. Comparing the characteristics of the grave goods can provide a better profile of the social identities of people, improve interpretation regarding social differences within SPA and test the proposal put forward here that gold and silver were not synonyms of a higher social rank.

More research needs to be focused on silver technology. Although silver was considered in this thesis, it was secondary compared to gold. Silver items from the MP were highly corroded but, unlike gold, silver continues to be used after AD 1000, and later objects are often recovered in better condition. A study of silver technology should focus on a diachronic perspective, including both production and consumption aspects.

Lastly, additional subjects derived from this work that were only outlined and could be explored in future research are the characterisation of the white-corroded metals which raise the possibility that tin or lead was also circulating as bars or finished objects; the study of possible technical ceramics from Coyo; the often cited dichotomy and correlation between gold/silver and female/male, which is not evident in SPA; or the role and status of mature females in Andean societies, considering that they gathered most gold grave goods.

Overall, it is hoped that this work has succeeded in addressing the aims posed at the beginning, answering some questions and raising many others, thus providing a justification and foundation for additional research in some of the directions outlined here.

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Appendix nº1. Glossary

- *Alpaca*: or *vicugna pacos*, is a domesticated South American camelid used in the Andes as meat and fine quality wool. The alpacas are smaller than the llamas in size.
- *Altiplano (Figure 1)*: Name of the high plateau (>3,500 m.a.s.l.) in the core of the South Central Andes that belongs to modern Bolivia (Nielsen, 2013).

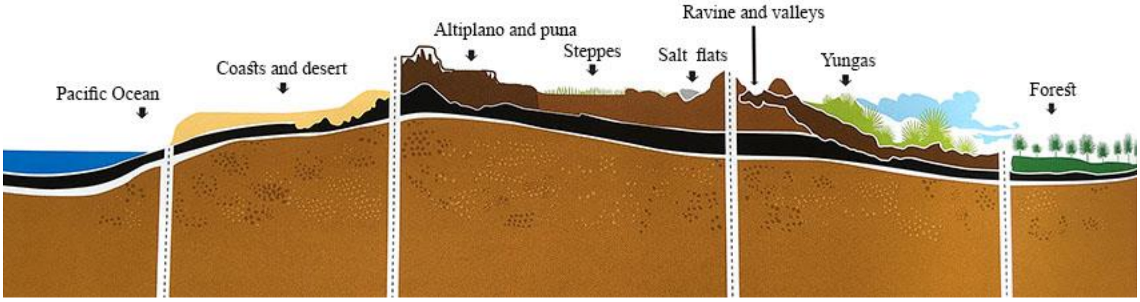


Figure 1: Cross section of the South Central Andes. Note the different geographic areas (modified from Goretti, 2012, p.48).

- *Ayllu (Figure 2)*: It is the basic level of social structure in the Andes. It refers to a corporate group composed of kin, descendants of a real or mythical common ancestor. They grouped in different levels, from micro-*ayllus* (extended family) to macro-*ayllus* (ethic group). Each level had their own leaders and organisation (Janusek, 1999; Nielsen, 2006).

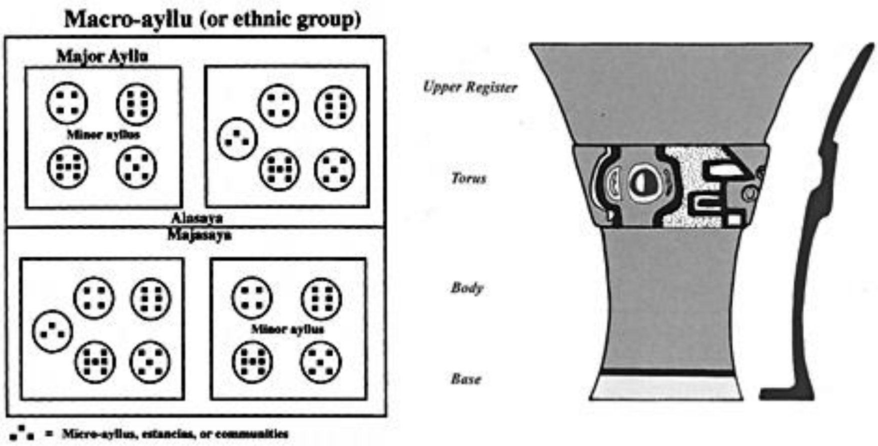


Figure 2: Left: Schematic model of Andean ayllu *organisation by Janusek, 1999, fig.2. Right: Classic Tiwanaku* kero *and its parts, after Janusek, 2003, fig.3.38.*

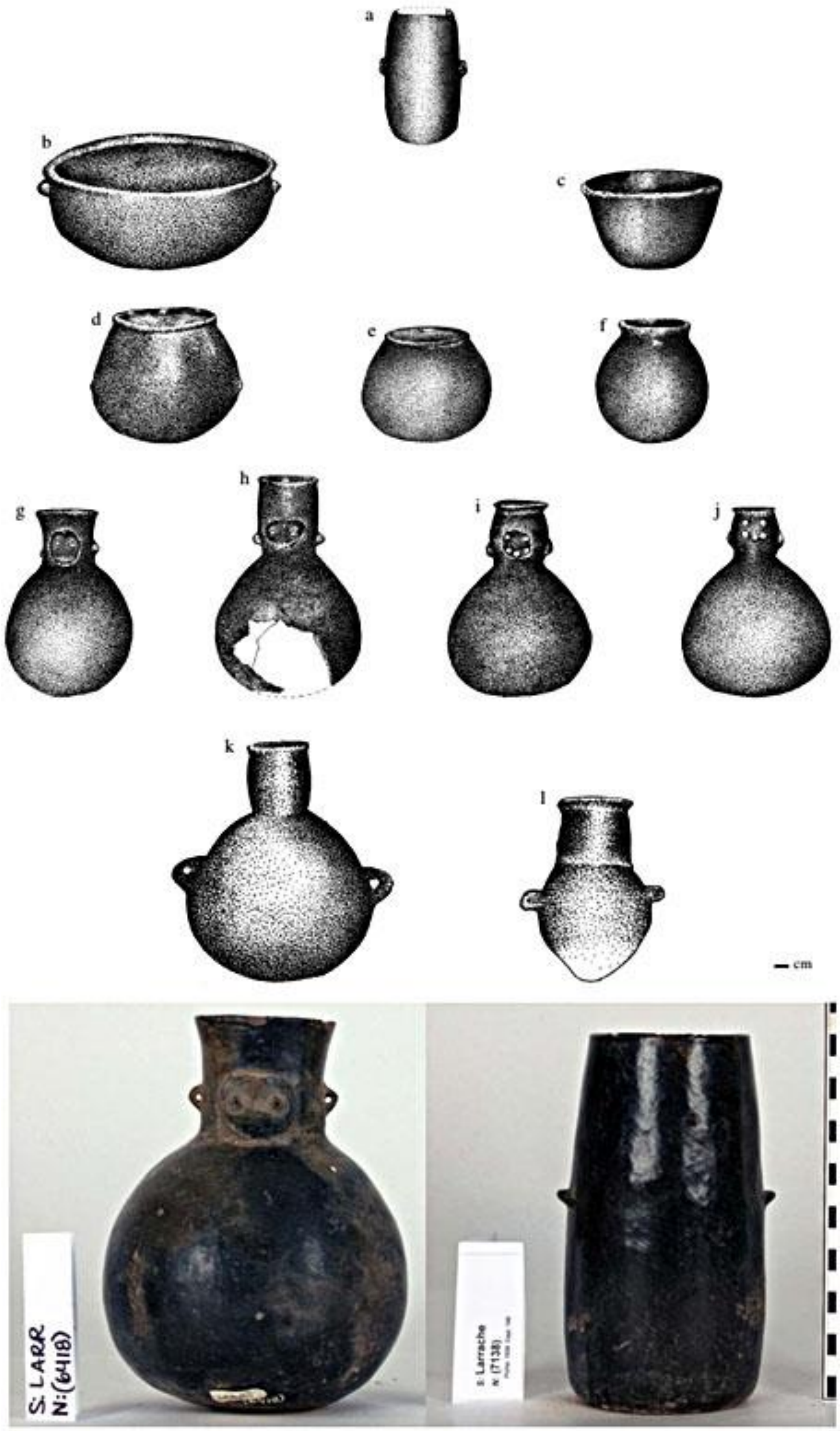
- *Chicha*: Alcoholic drink made of fermented maize or quinoa. It was a very important ritual drink, used in ceremonies and drunk special cups called *keros*.
- *Condor*: or *vultur gryphus*, is the largest flying bird in the South American Andes. It is a bird of prey, a scavenger. It was highly spiritual symbol in the Andean worldvision.
- *Kero (singular), keros (plural; Figure 2):* The *keros* represent the paradigmatic Tiwanaku drinking goblet that was used to serve and consume fermented drinks such as *chicha* and *ch'ua*. *Keros* are among the most distinctive emblems of Tiwanaku style, characterized by an elegant hyperboloid form, flaring rims, and elaborate iconography. They were produced and used on a major scale throughout the Tiwanaku period (Janusek, 2003, p.60).
- *Llama*: or *lama glama*, is a domesticated South American camelid used in the Andes as meat, wool and pack animal.
- *Parina*: It is a brid from the flamenco family (*phoenicoparrus*), typical of the South Central Andes, found in the lakes of the *Altiplano* and *puna*.

- *Puna (Figure 1)*: Name of the high plateau (>3,500 m.a.s.l.) in the core of the South Central Andes that belongs to modern Argentina and Chile (Nielsen, 2013).
- *Tawantinsuyu*: or the “Land of the four *suyus* or quarters”. Territory of South America conquest by the Inkas, between *ca.*1400-1530.
- *Tembetá*: Lip ornament made of stones or metals. It perforates the lower or upper lip.
- *Torus (singular), tori (plural; Figure 2)*: Protuberant band decorating the *keros*. It divided the vessel in an upper register (top) and the body (bottom).
- *Tumbaga*: Ternary alloy composed of gold-silver-copper.
- *Yungas (Figure 1)*: The *yungas* region, located at the eastern flank of the central Andes, is a mountain rainforest ecosystem between 400-3000 m.a.s.l. Several products were obtained from this area in prehistory, such as coloured feathers, psychotropic substances, wood and dyes.

Appendix nº2. Images

Appendix Nº2: 1: Early gold evidence in the Andes. Top- Bead from Jiskairumoko (after Aldenderfer et al. 2008, fig.4-5); Middle- Hammering toolkit and gold sheets from Waywaka (after Grossman 2013, fig.3-4); Bottom- Gold and copper foils from Mina Perdida (after Burger and Gordon 1998, fig.2-3).

Appendix Nº2: 2: Images of San Pedro de Atacama. Note the contrast between the oasis, near San Pedro River and the desert surroundings.



Appendix Nº2: 3: Examples of Negro Pulido (burnish black) pottery from SPA. After Uribe et al., 2016, fig 3; Torres-Rouff et al., 2015, fig.3. Note that these examples are from the Middle Period.

Appendix Nº2: 4: Ceramic pipes from the Formative Period, ayllu Sequitor. After Gili et al., 2017, fig.2.2.

Appendix Nº2: 5: Photography of the Museo of San Pedro de Atacama in its beginnings, image probably ca. 1961. Note the bodies, their disposition and textiles around them. Today, it is illegal in Chile to publically exhibit human bodies. Image after Pavez 2012, fig.13.

Appendix Nº2: 6: Examples of mineral beads from Larache (rescate). Image courtesy of Ana María Barón 2016.

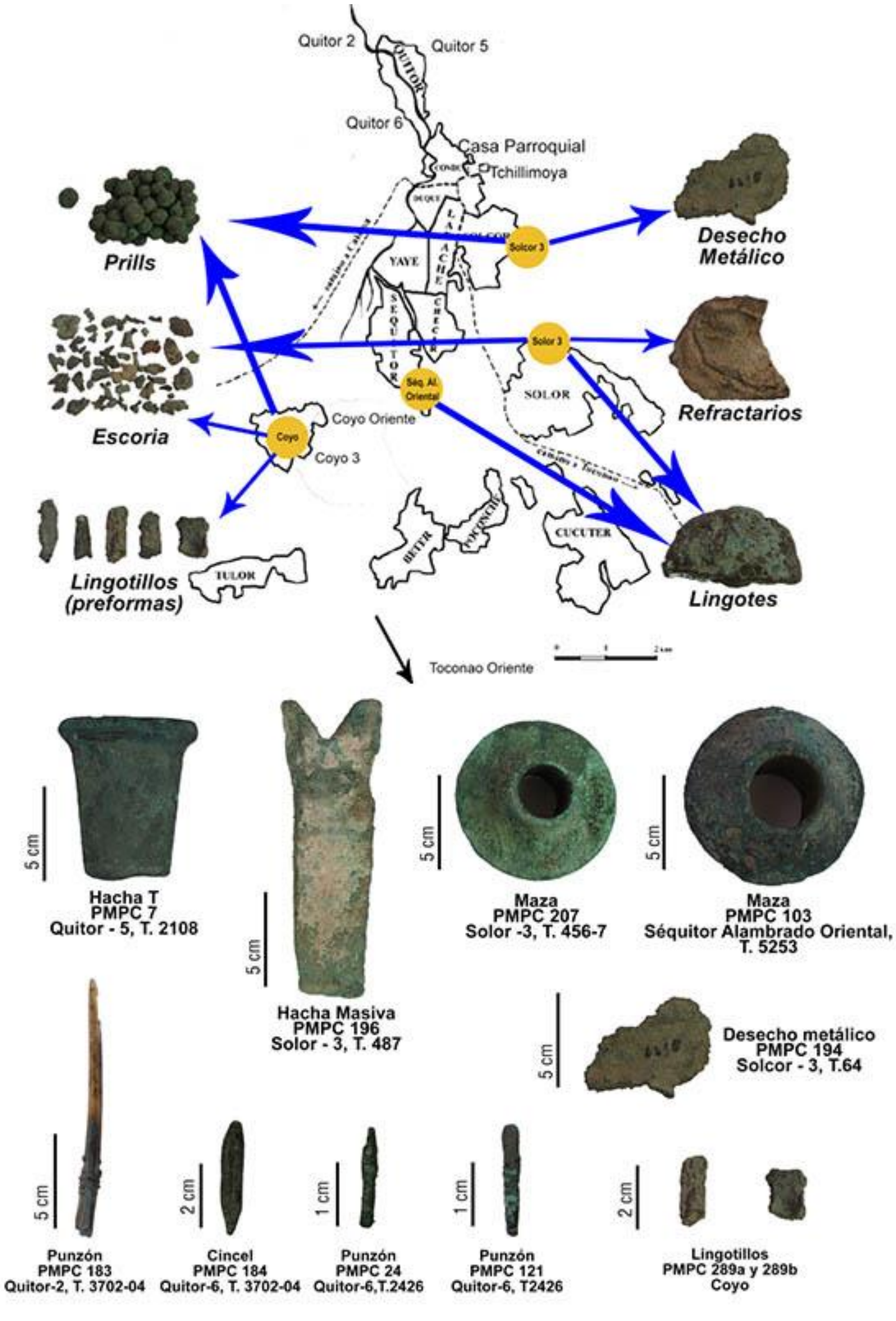
Appendix Nº2: 7: San Pedro style snuffing trays, after Horta, 2014, fig3-4a.

Appendix Nº2: 8: Copper mineral beads toolkits in Quitor-6. Top: copper mineral, preforms and finished beads in burial 2511. Bottom: wooden mould in burial 2670. After Horta and Faundes, In Press, fig.13-14

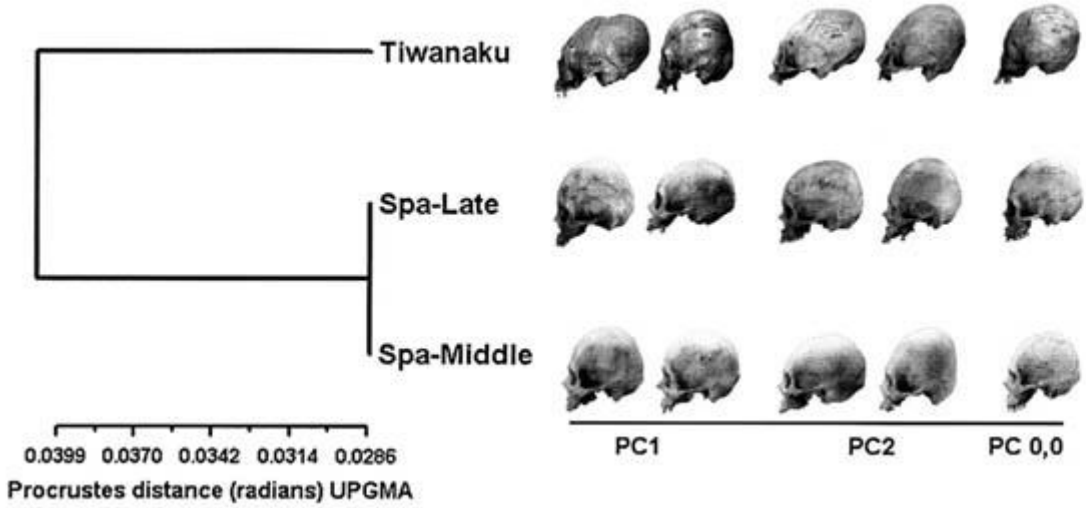
Appendix Nº2: 9: Examples of local textiles (tunics) from SPA, Coyo-oriente cemetery burials 5382 and 4060. After Niemeyer and Agüero 2015, supplementary data.

Appendix Nº2: 10: Examples of local hats. After Berenguer 2006, fig.9

Appendix Nº2: 11: Baskets. After Aldunate and Gallardo, 2017, p.35



Appendix Nº2: 12: Evidence of copper metallurgy in San Pedro (top) and objects made of unalloyed copper (bottom), thought to be locally made. After Cifuentes et al., 2018, fig.5-6.



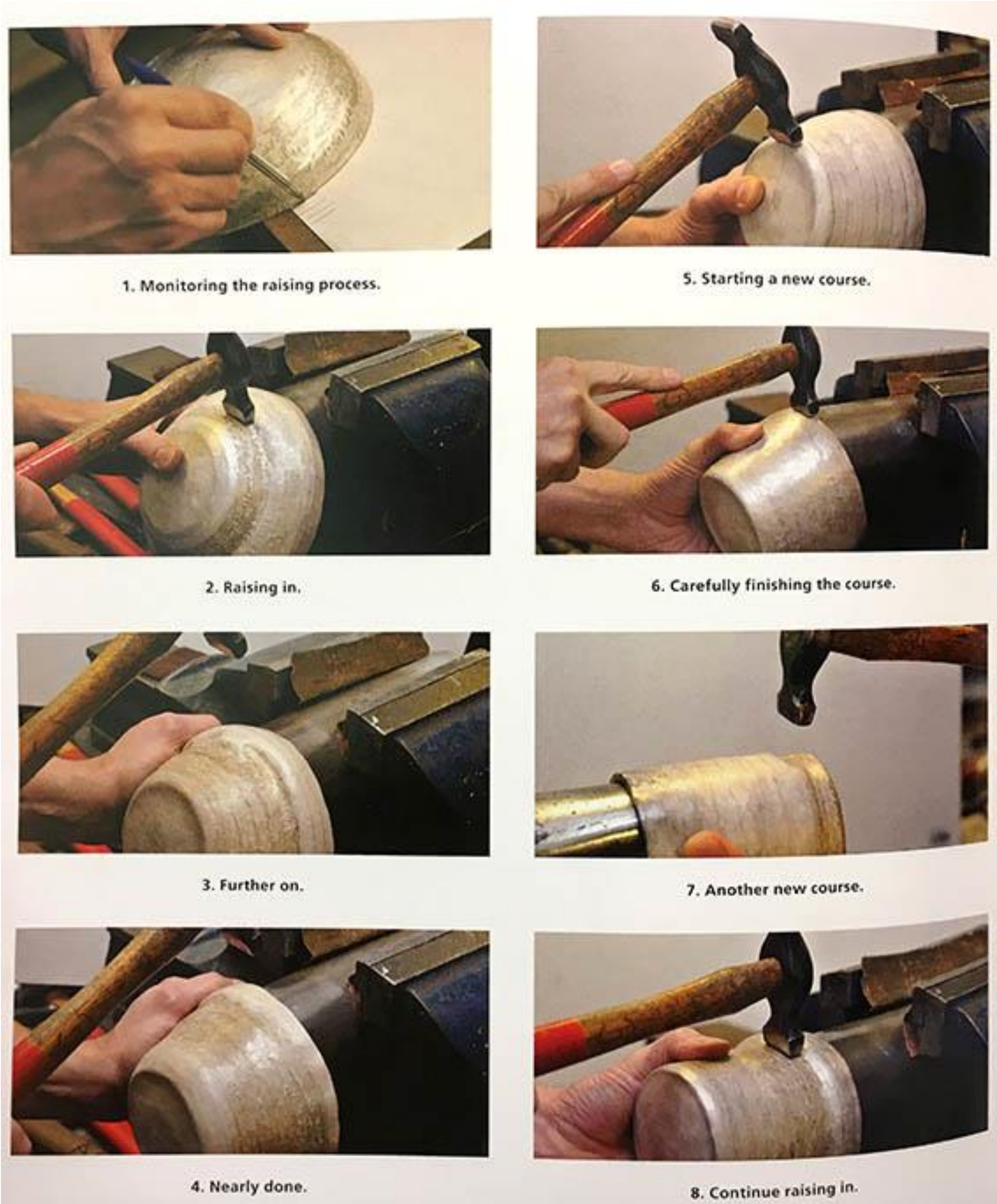
Appendix Nº2: 13: Different types of cranial vault modification from Tiwanaku (top), SPA during the Late Period (middle) and SPA during the Middle Period (bottom). The local style is called 'tabular erect'. After Salazar et al., 2014, fig.4.

Appendix Nº2: 14: The "copper man", miner from the Middle Period found in Chuquicamata. After Bird, 1979, fig.3.

Appendix Nº2: 15: Tiwanaku style snuffing tray, bone boxes, pottery and wooden portrait-vessel found in SPA. After Berenguer, 2000, p.81,82,91.

Appendix Nº2: 16: Tiwanaku style tunic, found in SPA. After Berenguer, 2000, p.90.

Appendix Nº2: 17: Raising. Example of a modern sequence to raise a cup. The final shape is similar to portrait-vessel popm141. Note the several cycles of hammering and annealing needed to close the shape (After Hill & Putland, 2014, pp.62-63).



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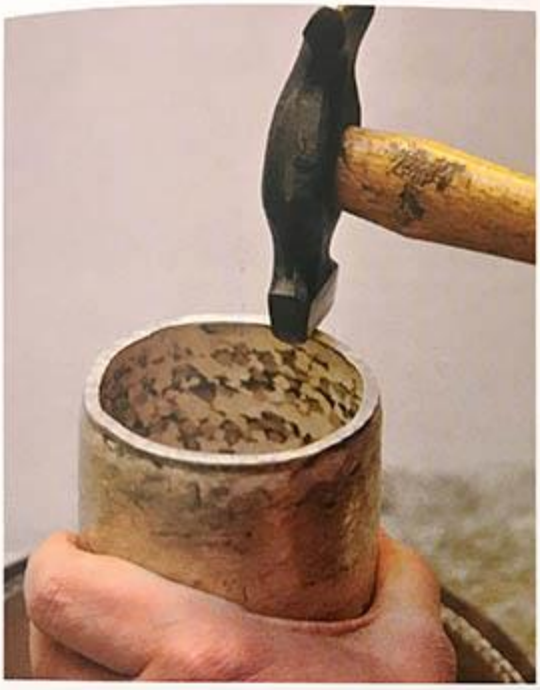


9. Concluding the caulking.

10. Checking for trueness.

11. Blocking out the base to give a more rounded form.

12. Annealing.

13. Raising in.

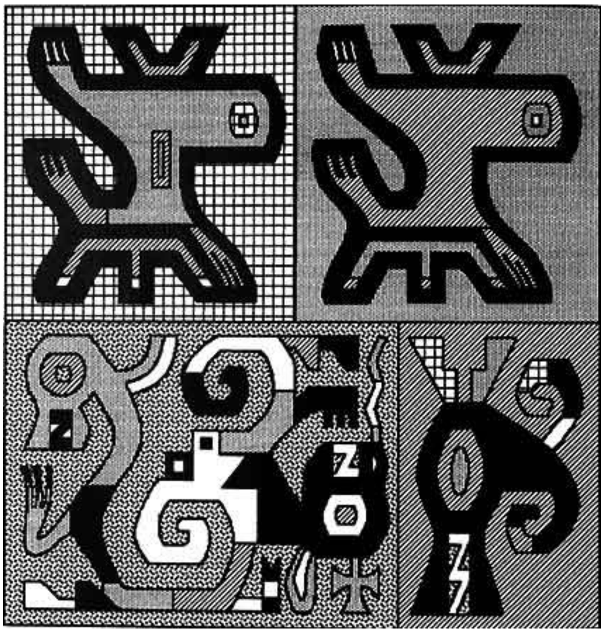
14. Back raising.

Appendix Nº2: 18: Finely-made items from SPA.

Appendix Nº2: 19: Coarsely-made items from SPA.

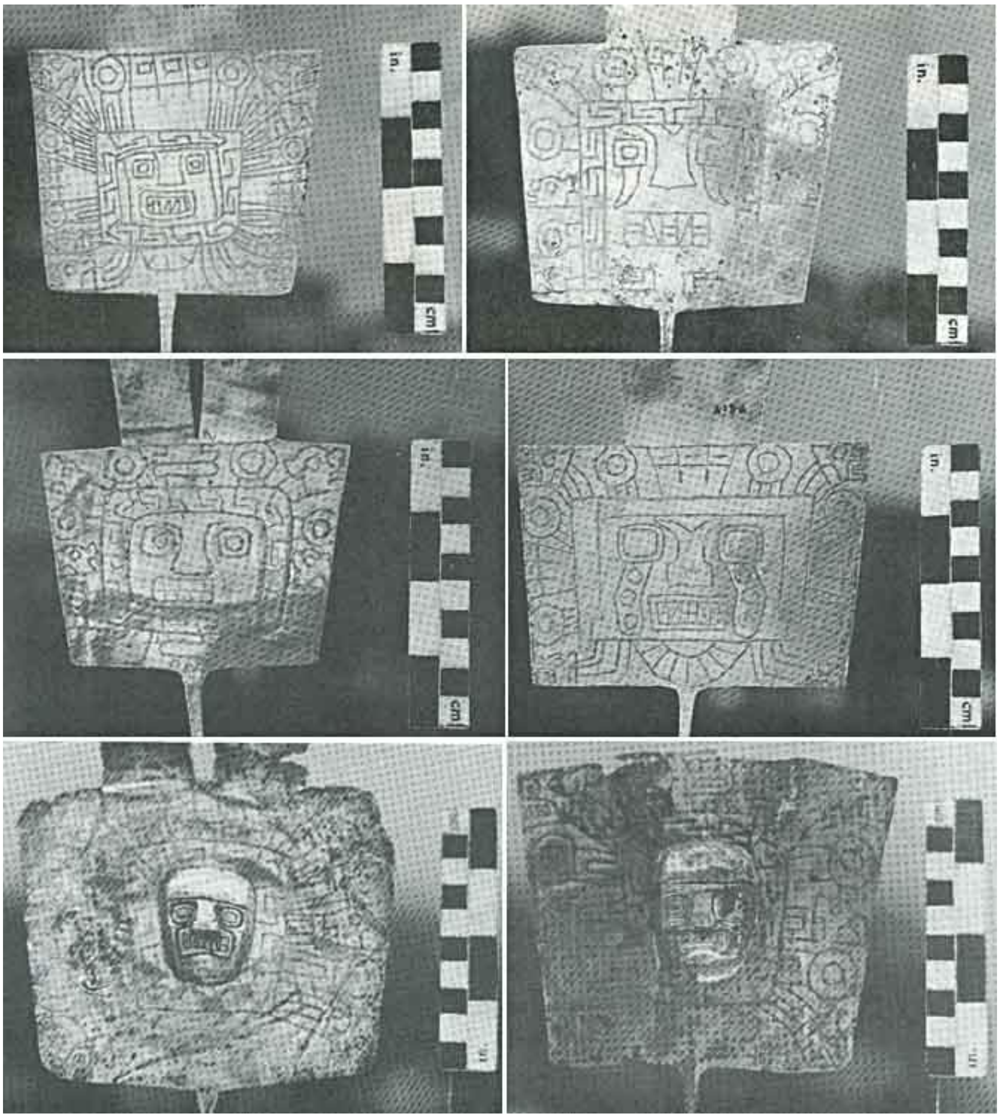
Appendix Nº2: 20: Examples of stone tools from (A-D) Peru (after Carcedo 1998, fig 6, 9-11); E- From the Pucará of Tilcara, NW Argentina; F- Central coast of Peru (modified from Lothrop 1978, fig 3); G- Peru highlands (Cuzco) (after Grossman 1972, pp 275). Note the variety of shapes, sizes and raw materials present.

Appendix Nº2: 21: A-C- Examples of copper-based tools used by metalsmiths in Peru (after Carcedo 1998, fig 20, 25, 26); D-F- Copper-based tools found in San Pedro de Atacama (D- after Llagostera 2011, pp 147; E-F modified from Cifuentes 2014, lam 29-30).

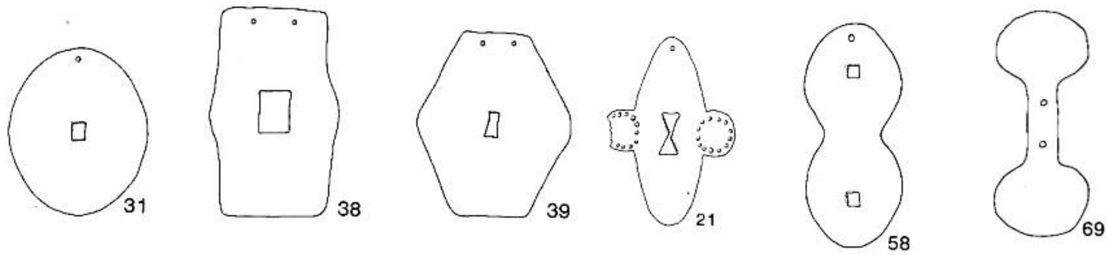


Appendix Nº2: 22: Nascoid textile found in SPA, Solcor-3, burial 112. After Llagostera, 1995, fig.14.

Appendix Nº2: 23: Possible Tiwanaku objects decorated using the wiggle or zigzag cut. Online catalogue, The Museum of Fine Arts, Houston. Catalogue number are included in the images.



Appendix Nº2: 24: Headdresses decorated with wiggle or zigzag cut, associated to a Huari mortuary context in Cusco Department, from the Middle Period. After Chávez, 1985, fig.8,9,13,14,21,22.



Appendix Nº2: 25: Gold pendants possible from Tiwanaku (31, 38, 39, 58, 69) and Pariti Island (21). After A. González, 1992, plate 1-2.

Appendix Nº2: 26: Headbands, headdresses and pendants of Tiwanaku style.
A-C- The Museum of Fine Arts, Houston. D- Metropolitan Museum of Art, New York. E- Silver pendant found in the Island of the Moon (Lake Titicaca; after Young-Sánchez, 2004, fig. 1.8).

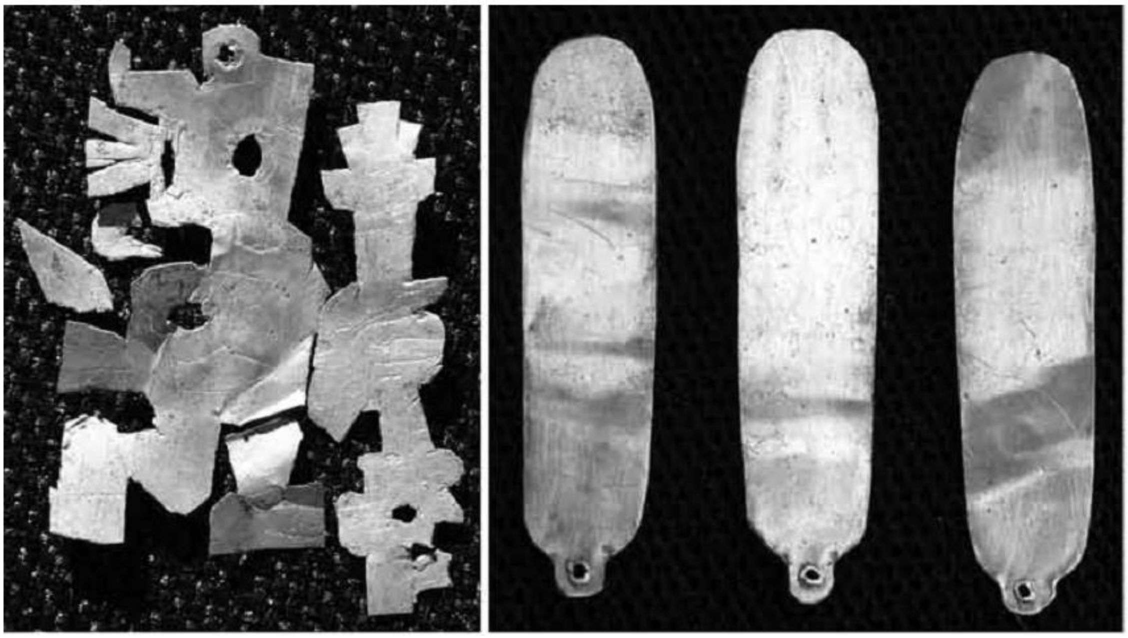
Appendix Nº2: 27: Tiwanaku style pendants, masks and discs. The Museum of Fine Arts, Houston

Object ID: 27273
Equivalencias: Ing. *cup*; alem. *trinkglas*, *tasse*; fran. *tasse*, *verre*.
Técnica de formación: Recopado
Técnica de acabado: Repujado
Componentes ppm: Au 49.958, Ag 42.291, Al 1.955 y Si 1.955.
Dimensiones: Alto máx. 1.6 cm; ancho máx. 1 cm.
Peso: 0.5 gr
Procedencia: Bolivia
Época: Periodo Inka (1450-1530 d.C.)

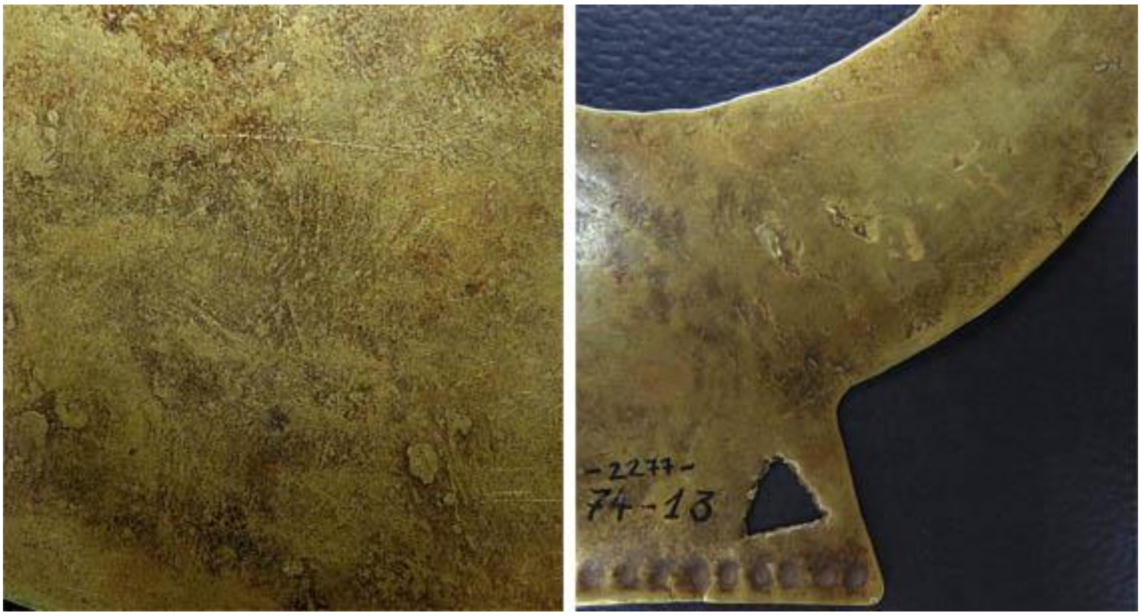
Object ID: 27256
Equivalencias: Ing. *cup*; alem. *trinkglas*, *tasse*; fran. *tasse*, *verre* .
Técnica de formación: Recopado
Técnica de acabado: Repujado
Componentes ppm: Au 41.534, Ag 49.361, Si 3.479, Cu 2.422 y Al 2.595.
Dimensiones: Alto máx. 1.5 cm; ancho máx. 1.1 cm.
Peso: 1.2 gr
Procedencia: Bolivia
Época: Periodo Inka (1450-1530 d.C.)

La pieza Object ID: 27273, caracterizada por tres líneas repujadas paralelas de manera horizontal, puede ser interpretada como una réplica en miniatura de un vaso *aquilla* utilizado en ceremonias y rituales propiciatorios de fertilidad.

Appendix Nº2: 28: Examples of conic bells found in Bolivia, nearly 15 bells are reported in the MUSEF, La Paz (after Férnandez, 2016, pp. 152-153).



Appendix Nº2: 29: Pendants from Pariti Island, after Korpisaari et al., 2012, fig.13.



Appendix Nº2: 30: Popm189. Detail of the back of the ornament.

Appendix Nº2: 31: Condor motif in Tiwanaku pottery and sculpture (after Posnansky, 1945, fig. 22,24).

Appendix nº3. Tables

Area	Alloys/metals used	References
Central *Altiplano* (Tiwanaku)	Cu-As-Ni Cu-As Cu-Sn Cu	(Lechtman, 2003b; Lechtman & Macfarlane, 2005, 2006)
Northwest Argentina	Cu-Sn Cu-As Cu-As-Zn Cu-Sn-Ni Cu-Sn-Sb	(Angiorama, 2001; Angiorama et al., 1999; Lechtman, 2003b)
San Pedro de Atacama	Cu-As-Ni Cu-As-Ni-Sn Cu-Sn Cu	(Lechtman, 2003b; Lechtman & Macfarlane, 2005, 2006; Salazar et al., 2011, 2014)

Appendix Nº3: 1: List of copper alloys used during the Middle Period (AD400-1000) in the South Central Andes.

Appendix Nº3: 2: Bulk chemical composition of 43 cross sections obtained through area scans by SEM-EDS. Results are normsalised to a 100%, however analytical totals are specified. Nd: not detected.

n° id lab	Magnification	Nº of readings	Cu	Ag	Au	O	Na	Cl	Total	Analytical total
popm001	3000x	2	4.0	56.5	39.6	-	-	-	100.0	100.7
popm002	9000x	5	2.4	24.2	73.4	-	-	-	100.0	93.1
popm003	8000x	5	1.6	19.1	79.4	-	-	-	100.0	99.3
popm005	3500x	3	1.6	70.8	27.6	-	-	-	100.0	99.5
popm006	3500x	3	1.6	70.9	27.5	-	-	-	100.0	101.1
popm007	3500x	3	1.4	74.7	23.9	-	-	-	100.0	100.5
popm008	5000x	3	1.7	20.3	78.0	-	-	-	100.0	96.0
popm009	4000x	3	1.6	18.9	79.5	-	-	-	100.0	97.7
popm010	1700x	3	3.9	61.6	34.5	-	-	-	100.0	100.9
popm011	5000x	3	2.3	20.4	77.2	-	-	-	100.0	97.8
popm012	5000x	3	10.2	17.1	72.6	-	-	-	100.0	101.5
popm013	2000x	3	4.1	43.0	52.9	-	-	-	100.0	103.2
popm014	1500x	2	4.1	37.4	58.5	-	-	-	100.0	105.4
popm015	1000x	3	1.2	7.6	91.2	-	-	-	100.0	100.7
popm016	1800x	3	2.6	9.7	87.7	-	-	-	100.0	100.4
popm017	500x	3	1.2	30.9	67.9	-	-	-	100.0	99.3
popm018	700x	3	1.1	30.9	68.0	-	-	-	100.0	101.4
popm019	7000x	5	2.8	13.2	84.0	-	-	-	100.0	99.1
popm020	1000x	3	0.0	8.5	91.5	-	-	-	100.0	95.1
popm021	7000x	3	4.2	28.4	67.4	-	-	-	100.0	100.7
popm022	3200x	2	3.8	25.7	70.5	-	-	-	100.0	98.0
popm023	2000x	2	3.6	11.3	85.1	-	-	-	100.0	110.2
popm024	1500x	3	1.6	58.8	39.6	-	-	-	100.0	99.9
popm025	1500x	3	1.5	50.9	47.5	-	-	-	100.0	99.5
popm026	1400x	3	3.2	14.5	82.4	-	-	-	100.0	99.6
popm027	1200x	3	55.3	4.8	39.9	-	-	-	100.0	95.8
popm028	3000x	4	4.8	23.6	71.6	-	-	-	100.0	97.2
popm029	3500x	2	3.1	31.4	65.6	-	-	-	100.0	105.3
popm030	1500x	3	4.8	34.7	60.5	-	-	-	100.0	103.7
popm032	2000x	3	1.5	66.3	32.2	-	-	-	100.0	100.8
popm033	3500x	3	1.1	66.3	32.6	-	-	-	100.0	99.6
popm034	1500x	3	1.1	66.2	32.6	-	-	-	100.0	101.2
popm035	1500x	3	6.2	40.8	53.0	-	-	-	100.0	101.1
popm036	900x	3	0.0	14.1	85.9	-	-	-	100.0	99.0
popm037	1500x	3	1.2	66.1	32.7	-	-	-	100.0	102.0
popm038	4500x	3	3.6	28.7	67.6	-	-	-	100.0	101.3
popm039	1600x	3	1.1	56.8	42.1	-	-	-	100.0	100.1
popm040	1500x	3	1.1	57.1	41.8	-	-	-	100.0	100.1
popm041	1500x	3	11.9	58.9	29.1	-	-	-	100.0	100.7
popm042	Spots	3	0.5	99.5	0.0	-	-	-	100.0	105.8
popm043	Spots	5	0.4	99.6	0.0	-	-	-	100.0	91.0
popm044	Spots	3	1.5	98.5	0.0	-	-	-	100.0	92.6
popm046	5000x	3	nd	78.0	nd	2.3	0.8	18.9	100.0	97.0

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Appendix Nº3: 3: Composition of native gold from deposits of Chile, Bolivia, Ecuador, Argentina and Peru. Copper content was not always mentioned in the publications; those cases are pointed out with the symbol "#", meaning that the absence of copper not necessarily mean that was not present in the gold or the description was not clear

Country	Area/region	Type of deposit	Deposit name	Au%	Ag%	Cu%	Fe%	Traces (<0.1%)	Technique	Reference
Chile	Atacama Region (North of Copiapo)	Primary (veins)	San Pedro de Cachiyuyo *	#	10.0	0.6	-	-	NAA	Hérail et al 1999
	Atacama region (East of Copiapo)	Primary (Au-rich prophyry)	Cerro Casale	96.7	3.8	0.2	-	-	EPMA	Palacios et al 2001
				97.0	4.1	0.3	-	-		
				95.9	5.0	0.1	-	-		
				95.4	5.4	0.1	-	-		
				95.1	5.5	0.2	-	-		
				95.3	5.7	0.1	-	-		
				93.9	5.7	0.2	-	-		
				91.3	9.9	0.2	-	-		
				90.0	10.8	0.0	-	-		
				86.7	11.9	0.2	-	-		
				87.5	13.2	0.2	-	-		
				86.6	14.4	0.02	-	-		
				82.4	18.5	0.03	-	-		
				81.0	20.0	0.01	-	-		
				79.7	21.0	0.1	-	-		

This table continues below…

**Results are the maximum values detected in a series of analyses (N° of samples not specified).*

*** Silver values are usually <1%*

 # Indicates values or information not given in the publications.

...continuation of the previous table

Country	Area/region	Type of deposit	Deposit name	Au%	Ag%	Cu%	Fe%	Traces (<0.1%)	Technique	Reference
Bolivia	Yani area, Cordillera Real	Primary (veins)	La Suerte	97.8	1.0	<0.1	-	As	EPMA	Alarcon & Fornari 1994
			Yani	96.7	1.5	<0.1	<0.1	As		
			Yani	97.7	2.2	<0.1	-	As		
			Pelechuco	96.3	3.1	<0.1	-	As		
			Pelechuco	95.8	3.2	<0.1	-	As		
			Lacayani	96.0	4.0	<0.1	-	As		
			Silusani	95.6	4.3	<0.1	-	As		
			Ananea	95.1	4.9	<0.1	-	As		
			Aucapata	94.9	5.1	<0.1	-	As		
			Santa Barbara	94.9	5.1	<0.1	-	As		
			Yani	94.6	5.9	<0.1	-	As		
	La Joya district	Polymetallic deposits	Korikollo	98.5	0.9	<0.1	-	**Bi**, Sb, As	EPMA	Alarcon & Fornari 1994
			Korikollo	97.2	2.3	<0.1	-	Sb, As		
			Cerro Llallagua	72.1	26.2	<0.1	-	Sb, As		
			Cerro Llallagua	73.2	26.3	<0.1	-	Sb, As		
			Cerro Llallagua	73.0	27.3	<0.1	-	Sb, As		
			Cerro Llallagua	72.4	27.7	<0.1	-	Sb, As		
			Cerro Llallagua	71.4	28.5	<0.1	-	Sb, As		
			Cerro Llallagua	70.3	29.4	<0.1	-	Sb, As		
			Tasna	80.0	20.0	#	-	nd	#	
			Tasna	77.0	23.0	#	-	nd		
			Chorolque	77.0	23.0	#	-	**Ti, Sn**, As		
	Eastern Cordillera of Bolivia	Sb-Au deposits	Cebadillas	98.5	0.0	<0.1	-	Sb, **Bi**	EPMA	Alarcon & Fornari 1994
			La Japonesa	99.6	0.1	#	-	Sb		
			San Bernardino	99.7	0.2	#	-	Sb, As, **Hg**		
			Los Machos	100.6	0.3	#	-	Sb		
			Capacirca	98.1	0.9	#	-	Sb		
			Amayapampa	99.1	0.9	#	-	Sb		
			Antofagasta	98.1	1.1	#	-	Sb, As		
			Sucre	94.6	4.4	#	-	Sb		

This table continues below…

...continuation of the previous table

Country	Area/region	Type of deposit	Deposit name	Au%	Ag%	Cu%	Fe%	Traces (<0.1%)	Technique	Reference
Bolivia	South Lipez	Placer	Placer Vilander	92.0	7.0	<0.1	<0.1	Te, Hg, As	EPMA	Fornari & Herail 1993, Ramos & Fornari 1994
			Placer Vilander	83.0	14.0	#	-	-		
			Guadalupe and Pedernal Rivers**	100.0	0.0	#	-	-		Fornari & Herail 1993
			Guadalupe and Pedernal Rivers**	97.0	3.0	#	-	-		
			Guadalupe River	99.2	0.8	#	-	-		Ramos & Fornari 1994
			Guadalupe River	94.0	6.0	#	-	-		
Argentina	Jujuy	Placer	Mina Eureka	#	3.9	#	-	-	#	Angiorama 2004:154
			Colquimayo	#	6.1	#	-	-		
			Rinconada	#	9.5	#	-	-		
Ecuador	Limit Peru/Ecuador	Placers	Zaruma (río Tumbes)	73.0	26.0	0.7	-	-	Spectrographic analysis ?	Petersen 1970
Peru	North Peru	Placers ?	Chinchipe	81.0	#	#	-	-		
			Ucayali	75.0	#	#	-	-		
	North Peru - Ancash		Pallasca	84.3	8.4	7.6	-	-		
			Ninamahua	89.2	4.8	6.5	-	-		
	South Peru - Carabaya	Placers	Chabuca	98.3	1.7	#	-	-		
			Ccapac-Orcco	97.1	1.8	0.04	0.8	-		
			Challuma	97.3	2.4	0.03	0.05	-		
			Quimsamayo	96.5	2.5	0.04	0.3	-		
			Quincemil	96.0	#	#	-	-		
			Marcapata	95.5	#	#	-	-		
	South Peru - Sandia	Placers	Sandia	98.5	#	#	-	-		
			Llamillami	98.2	1.9	#	-	-		
			Poto	94.4	5.6	#	-	-		
			Sandia	91.6	8.4	#	-	-		
			Vetasmayo	85.2	14.8	#	-	-		

Appendix Nº3: 4: Published data of native gold composition from different placers in Sandia Province, Peru. Petersen (1970) describes the analytical technique as "spectrographic analysis", no further details are given. Results are present in major, minor and trace elements. Modified from Petersen 1970: table 2.

Deposit name	>10%	1-10%	0.1-1%	100-1000ppm	<100ppm
Anccocala	Au, Ag	-	Cu, Fe, Hg, Si	Mn, W	Al, Bi, Cd, Na, Pb, Sb
Vetasmayo	Au, Ag	-	Fe	Cu	Bi, Cr, Pb, Sb, Si, Sn
Chinihuaya	Au, Ag	-	Fe, Hg, Sn	Cu, Si, W	Al, Bi, Cd, Mn, Na, Pb, Sb,
Llamillami	Au	Ag, Fe	Cu	-	Al, Cr, Pb, Si
Chabuca	Au, Ag	Fe	Cu	Sn	Al, Bi, Cd, Cr, Pb, Si
Sandia	Au, Ag	-	Cu, Fe, Hg, Si,	As	Al, B, Bi, Co, Cr, Na, Ni, Pb, Sn, Ti, Zn
Poto	Au, Ag, Sn	Fe, Hg, Si, W	Cu	Ti	Al, As, Bi, Cr, Mn, Pb, Sb, Zn

Appendix Nº3: 5: Ranges of gold composition from deposits in Bolivia.

					Ranges			
Country	**Area/region**	**Type of deposit**	**Deposit name**	**Au%**	**Ag%**	**Cu%**	**An. Technique**	**Reference**
Bolivia	Lipez (sur)	Placer	Placer Vilander	#	4-14	#	EPMA	Fornari & Herail 1993

Appendix Nº3: 6: Dimensions of the assemblage studied in SPA, organised by cemetery and lab id. Observations: objects that were not weight because (1) they were fixed on a support or (2) were in place on the individual. Cemeteries: Casa Parroquial (CP), Coyo-3 (C3), Larache (L), Quitor-1 (Q1), Quitor-5 (Q5), Sequitor Alambrado (SA), Solcor-3 (Sc3) and unknown cemetery (uk). Only sampled objects include the thickness in micrometers.

			Unit of measurement:	mm						µm		gr	
				Height/diameter		**Width**		**Thickness**		**Thickness**		**Weight**	
Id lab	**Object**	**Cemetery**	**Burial**	**min**	**max**	**min**	**max**	**min**	**max**	**min**	**max**		**Obs**
popm001	Attachment	CP	8	66.7	77.2	25.8	28.5	0.1	0.1	113.0	113.0	2.4	
popm002	Fragment	CP	7	20.0	31.8	20.1	27.6	0.1	0.1	54.4	54.4	0.2	
popm003	Fragment	CP	7	23.2	23.7	3.0	4.7	0.0	0.0	12.7	12.7	0.1	
popm007	Fragment	CP	16	31.9	37.0	27.6	29.3	0.04	0.04	42.2	42.2	0.9	
popm008	Fragment	CP	7	29.2	31.2	15.4	17.1	0.03	0.03	25.0	25.0	0.2	
popm009	Fragment	CP	7	20.9	27.2	21.1	21.6	0.03	0.03	33.0	33.0	0.3	
popm010	Pendant	CP	8	19.1	25.5	10.8	19.0	0.1	0.1	86.5	86.5	0.6	
popm011	Pendant	CP	7	24.9	29.8	16.3	25.2	0.02	0.02	18.0	18.0	0.2	
popm017	Headband	CP	18	131.5	172.5	47.5	62.0	0.2	0.2	223.6	223.6	36.0	
popm018	Headband	CP	18	154.2	196.3	48.9	55.9	0.2	0.2	232.0	232.0	35.8	
popm047	Pendant	CP	16	16.8	17.7	10.9	11.9	0.1	0.1	-	-	0.4	
popm050	Pendant	CP	16	16.0	16.4	12.9	13.0	0.1	0.1	-	-	0.3	
popm051	Pendant	CP	16	15.5	16.5	12.5	12.6	0.1	0.1	-	-	0.3	
popm073	Pendant	CP	16	17.4	17.6	11.5	12.0	0.1	0.1	-	-	0.3	
popm074	Pendant	CP	16	13.0	13.8	11.6	12.0	0.1	0.1	-	-	0.2	
popm075	Pendant	CP	16	16.4	17.6	12.9	13.2	0.2	0.2	-	-	0.3	
popm076	Pendant	CP	16	17.5	17.6	12.3	12.4	0.1	0.1	-	-	0.3	
popm077	Attachment	CP	16	45.3	47.7	23.7	28.4	0.1	0.1	-	-	1.8	
popm078	Attachment	CP	16	45.0	47.5	23.7	27.2	0.3	0.3	-	-	1.8	
popm079	Attachment	CP	16	141.3	143.8	27.3	28.0	0.2	0.2	-	-	5.5	
popm080	Attachment	CP	16	140.0	144.0	29.0	29.3	0.1	0.1	-	-	6.9	
popm081	Attachment	CP	18	48.0	50.3	46.7	50.3	0.2	0.2	-	-	4.0	
popm082	Headdress	CP	16	102.0	102.0	1.3	17.2	0.2	0.2	-	-	4.5	
popm083	Headdress	CP	16	102.0	102.0	1.3	18.3	0.3	0.3	-	-	4.0	
popm084	Headdress	CP	22	120.4	120.4	18.8	49.6	0.3	0.3	-	-	14.4	
popm085	Headdress	CP	11	73.3	73.3	2.7	29.6	0.2	0.2	-	-	3.6	
popm086	Headdress	CP	22	110.3	110.3	0.8	45.6	0.2	0.2	-	-	7.6	
popm087	Headdress	CP	13	131.0	154.0	115.0	36.6	0.2	0.2	-	-	32.4	
popm088	Ring	CP	21	15.8	17.5	19.8	20.7	0.4	0.4	-	-	4.8	
popm089	Ring	CP	3	10.6	11.0	15.4	18.6	0.5	0.5	-	-	1.9	
popm139	Goblet	CP	18	165.0	165.0	104.7	193.0	1.5	2.2	-	-	283.0	
popm140	Goblet	CP	18	167.0	168.0	87.6	163.0	0.9	1.2	-	-	274.0	
popm141	Goblet	CP	1	104.1	109.0	55.7	64.7	2.2	2.8	-	-	206.0	
popm042	Headband	C3	11	505.2	513.4	26.7	31.4	0.1	0.2	103.0	195.0	47.0	
popm046	Attachment	C3	6	26.6	27.3	-	-	0.05	0.05	45.8	45.8	-	1
popm052	Attachment	C3	35	149.6	150.6	-	-	0.2	0.2	-	-	-	1
popm143	Attachment	C3	35	27.0	30.0	-	-	-	-	-	-	-	1
popm144	Jug	C3	23	33.5	34.1	20.1	30.3	0.7	1.0	-	-	4.6	
popm035	Attachment	L	1714	65.8	65.8	22.6	22.6	0.3	0.3	328.0	328.0	3.2	
popm036	Pendant	L	1714	31.1	33.2	17.6	23.7	0.2	0.2	217.0	217.0	3.0	
popm056	Bell	L		26.5	27.3	5.6	16.2	0.4	0.4	-	-	3.4	
popm057	Bell	L	356	20.6	21.6	10.7	15.2	0.4	0.4	-	-	2.3	
popm058	Bell	L	356	20.2	20.3	9.8	13.0	0.4	0.4	-	-	2.8	
popm059	Bell	L	body2	17.4	18.5	6.5	12.7	0.4	0.4	-	-	3.1	
popm060	Bell	L	body2	18.4	18.7	6.3	12.9	0.5	0.5	-	-	3.5	
popm061	Bell	L	359	14.7	15.6	9.5	16.4	0.3	0.3	-	-	1.8	
popm062	Bell	L	359	14.6	15.3	10.0	17.3	0.3	0.3	-	-	1.9	
popm063	Bell	L		20.5	21.0	7.3	11.6	0.2	0.2	-	-	1.2	
popm064	Bell	L		19.4	20.4	11.3	12.9	0.2	0.2	-	-	1.7	
popm065	Bell	L		20.3	20.7	7.5	10.9	0.3	0.3	-	-	1.6	
popm066	Bell	L		11.0	11.7	5.6	12.0	0.3	0.3	-	-	1.0	
popm090	Attachment	L	356	72.4	72.4	-	-	0.2	0.2	-	-	12.2	
popm091	Attachment	L	356	59.4	60.5	67.1	67.2	0.1	0.1	-	-	7.4	
popm093	Headband	L	356	275.0	278.0	40.5	43.3	0.2	0.2	-	-	24.9	
popm094	Headband	L	356	149.0	150.0	31.4	29.4	0.2	0.2	-	-	10.0	
popm095	Attachment	L	356	101.6	102.8	29.5	31.3	0.2	0.2	-	-	6.8	
popm096	Ring	L	356	13.9	14.0	16.0	22.3	0.1	0.1	-	-	1.3	
popm097	Ring	L	356	14.0	14.7	16.5	20.3	0.1	0.1	-	-	1.5	
popm098	Bell	L	body2	18.4	18.8	6.3	12.9	0.4	0.4	-	-	3.1	
popm099	Bell	L	body2	18.1	18.4	6.2	13.2	0.5	0.5	-	-	3.4	
popm100	Bell	L	body2	18.2	19.2	7.0	12.4	0.5	0.5	-	-	3.4	
popm101	Bell	L	body2	19.2	18.2	6.6	12.7	0.6	0.6	-	-	3.4	
popm102	Bell	L	body2	18.8	19.0	6.6	13.3	0.5	0.5	-	-	3.5	
popm103	Ring	L	359	23.8	26.4	-	-	2.0	2.0	-	-	4.2	
popm104	Ring	L	356	22.5	29.6	-	-	2.0	2.0	-	-	4.4	

Unit of measurement:				mm						µm		gr	
				Height/diameter		**Width**		**Thickness**		**Thickness**		**Weight**	
Id lab	**Object**	**Cemetery**	**Burial**	**min**	**max**	**min**	**max**	**min**	**max**	**min**	**max**		**Obs**
popm105	Ring	L	356	23.4	29.4	-	-	2.0	2.0	-	-	4.5	
popm106	Bracelet	L	359	145.0	147.4	61.7	60.8	0.2	0.2	-	-	28.1	
popm107	Attachment	L	359	97.7	99.0	-	-	0.3	0.3	-	-	23.8	
popm108	Bracelet	L	359	159.0	161.0	76.8	82.0	0.2	0.2	-	-	39.5	
popm109	Bracelet	L	358	176.0	166.0	79.3	80.4	0.3	0.3	-	-	48.6	
popm110	Headband	L	358	194.0	195.0	45.5	48.5	0.5	0.5	-	-	33.5	
popm111	Headband	L	359	260.0	262.0	28.5	31.2	0.2	0.2	-	-	21.6	
popm112	Headband	L	359	212.0	271.0	42.6	48.8	0.6	0.6	-	-	36.6	
popm113	Ring	L	359	10.5	11.0	20.5	21.2	0.5	0.5	-	-	2.6	
popm114	Ring - disc	L	359	19.2	19.5	-	-	0.2	0.2	-	-	0.9	
popm115	Bell	L	356	20.3	20.8	9.4	12.0	0.4	0.4	-	-	2.6	
popm116	Bell	L	356	20.6	21.0	9.6	12.5	0.5	0.5	-	-	2.7	
popm118	Pendant	L	358	61.4	62.5	61.4	62.5	0.2	0.3	-	-	11.9	
popm119	Pendant	L	358	35.3	39.7	20.2	28.8	0.2	0.4	-	-	2.9	
popm120	Pendant	L	358	38.9	39.3	11.0	26.3	0.2	0.4	-	-	2.7	
popm121	Pendant	L	358	38.6	39.3	19.5	23.3	0.2	0.3	-	-	2.7	
popm122	Pendant	L	358	37.6	38.8	19.8	29.0	0.2	0.3	-	-	2.9	
popm123	Pendant	L	358	30.0	38.8	16.7	25.1	0.2	0.3	-	-	2.6	
popm124	Pendant	L	358	34.1	36.0	22.7	29.3	0.2	0.3	-	-	2.8	
popm125	Headdress	L	358	214.7	214.7	2.6	59.2	0.1	1.0	-	-	39.2	
popm126	Axe	L	358	104.5	113.6	33.8	44.0	3.4	4.9	-	-	-	1
popm132	Headband	L	359	471.0	447.0	29.7	33.7	0.2	0.6	-	-	50.9	
popm136	Goblet	L	358	160.0	162.0	83.6	125.7	1.2	1.4	-	-	252.0	
popm137	Goblet	L	358	134.2	142.5	68.5	92.3	0.8	1.2	-	-	210.0	
popm138	Goblet	L	358	135.4	145.4	65.6	90.0	0.8	1.1	-	-	187.0	
popm142	Headband	L	358	182.0	183.0	41.5	46.4	0.2	0.2	-	-	26.4	
popm145	Bell	L	body1	13.7	14.0	7.5	12.2	0.2	0.3	-	-	1.0	
popm146	Bell	L	body1	13.5	13.8	7.6	11.5	0.1	0.2	-	-	1.0	
popm147	Bell	L	body1	13.4	13.8	7.2	12.0	0.1	0.2	-	-	0.7	
popm071	Ring	L (?)	359 (?)	14.3	14.6	19.0	20.1	0.3	0.3	-	-	3.5	
popm127	Attachment	L (?)	356 (?)	42.4	42.9	42.4	42.9	0.1	0.2	-	-	2.6	
popm129	Ring	L (?)	359 (?)	7.5	7.5	18.0	19.5	0.2	0.3	-	-	1.7	
popm005	Attachment	Q1		91.3	97.0	17.6	20.0	0.1	0.1	55.5	55.5	1.0	
popm032	Pendant	Q1	889	112.2	112.7	19.8	22.0	0.1	0.1	74.9	74.9	1.5	
popm033	Ring	Q1	889	26.3	26.3	24.3	25.5	0.1	0.1	88.8	88.8	2.9	
popm034	Bell	Q1	889	40.4	40.0	1.9	11.6	0.3	0.3	341.6	341.6	1.8	
popm037	Fragment	Q1	889	41.9	45.7	22.0	22.5	0.1	0.1	117.4	117.4	1.8	
popm039	Attachment	Q1	889	42.0	47.5	18.5	38.5	0.1	0.2	69.5	173.0	1.1	
popm048	Attachment	Q1		105.0	105.0	13.5	16.0	0.1	0.1	55.5	55.5	0.9	
popm150	Attachment	Q1	889	91.2	91.2	51.7	64.0	0.2	0.3	-	-	7.8	
popm151	Headband	Q1	889	119.0	120.0	45.4	47.1	0.2	0.3	-	-	-	2
popm152	Headband	Q1	889	380.5	380.5	11.2	12.5	0.1	0.2	-	-	-	2
popm026	Bracelet	Q5	2003	101.2	102.9	21.8	41.5	0.1	0.1	59.0	59.0	5.7	
popm030	Attachment	Q5		30.2	30.8	-	-	0.1	0.1	58.4	58.4	0.5	
popm027	Attachment	Q5 (?)		35.0	35.6	3.3	33.0	0.1	0.1	93.0	93.0	0.8	
popm028	Attachment	Q5 (?)		50.1	52.9	9.5	11.1	0.2	0.2	208.3	208.3	0.7	
popm015	Pendant	SA	767	45.8	47.2	11.5	10.1	0.2	0.2	222.0	222.0	1.3	
popm016	Attachment	SA	No burial	25.8	27.6	17.5	19.7	0.1	0.1	78.7	78.7	0.5	
popm131	Attachment	SA	710-714	158.0	158.0	31.9	49.9	0.1	0.1	-	-	6.2	
popm133	Tip feline head	Sc3	107	22.5	26.2	6.8	10.5	0.2	0.2	-	-	-	1
popm134	Tip	Sc3	107	20.0	20.3	8.7	12.7	0.1	0.1	-	-	-	1
popm135	Body sheet	Sc3	107	-	-	16.0	16.4	0.1	0.1	-	-	-	1
popm021	Band	uk		60.0	65.7	23.5	25.7	0.02	0.02	20.4	20.4	0.6	
popm022	Band	uk		85.6	87.1	15.8	21.3	0.05	0.05	48.5	48.5	0.7	
popm023	Fragment	uk		63.5	76.8	8.8	16.3	0.1	0.1	142.0	142.0	1.3	
popm024	Band	uk		52.6	56.7	9.9	10.1	0.1	0.1	141.6	141.6	1.8	
popm025	Fragment	uk		44.4	45.7	18.4	19.7	0.2	0.2	160.0	160.0	1.7	
popm029	Band	uk		189.7	191.5	13.6	19.9	0.02	0.03	22.0	25.2	1.5	
popm041	Fragment	uk		36.5	44.7	10.8	15.3	0.4	0.4	378.0	378.0	2.7	
popm053	Attachment	uk		10.0	14.1	88.9	92.7	0.4	0.4	-	-	3.5	
popm054	Headband	uk		22.7	22.7	20.0	25.6	0.2	0.2	-	-	11.4	
popm055	Band	uk		9.2	10.2	65.3	65.3	0.1	0.1	-	-	1.5	
popm067	Unknown	uk		1.7	11.3	8.4	17.2	0.2	0.2	-	-	0.2	
popm069	Fragment	uk		17.9	17.9	22.9	22.9	0.1	0.1	-	-	0.1	
popm092	Headband	uk		136.3	143.4	28.0	61.7	0.2	0.2	-	-	12.7	
popm117	Ring	uk		11.3	16.7	17.6	26.4	0.1	0.1	-	-	3.9	
popm128	Pendant	uk		55.3	55.3	44.3	44.3	0.2	0.3	-	-	6.3	
popm130	Ring	uk		14.1	17.9	19.6	21.6	0.3	0.4	-	-	4.3	

Appendix Nº3: 7: Manufacturing trait identified in the assemblage from SPA, organised by cemetery and lab id. Cemeteries: Casa Parroquial (CP), Coyo-3 (C3), Larache (L), Quitor-1 (Q1), Quitor-5 (Q5), Sequitor Alambrado (SA), Solcor-3 (Sc3) and unknown cemetery (uk). (*) Quality of the work: (1) finely-made, (2) coarsely-made. n/a: not applicable, uk: unknown.

*** Given the large size of this table, it was attached as an excel file, in the USB associated***

Appendix Nº3: 8: List of museums consulted and mentioned in chapter 7.

Acronym	Museum	City	Country
ME	Museo Etnográfico Juan B. Ambrosetti	Buenos Aires	Argentina
MEC	Museo Arqueológico y Antropológico Dr. Eduardo Casanova	Tilcara	Argentina
MLP	Museo de La Plata	La Plata	Argentina
MUSEF	Museo Nacional de Etnografia y Folckore	La Paz	Bolivia
CCTC	Corporación de Cultura y Turismo de Calama	Calama	Chile
MChAP	Museo Chileno de Arte Precolombino	Santiago	Chile
IIAM	Instituto de Investigaciones Arqueológicas y Museo R.P. Gustavo Le Paige	San Pedro de Atacama	Chile
MQB	Musée du Quai Branly – Jacques Chirac	Paris	France
EM	Ethnologisches Museum	Berlin	Germany
BM	British Museum	London	UK
MET	The Metropolitan Museum of Art	New York	USA
MFAH	The Museum of Fine Arts, Houston	Houston	USA
NMAI	National Museum of American Indian, Smithsonian Institution	New York	USA

Appendix Nº3: 9: Published sources with chemical analysis on Central and South-central Andes gold and silver objects used in this research .

Reference	Analytical technique	Location	Nº analysis plotted*	Nº objects
Angiorama 2004	EDAX	NWA	7	7
Bárcena 2004	XRF	CWA	5	5
Boman 1908	Not specified	NCP, CCP, SWB, NWA	15	15
Fernandez 2016	pXRF	B, NWB, CWB	49	49
Gonzalez 2004:332	SEM	NWA	3	3
McEwan and Haeberli 2000	SEM-EDX	SCP	3	3
Miguez 2014	SEM-EDAX	YA	2	2
Petersen 1970	Not specified	NCP	1	1
Rolandi 1974	Not specified	NWA	3	3
Root 1949	Not specified	SCP	36	36
Rovira 1992	XRF	P, NCP, CHP, SCP	70	70
Schlosser et al 2009	LA-ICP-MS	NCP, CHP, SCP	65	65
Shimada et al 2000	NAA	NCP	39	364
Ventura & Scambato 2013	SEM-EDAX	Y	6	6
Ventura 1985	EPMA	Y	1	1
TOTALS			**305**	**630**

Acronyms for location	Meaning
P	Peru
NCP	North coast of Peru
CCP	Central coast Peru
CHP	Central highlands Peru
SCP	South coast of Peru
NWA	Northwest Argentina
CWA	Central west Argentina
Y	Argentinean yungas
NWB	Northwest Bolivia
CWB	Central west Bolivia
SWB	Southwest Bolivia
B	Bolivia

* Some analysis plotted are the average of several analysis

Appendix Nº3: 10: Bulk chemical composition of 155 objects from Peru, Bolivia, Chile and Argentina by pXRF. n/n: no number or identification code.

Type	Nº	Location	Site	Museum	Museum id	Lab id	Cu	Ag	Au	Total
PERU										
Pendant	1	CHP	-	BM	Am1846,1217.31	-	1.9	30.2	67.9	100.0
Pendant	1	CHP	-	BM	Am1846,1217.32	-	2.1	30.8	67.1	100.0
Tupu	1	Peru	-	BM	Am1844,0729.1	-	9.1	6.9	84.0	100.0
Feminine figure	1	Peru	-	BM	Am.7082	-	2.4	51.4	46.2	100.0
Masculine figure	1	Peru	-	BM	Am1847,0527.2	-	1.7	54.2	44.1	100.0
Feminine figure (head)	1	Peru	-	BM	Am,+.6175	-	1.9	56.0	42.1	100.0
BOLIVIA										
Pendant, oval	1	NWB - Tiwanaku	-	MQB	249	popm158	0.0	1.9	98.1	100.0
Pendant, cross	1	NWB - Tiwanaku	-	MQB	251	popm156	0.1	2.6	97.3	100.0
Sheet, square	1	NWB - Tiwanaku	-	MQB	254	popm159	0.0	3.6	96.4	100.0
Pendant, tie	1	NWB - Tiwanaku	-	MQB	248	popm154	0.0	7.0	93.0	100.0
Bell, frag	1	NWB - Tiwanaku	-	MQB	253	popm155	2.8	9.1	88.0	100.0
Headdress	1	NWB - Tiwanaku	-	MQB	246	popm153	3.3	14.4	82.3	100.0
Pendant, cross	1	NWB - Tiwanaku	-	MQB	250	popm157	5.4	20.9	73.7	100.0
Sheet, square	1	SWB - Puna	-	MQB	1053	popm164	0.0	3.8	96.2	100.0
Disc	1	SWB - Puna	-	MQB	1052_d	popm165_4	7.1	11.3	81.5	100.0
Disc	1	SWB - Puna	-	MQB	1052_b	popm165_2	6.1	11.4	82.5	100.0
Disc	1	SWB - Puna	-	MQB	1052_a	popm165_1	7.1	11.4	81.5	100.0
Disc	1	SWB - Puna	-	MQB	1052_c	popm165_3	6.5	11.4	82.1	100.0
Pendant, rectangular	1	SWB - Puna	-	MQB	245	popm161	5.0	29.5	65.5	100.0
Pendant, fish	1	SWB - Puna	-	MQB	244	popm160_2	4.7	40.3	55.1	100.0
Pendant, fish	1	SWB - Puna	-	MQB	243	popm160_1	4.2	40.8	55.0	100.0
Sheet, rectangular	1	SWB - Puna	-	MQB	2447	popm163	2.1	47.0	51.0	100.0
Headdress, T-shaped	1	SWB - Puna	-	MQB	242	popm162	2.0	52.8	45.2	100.0
CHILE										
Sheet fragment	1	Arid North	Arica	BM	Am,S.1319	-	1.9	29.6	68.5	100.0
Pendant	1	Arid North	Caleta Urcu		NG08	popm219	0.6	4.5	94.9	100.0
Pendant, rectangular	1	Arid North	Chorrillos cemetery	CCTC	n/n	popm148	3.7	3.8	92.4	100.0
Half pendant	1	Arid North	Chorrillos cemetery	CCTC	n/n	popm149	3.0	5.5	91.6	100.0
Tubular sheet	1	Arid North	Hornitos 01		NG01b	popm220	4.5	2.9	92.5	100.0
Headdress	1	Semi-arid north	-	MChAP	2731	-	1.8	18.5	79.7	100.0
Earring	1	Semi-arid north	-	MChAP	2610	-	2.4	20.4	77.2	100.0
Wire	1	Semi-arid north	-	MChAP	2539	-	1.1	23.7	75.3	100.0
Earring	1	Semi-arid north	-	MChAP	2540	-	1.6	47.9	50.4	100.0
Tupu	1	SPA	-	MEC	114	-	20.9	79.1	0.0	100.0
Bead	1	SPA oasis	Yona2	IIAM	18.149 (87)	popm072_6	0.0	2.9	97.1	100.0
Bead	1	SPA oasis	Yona2	IIAM	18.147 (85)	popm072_4	0.0	3.4	96.6	100.0
Bead	1	SPA oasis	Yona2	IIAM	18.152 (90)	popm072_9	0.0	3.6	96.4	100.0
Bead	1	SPA oasis	Yona2	IIAM	18.160 (9..)	popm072_18	0.0	4.3	95.7	100.0
Bead	1	SPA oasis	Yona2	IIAM	18.172 (111)	popm020	0.0	6.2	93.8	100.0
Bead	1	SPA oasis	Yona2	IIAM	18.155 (93)	popm072_12	0.0	6.6	93.4	100.0
Bead	1	SPA oasis	Yona2	IIAM	18.159 (97)	popm072_17	0.0	6.7	93.3	100.0
Bead	1	SPA oasis	Yona2	IIAM	18.145 (83)	popm072_2	0.0	6.8	93.2	100.0
Bead	1	SPA oasis	Yona2	IIAM	18.156 (94)	popm072_13	0.0	6.9	93.1	100.0
Bead	1	SPA oasis	Yona2	IIAM	18.161 (99)	popm072_19	0.0	7.3	92.7	100.0
Bead	1	SPA oasis	Yona2	IIAM	18.171 (109)	popm072_28	0.0	7.4	92.6	100.0
Bead	1	SPA oasis	Yona2	IIAM	18.154 (92)	popm072_11	0.0	7.6	92.4	100.0
Bead	1	SPA oasis	Yona2	IIAM	18.157 (95)	popm072_14	0.0	7.9	92.1	100.0
Bead	1	SPA oasis	Yona2	IIAM	18.164 (102)	popm072_22	0.0	8.0	92.0	100.0
Bead	1	SPA oasis	Yona2	IIAM	18.148 (98)	popm072_5	0.0	8.1	91.9	100.0
Bead	1	SPA oasis	Yona2	IIAM	18.157 (95)	popm072_15	0.0	8.1	91.9	100.0
Bead	1	SPA oasis	Yona2	IIAM	18.151 (89)	popm072_8	0.0	8.1	91.9	100.0
Bead	1	SPA oasis	Yona2	IIAM	18.146 (84)	popm072_3	0.0	8.2	91.8	100.0
Bead	1	SPA oasis	Yona2	IIAM	18.144 (82)	popm072_1	0.0	8.2	91.8	100.0
Bead	1	SPA oasis	Yona2	IIAM	18.166 (104)	popm045	0.0	8.4	91.6	100.0
Bead	1	SPA oasis	Yona2	IIAM	18.153 (91)	popm072_10	0.0	8.4	91.6	100.0
Bead	1	SPA oasis	Yona2	IIAM	18.162 (100)	popm072_20	0.0	8.5	91.5	100.0
Bead	1	SPA oasis	Yona2	IIAM	18.150 (88)	popm072_7	0.0	8.5	91.5	100.0
Bead	1	SPA oasis	Yona2	IIAM	18.174 (110)	popm072_30	0.0	8.6	91.4	100.0
Bead	1	SPA oasis	Yona2	IIAM	18.170 (108)	popm072_27	0.0	8.6	91.4	100.0
Bead	1	SPA oasis	Yona2	IIAM	18.158 (96)	popm072_16	0.0	8.6	91.4	100.0
Bead	1	SPA oasis	Yona2	IIAM	18.165 (103)	popm072_23	0.0	8.8	91.2	100.0
Bead	1	SPA oasis	Yona2	IIAM	18.173 (81)	popm072_29	0.0	9.1	90.9	100.0
Bead	1	SPA oasis	Yona2	IIAM	18.168 (106)	popm072_25	0.0	9.1	90.9	100.0
Bead	1	SPA oasis	Yona2	IIAM	18.167 (105)	popm072_24	0.0	9.1	90.9	100.0
Bead	1	SPA oasis	Yona2	IIAM	18.169 (107)	popm072_26	0.0	9.4	90.6	100.0
Bead	1	SPA oasis	Yona2	IIAM	18.163 (101)	popm072_21	0.0	9.7	90.3	100.0
ARGENTINA										
Headband - solder	1	Puna	Casabindo	MEC	1882	-	11.6	88.4	0.0	100.0
Headband	1	Puna	Casabindo	MEC	1883	-	4.0	96.0	0.0	100.0
Headband	1	Puna	Casabindo	MEC	1888	-	3.5	96.5	0.0	100.0
Headband - body	1	Puna	Casabindo	MEC	1882	-	3.3	96.7	0.0	100.0
Headband - snake head	1	Puna	Casabindo	MEC	1882	-	3.0	97.0	0.0	100.0
Headband	1	Puna	Casabindo	MEC	24393	-	2.9	97.1	0.0	100.0
Bead - tube	1	Puna	Doncellas	ME	42-1526d	-	3.8	40.1	56.1	100.0
Bead – tube	1	Puna	Doncellas	ME	42-1526b	-	2.1	41.4	56.5	100.0
Bead – tube	1	Puna	Doncellas	ME	42-1526c	-	2.1	41.9	56.1	100.0
Bead – tube	1	Puna	Doncellas	ME	42-1526a	-	1.9	42.3	55.8	100.0
Bead – tube	1	Puna	Doncellas	ME	42-1526e	-	2.0	42.4	55.6	100.0
Pendant, bow-tie	1	Puna	Doncellas	ME	42-1260	-	0.8	50.3	49.0	100.0
Disc	1	Puna	Doncellas	ME	42-1950	-	1.6	68.2	30.2	100.0
Mask	1	Puna	Doncellas	MEC	1675	popm216	8.0	92.0	0.0	100.0

Type	Nº	Area 3	Site	Museum/Ref	Museum id	Lab id	Cu	Ag	Au	Total
Oval plate	1	Puna	Doncellas	ME	43-1303	-	5.2	94.8	0.0	100.0
Oval plate	1	Puna	Doncellas	ME	43-1303	-	4.9	95.1	0.0	100.0
Bowl	1	Puna	Doncellas	ME	42-2118	-	0.6	99.4	0.0	100.0
Tupu	1	Puna	Mayinte	MLP	8361-367	-	5.7	94.2	0.1	100.0
Tupu	1	Puna	Queta	ME	44-1736	-	4.4	95.5	0.1	100.0
Disc	1	Puna	Sorcuyo (PV Tucute)	ME	44-935	-	2.1	97.9	0.0	100.0
Pectoral Y-shaped	1	Puna	Tebenquiche	ME	52.33	popm189	2.4	12.3	85.3	100.0
Kero	1	Humahuaca	El Volcán	ME	35.224	popm190	0.8	45.1	54.1	100.0
Attachment	1	Humahuaca	Huacalera	MEC	4385	popm204	0.9	15.5	83.6	100.0
Attachment	1	Humahuaca	Huacalera	MEC	4382	popm202	0.8	15.8	83.4	100.0
Attachment	1	Humahuaca	Huacalera	MEC	4384	popm203	0.9	15.9	83.3	100.0
Attachment	1	Humahuaca	Huacalera	MEC	4383	popm205	0.8	19.5	79.8	100.0
Ring - appliqued	1	Humahuaca	Huacalera	MEC	4389	popm209	0.6	20.1	79.3	100.0
Pendant	1	Humahuaca	Huacalera	MEC	4392	popm212	0.9	23.0	76.2	100.0
Attachment	1	Humahuaca	Huacalera	MEC	4386	popm206	0.9	23.0	76.2	100.0
Bell - 4 points	1	Humahuaca	Huacalera	MEC	4388	popm208	0.9	23.2	75.9	100.0
Attachment	1	Humahuaca	Huacalera	MEC	4390	popm210	0.8	24.0	75.2	100.0
Pendant - axe shape	1	Humahuaca	Huacalera	MEC	4380	popm200	0.8	24.1	75.1	100.0
Pendant	1	Humahuaca	Huacalera	MEC	4391	popm211	0.7	27.4	71.9	100.0
Ring - soldering	1	Humahuaca	Huacalera	MEC	4389	popm209	3.4	31.3	65.3	100.0
Mask	1	Humahuaca	Huacalera	MEC	4395	popm215	1.0	33.8	65.2	100.0
Pendant	1	Humahuaca	Huacalera	MEC	4376	popm196	1.0	34.3	64.7	100.0
Pendant	1	Humahuaca	Huacalera	MEC	4378	popm198	1.1	34.5	64.4	100.0
Pendant	1	Humahuaca	Huacalera	MEC	4394	popm214	1.5	34.5	64.0	100.0
Pendant	1	Humahuaca	Huacalera	MEC	4377	popm197	1.1	34.7	64.2	100.0
Pendant	1	Humahuaca	Huacalera	MEC	4379	popm199	0.8	36.4	62.8	100.0
Pendant	1	Humahuaca	Huacalera	MEC	4393	popm213	0.8	37.0	62.2	100.0
Pendant	1	Humahuaca	Huacalera	MEC	4375	popm195	0.8	37.2	62.0	100.0
Attachment	1	Humahuaca	Huacalera	MEC	4387	popm207	0.8	37.5	61.7	100.0
Pendant - axe shape	1	Humahuaca	Huacalera	MEC	4381	popm201	0.7	37.6	61.7	100.0
Ring - band	1	Humahuaca	Huacalera	MEC	4389	popm209	2.0	45.0	53.0	100.0
Headband	1	Humahuaca	La Falda de Tilcara	MEC	n/n	-	0.1	99.9	0.0	100.0
Pendant	1	Humahuaca	La Huerta	MEC	26546	-	1.7	98.3	0.0	100.0
Attachment	1	Humahuaca	La Isla de T.	MEC	2950	popm192	0.1	10.9	89.0	100.0
Bell 4 points	1	Humahuaca	La Isla de T.	ME	2998	popm175	0.5	17.2	82.3	100.0
Bell 4 points	1	Humahuaca	La Isla de T.	ME	2997	popm174	0.5	17.4	82.1	100.0
Bell 4 points	1	Humahuaca	La Isla de T.	ME	2999	popm176	0.5	17.5	82.0	100.0
Pendant - llama	1	Humahuaca	La Isla de T.	ME	3001	popm183	0.5	17.8	81.7	100.0
Pendant - llama	1	Humahuaca	La Isla de T.	ME	3000	popm182	0.5	17.9	81.6	100.0
Attachment - rectangular	1	Humahuaca	La Isla de T.	ME	2991	popm178	0.5	18.4	81.1	100.0
Bell 4 points	1	Humahuaca	La Isla de T.	ME	2996	popm173	0.6	18.7	80.8	100.0
Attachment - trapezoid	1	Humahuaca	La Isla de T.	ME	2992	popm179	0.5	18.8	80.6	100.0
Bell 4 points	1	Humahuaca	La Isla de T.	ME	2994	popm171	0.5	18.9	80.6	100.0
Bell 4 points	1	Humahuaca	La Isla de T.	ME	2995	popm172	0.5	19.1	80.3	100.0
Attachment - rectangular	1	Humahuaca	La Isla de T.	ME	2990	popm177	0.8	20.3	78.9	100.0
Headband	1	Humahuaca	La Isla de T.	ME	2989	popm184	0.5	23.4	76.0	100.0
Irregular pendant - large	1	Humahuaca	La Isla de T.	ME	2697c	popm181	0.6	24.9	74.6	100.0
Irregular pendant	1	Humahuaca	La Isla de T.	ME	2697b	popm180b	1.2	53.5	45.4	100.0
Irregular pendant	1	Humahuaca	La Isla de T.	ME	2697a	popm180a	1.1	53.6	45.3	100.0
Headband	1	Humahuaca	Malka (rescate)	MEC	C.9	popm217	4.7	36.4	58.8	100.0
Pendant	1	Humahuaca	Malka (rescate)	MEC	C.9	popm218	7.9	45.4	46.6	100.0
Attachment	1	Humahuaca	Muyuna	MEC	53-266	popm191	0.9	23.2	75.9	100.0
Pendant	1	Humahuaca	Pucara Tilcara	MEC	703.2	-	0.6	47.8	51.6	100.0
Disc	1	Humahuaca	Pucara Tilcara	MEC	2452	-	9.3	90.5	0.2	100.0
Disc	1	Humahuaca	Pucara Tilcara	MEC	2135	-	8.8	90.9	0.2	100.0
Bowl	1	Humahuaca	Pucara Tilcara	MEC	2143	-	8.8	91.0	0.2	100.0
Disc	1	Humahuaca	Pucara Tilcara	MEC	2134	-	3.6	96.4	0.0	100.0
Disc	1	Humahuaca	Pucara Tilcara	MEC	2136	-	3.1	96.5	0.4	100.0
Disc	1	Humahuaca	Pucara Tilcara	MEC	3600	-	2.4	97.6	0.0	100.0
Feminine figure	1	Humahuaca	Puerta de Juella	MLP	8777	-	2.0	49.5	48.5	100.0
Attachment (a pair)	1	Humahuaca	PV de Coctaca	MEC	3203b	-	1.5	98.5	0.0	100.0
Attachment (a pair)	1	Humahuaca	PV de Coctaca	MEC	3203a	-	1.5	98.5	0.0	100.0
Ring - band	1	Humahuaca	PV de la Cueva	ME	31.324	popm188	1.4	28.7	69.9	100.0
Bracelet - small	1	Humahuaca	PV de la Cueva	ME	31.323	popm185	0.9	28.8	70.2	100.0
Pendant - bird	1	Humahuaca	PV de la Cueva	ME	31.326	popm187	1.4	55.4	43.3	100.0
Ring - fragment	1	Humahuaca	PV de la Cueva	ME	31.325	popm186	1.1	59.0	39.9	100.0
Ring - band	1	Humahuaca	-	MLP	24412	-	1.1	49.1	49.8	100.0
Ring - band	1	Humahuaca	-	MLP	24413	-	1.1	49.3	49.6	100.0
Bell - with neck	1	Humahuaca	Sn Jose	MEC	3610	popm194	0.8	54.1	45.2	100.0
Bell - with bands	1	Humahuaca	Sn Jose	MEC	3609	popm193	0.9	54.1	45.1	100.0
Bell - with bands	1	Yungas	HuairaHuasi	MLP	25.733	popm168	0.2	4.5	95.3	100.0
Bell - with bands	1	Yungas	HuairaHuasi	MLP	25.732	popm167	0.5	17.1	82.4	100.0
Bell - with bands	1	Yungas	HuairaHuasi	MLP	25.734	popm169	1.0	52.1	46.9	100.0
Bell - with bands	1	Yungas	HuairaHuasi	MLP	25.735	popm170	1.4	52.3	46.3	100.0
Pendant - oval	1	Yungas	Pampa Grande	MLP	50188	popm166	5.8	25.0	69.3	100.0
Silver bar/ingot	1	Yungas	Titiconte	MEC	3051	-	8.6	90.9	0.5	100.0

Appendix Nº3: 11: Excavation reports with documented noble metals consulted in this thesis. Reports were written by R.P. Gustavo Le Paige, courtesy of the IIAM.

Cemetery	**Year of excavation**
Catarpe-2	1962
Coyo	1964
Coyo oriental	1964, 1975
Larache callejón	1958, 1960, 1961, 1965
Quitor-1	1961, 1964
Quitor-2	1961, 1962, 1965
Quitor-5	1962, 1963, 1964
Quitor-6	1962, 1964, 1965, 1975
Quitor-9	1963
Sequitor Alambrado Acequia	1960, 1961
Sequitor Alambrado Occidental	1974
Sequitor Alambrado Oriental	1961, 1975
Solor-3	1959, 1960, 1961
Tchilimoya	1966, 1972
Yaye-1	1961, 1964

Appendix Nº3: 12: Published radiocarbon dates for cemeteries with metals in SPA. After (6) Berenguer et al., 1986; (4) Costa-Junqueira & Llagostera, 1994; (2) Hubbe et al., 2011; (7) Llagostera et al., 1988; (3) Oakland, 1992; (5) Richardin et al., 2015; (8) Torres-Rouff, 2002; (1) Torres-Rouff & Hubbe, 2013.

Cemetery	Individual	Laboratory sample	Absolute date (Years BP)	Calibrated Date (2 sigma; calendric years)	Metallic evidence	Material dated	Reference
Casa Parroquial	6	AA87007	1067±44	880-1035 AD		human bone	1
Casa Parroquial	18	AA87008	1113±44	777-1017 AD	7 gold objects and fragments of a silver sheet.	human bone	1
Catarpe-2	1753	Beta-251747	1220±40	684-892 AD		human bone	2
Catarpe-2	1786	Beta-251748	750±40	1206-1380 AD		human bone	2
Catarpe-2	1801	Beta-251749	1030±40	896-1150 AD		human bone	2
Catarpe-2	1850	Beta-251750	770±40	1185-1290 AD		human bone	2
Coyo Oriental	4012	Beta-33853	1310±70	610-884 AD		bone	3
Coyo Oriental	4026	Beta-33854	1100±70	720-1118 AD		muscle, skin	3
Coyo Oriental	4064	Beta-33855	1310±80	583-937 AD		bone, muscle	3
Coyo Oriental	5341	Beta-33856	1320±60	610-868 AD	silver discs	textiles	3
Coyo Oriental	5347	Beta-33857	1155±80	689-1018 AD		textiles	3
Coyo Oriental	5383	Beta-33858	1430±60	430-758 AD		textiles	3
Coyo-3	17	Beta-44673	1030±80	777-1184 AD		textile	4
Coyo-3	5	Beta-44674	990±50	904-1165 AD		textile	4
Coyo-3	15	Beta-44675	1040±70	778-1161 AD		textile	4
Larache Callejón	5056	AA87013	1667±45	250-534 AD		human bone	2
Quitor-1	3487	AA87014	956±44	995-1169 AD		human bone	2
Quitor-1	1178	SacA-33290	1135±30	777-986 AD		wooden tray	5
Quitor-2	3684	AA87015	1491±46	429-649 AD		human bone	2
Quitor-2	3770	AA87016	1696±46	232-505 AD		human bone	2
Quitor-2	3716	Beta-251751	1520±40	426-618 AD		human bone	2
Quitor-2	3783	Beta-251752	1310±40	651-772 AD		human bone	2
Quitor-5	3394	AA87020	1623±46	333-548 AD		human bone	2
Quitor-5	2009	AA87018	1511±46	428-636 AD		human bone	2
Quitor-5	2179	AA87019	1338±45	620-770 AD		human bone	2
Quitor-5	1921	AA87017	1164±44	728-981 AD		human bone	2
Quitor-5	2077-2089	SacA-33785	1635±30	340-535 AD	Copper: 1 mace, 2 bracelets	wooden tray	5
Quitor-5	2163	SacA-33696	1150±30	776-971 AD		wooden tray	5
Quitor-5	3397	Q5-3397	1750±80	76-527 AD			6
Quitor-5	ns	Quitor-5ns	1715±80	128-535 AD			6
Quitor-6	2529	Beta-263467	1050±40	891-1036 AD		human bone	2
Quitor-6	2588	Beta-263468	1290±40	652-861 AD		human bone	2
Quitor-6	2928	Beta-263469	1180±40	720-970 AD		human bone	2
Quitor-6	3633	Beta-263470	1490±40	430-648 AD		human bone	2
Quitor-6	2509	SacA-33697	1845±30	85-239 AD		wooden tray	5
Quitor-6	ns	Quitor-6ns	1700±150	20-642 AD			6
Quitor-6	35	Beta-11027	710±70	1186-1405 AD		wood	6
Quitor-6	2532	Quitor-62532	1700±150	20-642 AD	1 copper headdress	wood	7
Quitor-9	3251	AA87022	1068±44	879-1035 AD		human bone	2
Quitor-9	ns	Quitor-9_ns	900±80	997-1267 AD			6
Sequitor Al.	1062	Beta-251745	1600±40	383-557 AD		human bone	2
Sequitor Al.	1068	Beta-251746	1680±40	245-506 AD		human bone	2
Sequitor Al.	533	Beta-263471	1430±40	558-663 AD		human bone	2
Sequitor Al.	1043	Beta-263472	1630±40	338-539 AD		human bone	2
Sequitor Al.	5203-05	SacA-33292	1590±30	406-542 AD		wooden tray	5
Sequitor Al.	1702	SacA-33686	1525±30	428-604 AD	1 tray with gold inlay	wooden tray	5
Solcor Plaza	759	AA87023	1535±45	418-611 AD		human bone	2
Solcor Plaza	1241	AA87024	987±44	981-1160 AD		human bone	2
Solcor-3	107-13118	Sc3107_04	1220±60	669-961 AD	1 tube wrapped with a gold sheet and 19 copper folded-bells		8
Solcor-3	113-13120	Sc3_107_05	1380±60	553-770 AD			8
Solcor-3	107-13156	Sc3_107_06	1470±60	428-660 AD			8
Solor-3	983	AA87026	1616±46	338-550 AD		human bone	2
Solor-3	991	AA87027	1859±47	52-317 AD		human bone	2
Yaye-1	5494	Beta-251755	920±40	1026-1206 AD		human bone	2
Yaye-1	5498	Beta-251756	1100±40	778-1022 AD		human bone	2

Appendix Nº3: 13: Presence/absence of local pottery in burials with gold or silver

Cemetery	Individual	NP	NcP	RP	Other local	Gold obj	Silver obj
Casa Parroquial	2				x		1
Casa Parroquial	3				x	1	3
Casa Parroquial	5				x		1
Casa Parroquial	7			x		5	1
Casa Parroquial	8		x		x	2	
Casa Parroquial	13		x		x	1	
Casa Parroquial	22			x		2	
Catarpe-2	1777		x	x	x		1
Coyo oriental	4111		x			1	
Coyo oriental	5341		x				1
Coyo oriental	5322-25				x		3
Larache (callejón)	356			x		18	
Larache (callejón)	1713-14	x				8	
Larache (rescate)	6	x			x	4	
Larache (rescate)	8	x			x	22	
Larache (rescate)	13	x	x	x		13	
Larache (rescate)	15	x	x	x		2	
Quitor-1	889				x		8
Quitor-1	890				x		1
Quitor-1	899				x	1	
Quitor-1	905				x	1	
Quitor-2	3706-07				x		10
Quitor-5	1994-96	x			x	1	
Quitor-5	2003-10	x			x	1	
Quitor-5	2047-76	x			x	1	
Quitor-5	2094-2108	x			x	1	
Quitor-6	2565	x				1	
Quitor-6	3582		x			1	
Quitor-6	2442-47	x			x	1	
Quitor-9	3236-37				x		2
Seq Al acequia	767	x				1	
Seq Al acequia	710-757			x	x	1	
Seq Al occidental	5216	x				1	
Seq Al oriental	1660	x				1	
Seq Al oriental	1702	x				1	
Seq Al oriental	1300-03				x	1	
Solor-3	nn_04	x				3	
Tchilimoya	4866	x			x		90
Total	***38***					***97***	***122***
%	***52***					***55***	***77***

Appendix Nº3: 14: Presence/absence of foreign objects in burials with gold or silver

Cemetery	Individual	Tw objects	Aguada objects	Other objects	Gold obj	Silver obj
Coyo oriental	5340	x				1
Coyo oriental	5341	x				1
Larache (callejón)	356	x			18	
Quitor-5	2047-76	x			1	
Quitor-9	3236-37	x		x		2
Yaye-1	1419	x			1	
Yaye-1	3706-07	x				10
Coyo-3	13363		x			1
Solcor-3	107		x		1	
Quitor-1	889			x		8
Total	***10***				***21***	***23***
%	***14***				***12***	***15***

Appendix Nº3: 15: Snuffing implements in burials with gold or silver

Cemetery	Individual	tablet	tube	mortar	pestle	spatula	spoon	*Total*	Gold obj	Silver obj
Casa Parroquial	5		1					*1*		1
Casa Parroquial	18		1					*1*	7	1
Catarpe-2	1777	1	1			1	3	*6*		1
Coyo Oriente	5340	1						*1*		1
Coyo Oriente	5341		2	1	1	3	3	*10*		1
Larache (rescate)	8		2					*2*	22	
Quitor-2	3706-07	1	1	1	1			*4*		10
Quitor-5	1994-96		2			1		*3*	1	
Quitor-5	2003-10	1	3		2		4	*10*	2	
Quitor-5	2047-76	2	3				3	*8*	1	
Quitor-6	2565			1			1	*2*	1	
Quitor-6	3582	2	1	1				*4*	1	
Quitor-6	2442-47	2	5	3	2		1	*13*	1	
Quitor-6	2482-90	1		1			2	*4*	1	
Quitor-9	3236-37	2	2	1	1	2	1	*9*		2
Seq Al Ac	767	2	1				3	*6*	1	
Seq Al Oc	5216					1		*2*	1	
Seq Al Or	1660	1	2			1		*4*	1	
Seq Al Or	1702	1	1					*2*	1	
Seq Al Or	1300-03	2	1			1		*4*	1	
Solcor Plaza	1393	1				2	1	*4*	1	
Solor-3	487		1					*1*	1	
Tchilimoya	4866	1				1	1	*3*		90
Total	***23***	***21***	***30***	***9***	***7***	***13***	***23***	***104***	***44***	***107***
%	***32***								***25***	***68***

Appendix Nº3: 16: Axes in burials with gold or silver

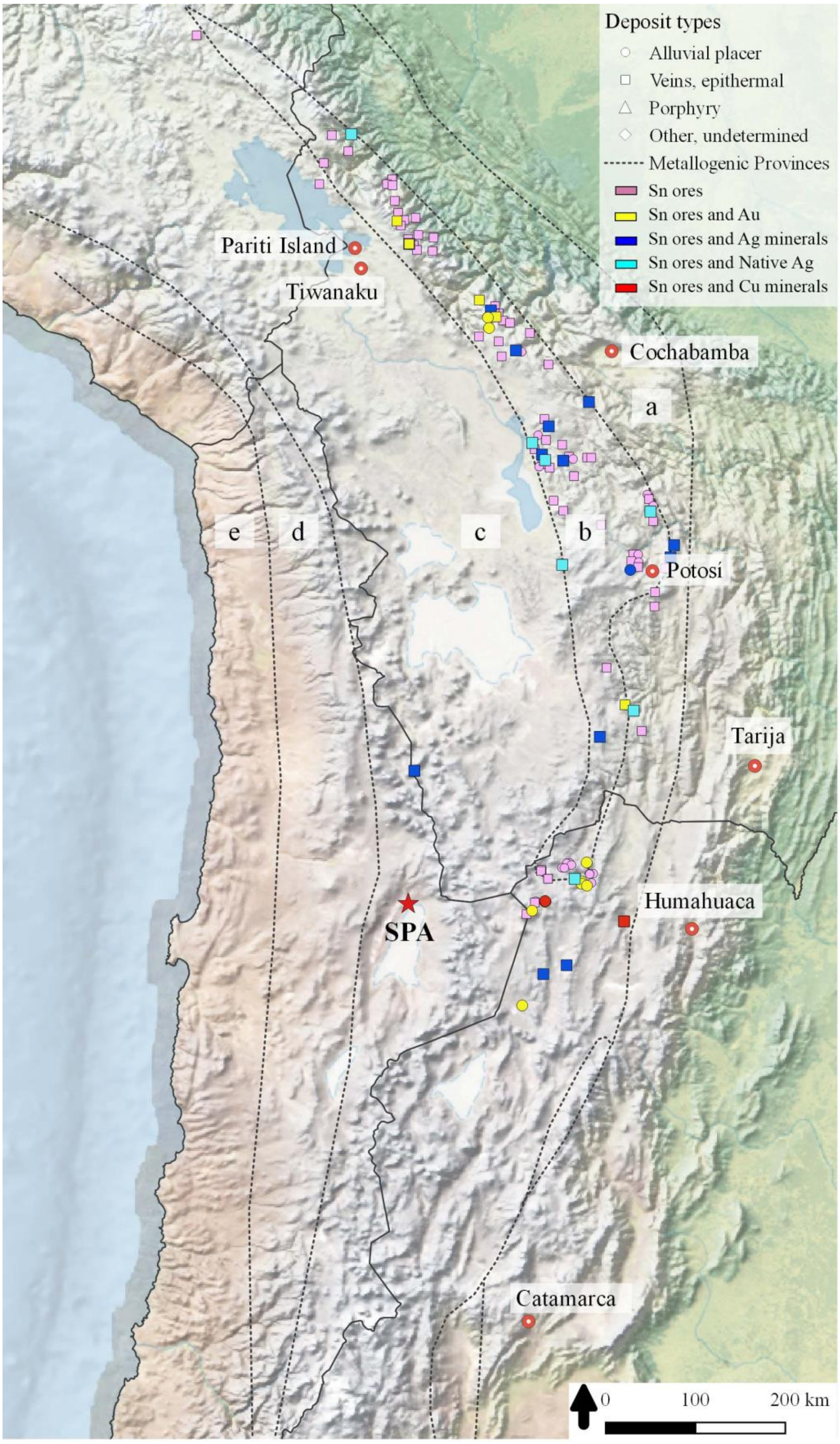
Cemetery	Individual	Lithic	Copper	Gold	Bone	Unknown metal	Not specified	*Total*	Gold obj	Silver obj
Casa Parroquial	13		1					*1*	1	
Casa Parroquial	18			1				*1*	7	1
Casa Parroquial	22		1					*1*	2	
Catarpe-2	1777						1	*1*		1
Larache (callejón)	358		1	1		1		*3*	18	
Quitor-2	3706-07				1			*1*		10
Quitor-5	1994-96		1					*1*	1	
Quitor-5	2047-76		1					*1*	1	
Quitor-6	2442-47	2						*2*	1	
Seq Al Ac	710-757	6						*6*	1	
Seq Al Oc	5216	1	1					*2*	1	
Solor-3	487		1					*1*	1	
Total	***12***	***9***	***7***	***2***	***1***	***1***	***1***	***21***	***34***	***12***
%	***16***								***19***	***8***

Appendix Nº3: 17: Goblets in burials with gold or silver

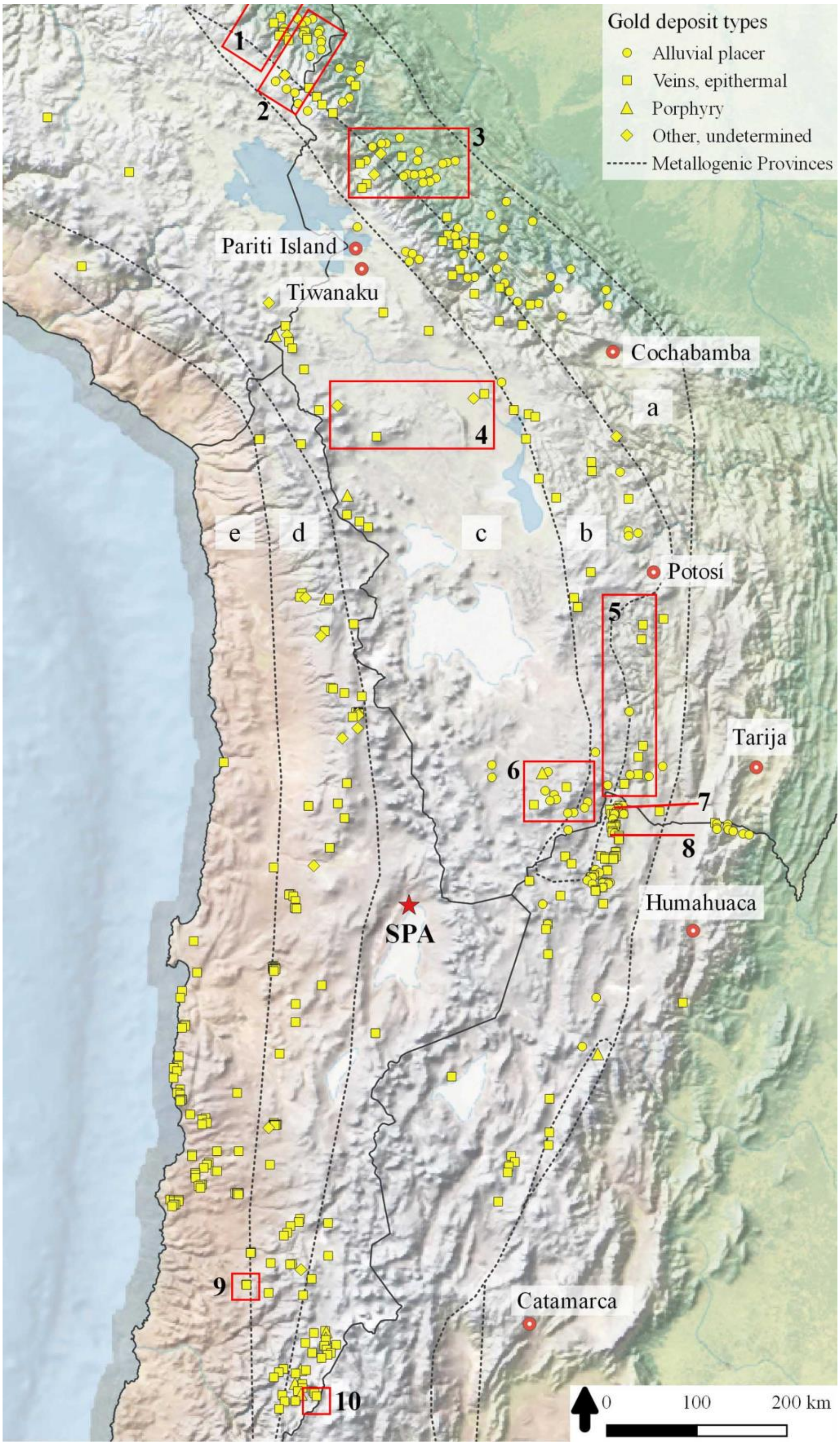
Cemetery	Individual	Gold	Silver	Pottery	Wood	*Total*	Gold obj	Silver obj
Casa Parroquial	1	1				*1*	1	1
Casa Parroquial	18	2				*2*	7	1
Larache (callejón)	358	3				*3*	18	
Quitor-5	2047-76				1	*1*	1	
Quitor-9	3236-37		1		1	*2*		2
Solcor-3	107			1		*1*	1	
Total	***6***	***6***	***1***	***1***	***2***	***10***		
%	***8***							

Appendix nº4. Metallurgical maps

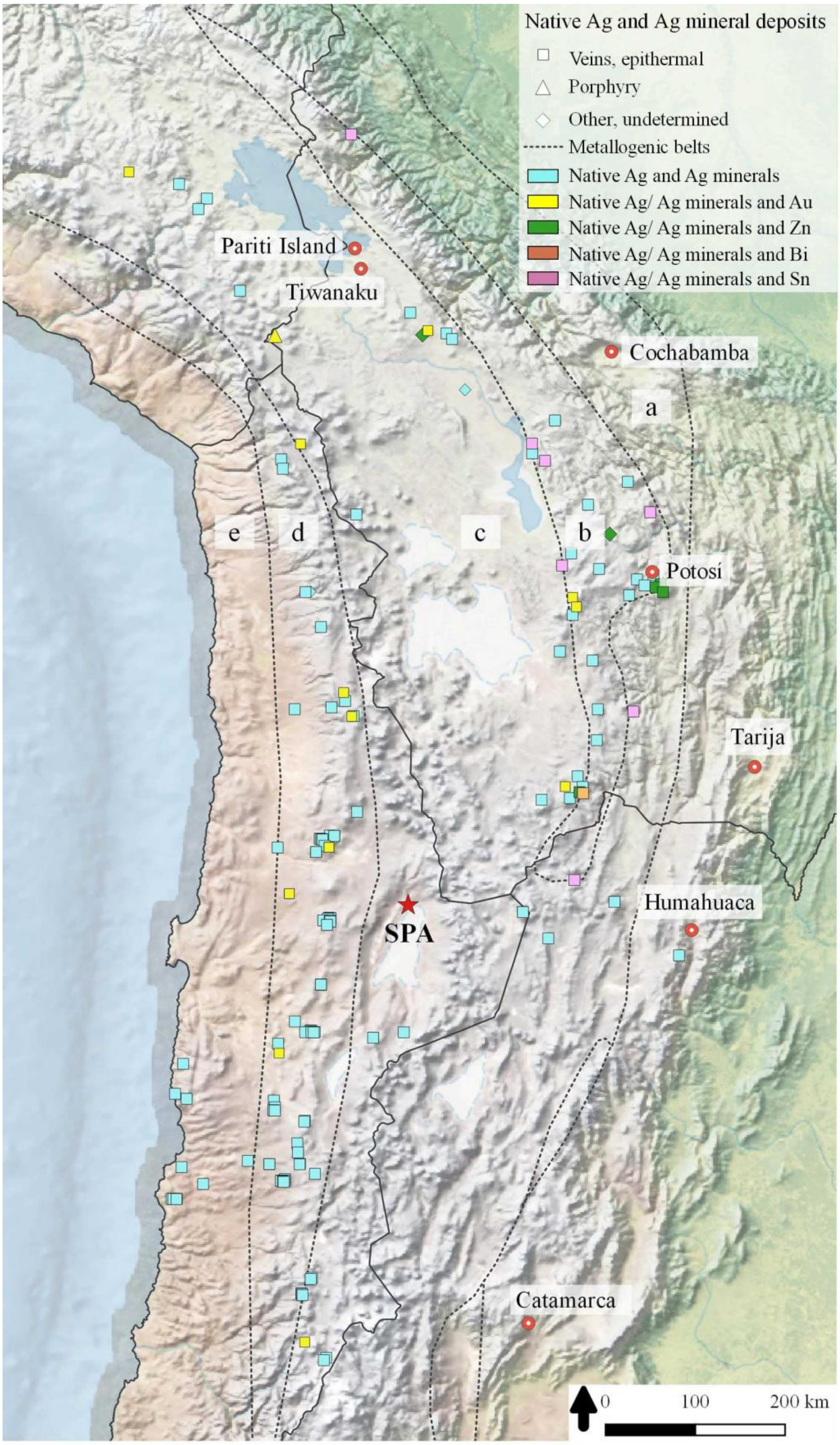
Appendix Nº4: 1: Tin ores deposits. Distribution and other metals associated.



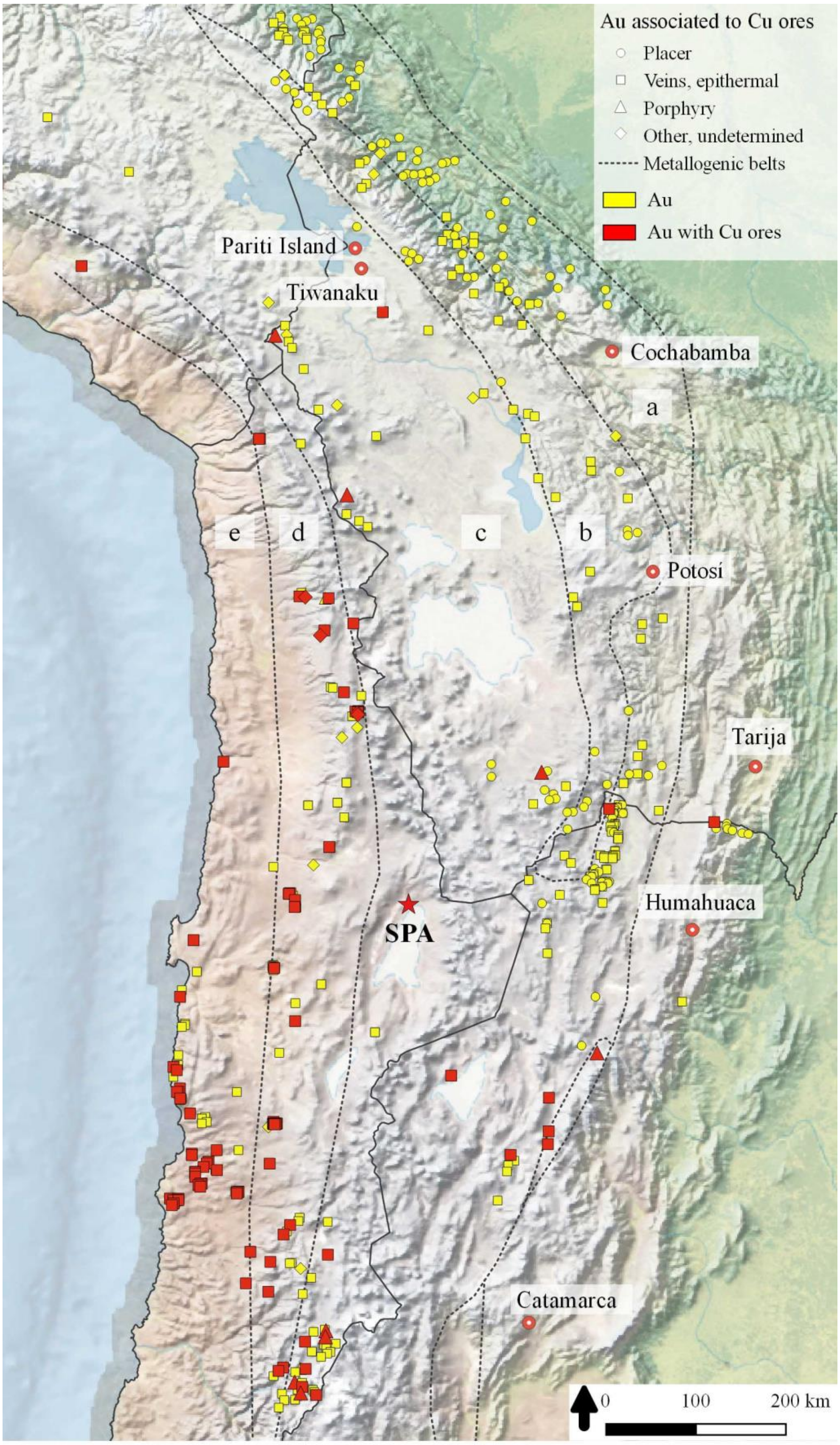
Appendix Nº4: 2: Gold deposits. Areas with analysed gold samples. Mineral districts: 1-Carabaya; 2-Sandia-Vestamayo; 3- Yani-Tipuani-Mapiri; 4- La Joya; 5-Eastern Cordillera, Sb-Au deposits; 6- Sud Lipez (Vilander); 7-Eureka-Casa Blanca; 8-Rinconada-Colquimayo; 9-San Pedro de Cachiyuyo-La Coipa; 10-Cerro Casale.



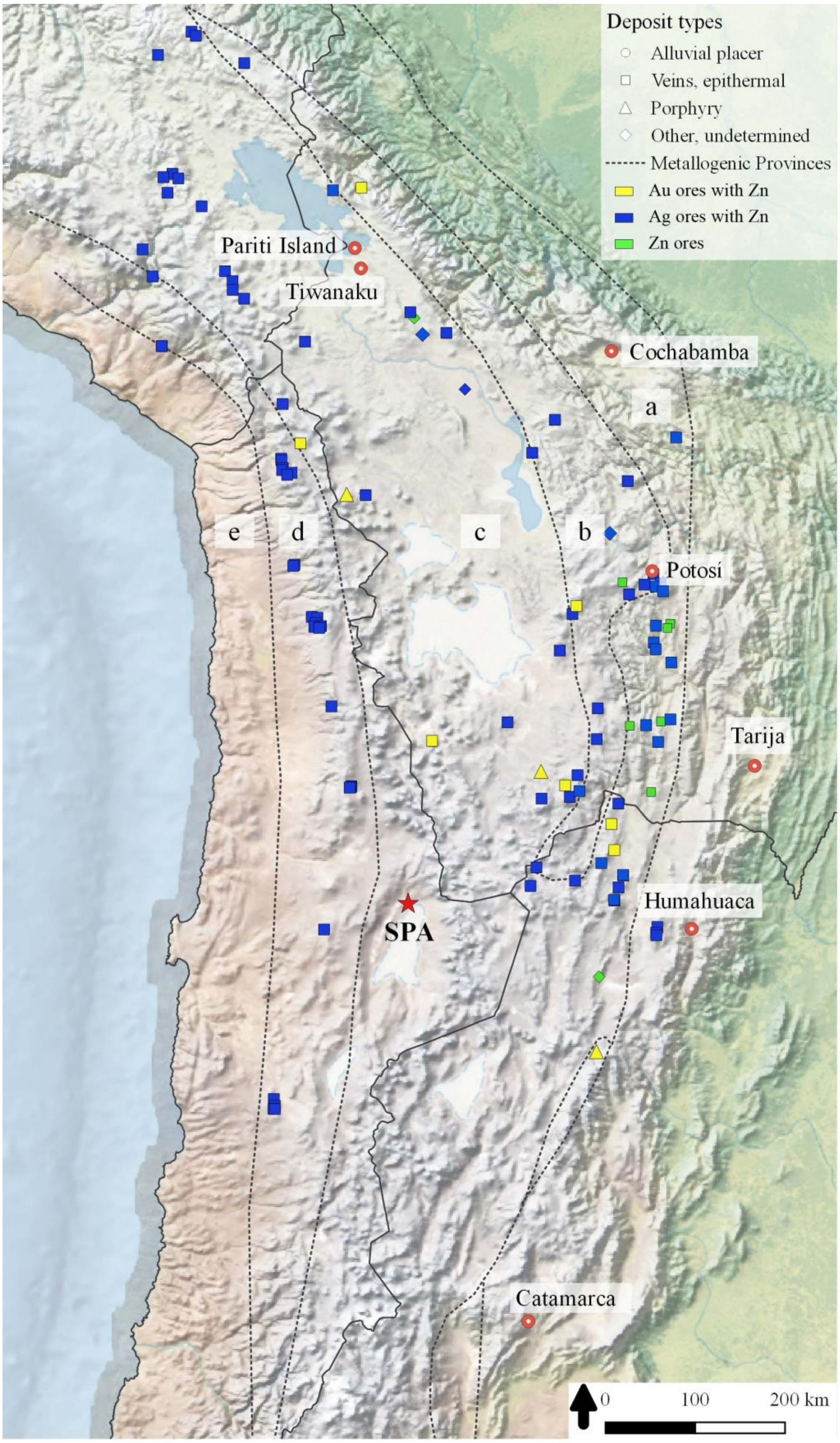
Appendix Nº4: 3: Native silver and silver mineral deposits associated with gold, zinc, bismuth and tin minerals.



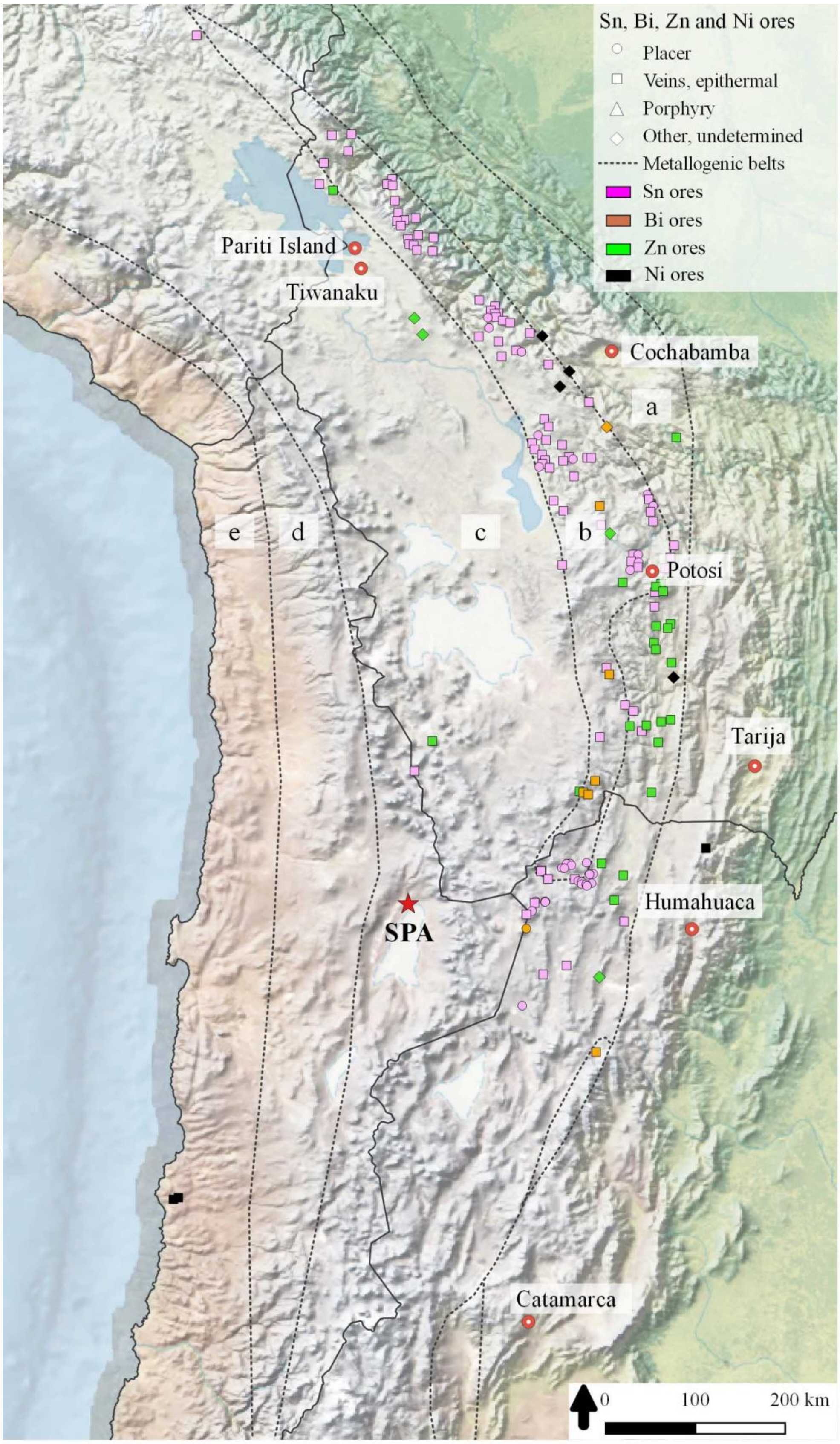
Appendix Nº4: 4: Gold deposits associated with copper ores.



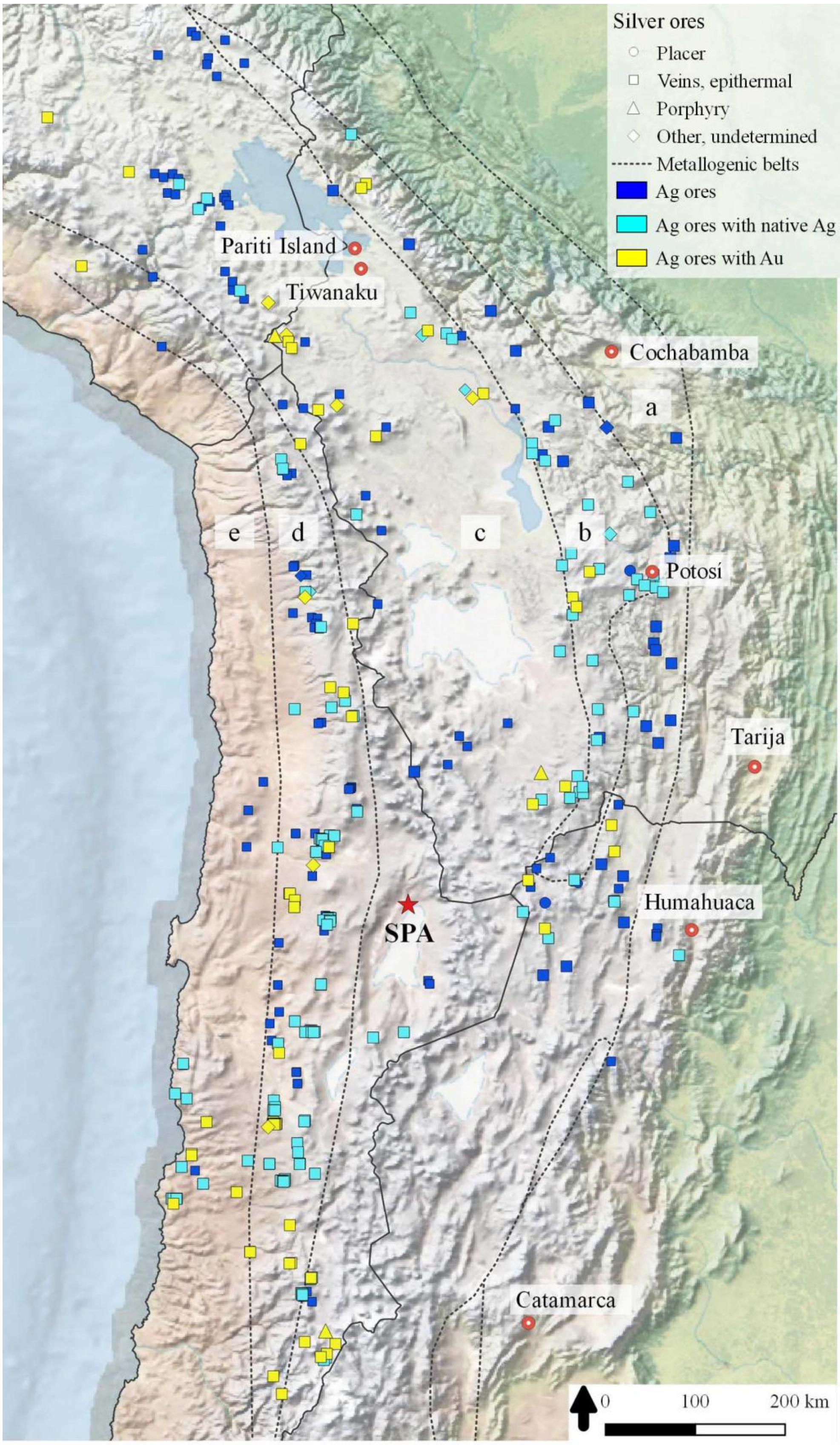
Appendix Nº4: 5: Zinc. Map showing gold (yellow) and silver (blue) deposits associated with zinc minerals, and zinc ores (green).



Appendix Nº4: 6: Tin, bismuth, zinc and nickel mineral deposits.



Appendix Nº4: 7: Silver ores. Deposits associated with native silver, silver halides and gold.

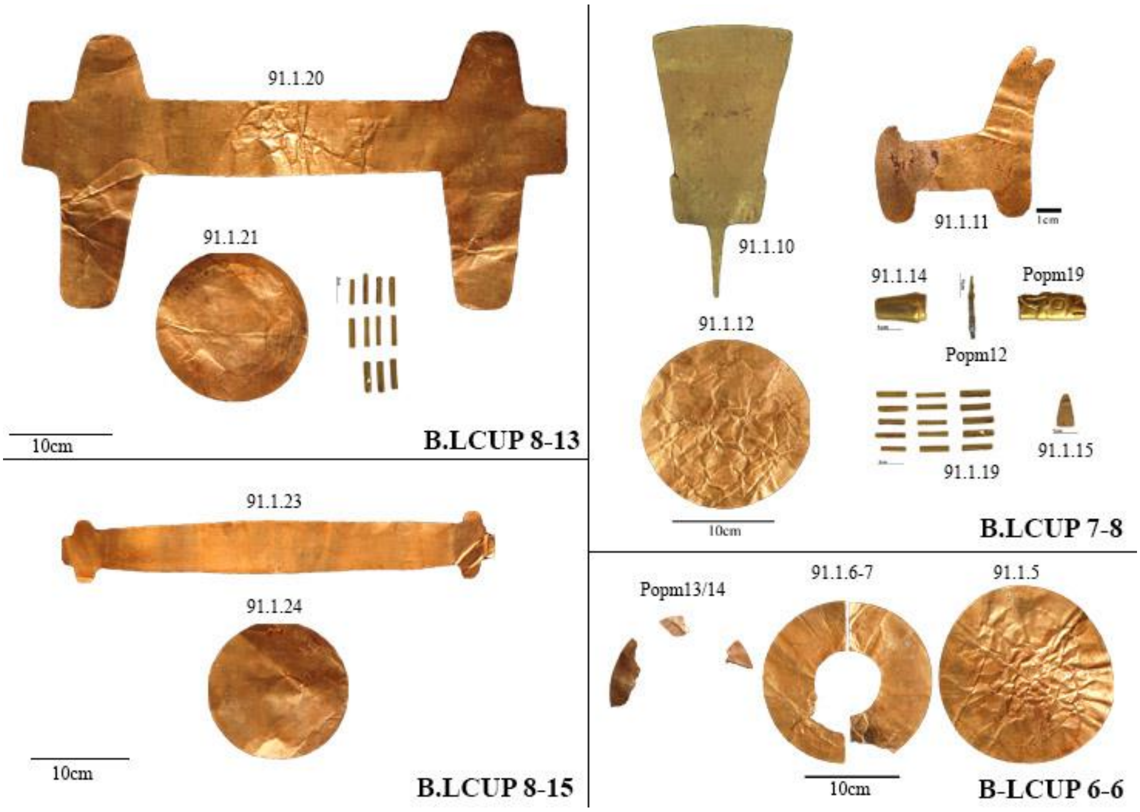


Appendix nº5. Objects analysed, organised by burial

Appendix Nº5: 1: Noble metal grave goods from Casa Parroquial, organised by burial. Numbers given are the "popm" code number; and burials are in bold indicated with a B.

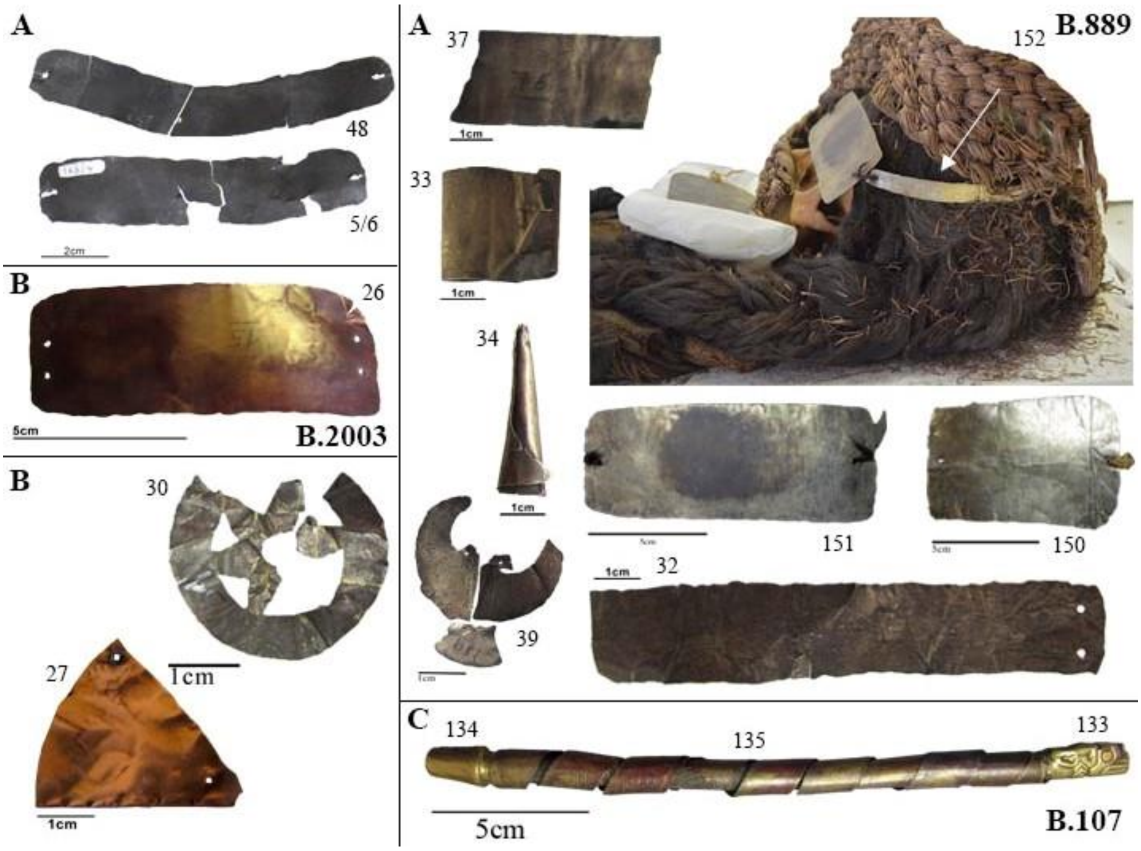
Appendix Nº5: 2 Noble metal grave goods from Larache (Callejón, excavated in 1960), organised by burial. Numbers given are the "popm" code number; and burials are in bold indicated with a B.

Appendix Nº5: 3: Noble metal grave goods from Larache (Rescate, excavated in 1989), organised by burial. Only three of these objects were analysed. Numbers are the original excavation codes, except those analysed (with the "popm" code). Burials are in bold indicated with a B.



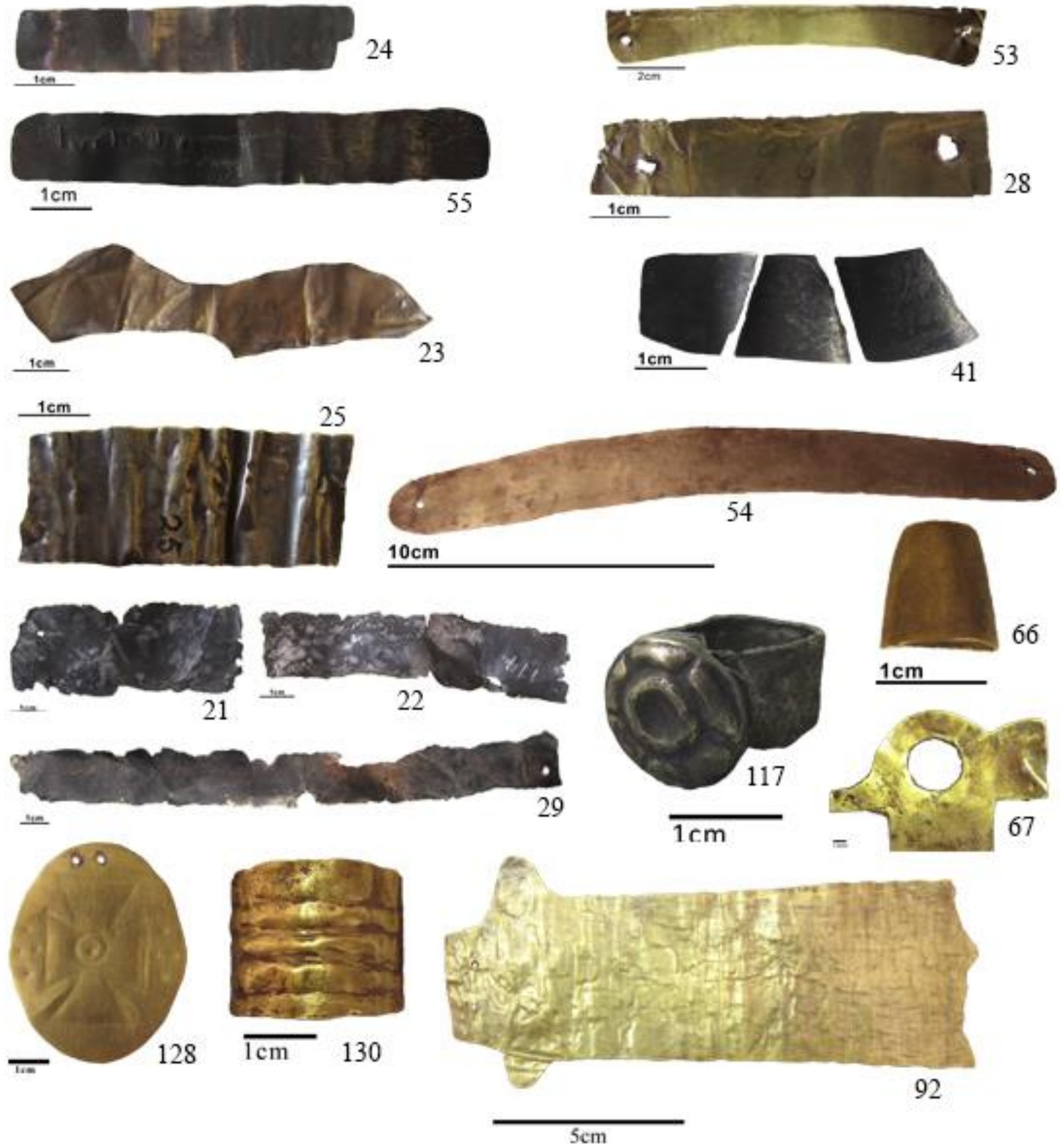
Appendix Nº5: 4: Noble metal grave goods from Coyo-3, organised by burial. Numbers given are the "popm" code number; and burials are in bold indicated with a B.

Appendix Nº5: 5: Noble metal grave goods from (A) Quitor-1, (B) Quitor-5 and (C) Solcor-3, organised by burial. Numbers given are the "popm" code number; and burials are in bold indicated with a B.



Appendix Nº5: 6: Noble metal grave goods from Sequitor Alambrado, organised by burial. Numbers given are the "popm" code number; and burials are in bold indicated with a B.

Appendix Nº5: 7: Noble metal grave goods of uncertain cemetery. Numbers given are the "popm" code number.



Appendix nº6. Typology of gold objects found in SPA

1. *Attachments* (Figure 1)*:* This type includes all metallic sheets that, in spite of their shape and size, have more than one perforation (usually 2 or 4). In this case, it has been assumed that the perforations were made to attach these sheets to other support, such as textiles. Their orientation in the support is not certain.

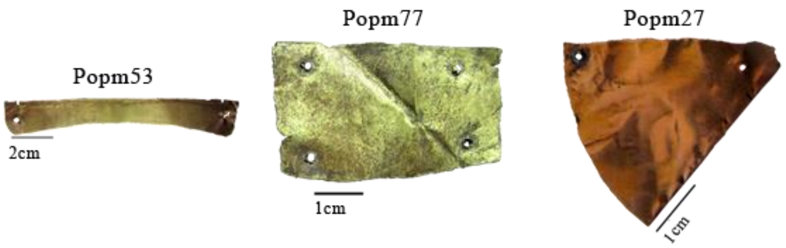


Figure 1: Attachments

2. *Pendants* (Figure 2): Include all metallic sheets that, in spite of their shape and size, have one or two perforations at one end, giving clear indication of the orientation of their use. It has been assumed that the sheet was hanged from- or attached to- another support.

Figure 2: Pendants

3. *Headbands* (Figure 3): Include long bands made to surround the head, cover eyes or face. They are usually perforated at both ends and were used horizontally.

Figure 3: Headbands

4. *Headdresses* (Figure 4): Also called "feathers", are elongated sheets used vertically on the head and typically associated to headbands. There are two main types: with and without appendix. The most common is the first type, composed of a body and a pointy appendix. The appendix is thick and it is hammered make it pointy. The body is made by expanding and hammering the appendix, achieving an elongated thin section. It may vary in shape and can be decorated. The second type are flat sheets, shaped with different designs, with one end narrower than the other.

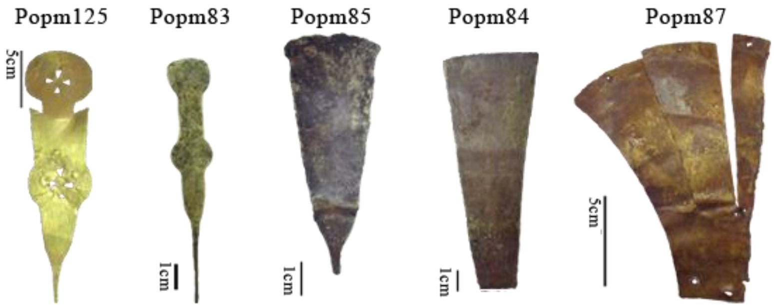


Figure 4: Headdresses

5. *Bracelets* (Figure 5): Include rectangular sheets that are bent forming a cylinder. The ends may be or not perforated.

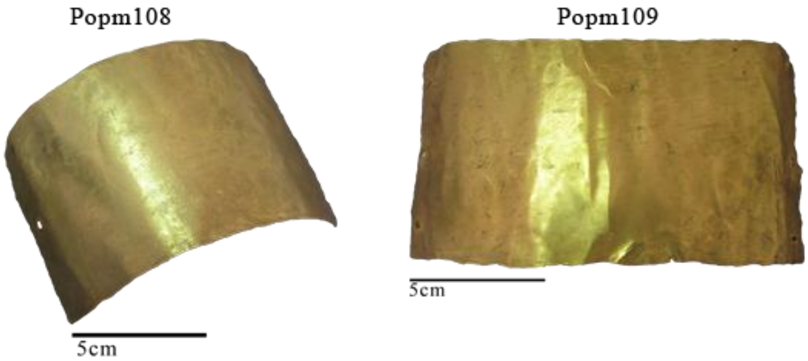


Figure 5: Bracelets

6. *Beads* (Figure 6): Include two sub-types: a) small sheets with a central perforation or b) items made by bent sheets, such as tubes. They are small in size and usually many in number.
7. *Rings* (Figure 6): Include two sub-types: a) band rings and b) wire rings. The former are wide bands that were bent forming shallow cylinders; the latter are made of wires of circular or sub-circular section also bent. In both cases are open rings, i.e. the ends are not closed or soldered together. They can be decorated by treating the band or attaching an appliquéd.

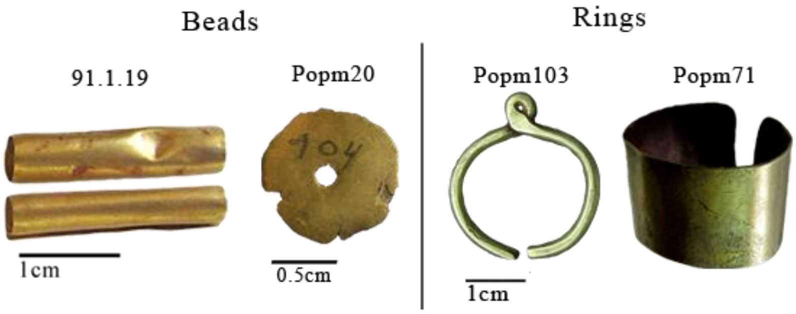


Figure 6: Beads and rings

8. *Bands* (Figure 7): include elongated sheets of small size and without perforations. Their use is uncertain. Some of them look like band rings that were flattened.

Figure 7: Bands

9. *Inhalation tubes* (Figure 8): Wooden inhalation tubes are commonly found in SPA; however examples wrapped in gold sheets are very unusual. Five parts of two tubes are found in SPA: Two distal tips, which are in contact with the substance to be consumed, both representing a feline head; two proximal tips, which are in contact the mouth or nose of the individual, these are conic in shape and plain in design; and one sheet wrapping the body, which was decorated with feline faces.

Figure 8: Inhalation tube

10. *Bells* (Figure 9): There are two sub-types of bells: a) a conic bell made by a rolled sheet, forming a cone; and b) bells of conic frustum shape, which are small metal caps -similar to a thimble- with a perforation on the base. It is widely accepted that these items were musical instruments that produce sound when they were tight together and crashed (Gudemos, 2013; Gudemos & Casanova, 1998). However, their use is still not completely clear, in some areas of the *Altiplano* similar artefacts are used as hair decoration or to mark the ears of the *llamas* (Carolina Rivet, *pers. comm.* 2015).

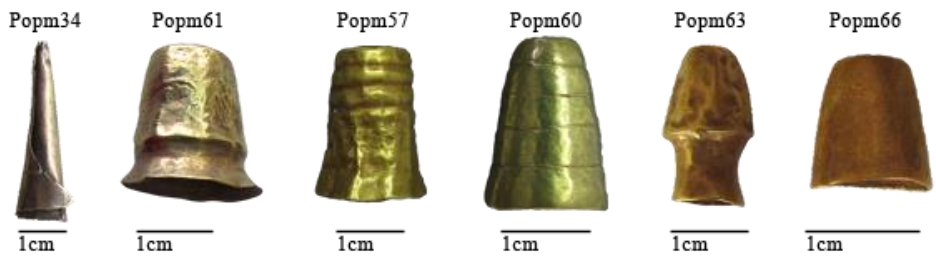


Figure 9: Bells

11. *Goblets* (Figure 10): The goblets include two sub-types as well: a) *keros* and b) portrait-vessels. Both types are drinking goblets where fermented drinks were served and consumed during feasts and ceremonies. The *keros* are the emblematic Tiwanaku style goblet of hyperboloid form, wide rims and single or double torus. The portrait vessels are cups with modelled human faces, usually with unique designs representing different people (Janusek 2003).

Figure 10: Goblets: keros popm136 and popm140, portrait-vessel popm138

12. *Miniature jug* (Figure 11)
13. *Axes* (Figure 11)

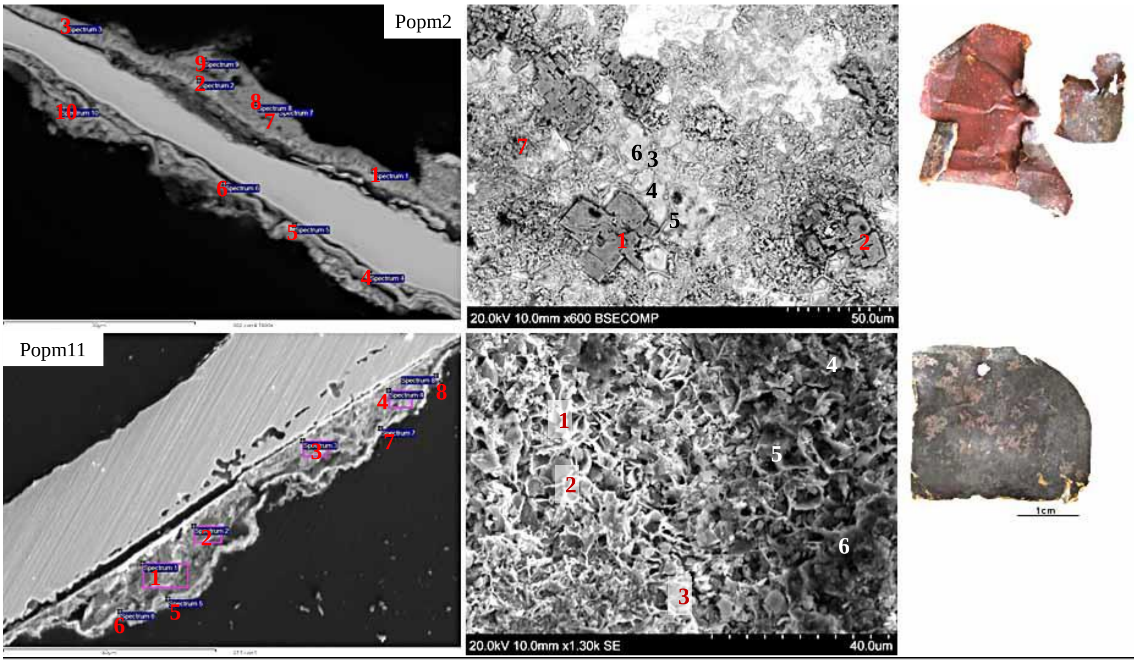
Figure 174: Axes and the miniature jug

Appendix nº7. Corrosion

Figure 1: BSE images of the red layer in cross-section and from the surface, by SEM-EDS. Numbers show the points analysed. Results in table are normalised to a 100%, although analytical totals are given. In the case of surface analysis, figures are only qualitative, given that surfaces were not prepared.

Red corrosion

Cross section — Surface



Composition of the red corrosion by SEM-EDS (wt%)																	
Lab Id	**Area**	**Point**	**C**	**O**	**Na**	**Mg**	**Al**	**Si**	**S**	**Cl**	**Ca**	**Ti**	**Fe**	**Ag**	**Au**	**Pb**	**An total**
Popm2	cross-section	1	-	11.7	-	-	-	0.6	**9.1**	**3.1**	-	-	-	31.9	43.7	-	91.5
		2	-	4.1	-	-	-	-	**9.7**	**1.8**	-	-	-	37.5	46.9	-	96.5
		3	-	11.3	-	-	-	-	**8.1**	**0.8**	-	-	-	36.8	43.0	-	100.3
		4	-	3.7	-	-	-	-	**3.7**	**0.4**	-	-	-	34.5	57.8	-	57.9
		5	-	2.1	-	-	-	-	**3.8**	**0.3**	-	-	-	33.6	60.2	-	75.5
		6	-	6.7	-	-	-	0.5	**3.5**	**4.2**	-	-	-	58.8	26.4	-	67.0
		7	-	1.6	-	0.3	-	1.2	-	**7.6**	-	-	-	88.2	1.1	-	92.7
		8	-	6.9	-	-	-	-	**0.9**	**6.8**	-	-	-	79.0	5.9	0.6	98.4
		9	-	4.8	-	0.3	-	-	-	**6.3**	-	-	-	87.6	1.1	-	100.1
		10	-	6.2	-	0.3	-	-	-	**12.1**	-	-	-	80.6	0.7	-	73.5
	surface	1	12.6	-	-	-	-	-	-	**14.4**	-	-	-	73.1	-	-	103.8
		2	7.1	-	-	-	-	-	-	**12.6**	-	-	-	80.3	-	-	96.2
		3	10.1	3.1					**7.3**	**3.5**				36.2	39.7		83.7
		4	10.7	2.0	-	-	-	-	**6.6**	**5.1**	-	-	-	39.6	35.9	-	100.8
		5	8.0	-	-	-	-	-	**5.7**	**5.1**	-	-	-	47.0	34.2	-	91.9
		6	9.6	-	-	-	-	-	**6.5**	**3.9**	-	-	-	43.1	36.9	-	97.9
		7	13.7	6.8	0.5	-	-	-	**2.9**	**6.4**	-	-	-	52.1	17.6	-	124.6
Popm11	cross-section	1	-	37.4	0.8	0.5	2.7	10.0	**5.7**	-	0.2	1.5	0.5	37.7	2.9	-	108.5
		2	-	36.0	-	0.5	1.5	9.8	**5.7**	**0.2**	0.4	1.7	1.0	36.1	7.0	-	100.0
		3	-	22.1	0.3	0.7	2.0	4.2	**7.8**	**0.2**	0.6	-	0.8	45.4	15.9	-	103.1
		4	-	17.5	-	0.4	1.3	3.6	**8.4**	-	0.4	-	0.5	45.2	22.7	-	94.8
		5	-	10.0	-	-	0.7	1.4	**10.9**	**0.2**	-	-	-	51.8	25.1	-	96.5
		6	-	18.7	-	-	1.8	3.4	**9.0**	-	-	0.5	-	50.1	16.5	-	95.7
		7	-	17.6	-	0.3	2.0	4.1	**9.0**	**0.2**	-	0.2	0.4	47.2	19.0	-	86.8
		8	-	14.7	-	-	1.1	0.7	**7.8**	**0.2**	-	-	-	52.5	23.1	-	82.3
	surface	1	6.5	-	-	-	0.4	0.5	**11.2**	**0.8**	0.6	-	-	49.0	31.1	-	102.0
		2	1.8	-	-	-	-	-	**12.0**	**0.6**	0.5	-	-	52.3	32.7	-	88.1
		3	5.5	-	-	-	-	-	**12.0**	**0.6**	0.9	-	-	50.2	30.9	-	89.4
		4	19.8	-	0.6	0.4	0.9	1.7	**9.3**	**0.6**	2.8	-	-	40.0	24.0	-	92.2
		5	35.4	-	1.1	0.4	2.3	3.9	**6.4**	**0.6**	3.7	-	1.0	30.8	14.4	-	106.3
		6	24.3	-	-	0.3	0.6	0.7	**5.6**	**0.9**	3.3	-	-	50.2	14.0	-	110.1

Figure 2: XRD pattern of the red surface in samples popm1 and popm47. I thanks Diego Gómez, from the XRD Laboratory in the Universidad de los Andes, Bogotá, Colombia, who provided the interpretation of the patterns.

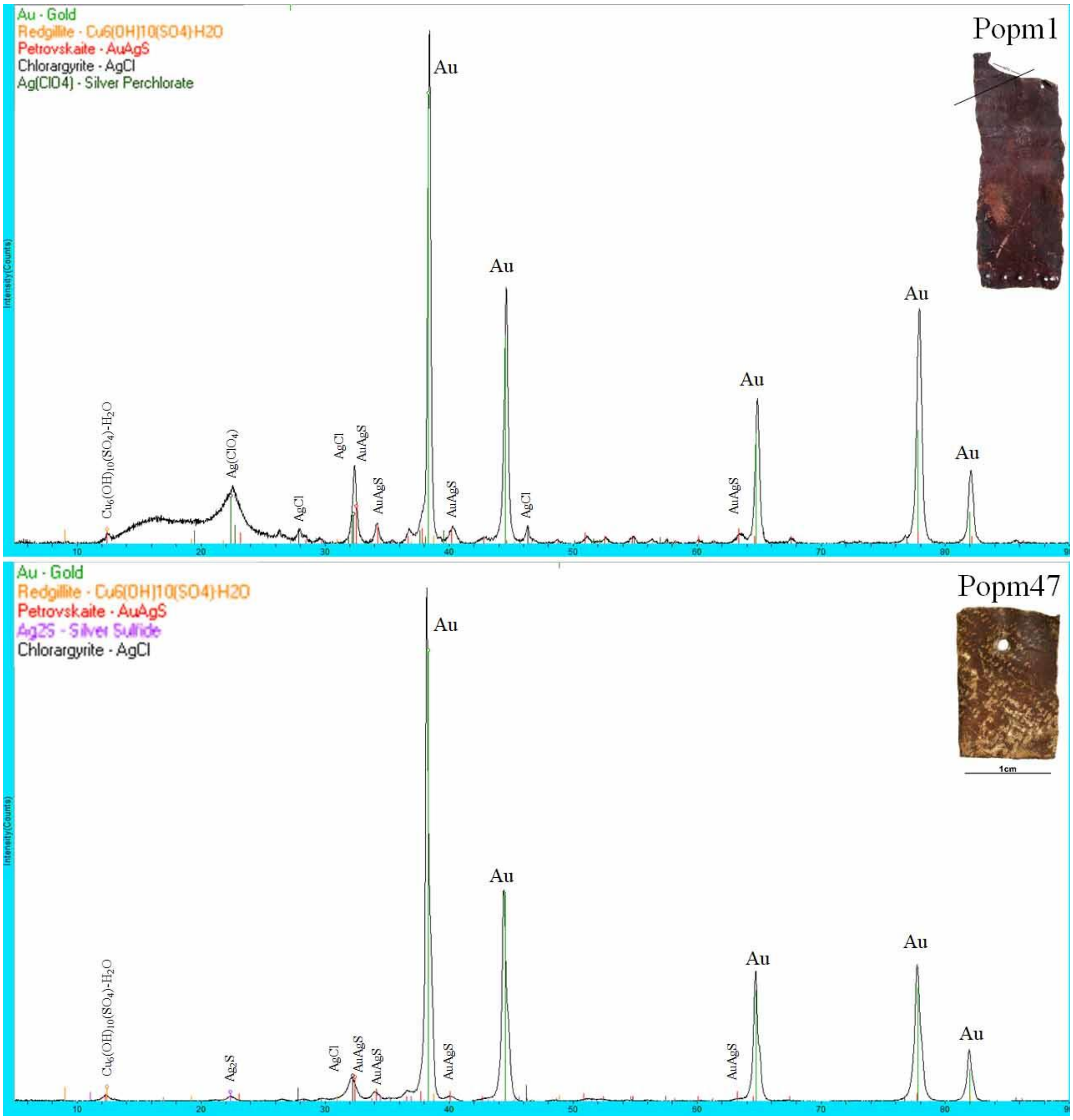
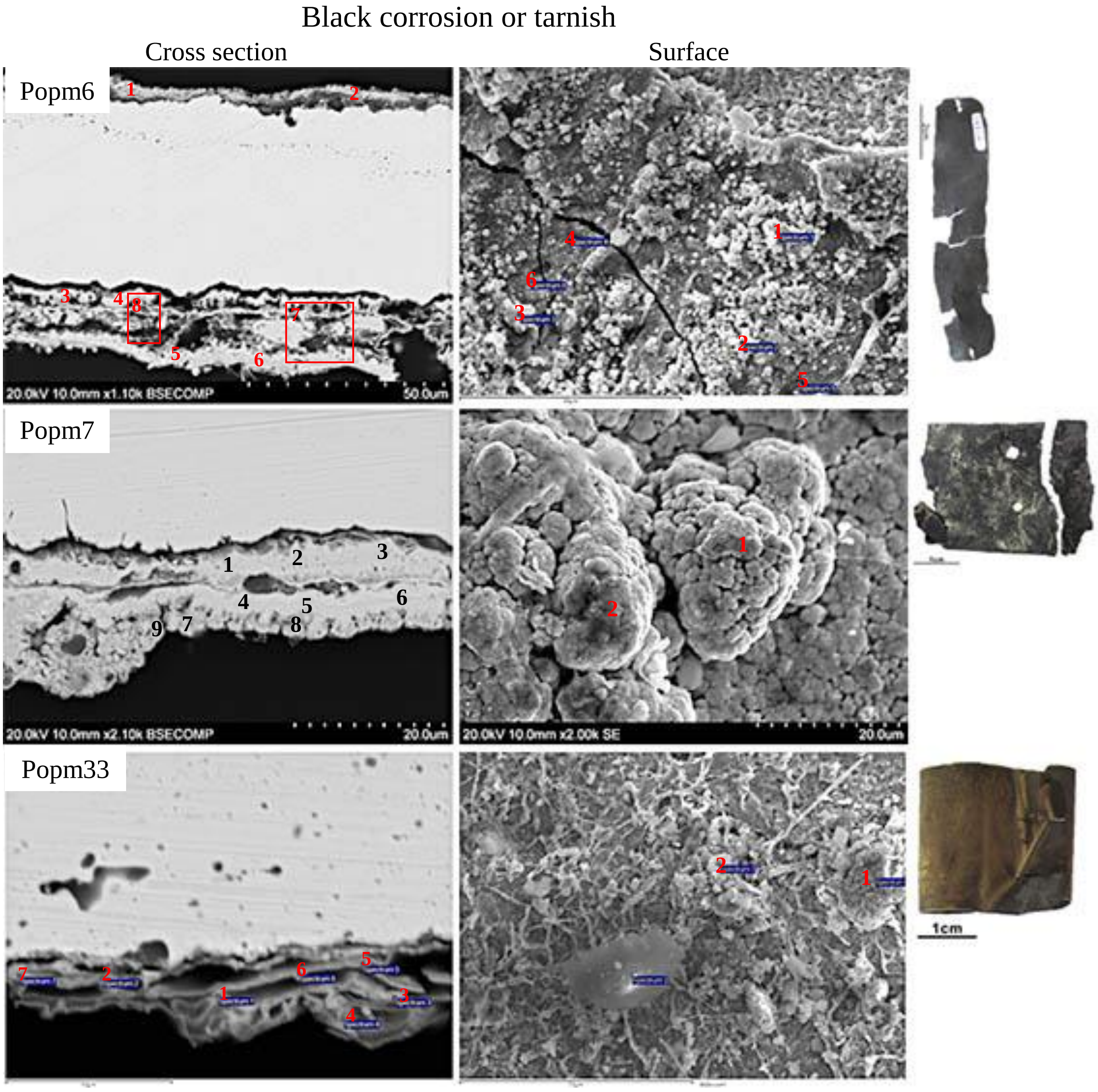


Figure 3: BSE images of the black layer in cross-section and from the surface, by SEM-EDS. Numbers show the points analysed. Results in table are normalised to a 100%, although analytical totals are given. In the case of surface analysis, figures are only qualitative, given that surfaces were not prepared.



Lab Id	Area	Point	C	O	Na	Mg	Al	Si	S	Cl	K	Ca	Ti	Fe	Cu	Ag	I	Au	Analytical total
						omposition of the black corrosion by SEM-EDS (wt%)													
Popm6	cross-section	1	-	7.3	-	-	-	-	**10.4**	-	-	-	-	-	-	54.5	-	27.8	82.6
		2	-	10.7	-	-	0.4	0.5	**10.2**	-	-	-	-	-	-	51.7	-	26.5	84.4
		3	-	8.0	-	-	-	-	**10.4**	-	-	-	-	-	-	51.2	1.6	28.7	97.8
		4	-	5.4	-	-	0.4	0.6	**10.2**	-	-	-	-	-	-	52.1	1.9	29.5	99.7
		5	-	4.4	-	-	0.4	-	**10.4**	-	-	-	-	-	0.8	56.7	-	27.3	101.3
		6	-	2.9	-	-	0.3	-	**11.2**	-	-	-	-	-	-	56.0	-	29.6	94.7
		7	-	24.5	-	-	1.4	1.0	**7.9**	-	-	2.9	-	-	-	40.4	1.2	20.7	78.8
		8	-	26.3	-	-	2.9	0.6	**7.9**	-	-	1.1	-	-	-	39.4	-	21.8	84.1
	surface	1	6.7	1.7	-	-	-	-	**10.9**	-	-	-	-	-	-	49.4	-	31.3	85.7
		2	3.8	-	-	-	-	-	**11.0**	-	-	-	-	-	-	51.8	-	33.3	76.3
		3	11.5	5.2	0.9	-	-	-	**11.3**	-	-	0.8	-	-	0.8	40.4	1.1	28.0	92.4
		4	15.2	4.6	0.9	-	0.5	1.4	**9.2**	**0.6**	-	-	-	-	0.9	42.1	1.3	23.3	71.6
		5	9.8	6.7	0.6	-	0.4	1.7	**6.7**	-	-	-	-	-	-	51.6	1.2	21.3	100.0
		6	5.9	-	-	-	-	-	**9.5**	-	-	-	-	-	1.2	56.3	-	27.2	66.6
Popm7	cross-section	1	-	2.8	-	-	-	-	**10.9**	**0.3**	-	-	-	-	-	57.1	-	29.0	103.6
		2	-	2.7	-	-	-	-	**10.2**	**0.5**	-	-	-	-	-	60.0	0.8	25.9	105.4
		3	-	1.6	-	-	-	-	**11.1**	**0.3**	-	-	-	-	-	58.1	-	28.9	103.3
		4	-	0.9	-	-	-	-	**12.4**	-	-	-	-	-	-	55.8	-	30.8	94.4
		5	-	1.5	-	-	-	-	**11.5**	-	-	-	-	-	-	55.1	-	31.8	96.6
		6	-	-	-	-	-	-	**11.8**	**0.3**	-	-	-	-	-	57.3	-	30.6	94.0
		7	-	6.8	-	-	-	-	**12.9**	**0.5**	-	-	-	-	-	59.1	1.9	18.8	86.9
		8	-	3.7	-	-	-	-	**11.1**	**0.5**	-	-	-	-	-	59.9	1.2	23.7	91.7
		9	-	3.6	-	-	-	-	**12.6**	**0.6**	-	0.3	-	-	-	73.9	1.3	7.6	84.5
	surface	1	7.8	27.8	0.3	0.4	1.2	2.2	**8.8**	**0.3**	-	0.2	-	-	-	44.9	1.0	5.1	135.9
		2	9.9	7.0	0.5	-	-	-	**11.4**	**0.6**	-	0.7	-	-	-	56.5	1.5	11.9	100.3

Composition of the black corrosion by SEM-EDS (wt%)																				
Lab Id	**Area**	**Point**	**C**	**O**	**Na**	**Mg**	**Al**	**Si**	**S**	**Cl**	**K**	**Ca**	**Ti**	**Fe**	**Cu**	**Ag**	**I**	**Au**	**Analytical total**
Popm33	cross-section	1	-	13.6	-	-	0.4	-	**10.5**	**0.4**	-	1.4	-	-	-	43.7	1.5	28.5	59.8
		2	-	19.0	-	-	1.1	-	**9.3**	**-**	-	1.3	-	-	-	40.3	1.8	27.2	58.3
		3	-	10.2	-	-	0.6	-	**8.5**	**-**	-	0.5	-	-	-	52.1	1.2	26.9	63.1
		4	-	13.0	-	-	0.6	-	**8.4**	**0.5**	-	0.7	-	-	-	49.8	1.2	25.8	67.2
		5	-	17.6	-	-	0.6	-	**8.2**	**0.5**	-	-	-	-	-	44.1	1.3	27.8	55.3
		6	-	19.4	-	-	1.0	-	**8.0**	**-**	-	1.0	-	-	-	43.0	1.3	26.2	46.7
		7	-	20.0	-	-	0.4	-	**7.9**	**0.3**	-	3.2	-	-	-	47.8	-	20.5	64.9
	surface	1	15.6	16.9	1.0	0.4	0.8	2.3	**4.7**	**0.7**	-	6.0	-	2.5	0.8	33.4	-	14.9	71.1
		2	14.2	32.5	0.7	1.3	5.6	13.6	**2.8**	**0.4**	1.8	0.4	0.3	2.4	-	13.9	-	10.2	83.8

Appendix nº8. Penetration depth

To understand how deep the x-rays are penetrating the samples and from where the detected signal is derived when samples are analysed by pXRF, SEM-EDS and PIXE, the penetration depths on five custom-made certificate reference materials (MAC1-3 and AGA1-2) were calculated using the equation 1. The depth profiles of each element depend on a) the composition of the alloys to be analysed, b) the energy and the ionising source and c) the spectral lines used for the analyses (Troalen et al. 2014).

$$t_{crit} = -\frac{LN\left(\frac{I}{I_o}\right)}{\rho\ \mu tot}$$

Where:

$$\mu tot = \mu(E0)\csc\Psi 1 + \mu(Ei)\csc\Psi 2$$

Equation 1: Equation from Potts et al 1997(equation 2) and Nicholas 2016 (equation 6) for calculating the critical penetration depth.

Equation 1 calculates the depth from which a specific percentage of the detected x-ray signal is derived. The critical penetration depth (**t_{crit}**) represents the thickness from which 99% of the signal originates. Above this thickness, the signal is attenuated and cannot be detected by the instruments (Potts et al. 1997; Nicholas 2015; 2016). For a step-by-step explanation of the formula, see Nicholas (2015, p.25).

The rest of the equation comprises:

- $\boldsymbol{LN\left(\frac{I}{Io}\right)}$: represents the amount of attenuation we want to calculate. I used here the depth from which 99% (t_{crit}), 95%, 80% and 50% of the signal would derive.
- **ρ**: the density of the sample, the different gold and silver alloys in this case (table 1).
- **μ(E0)**: Mass attenuation coefficient of the primary radiation: 40KeV for pXRF, 20KeV for SEM-EDS and 3MeV for PIXE.
- **μ(Ei)**: Mass attenuation coefficient of the characteristics radiation. I.e. the attenuation coefficient of the specific spectral lines used to identify each element of the alloy (e.g. Kα, Lα, Mα).

The values for μ(E0) and μ(Ei) were obtained from the NIST XCOM database (http://physics.nist.gov/PhysRefData/Xcom/Text/intro.html).

- **Ψ1**: Incident angle in radians (from tube to sample), for each instrument.
- **Ψ2**: Take-off angle in radians (from sample to detector), for each instrument[26].

Full results of the penetrations depth by pXRF, SEM-EDS and PIXE at 99%, 95%, 80% and 50% are given in tables 2-7. A graphic example comparing penetrations depth of AGA1 and MAC2, at 95% is given in table 1 and figure 1.

[26] The incident and take-off angle of the pXRF instrument use in this study cannot be reveal here due to patent issues.

(wt%)	Cu	Pb	Au	Zn	Sn	Sb	Bi	Fe	Ag	ρ (g/cm3)
AGA1	20.0	0.2	1.5	0.2	0.3	0.1	0.2	0.04	77.5	10.19
AGA2	10.0	1.0	0.5	0.5	0.5	0.2	0.1	0.03	87.1	10.29
MAC1	1.0		93.8		0.5				4.6	18.24
MAC2	5.1		74.7		1.0				19.2	15.62
MAC3	9.1		59.2		2.0				29.7	13.93

Table 1: Normalised composition (wt%) and density (ρ) of the standards used to estimate the penetration depth of the instruments.

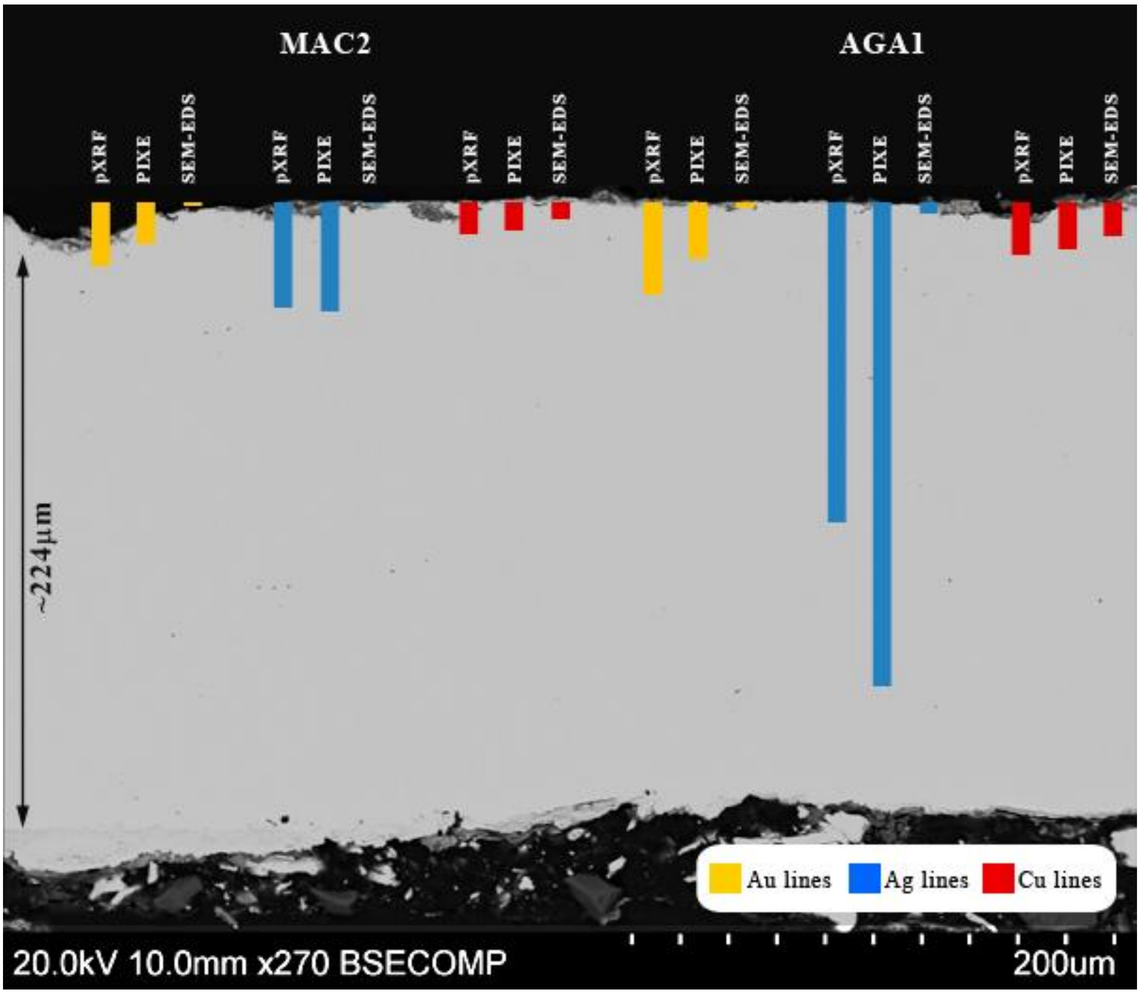


Figure 1: Back scattered image of a cross section of a 224 μm thick sample (headband popm17), showing the penetration depth using the values of MAC2 (density=15.6 gcm^{-3}) and AGA1 (density=10.2 gcm^{-3}) as examples.

pXRF results:

MAC1											
		μ(E0)	13.1300	cscΨ1	-		ρ	18.2352			
				cscΨ2	-	-4.61	-3.00	-2.30	-1.61	-0.69	
			Mass Absorption Coefficients			Analysis Depth (μm)					(mm)
Element	wt%	Peak	Energy (MeV)	μ(cm2/g) [μ(Ei)]	**μtot**	**99%**	**95%**	**90%**	**80%**	**50%**	**99%**
Au	93.8	Lb	1.14E-02	84.8	104.7	24.1	15.7	12.1	8.4	3.6	0.02
Ag	4.6	Ka	2.22E-02	57.6	75.8	33.3	21.7	16.7	11.6	5.0	0.03
Cu	1.0	Ka	8.05E-03	203.1	230.6	11.0	7.1	5.5	3.8	1.6	0.01
Sn	0.5	Ka	2.53E-02	40.9	58.0	43.5	28.3	21.8	15.2	6.5	0.04

MAC2											
		μ(E0)	13.4400	cscΨ1	-		ρ	15.6172			
				cscΨ2	-	-4.61	-3.00	-2.30	-1.61	-0.69	
			Mass Absorption Coefficients			Analysis Depth (μm)					(mm)
Element	wt%	Peak	Energy (MeV)	μ(cm2/g) [μ(Ei)]	**μtot**	**99%**	**95%**	**90%**	**80%**	**50%**	**99%**
Au	74.7	Lb	1.14E-02	89.9	110.5	26.7	17.4	13.3	9.3	4.0	0.03
Ag	19.2	Ka	2.22E-02	49.6	67.6	43.6	28.4	21.8	15.2	6.6	0.04
Cu	5.1	Ka	8.05E-03	204.5	232.5	12.7	8.3	6.3	4.4	1.9	0.01
Sn	1.0	Ka	2.53E-02	35.2	52.3	56.4	36.7	28.2	19.7	8.5	0.06

MAC3											
		μ(E0)	13.6200	cscΨ1	-		ρ	13.9295			
				cscΨ2	-	-4.61	-3.00	-2.30	-1.61	-0.69	
			Mass Absorption Coefficients			Analysis Depth (μm)					(mm)
Element	wt%	Peak	Energy (MeV)	μ(cm2/g) [μ(Ei)]	**μtot**	**99%**	**95%**	**90%**	**80%**	**50%**	**99%**
Au	59.2	Lb	1.14E-02	94.0	115.1	28.7	18.7	14.4	10.0	4.3	0.03
Ag	29.7	Ka	2.22E-02	43.1	60.9	54.3	35.3	27.1	19.0	8.2	0.05
Cu	9.1	Ka	8.05E-03	202.9	230.9	14.3	9.3	7.2	5.0	2.2	0.01
Sn	2.0	Ka	2.53E-02	30.6	47.6	69.5	45.2	34.7	24.3	10.5	0.07

Table 2: Penetration depth of the gold standards (MAC1-3) from which the 99%, 95%, 80% and 50% of the relevant peak energy originates within the sample, using a pXRF instrument with a 40KeV incident x-ray. Figures calculated using the equation from Potts et al (1997) and Nicholas (2015, 2016).

AGA1											
	μ(E0)	14.6300		cscΨ1	-			ρ	10.1915		
				cscΨ2	-	-4.61	-3.00	-2.30	-1.61	-0.69	
			Mass Absorption Coefficients			Analysis Depth (μm)					(mm)
Element	wt%	Peak	Energy (MeV)	μ(cm2/g) [μ(Ei)]	μtot	99%	95%	90%	80%	50%	99%
Ag	77.5	Ka	2.22E-02	17.16	34.4	131.3	85.44	65.7	45.9	19.8	0.13
Cu	20.0	Ka	8.05E-03	180.5	208.2	21.7	14.1	10.9	7.6	3.3	0.02
Au	1.5	Lb	1.14E-02	97.32	119.7	37.7	24.6	18.9	13.2	5.7	0.04
Sn	0.3	Ka	2.53E-02	12.02	28.9	156.2	101.6	78.1	54.6	23.5	0.16
Zn	0.2	Ka	8.64E-03	149.3	175.0	25.8	16.8	12.9	9.0	3.9	0.03
Pb	0.2	Lb	1.26E-02	76.34	97.4	46.4	30.2	23.2	16.2	7.0	0.05
Bi	0.2	Lb	1.30E-02	70.04	90.7	49.8	32.4	24.9	17.4	7.5	0.05
Sb	0.1	Ka	2.64E-02	43.5	62.4	72.4	47.1	36.2	25.3	10.9	0.07
Fe	0.0	Ka	6.40E-03	329.2	366.5	12.3	8.0	6.2	4.3	1.9	0.01

AGA2											
	μ(E0)	15.8600		cscΨ1	-			ρ	10.2935		
				cscΨ2	-	-4.61	-3.00	-2.30	-1.61	-0.69	
			Mass Absorption Coefficients			Analysis Depth (μm)					(mm)
Element	wt%	Peak	Energy (MeV)	μ(cm2/g) [μ(Ei)]	μtot	99%	95%	90%	80%	50%	99%
Ag	87.1	Ka	2.22E-02	16.0	34.5	129.7	84.34	64.8	45.3	19.5	0.13
Cu	10.0	Ka	8.05E-03	196.4	226.5	19.8	12.8	9.9	6.9	3.0	0.02
Pb	1.0	Lb	1.26E-02	70.2	92.2	48.5	31.6	24.3	17.0	7.3	0.05
Sn	0.5	Ka	2.53E-02	11.2	29.4	152.0	98.9	76.0	53.1	22.9	0.15
Au	0.5	Lb	1.14E-02	90.6	113.9	39.3	25.6	19.6	13.7	5.9	0.04
Zn	0.5	Ka	8.64E-03	162.5	190.4	23.5	15.3	11.7	8.2	3.5	0.02
Sb	0.2	Ka	2.64E-02	46.8	67.3	66.4	43.2	33.2	23.2	10.0	0.07
Bi	0.1	Lb	1.30E-02	64.4	86.0	52.0	33.8	26.0	18.2	7.8	0.05
Fe	0.03	Ka	6.40E-03	358.1	398.6	11.2	7.3	5.6	3.9	1.7	0.01

Table 3: Penetration depth of the silver standards (AGA1-2) from which the 99%, 95%, 80% and 50% of the relevant peak energy originates within the sample, using a pXRF instrument with a 40KeV incident x-ray. Figures calculated using the equation from Potts et al. (1997) and Nicholas (2015; 2016).

SEM-EDS results:

MAC1											
		μ(E0)	75.2500	**cscΨ1**	1.0000		**ρ**	18.2352			
				cscΨ2	1.7434	-4.61	-3.00	-2.30	-1.61	-0.69	
			Mass Absorption Coefficients			**Analysis Depth (μm)**					**(mm)**
Element	wt%	Peak	Energy (MeV)	μ(cm2/g) **[μ(Ei)]**	**μtot**	**99%**	**95%**	**90%**	**80%**	**50%**	**99%**
Au	93.8	Ma	2.12E-03	1019.0	1851.8	1.4	0.9	0.7	0.5	0.2	0.001
Ag	4.6	La	2.98E-03	1982.0	3530.8	0.7	0.5	0.4	0.2	0.1	0.001
Cu	1.0	Ka	8.05E-03	203.1	429.3	5.9	3.8	2.9	2.1	0.9	0.006
Sn	0.5	La	3.44E-03	1592.0	2850.8	0.9	0.6	0.4	0.3	0.1	0.001

MAC2											
		μ(E0)	64.3200	**cscΨ1**	1.0000		**ρ**	15.6172			
				cscΨ2	1.7434	-4.61	-3.00	-2.30	-1.61	-0.69	
			Mass Absorption Coefficients			**Analysis Depth (μm)**					**(mm)**
Element	wt%	Peak	Energy (MeV)	μ(cm2/g) **[μ(Ei)]**	**μtot**	**99%**	**95%**	**90%**	**80%**	**50%**	**99%**
Au	74.7	Ma	2.12E-03	1128.0	2030.9	1.5	0.9	0.7	0.5	0.2	0.001
Ag	19.2	La	2.98E-03	1713.0	3050.8	1.0	0.6	0.5	0.3	0.1	0.001
Cu	5.1	Ka	8.05E-03	204.5	420.9	7.0	4.6	3.5	2.4	1.1	0.007
Sn	1.0	La	3.44E-03	1339.0	2398.8	1.2	0.8	0.6	0.4	0.2	0.001

MAC3											
		μ(E0)	55.6300	**cscΨ1**	1.0000		**ρ**	13.9295			
				cscΨ2	1.7434	-4.61	-3.00	-2.30	-1.61	-0.69	
			Mass Absorption Coefficients			**Analysis Depth (μm)**					**(mm)**
Element	wt%	Peak	Energy (MeV)	μ(cm2/g) **[μ(Ei)]**	**μtot**	**99%**	**95%**	**90%**	**80%**	**50%**	**99%**
Au	59.2	Ma	2.12E-03	1210.0	2165.2	1.5	1.0	0.8	0.5	0.2	0.002
Ag	29.7	La	2.98E-03	1493.0	2658.6	1.2	0.8	0.6	0.4	0.2	0.001
Cu	9.1	Ka	8.05E-03	202.9	409.4	8.1	5.3	4.0	2.8	1.2	0.008
Sn	2.0	La	3.44E-03	1165.0	2086.7	1.6	1.0	0.8	0.6	0.2	0.002

Table 4: Penetration depth of the gold standards (MAC1-3) from which the 99%, 95%, 80% and 50% of the relevant peak energy originates within the sample, using a SEM-EDS instrument with a 20KeV incident x-ray. Figures calculated using the equation from Potts et al., (1997) and Nicholas (2015; 2016).

AGA1											
		μ(E0)	22.6700	cscΨ1	1.0000			ρ	10.1915		
				cscΨ2	1.7434	-4.61	-3.00	-2.30	-1.61	-0.69	
			Mass Absorption Coefficients			Analysis Depth (μm)					(mm)
Element	wt%	Peak	Energy (MeV)	μ(cm2/g) [μ(Ei)]	μtot	99%	95%	90%	80%	50%	99%
Ag	77.5	La	2.98E-03	598.2	1065.6	4.2	2.8	2.1	1.5	0.6	0.004
Cu	20.0	Ka	8.05E-03	180.5	337.4	13.4	8.7	6.7	4.7	2.0	0.013
Au	1.5	Ma	2.12E-03	1334.0	2348.4	1.9	1.3	1.0	0.7	0.3	0.002
Sn	0.3	La	3.44E-03	1061.0	1872.5	2.4	1.6	1.2	0.8	0.4	0.002
Zn	0.2	Ka	8.64E-03	149.3	283.0	16.0	10.4	8.0	5.6	2.4	0.016
Pb	0.2	Ma	2.35E-03	1062.0	1874.2	2.4	1.6	1.2	0.8	0.4	0.002
Bi	0.2	Ma	2.42E-03	981.3	1733.5	2.6	1.7	1.3	0.9	0.4	0.003
Sb	0.1	La	3.61E-03	1256.0	2212.4	2.0	1.3	1.0	0.7	0.3	0.002
Fe	0.0	Ka	6.40E-03	329.2	596.6	7.6	4.9	3.8	2.6	1.1	0.008

AGA2											
		μ(E0)	21.1100	cscΨ1	1.0000			ρ	10.2935		
				cscΨ2	1.7434	-4.61	-3.00	-2.30	-1.61	-0.69	
			Mass Absorption Coefficients			Analysis Depth (μm)					(mm)
Element	wt%	Peak	Energy (MeV)	μ(cm2/g) [μ(Ei)]	μtot	99%	95%	90%	80%	50%	99%
Ag	87.1	La	2.98E-03	571.2	1017.0	4.4	2.9	2.2	1.5	0.7	0.004
Cu	10.0	Ka	8.05E-03	196.4	363.5	12.3	8.0	6.2	4.3	1.9	0.012
Pb	1.0	Ma	2.35E-03	1003.0	1769.8	2.5	1.6	1.3	0.9	0.4	0.003
Sn	0.5	La	3.44E-03	1122.0	1977.3	2.3	1.5	1.1	0.8	0.3	0.002
Au	0.5	Ma	2.12E-03	1276.0	2245.7	2.0	1.3	1.0	0.7	0.3	0.002
Zn	0.5	Ka	8.64E-03	162.5	304.4	14.7	9.6	7.3	5.1	2.2	0.015
Sb	0.2	La	3.61E-03	1351.0	2376.5	1.9	1.2	0.9	0.7	0.3	0.002
Bi	0.1	Ma	2.42E-03	925.9	1635.4	2.7	1.8	1.4	1.0	0.4	0.003
Fe	0.03	Ka	6.40E-03	358.1	645.4	6.9	4.5	3.5	2.4	1.0	0.007

Table 5: Penetration depth of the silver standards (AGA1-2) from which the 99%, 95%, 80% and 50% of the relevant peak energy originates within the sample, using a SEM-EDS instrument with a 20KeV incident x-ray. Figures calculated using the equation from Potts et al., (1997) and Nicholas (2015; 2016).

PIXE results:

MAC1												
	μ(E0)	0.0417		cscΨ1	1.0000		ρ	18.24				
				cscΨ2	1.3054	-4.61	-3.00	-2.30	-1.61	-0.69		
			Mass Absorption Coefficients			Analysis Depth (μm)					(mm)	
Element	wt%	Peak	Energy (MeV)	μ(cm2/g) [μ(Ei)]	μtot	99%	95%	90%	80%	50%	99%	
Au	93.8	La	9.63E-03	131.2	171.3	14.7	9.6	7.4	5.2	2.2	0.01	
Ag	4.6	Ka	2.22E-02	57.6	75.2	33.6	21.8	16.8	11.7	5.1	0.03	
Cu	1.0	Ka	8.05E-03	203.1	265.2	9.5	6.2	4.8	3.3	1.4	0.01	
Sn	0.5	Ka	2.53E-02	40.9	53.5	47.2	30.7	23.6	16.5	7.1	0.05	

MAC2												
	μ(E0)	0.0408		cscΨ1	1.0000		ρ	15.6172				
				cscΨ2	1.3054	-4.61	-3.00	-2.30	-1.61	-0.69		
			Mass Absorption Coefficients			Analysis Depth (μm)					(mm)	
Element	wt%	Peak	Energy (MeV)	μ(cm2/g) [μ(Ei)]	μtot	99%	95%	90%	80%	50%	99%	
Au	74.7	La	9.63E-03	139.8	182.5	16.2	10.5	8.1	5.6	2.4	0.02	
Ag	19.2	Ka	2.22E-02	49.6	64.8	45.5	29.6	22.8	15.9	6.9	0.05	
Cu	5.1	Ka	8.05E-03	204.5	267.0	11.0	7.2	5.5	3.9	1.7	0.01	
Sn	1.0	Ka	2.53E-02	35.2	46.0	64.1	41.7	32.0	22.4	9.6	0.06	

MAC3												
	μ(E0)	0.0400		cscΨ1	1.0000		ρ	13.9295				
				cscΨ2	1.3054	-4.61	-3.00	-2.30	-1.61	-0.69		
			Mass Absorption Coefficients			Analysis Depth (μm)					(mm)	
Element	wt%	Peak	Energy (MeV)	μ(cm2/g) [μ(Ei)]	μtot	99%	95%	90%	80%	50%	99%	
Au	59.2	La	9.63E-03	146.5	191.3	17.3	11.2	8.6	6.0	2.6	0.02	
Ag	29.7	Ka	2.22E-02	43.1	56.4	58.7	38.2	29.3	20.5	8.8	0.06	
Cu	9.1	Ka	8.05E-03	202.9	264.9	12.5	8.1	6.2	4.4	1.9	0.01	
Sn	2.0	Ka	2.53E-02	30.6	40.0	82.7	53.8	41.4	28.9	12.4	0.08	

Table 6: Penetration depth of the gold standards (MAC1-3) from which the 99%, 95%, 80% and 50% of the relevant peak energy originates within the sample, using a PIXE instrument with a 3MeV incident x-ray. Figures calculated using the equation from Potts et al., (1997) and Nicholas (2015; 2016).

AGA1											
	μ(E0)	0.0373		cscΨ1	1.0000			ρ 10.1915			
				cscΨ2	1.3054	-4.61	-3.00	-2.30	-1.61	-0.69	
Mass Absorption Coefficients						Analysis Depth (μm)					(mm)
Element	wt%	Peak	Energy (MeV)	μ(cm2/g) [μ(Ei)]	μtot	99%	95%	90%	80%	50%	99%
Ag	77.5	Ka	2.22E-02	17.16	22.4	201.4	131.0	100.7	70.4	30.3	0.20
Cu	20.0	Ka	8.05E-03	180.5	235.7	19.2	12.5	9.6	6.7	2.9	0.02
Au	1.5	La	9.63E-03	152.8	199.5	22.6	14.7	11.3	7.9	3.4	0.02
Sn	0.3	Ka	2.53E-02	12.02	15.7	287.3	186.9	143.6	100.4	43.2	0.29
Zn	0.2	Ka	8.64E-03	149.3	194.9	23.2	15.1	11.6	8.1	3.5	0.02
Pb	0.2	La	1.05E-02	123.8	161.6	28.0	18.2	14.0	9.8	4.2	0.03
Bi	0.2	La	1.07E-02	115.4	150.7	30.0	19.5	15.0	10.5	4.5	0.03
Sb	0.1	Ka	2.64E-02	43.5	56.8	79.5	51.7	39.8	27.8	12.0	0.08
Fe	0.0	Ka	6.40E-03	329.2	429.8	10.5	6.8	5.3	3.7	1.6	0.01

AGA2											
	μ(E0)	0.0375		cscΨ1	1.0000			ρ 10.2935			
				cscΨ2	1.3054	-4.61	-3.00	-2.30	-1.61	-0.69	
Mass Absorption Coefficients						Analysis Depth (μm)					(mm)
Element	wt%	Peak	Energy (MeV)	μ(cm2/g) [μ(Ei)]	μtot	99%	95%	90%	80%	50%	99%
Ag	87.1	Ka	2.22E-02	16.0	20.9	214.1	139.3	107.0	74.8	32.2	0.21
Cu	10.0	Ka	8.05E-03	196.4	256.4	17.4	11.3	8.7	6.1	2.6	0.02
Pb	1.0	La	1.05E-02	115.5	150.8	29.7	19.3	14.8	10.4	4.5	0.03
Sn	0.5	Ka	2.53E-02	11.2	14.7	304.7	198.2	152.3	106.5	45.9	0.30
Au	0.5	La	9.63E-03	142.2	185.7	24.1	15.7	12.0	8.4	3.6	0.02
Zn	0.5	Ka	8.64E-03	162.5	212.2	21.1	13.7	10.5	7.4	3.2	0.02
Sb	0.2	Ka	2.64E-02	46.8	61.2	73.1	47.6	36.6	25.6	11.0	0.07
Bi	0.1	La	1.07E-02	107.6	140.5	31.8	20.7	15.9	11.1	4.8	0.03
Fe	0.03	Ka	6.40E-03	358.1	467.5	9.6	6.2	4.8	3.3	1.4	0.01

Table 7: Penetration depth of the silver standards (AGA1-2) from which the 99%, 95%, 80% and 50% of the relevant peak energy originates within the sample, using a PIXE instrument with a 3MeV incident x-ray. Figures calculated using the equation from Potts et al., (1997) and Nicholas (2015; 2016).

Appendix nº9. Accuracy and precision

Five custom-made certificate reference materials were analysed by pXRF, SEM-EDS, EPMA and PIXE to assess precision and accuracy. The standards cover two different matrices: silver-rich and gold-rich alloys. I used two silver standards: AGA1 and AGA2, certified by MBH Analytical Ltd; in addition to three gold standards MAC1, MAC2 and MAC3, certified by Micro-analysis consultants Ltd. Precision and accuracy for the different instruments are specified below.

Handheld XRF

The five standards specify above were analysed by pXRF: three gold and two silver alloys. They are discs that were analysed from the surface, measuring areas of 3mm and 10mm diameter. Two different instruments were used: pXRF2015 and pXRF2016. Results are given for both instruments.

The measurements of AGA1 (Table 1-2) with both instruments show a high precision for major elements (silver, copper and gold) with coefficients of variation below 3.2% with pXRF2015 and below 2.1% with pXRF2016. However, precision is lower for the elements present in minor concentrations ≤0.3% such as lead, zinc and bismuth with coefficients between 16-7% with pXRF2015 and 12-6% with pXRF2016. Iron (present at 0.03%) and antimony (present at 0.1%) were below detection limits; the former was detected by both instruments unsystematically, and the latter was not detected at all. Both instruments show high accuracy for major elements with relative errors <8% with pXRF2015 and <2.9% with pXRF2016. The pXRF2015 overestimates lead in 16.1%, whereas underestimates zinc in 11%. On the contrary, pXRF2016 show high accuracy for lead and bismuth, with relative errors below 10%; whereas zinc was underestimated in 58.3%.

Tin, present at 0.3% in the alloy, was not always detected by pXRF2015 (only 8 of 15 readings), and when it was detected was overestimated in 0.1%. Conversely, pXRF2016 was able to identify tin in all readings showing a good precision with 10% coefficient of variation. These results however, have to be taken with caution. Initially, it was found that during the analysis of high-silver objects using pXRF2015, tin was being overestimated and false-positives were appearing. This inaccuracy is most certain related to the high silver content, creating an overlap between the spectral lines of tin ($K\alpha/L\alpha$) and silver ($K\beta/L\beta/L\gamma$). So pXRF2015 was set up to increase the limit of detection of tin, when silver was over 30%. This modification allowed to eliminate the false peaks, and also explains why tin at 0.3% on a silver-matrix is more difficult to estimate with pXRF2015. This modification was not applied to pXRF2016, and the spectrum was in this case cleaned manually when tin was detected. False-positive values between 0.1-0.4% of tin were found in objects analysed with pXRF2016. Values reported in Table 2 therefore, agree with the content of the standards, but also to the false-positives. These results make clear that under 0.5% tin values are not reliable, especially coming from pXRF2016.

In AGA2 (Table 3-4), both instruments show high precision for all elements, with coefficients of variation below 10.6%. Accuracy in pXRF2015 is high for all elements, with relative errors below 10%; except for lead (27.3%), tin (17.3%) and antimony (13%), all contained in 0.2-1%. The lowest accuracy obtained by lead (relative error 27.3%) may correspond to its heterogeneous distribution within the metallic matrix. pXRF2016 shows a high accuracy in all elements (relative errors ≤9.5%), except for tin and antimony with 14.9% and 22.1% relative errors, respectively. Iron present at 0.03% is not detected, while antimony now present at 0.2% is detected by both instruments.

In MAC1 (Table5-6), precision proved to be high in all the elements, with both instruments; the coefficients of variation are ≤6.1% for pXRF2015 and ≤4.1% for PXRF2016. Moreover, with pXRF2015 copper, gold and silver have a coefficient of variation between 0.03-1.6%. Tin, the only element present in minor concentrations (0.5%), shows the lowest precision with 6.1%. Similar patterns shows pXRF2016, with coefficients between 0.1-1.5% for major elements and 4.1% for tin. Accuracy is high for gold, copper and silver, with a relative errors ≤6.9% with pXRF2015 and ≤5.5% with pXRF2016. Tin shows lower accuracy with a relative error of 15.8% (pXRF2015) and 12.6% (pXRF2016). It is clear that tin present in 0.5%, is more difficult to read and less consistent than the other elements present >1%; nevertheless, precision and accuracy is still acceptable.

In MAC2 (Table 5-6), precision is very good for the four elements measured, and with both instruments. Coefficients of variation between 0.4-3.7% are obtained with pXRF2015 and between 0.2-2.9% with pXRF2016. Accuracy is also high with a relative error ranging between 1.0-4.5% (pXRF2015) and 0.2-6.7% (pXRF2016). In MAC2, all the elements were present ≥1%.

In MAC3 (Table 5-6), as in MAC2, precision and accuracy were high. The coefficients of variation are ≤2.0% with pXRF2015 and ≤2.3% with pXRF2016. Relative error is ≤4.3% with pXRF2015 and ≤3.8% with pXRF2016.

Summing up, precision and accuracy are high in all cases and for both instruments, with coefficients of variation and relative errors below 10% when elements were present above 0.5%. For elements present in amounts below 0.5% precision and accuracy decreases and vary considerably, suggesting that at low amounts, elements are more difficult to measure under the current setup.

On a silver-matrix, elements ≤0.5% are in general more difficult to measure and are less consistent in their readings with the pXRF. Tin in particular, present high detection limits of 0.5% with both instruments, showing that detected values under 0.5% are not reliable: with pXRF2016, figures <0.5% need to be checked on the spectra to avoid false-positives, while with pXRF2015 it was unsystematically detected. The problem with tin, resides in the overlap between silver (Kβ/Lβ/Lγ) and tin (Kα/Lα) spectral lines. For gold standards, it is clear that when the elements are present above 1%, precision and accuracy is very high with both instruments, with coefficients of variations and relative errors <7%. Tin in this matrix, was not problematic. In general, results indicate that pXRF2016 shows slightly better values for precision and accuracy than pXRF2015.

Given these results, the limits of detection of the pXRF instruments for the elements present in the standards are around 0.2% for lead, zinc, antimony and bismuth. Limits of detection for tin are 0.5%, under this limit both instruments have problems detecting tin; pXRF2015 not always detected the element, whereas pXRF2016 tends to give false-positives. The lowest amount of gold found in AGA1 is 0.5%, which was detected without problems by both instruments. The limits of detection of copper and silver cannot be estimated here due to the lowest values in the standards are 1% and 4.6% respectively (MAC1); very high values to determine the limits of detection. Finally, iron present at 0.03% was not detected and at 0.04% is detected only in some cases, so its limits of detection are still above this value.

Having say this, is important to remember that all the pXRF analyses performed in this research were made on unprepared surfaces. In spite of the fact that the pXRF is able to identify and quantify heavy elements in concentrations down to 0.1 and sometimes below (see iron above); in this study sampling uncertainty is increased due to surface contamination, corrosion, tarnish and irregularities. These factors increment the background noise resulting in potential false peaks identifications. Surface corrosion or contamination can also contribute to identify minor elements which, in this case, would not be representative of the metal alloy, but results of post-depositional processes. Therefore, it was decided not to report small concentrations (<0.5%) of elements such as Fe, Zn, Ni, Ti, Bi, Sn and Sb that were detected during the pXRF analyses of the archaeological materials. For minor and trace elements, PIXE, SEM-EDS and EPMA results will be used as more reliable sources.

	pXRF 2015					**AGA 1**					
	(wt%)	**Cu**	**Pb**	**Au**	**Zn**	**Sn**	**Sb**	**Bi**	**Fe**	**Ag**	**Total**
		18.8	0.2	1.6	0.2	<dl	<dl	0.2	0.05	78.9	100.0
		18.9	0.3	1.6	0.2	<dl	<dl	0.2	<dl	78.8	100.0
		19.2	0.3	1.6	0.2	0.4	<dl	0.2	<dl	78.0	100.0
		17.7	0.2	1.6	0.2	<dl	<dl	0.1	0.05	80.0	99.9
		18.8	0.3	1.6	0.2	<dl	<dl	0.2	<dl	78.9	100.0
		19.1	0.3	1.6	0.2	0.4	<dl	0.2	0.04	78.1	100.0
		18.1	0.2	1.6	0.2	<dl	<dl	0.2	0.05	79.6	99.9
		19.2	0.3	1.6	0.2	0.4	<dl	0.2	0.06	78.0	100.0
		19.2	0.3	1.6	0.2	0.4	<dl	0.2	<dl	78.1	100.0
		17.5	0.2	1.6	0.2	<dl	<dl	0.1	0.05	80.2	100.0
		19.0	0.3	1.6	0.2	0.4	<dl	0.2	0.05	78.1	100.0
		17.6	0.2	1.7	0.2	0.5	<dl	0.1	0.05	79.6	100.0
		18.8	0.2	1.6	0.2	<dl	<dl	0.2	0.05	79.0	100.0
		18.8	0.3	1.6	0.2	<dl	<dl	0.2	<dl	78.9	100.0
		17.9	0.2	1.6	0.2	<dl	<dl	0.1	<dl	79.9	100.0
		18.9	0.3	1.6	0.2	0.4	<dl	0.2	<dl	78.4	100.0
	10-2015 - Ø3mm - 20s	19.1	0.3	1.6	0.2	0.4	<dl	0.2	0.05	78.2	100.0
	Normalised mean values	**18.6**	**0.2**	**1.6**	**0.2**	**<0.5**	**<dl**	**0.2**	**<dl**	**78.7**	**100.0**
Precision	Standard deviation (σ)	0.6	0.03	0.03	0.01	-	-	0.03	-	0.8	
	Coefficient of variation (%RSD)	3.2	13.3	1.6	7.2	-	-	16.1	-	1.0	
Accuracy	**Normalised reference values**	**20.0**	**0.2**	**1.5**	**0.2**	**0.3**	**0.1**	**0.2**	**0.04**	**77.5**	**100.0**
	Absolute error	-1.4	0.03	0.1	-0.02	-	-	-0.004	-	1.2	
	Relative error (%)	7.0	16.1	8.0	11.0	-	-	1.9	-	1.5	

Table 1: AGA1 silver standard, results by pXRF 2015. Symbol "Ø" means diameter. Antimony and iron were below detection limits. In the case of tin, under 0.5% is not easily detected by pXRF 2015, and when is detected it is overestimated in ~0.1%.

	pXRF 2016	AGA 1									
	(wt%)	**Cu**	**Pb**	**Au**	**Zn**	**Sn**	**Sb**	**Bi**	**Fe**	**Ag**	**Total**
		19.3	0.2	1.5	0.3	0.3	<dl	0.2	<dl	78.2	100.0
		19.0	0.2	1.5	0.3	0.3	<dl	0.2	0.03	78.5	100.0
		19.6	0.2	1.5	0.3	0.3	<dl	0.2	<dl	77.8	100.0
		20.0	0.2	1.5	0.3	0.3	<dl	0.2	<dl	77.4	100.0
		19.7	0.2	1.5	0.4	0.3	<dl	0.2	<dl	77.8	100.0
		19.7	0.2	1.5	0.3	0.4	<dl	0.2	0.03	77.7	100.0
		19.0	0.2	1.5	0.3	0.4	<dl	0.2	<dl	78.4	100.0
		18.9	0.2	1.5	0.3	0.3	<dl	0.2	<dl	78.6	100.0
		18.8	0.2	1.5	0.3	0.3	<dl	0.2	<dl	78.7	100.0
		19.0	0.2	1.5	0.3	0.4	<dl	0.1	<dl	78.6	100.0
		18.9	0.2	1.5	0.3	0.3	<dl	0.2	0.03	78.6	100.0
		18.9	0.2	1.5	0.3	0.3	<dl	0.2	0.03	78.7	100.0
		19.7	0.2	1.5	0.4	0.3	<dl	0.2	<dl	77.7	100.0
		19.8	0.3	1.5	0.3	0.3	<dl	0.2	<dl	77.6	100.0
		19.8	0.2	1.5	0.3	0.4	<dl	0.2	<dl	77.6	100.0
		19.4	0.2	1.5	0.3	0.3	<dl	0.2	0.03	78.0	100.0
		19.9	0.3	1.5	0.4	0.3	<dl	0.2	0.03	77.4	100.0
		19.9	0.3	1.5	0.4	0.3	<dl	0.2	<dl	77.5	100.0
		19.8	0.2	1.5	0.3	0.3	<dl	0.2	<dl	77.7	100.0
		19.4	0.2	1.5	0.3	0.3	<dl	0.2	<dl	78.1	100.0
	04-2016 - Ø10mm - 20s	19.3	0.2	1.5	0.3	0.3	<dl	0.2	<dl	78.2	100.0
	Normalised mean values	**19.4**	**0.2**	**1.5**	**0.3**	**0.3**	<dl	**0.2**	<dl	**78.0**	**100.0**
Precision	Standard deviation	0.4	0.03	0.02	0.02	0.03	-	0.02	-	0.5	
	Coefficient of variation (%RSD)	2.1	11.8	1.6	6.1	10.0	-	12.2	-	0.6	
Accuracy	**Normalised reference values**	**20.0**	**0.2**	**1.5**	**0.2**	**0.3**	**0.1**	**0.2**	**0.04**	**77.5**	**100.0**
	Absolute error	-0.6	0.01	0.01	0.1	0.03	-	-0.01	-	0.5	
	Relative error (%)	2.9	4.9	0.8	58.3	9.4	-	6.8	-	0.7	

Table 2: AGA1 silver standard, results by pXRF 2016. Symbol "Ø" means diameter. Antimony and iron are below detection limits

	pXRF 2015	AGA 2									
	(wt%)	**Cu**	**Pb**	**Au**	**Zn**	**Sn**	**Sb**	**Bi**	**Fe**	**Ag**	**Total**
		9.7	1.4	0.6	0.5	0.6	0.2	0.1	<dl	87.0	100.0
		10.0	1.2	0.6	0.5	0.6	0.2	0.1	<dl	86.7	100.0
		9.2	1.2	0.5	0.4	0.6	0.1	0.1	<dl	87.8	100.0
		10.1	1.4	0.5	0.5	0.7	0.2	0.1	<dl	86.6	100.0
		10.2	1.4	0.5	0.5	0.6	0.2	0.1	<dl	86.5	100.0
		10.0	1.3	0.6	0.5	0.6	0.2	0.1	<dl	86.7	100.0
		10.0	1.3	0.6	0.5	0.6	0.2	0.1	<dl	86.7	100.0
		10.0	1.4	0.6	0.5	0.6	0.2	0.1	<dl	86.7	100.0
		9.3	1.2	0.6	0.5	0.6	0.1	0.1	<dl	87.6	100.0
		9.6	1.4	0.6	0.5	0.7	0.2	0.1	<dl	87.0	100.0
		9.7	1.4	0.5	0.5	0.6	0.2	0.1	<dl	87.0	100.0
		9.4	1.2	0.6	0.4	0.5	0.2	0.1	<dl	87.7	100.0
		9.3	1.2	0.6	0.5	0.6	0.1	0.1	<dl	87.7	100.0
		9.8	1.4	0.6	0.4	0.6	0.2	0.1	<dl	87.0	100.0
		8.8	1.1	0.6	0.4	0.7	<dl	0.1	<dl	88.4	100.0
		9.9	1.3	0.6	0.5	0.7	0.2	0.1	<dl	86.8	100.0
	10-2015 - Ø3mm - 20s	9.7	1.4	0.6	0.5	0.6	0.2	0.1	0.03	87.0	100.0
	Normalised mean values	**9.7**	**1.3**	**0.6**	**0.5**	**0.6**	**0.2**	**0.1**	**<dl**	**87.1**	**100.0**
Precision	Standard deviation (σ)	0.4	0.1	0.01	0.01	0.05	0.02	0.01	-	0.5	
	Coefficient of variation (%RSD)	3.9	8.8	2.1	2.7	7.4	10.6	9.1	-	0.6	
Accuracy	**Normalised reference values**	**10.0**	**1.0**	**0.5**	**0.5**	**0.5**	**0.2**	**0.1**	**0.03**	**87.1**	**100.0**
	Absolute error	-0.3	0.3	0.05	-0.04	0.1	-0.02	0.01	-	0.0	
	Relative error (%)	3.2	27.3	9.6	8.9	17.3	13.0	7.9	-	0.01	

Table 3: AGA2 silver standard, results by pXRF 2015. Symbol "Ø" means diameter.

pXRF 2016						AGA 2					
	(wt%)	**Cu**	**Pb**	**Au**	**Zn**	**Sn**	**Sb**	**Bi**	**Fe**	**Ag**	**Total**
		10.0	1.2	0.5	0.5	0.5	0.2	0.1	<dl	87.0	100.0
		9.8	1.1	0.5	0.5	0.5	0.1	0.1	<dl	87.4	100.0
		10.1	1.2	0.5	0.5	0.4	0.2	0.1	<dl	86.9	100.0
		10.3	1.3	0.5	0.5	0.4	0.2	0.1	<dl	86.7	100.0
		9.4	1.1	0.5	0.5	0.5	0.1	0.1	<dl	87.8	100.0
		9.5	1.1	0.5	0.5	0.4	0.2	0.1	<dl	87.8	100.0
		9.7	1.1	0.5	0.5	0.5	0.2	0.1	<dl	87.5	100.0
		9.5	1.0	0.5	0.5	0.5	0.2	0.1	<dl	87.7	100.0
		9.7	1.1	0.5	0.5	0.4	0.1	0.1	<dl	87.5	100.0
		9.8	1.2	0.5	0.5	0.4	0.1	0.1	<dl	87.4	100.0
		9.8	1.1	0.5	0.5	0.5	0.1	0.1	<dl	87.3	100.0
		9.7	1.1	0.5	0.5	0.5	0.2	0.1	<dl	87.4	100.0
		9.7	1.1	0.5	0.5	0.5	0.2	0.1	<dl	87.5	100.0
		9.6	1.1	0.5	0.5	0.4	0.2	0.1	<dl	87.6	100.0
		9.4	1.0	0.5	0.5	0.5	0.2	0.1	<dl	87.7	100.0
		9.1	1.0	0.5	0.5	0.5	0.1	0.1	<dl	88.1	100.0
		10.2	1.3	0.5	0.5	0.4	0.2	0.1	<dl	86.8	100.0
		9.5	1.1	0.5	0.5	0.4	0.1	0.1	<dl	87.7	100.0
		9.0	1.0	0.5	0.5	0.4	0.2	0.1	<dl	88.3	100.0
		10.2	1.3	0.5	0.5	0.4	0.1	0.1	<dl	86.9	100.0
		10.0	1.3	0.5	0.5	0.4	0.1	0.1	<dl	87.1	100.0
		9.6	1.1	0.5	0.5	0.4	0.2	0.1	<dl	87.7	100.0
	04-2016 - Ø10mm - 20s	9.3	1.0	0.5	0.5	0.4	0.2	0.1	<dl	88.0	100.0
	Normalised mean values	**9.7**	**1.1**	**0.5**	**0.5**	**0.4**	**0.1**	**0.1**	<dl	**87.5**	**100.0**
Precision	Standard deviation	0.3	0.1	0.01	0.02	0.04	0.01	0.01	-	0.4	
	Coefficient of variation (%RSD)	3.5	7.9	2.0	3.2	8.8	9.6	8.3	-	0.5	
Accuracy	**Normalised reference values**	**10.0**	**1.0**	**0.5**	**0.5**	**0.5**	**0.2**	**0.1**	0.03	**87.1**	**100.0**
	Absolute error	-0.3	0.1	-0.01	0.01	-0.1	-0.04	-0.004	-	0.4	
	Relative error (%)	3.1	9.5	1.8	2.3	14.9	22.1	3.5	-	0.4	

Table 4: AGA2 silver standard, results by pXRF 2016. Symbol "Ø" means diameter.

pXRF 2015		MAC 1					MAC 2					MAC 3				
	(wt%)	**Cu**	**Au**	**Ag**	**Sn**	**Total**	**Cu**	**Au**	**Ag**	**Sn**	**Total**	**Cu**	**Au**	**Ag**	**Sn**	**Total**
		1.0	94.3	4.3	0.4	100.0	4.9	75.4	18.6	1.1	100.0	8.7	59.4	30.0	2.0	100.0
		1.0	94.3	4.3	0.4	100.0	4.9	75.4	18.6	1.1	100.0	8.7	59.4	29.9	2.1	100.0
		1.0	94.2	4.3	0.4	100.0	4.8	75.6	18.6	1.0	100.0	8.7	59.4	29.9	2.1	100.0
		1.0	94.3	4.3	0.4	100.0	4.9	75.4	18.6	1.1	100.0	8.8	59.4	29.7	2.0	100.0
		1.0	94.3	4.3	0.4	100.0	4.9	75.4	18.6	1.1	100.0	8.7	59.4	29.8	2.1	100.0
		0.9	94.4	4.3	0.4	100.0	4.8	75.5	18.7	1.0	100.0	8.7	59.3	29.9	2.1	100.0
		1.0	94.3	4.3	0.4	100.0	4.9	75.5	18.6	1.1	100.0	8.6	59.5	29.9	1.9	100.0
		1.0	94.3	4.3	0.5	100.0	4.8	75.5	18.7	1.1	100.0	8.6	59.4	30.0	2.1	100.0
		1.0	94.3	4.3	0.5	100.0	4.9	75.3	18.7	1.1	100.0	8.7	59.4	29.9	2.1	100.0
		1.0	94.3	4.3	0.4	100.0	4.8	75.4	18.8	1.0	100.0	8.7	59.4	29.9	2.1	100.0
		1.0	94.3	4.3	0.5	100.0	4.8	75.4	18.6	1.1	100.0	8.6	59.3	30.0	2.1	100.0
		0.9	94.3	4.3	0.5	100.0	5.0	75.4	18.5	1.1	100.0	8.7	59.6	29.7	2.0	100.0
		1.0	94.3	4.3	0.5	100.0	4.9	75.4	18.7	1.1	100.0	8.7	59.3	29.9	2.0	100.0
		1.0	94.3	4.3	0.5	100.0	4.9	75.5	18.6	1.0	100.0	8.7	59.4	29.9	2.1	100.0
		1.0	94.2	4.3	0.5	100.0	4.9	75.5	18.5	1.1	100.0	8.7	59.4	29.9	2.0	100.0
		1.0	94.3	4.3	0.5	100.0	4.8	75.4	18.7	1.1	100.0	8.6	59.4	29.9	2.1	100.0
	10-2015 - Ø3mm - 20s	1.0	94.3	4.3	0.5	100.0	4.8	75.5	18.6	1.1	100.0	8.7	59.4	29.9	2.1	100.0
	Normalised mean values	**1.0**	**94.3**	**4.3**	**0.5**	**100.0**	**4.9**	**75.4**	**18.6**	**1.1**	**100.0**	**8.7**	**59.4**	**29.9**	**2.0**	**100.0**
Precision	Standard deviation (σ)	0.02	0.03	0.03	0.03		0.1	0.1	0.1	0.04		0.1	0.1	0.1	0.04	
	Coefficient of variation (%RSD)	1.6	0.03	0.6	6.1		1.2	0.1	0.4	3.7		0.6	0.1	0.3	2.0	
Accuracy	**Normalised reference values**	**1.0**	**93.8**	**4.6**	**0.5**	**100.0**	**5.1**	**74.7**	**19.2**	**1.0**	**100.0**	**9.1**	**59.2**	**29.7**	**2.0**	**100.0**
	Absolute error	-0.1	0.5	-0.3	-0.1		-0.2	0.8	-0.6	0.04		-0.4	0.2	0.2	0.1	
	Relative error (%)	6.9	0.5	6.5	15.8		4.5	1.0	3.0	3.9		4.3	0.3	0.6	3.4	

Table 5: MAC1-3 gold standards, results by pXRF 2015. Symbol "Ø" means diameter.

pXRF 2016		MAC 1					MAC 2					MAC 3				
	(wt%)	Cu	Au	Ag	Sn	Total	Cu	Au	Ag	Sn	Total	Cu	Au	Ag	Sn	Total
		1.0	94.1	4.4	0.5	100.0	5.3	74.8	18.8	1.1	100.0	9.6	58.5	29.9	2.0	100.0
		1.1	94.1	4.4	0.5	100.0	5.3	74.7	18.8	1.1	100.0	9.5	58.2	29.8	1.9	99.6
		1.1	94.0	4.4	0.4	100.0	5.4	74.9	18.6	1.1	100.0	9.6	58.3	30.0	2.0	99.9
		1.1	94.1	4.4	0.5	100.0	5.4	74.9	18.6	1.0	100.0	9.6	58.8	29.3	1.9	99.6
		1.1	94.1	4.3	0.5	100.0	5.2	75.0	18.7	1.1	100.0	9.5	58.8	29.4	1.9	99.6
		1.1	94.1	4.4	0.5	100.0	5.2	75.0	18.8	1.0	100.0	9.5	58.9	29.6	1.9	100.0
		1.1	94.2	4.3	0.5	100.0	5.4	75.0	18.5	1.1	100.0	9.4	58.9	29.7	2.0	100.0
		1.1	94.2	4.3	0.5	100.0	5.4	74.9	18.6	1.1	100.0	9.4	58.8	29.5	1.9	99.6
		1.1	94.2	4.3	0.5	100.0	5.4	75.0	18.6	1.1	100.0	9.5	58.9	29.7	2.0	100.0
		1.1	94.1	4.4	0.5	100.0	5.3	74.6	18.9	1.1	100.0	9.2	58.3	30.0	2.0	99.5
		1.1	94.1	4.4	0.4	100.0	5.3	74.6	19.0	1.1	100.0	9.3	58.2	30.0	2.0	99.5
		1.1	94.0	4.4	0.5	100.0	5.3	74.7	18.9	1.1	100.0	9.3	58.3	30.4	2.1	100.0
		1.1	94.2	4.3	0.5	100.0	5.3	74.9	18.6	1.1	100.0	9.4	58.8	29.8	2.0	100.0
		1.1	94.2	4.3	0.4	100.0	5.3	74.8	18.7	1.2	100.0	9.4	58.6	29.6	2.0	99.5
		1.1	94.1	4.3	0.5	100.0	5.3	74.9	18.7	1.1	100.0	9.4	58.6	29.6	1.9	99.5
		1.0	94.2	4.3	0.5	100.0	5.2	74.9	18.8	1.1	100.0	9.4	58.6	29.9	2.0	100.0
		1.1	94.1	4.3	0.5	100.0	5.1	75.1	18.7	1.1	100.0	9.3	58.5	29.8	2.0	99.5
		1.1	94.1	4.3	0.5	100.0	5.1	75.1	18.7	1.1	100.0	9.3	58.5	29.8	2.0	99.5
		1.1	94.1	4.4	0.5	100.0	5.3	74.6	19.0	1.1	100.0	9.2	58.1	30.3	2.0	99.5
		1.1	94.1	4.4	0.4	100.0	5.3	74.7	19.0	1.1	100.0	9.3	58.3	30.4	2.0	100.0
	04-2016 - Ø10mm - 20s	1.1	94.1	4.4	0.5	100.0	5.2	74.8	18.9	1.1	100.0	9.2	58.3	30.5	2.0	100.0
	Normalised mean values	**1.1**	**94.1**	**4.3**	**0.5**	**100.0**	**5.3**	**74.8**	**18.8**	**1.1**	**100.0**	**9.4**	**58.7**	**29.9**	**2.0**	**100.0**
Precision	Standard deviation	0.02	0.1	0.05	0.02		0.1	0.1	0.2	0.03		0.1	0.3	0.3	0.05	
	Coefficient of variation (%RSD)	1.5	0.1	1.1	4.1		1.7	0.2	0.8	2.9		1.3	0.5	1.1	2.3	
Accuracy	**Normalised reference values**	**1.0**	**93.8**	**4.6**	**0.5**	**100.0**	**5.1**	**74.7**	**19.2**	**1.0**	**100.0**	**9.1**	**59.2**	**29.7**	**2.0**	**100.0**
	Absolute error	0.03	0.3	-0.3	-0.1		0.2	0.2	-0.4	0.1		0.3	-0.6	0.2	0.02	
	Relative error (%)	2.8	0.3	5.5	12.6		3.9	0.2	-2.3	6.7		3.8	1.0	0.7	0.9	

Table 6: MAC1-3 gold standards, results by pXRF 2016. Symbol "Ø" means diameter.

PIXE

To calibrate AGLAE accelerator, two silica standards (SiO2 and SiO2 + Au coating of 1.5µm) and one gold standard (LA6917) were used as internal standards. To calibrate the compositional data, three gold (MAC1-3, Micro-Analysis Consultants Ltd) and silver (133x AGA1-3, MBH Analytical LTD) standards mounted in polished blocks were used. However, for time constraints not all the standards were analysed the same amount of times: MAC2 was analysed three times; AGA1 and AGA2 were analysed two times; while MAC1 and MAC3 were analysed only once. To estimate precision and accuracy a minimum of three readings in each standard is necessary, therefore I calculated them using MAC2 only. For the other standards, I present only the readings.

In MAC2 precision is very high, with a coefficient of variation <4.3%. Accuracy is also high for all elements (relative error <2%), except tin that was less accurate with a relative error of 15%, being slightly overestimated (Table 7). In MAC1 Cu and Au show a good agreement with the given values, while Ag and Sn were off in 0.1% each. In MAC3 silver show good agreement with the given, while copper was high in 0.7%, gold was low in 0.9% and tin was high in 0.3% (Table 8).

In AGA1, Tin (0.3%), antimony (0.1%) and iron (0.04%) were not detected by the instrument. The standard has several trace elements, but most of them present below 100ppm. Only three trace elements were detected, but not in both readings: Ni, As and Co (Table 9). In AGA2, all major and minor elements were detected, except Sn present in 0.5% and Fe present in 0.03%. Only Ni was detected as trace element (Table 10).

In general, precision and accuracy is high for all the elements analysed in MAC2, with all elements present in concentrations above 1%. Tin in amounts of 0.3% and 0.5% was not detected in the silver-rich alloys, while it was perfectly identified in the gold-rich alloys (0.5%, 1% and 2%); being, however, overestimated in ~0.2%. In silver alloys only three trace elements were detected As, Co and Ni in AGA1; Ni in AGA2. Several trace elements present in 13-406ppm and Fe (in 0.03%) were not detected.

		MAC 2				
	(wt%)	Cu	Au	Ag	Sn	Total
	600000 dose	5.2	74.6	18.9	1.2	99.9
	300000 dose	5.1	74.6	19.0	1.2	99.9
	300000 dose	5.2	74.7	18.9	1.1	100.0
	Normalised mean values	**5.2**	**74.7**	**18.9**	**1.2**	**100.0**
Precision	Standard deviation	0.05	0.1	0.1	0.1	
	Coeficient of variation (%RSD)	0.9	0.1	0.3	4.3	
Accuracy	**Normalised reference values**	**5.1**	**74.7**	**19.2**	**1.0**	**100.0**
	Absolute error	0.1	0.01	-0.2	0.2	
	Relative error (%)	2	0	1	15	

Date: 10-06-2015 - 500x500 µm

Table 7: MAC2 gold standard, by PIXE.

	MAC 1					MAC 3				
(wt%)	Cu	Au	Ag	Sn	Total	Cu	Au	Ag	Sn	Total
600000 dose	1.0	93.9	4.5	0.6	100.0	9.7	58.3	29.7	2.3	100.0
Normalised reference values	**1.0**	**93.8**	**4.6**	**0.5**	**100.0**	**9.1**	**59.2**	**29.7**	**2.0**	**100.0**

Date: 10-06-2015 - 500x500 mm

Table 8: MAC1 and MAC3 gold standard, by PIXE.

	AGA 1								
(wt%)	Cu	Pb	Au	Zn	Sn	Sb	Bi	Fe	Ag
300000 dose	20.0	0.2	1.5	0.3	< 0.6	< 0.05	0.2	< 0.05	77.7
600000 dose	20.4	0.2	1.5	0.3	< 0.4	< 0.05	0.2	< 0.03	77.3
Normalised mean values	**20.2**	**0.2**	**1.5**	**0.3**	**nd**	**nd**	**0.2**	**nd**	**77.5**
Standard deviation	0.3	0.01	0.01	0.01	-	-	0.01	-	0.3
Normalised reference values	**20.0**	**0.2**	**1.5**	**0.2**	**0.3**	**0.1**	**0.2**	**0.04**	**77.5**

(ppm)	Ni	As	Co	Al	Cd	Cr	Ge	In	Mg	Mn	Pd	Pt	Rh	Se	Si	Ti	Te	Total
300000 dose	< 0.01	< 0.02	610	na	< 0.035	< 0.0026	na	< 0.1	na	< 0.073	< 0.08	< 0.076	< 0.061	< 0.014	< 0.42	< 0.0037	< 0.061	99.8
600000 dose	100	250	640	na	< 0.036	< 0.0022	na	< 0.064	na	< 0.081	< 0.024	< 0.048	< 0.035	< 0.01	< 1.12	< 0.0034	< 0.025	99.8
Normalised mean values	**100**	**250**	**625**	**na**	**nd**	**nd**	**na**	**nd**	**na**	**nd**	**nd**	**nd**	**nd**	**nd**	**nd**	**nd**	**nd**	**100.0**
Standard deviation	-	-	21.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Normalised reference values	**118**	**255**	**407**	**96**	**165**	**20**	**107**	**37**	**45**	**61**	**54**	**67**	**16**	**169**	**91**	**79**	**271**	**100.0**

Date: 10-06-2015 - 500x500 mm

Table 9: AGA1 silver standard, by PIXE. Values below the limit of detection are indicated with the symbol '<' in wt%. Nd: not detected.

	AGA 2								
(wt%)	Cu	Pb	Au	Zn	Sn	Sb	Bi	Fe	Ag
300000 dose	10.9	1.1	0.5	0.6	< 0.9	0.3	0.1	< 0.04	86.6
600000 dose	11.2	1.0	0.5	0.6	< 1.0	0.2	0.1	< 0.03	86.3
Normalised mean values	**11.1**	**1.0**	**0.5**	**0.6**	**nd**	**0.2**	**0.1**	**nd**	**86.5**
Standard deviation	0.2	0.02	0.01	0.01	-	0.1	0.01	-	0.2
Normalised reference values	**10.0**	**1.0**	**0.5**	**0.5**	**0.5**	**0.2**	**0.1**	**0.03**	**87.1**

(ppm)	Ni	Al	As	Cd	Co	Cr	Ge	In	Mg	Mn	Pd	Pt	Rh	Se	Si	Ti	Te	Total
300000 dose	150	na	< 0.025	< 0.08	< 0.027	< 0.0049	na	< 0.12	na	< 0.1	< 0.063	< 0.049	< 0.065	< 0.006	< 1.1	< 0.0068	< 0.057	100.0
600000 dose	180	na	< 0.02	< 0.041	< 0.016	< 0.0019	na	< 0.075	na	< 0.056	< 0.059	< 0.046	< 0.029	< 0.0074	< 1.28	< 0.0067	< 0.031	99.9
Normalised mean values	**165**	**na**	**nd**	**na**	**nd**	**nd**	**nd**	**nd**	**na**	**nd**	**nd**	**nd**	**nd**	**nd**	**nd**	**nd**	**nd**	**100.0**
Standard deviation	21.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Normalised reference values	**264**	**19**	**144**	**113**	**163**	**76**	**47**	**65**	**17**	**115**	**76**	**114**	**13**	**78**	**43**	**69**	**98**	**100.0**

Date: 10-06-2015 - 500x500 mm

Table 10: AGA2 silver standard, by PIXE. Values below the limit of detection are indicated with the symbol '<' in wt%. Nd: not detected.

SEM-EDS

Five custom-made certificate reference materials were analysed by SEM-EDS (Hitachi s-3400N) to assess precision and accuracy. Samples in this case were mounted in resin blocks and polished, analysis were applied in areas of 159x109μm (800x magnification).

The measurements of AGA1 (Table 11) show a high precision for major elements (≥1.5%), with a coefficient of variation below 8.0% for gold, copper and silver. Accuracy is very high as well, with a relative error below 1.5%. The least accurate element is silver, being consistently overestimated in 1.3%. However, minor elements (≤0.3%) such as lead, zinc, tin, antimony, bismuth and iron are not detected at all. The results indicate that at smaller concentrations, measurements are less precise; and in a silver-rich matrix, elements such as lead, zinc, tin antimony and bismuth when are below 0.3% are not detected, estimating a limit of detection of 0.3% in this case.

The measurements of AGA2 (Table 12) show high precision for copper and silver, with a coefficient of variation below 2.4%. However, precision is lower (>10%RSD) for lead, gold and zinc, which are present in low concentrations (≤1%). Accuracy is high for copper, silver and lead with a relative error below 5.7%, but the relative error increases above 15% for gold and zinc (both present in 0.5%). The results indicate that in silver-rich alloys, minor amounts gold and zinc are more difficult to measure, and together with lead, their results are less precise when concentrations are ≤1%. In AGA2, concentrations of antimony and bismuth ≤0.2% are still not detected. In the case of zinc, at 0.5% started to be detected (compared to the undetected 0.2% in AGA1); but for tin, also at 0.5%, the results are below limits of detection. In the particular case of tin, its Lα peaks are too close to the Lβ peaks of silver; so when silver is high, they can easily overlap and be hided during the analysis, increasing tin's limits of detection.

The measurements of MAC1 (Table 13) show high precision for gold and silver, both major elements (≥4.6%), but for copper and tin present as minor elements (<1%) results were less precise, with a coefficient of variation between 14.5-22.6%, respectively. The relative error was below 6.0% in all cases. The results show that in gold-rich alloys concentrations of 0.5% tin are detectable (but also are less precise than other elements present in higher concentrations), confirming the possible overlap between silver and tin lines in silver-rich alloys (e.g. AGA1-2). Therefore, in gold-rich alloys, tin at 0.5% is above the limits of detection.

The measurements of MAC2 (Table 13) show high precision in general, with a coefficient of variation between 0.1-2.9% for elements in concentrations above 1%. But precision was lower for tin, present at 1%. The relative error of all elements was below 7.8%, showing a better accuracy for gold and silver (both in concentrations >19%), compared to copper and tin (both present at <5%).

The measurements of MAC3 (Table 13) show a high precision for all the elements, with a coefficient of variation below 8.2%. The most precise element was gold present in 59% in the alloy (0.2%RSD) and the least precise was tin, present in 2% (8.2%RSD), indicating that precision improves when concentrations are higher. Accuracy was also high, with a relative error between 0.01-1.6%.

For a silver-rich alloys, precision and accuracy were good (<10%), except when concentrations were below 0.3% in AGA1 and below 1% in AGA2, where precision and accuracy appears low and more variable. In the case of gold-rich alloys, all elements up to 0.5% were detected; showing however, less precision when concentrations were low (0.5-1%). Nonetheless, accuracy was very high in all cases (relative error <7.8%).

Regarding limits of detection, results indicate that depending on the main element of the alloy, the limits of detection of some elements vary. The clearest case is tin. In a silver-rich matrix, tin limits of detection are above 0.5%, while the same amount is perfectly detectable in gold-rich alloys. Unfortunately, there was no access to gold standards with less than 0.5% of tin, to compare the detection limits for lower concentrations; and our silver standards do not have higher tin percentages to confirm when tin starts to be detectable. Despite of that, we can estimate limits of detection for tin around 0.5%.

						AGA 1					
	(wt%)	**Cu**	**Pb**	**Au**	**Zn**	**Sn**	**Sb**	**Bi**	**Fe**	**Ag**	**Total**
		20.5	nd	1.5	nd	nd	nd	nd	nd	79.3	101.3
		19.7	nd	1.7	nd	nd	nd	nd	nd	80.7	102.1
		21.2	nd	1.3	nd	nd	nd	nd	nd	78.8	101.3
		19.6	nd	1.5	nd	nd	nd	nd	nd	79.9	101.0
	Date: 15-09-2015	20.2	nd	1.5	nd	nd	nd	nd	nd	79.9	101.6
	Normalised mean values	**20.0**	**nd**	**1.5**	**nd**	**nd**	**nd**	**nd**	**nd**	**78.6**	**100.0**
Precision	Standard deviation	0.6	-	0.1	-	-	-	-	-	0.7	
	Coefficient of variation (%RSD)	3.2	-	8.0	-	-	-	-	-	0.9	
Accuracy	Reference values	20.0	0.2	1.5	0.2	0.3	0.1	0.2	0.04	77.4	99.8
	Normalised reference values	**20.0**	**0.2**	**1.5**	**0.2**	**0.3**	**0.1**	**0.2**	**0.04**	**77.5**	**100.0**
	Absolute error	-0.03	-	-0.005	-	-	-	-	-	1.0	
	Relative error (%)	0.1	-	0.3	-	-	-	-	-	1.3	

Table 11: AGA1 silver standard, by SEM-EDS.

						AGA 2					
	(wt%)	**Cu**	**Pb**	**Au**	**Zn**	**Sn**	**Sb**	**Bi**	**Fe**	**Ag**	**Total**
		9.8	0.9	0.8	0.5	nd	nd	nd	nd	88.4	100.4
		10.2	1.2	0.5	0.4	nd	nd	nd	nd	87.9	100.2
		10.5	1.0	0.5	0.4	nd	nd	nd	nd	87.9	100.2
		10.0	1.3	0.8	0.4	nd	nd	nd	nd	88.8	101.3
	Date: 15-09-2015	10.1	1.1	0.6	0.4	nd	nd	nd	nd	88.6	100.8
	Normalised mean values	**10.1**	**1.1**	**0.6**	**0.4**	**nd**	**nd**	**nd**	**nd**	**87.8**	**100.0**
Precision	Standard deviation	0.2	0.1	0.1	0.1	-	-	-	-	0.4	
	Coefficient of variation (%RSD)	2.4	13.3	23.9	16.1	-	-	-	-	0.5	
Accuracy	Reference values	10.0	1.0	0.5	0.5	0.5	0.2	0.1	0.03	87.0	99.8
	Normalised reference values	**10.0**	**1.0**	**0.5**	**0.5**	**0.5**	**0.2**	**0.1**	**0.03**	**87.1**	**100.0**
	Absolute error	0.05	0.1	0.1	-0.1	-	-	-	-	0.7	
	Relative error (%)	0.5	5.7	23.6	15.8	-	-	-	-	0.8	

Table 12: AGA2 silver standard, by SEM-EDS.

		MAC 1					MAC 2					MAC 3				
	(wt%)	**Cu**	**Au**	**Ag**	Sn	**Total**	**Cu**	**Au**	**Ag**	**Sn**	**Total**	**Cu**	**Au**	**Ag**	**Sn**	**Total**
		1.0	94.7	4.2	0.5	100.4	5.5	76.1	19.3	0.8	101.7	9.8	60.6	30.1	2.0	102.5
		1.2	95.4	4.5	0.5	101.6	5.5	76.3	18.9	1.0	101.8	9.3	60.5	30.6	1.9	102.3
		1.0	95.3	4.4	0.5	101.3	5.6	76.2	19.3	0.8	101.9	9.4	60.4	30.3	1.8	101.9
		0.9	95.5	4.4	0.6	101.4	5.2	76.1	19.0	1.2	101.5	9.4	60.4	30.7	2.2	102.7
	Date: 15-09-2015	1.2	95.6	4.3	0.8	101.9	5.6	76.0	19.1	1.0	101.8	9.2	60.5	30.4	2.2	102.4
	Normalised mean values	**1.1**	**94.1**	**4.3**	**0.6**	**100.0**	**5.4**	**74.9**	**18.8**	**0.9**	**100.0**	**9.2**	**59.1**	**29.7**	**2.0**	**100.0**
Precision	Standard deviation	0.2	0.4	0.1	0.1		0.2	0.1	0.2	0.2		0.2	0.1	0.2	0.2	
	Coefficient of variation (%RSD)	14.5	0.4	2.9	22.6		2.9	0.1	0.9	17.6		2.6	0.2	0.8	8.2	
Accuracy	Reference values	1.0	93.9	4.6	0.5	100.1	5.1	74.7	19.2	1.0	100.0	9.1	59.4	29.8	2.0	100.3
	Normalised reference values	**1.0**	**93.8**	**4.6**	**0.5**	**100.0**	**5.1**	**74.7**	**19.2**	**1.0**	**100.0**	**9.1**	**59.2**	**29.7**	**2.0**	**100.0**
	Absolute error	0.02	0.2	-0.3	0.02		0.3	0.2	-0.4	-0.1		0.1	-0.1	0.003	-0.01	
	Relative error (%)	1.5	0.3	6.0	3.7		5.7	0.2	2.1	7.8		1.6	0.2	0.01	0.4	

Table 13: MAC1, MAC2 and MAC3 gold standards, by SEM-EDS.

Appendix nº10. Supplementary information on pXRF analyses

The analyses of the materials from San Pedro de Atacama were made in two field trips, in 2015 and 2016, using two different pXRF instruments. Both instruments are from the same manufacturer and comparable evaluation settings were selected. The difference between both instruments is that the analyses with the pXRF2015 were performed using a collimator with a beam of 3mm diameter and higher beam current; while the pXRF2016 was uncollimated with a beam of 10mm diameter and lower beam current. The technical specifications of both instruments are summarised in Table 1.

Instrument	Manufacturer / Model	Model N°	Tube	Mode	Voltage	Current	Collimator	Spot diameter
pXRF2015	Olympus Innov-X / Delta Premium	6000CC	Rh	Alloy Plus	40kV	100μA	Yes	3mm
pXRF2016		4000	Au			15μA	No	10mm

Table 1: Technical specifications of both pXRF instruments used for this research.

Five certificate reference materials were analysed with both instruments to assess compatibility. The results summarised in Table 2 and plotted in figures 1-4 show a small and unsystematic difference between instruments. Therefore, it was decided not to apply further corrections factors, presenting the data as it is. Both instruments show a good precision, with coefficients of variation for repeated analysis of ≤3.9% for major elements. Accuracy was also high for major elements with relative errors on gold standards ≤6.9% (MAC1-3) and on silver standards <10% (AGA1-2; see).

	MAC 1				MAC 2				MAC 3			
(wt%)	**Cu**	**Au**	**Ag**	**Sn**	**Cu**	**Au**	**Ag**	**Sn**	**Cu**	**Au**	**Ag**	**Sn**
Given values	**1.0**	**93.8**	**4.6**	**0.5**	**5.1**	**74.7**	**19.2**	**1.0**	**9.1**	**59.2**	**29.7**	**2.0**
pXRF 2015	1.0	94.3	4.3	0.5	4.9	75.4	18.6	1.1	8.7	59.4	29.9	2.0
pXRF 2016	1.1	94.1	4.3	0.5	5.3	74.8	18.8	1.1	9.4	58.7	29.9	2.0

	AGA 1									AGA 2								
(wt%)	**Cu**	**Pb**	**Au**	**Zn**	**Sn**	**Sb**	**Bi**	**Fe**	**Ag**	**Cu**	**Pb**	**Au**	**Zn**	**Sn**	**Sb**	**Bi**	**Fe**	**Ag**
Given values	**20.0**	**0.2**	**1.5**	**0.2**	**0.3**	**0.1**	**0.2**	**0.04**	**77.5**	**10.0**	**1.0**	**0.5**	**0.5**	**0.5**	**0.2**	**0.1**	**0.03**	**87.1**
pXRF 2015	18.6	0.2	1.6	0.2	<0.5	<0.1	0.2	<0.1	78.7	9.7	1.3	0.6	0.5	0.6	0.2	0.1	<0.1	87.1
pXRF 2016	19.4	0.2	1.5	0.3	<0.5	<0.1	0.2	<0.1	78.0	9.7	1.1	0.5	0.5	0.4	0.1	0.1	<0.1	87.5

Table 2: Summary of the analytical results (normalised to a 100%) and given values of five standards analysed by pXRF-2015 and pXRF-2016. Note that despite small differences, values are very close to the given values and between instruments, allowing pooling both dataset together.

Both instruments are compared in Table 3. In general, the relative difference between machines is less on the gold standards, than on the silver standards. On a gold-matrix, the relative differences between instruments is very low for gold and silver, with a δ relative ≤1%; copper however, is overestimated by pXRF2016 on 8-9% relative. On the silver-matrix the relative difference for silver and copper is low (δ relative ≤4%); whereas the difference between machines on minor elements such as lead, zinc, tin, antimony and bismuth increases with δ relative between 10-44%. No systematic differences are found in the dataset, making difficult to apply correction factors to improve results. Even though copper is systematically overestimated on the gold standards with pXRF2016, on the silver standards the error is much less and a correction of this element would affect the quantification on silver-rich objects.

However, in spite of the small difference, generally speaking the data of both instruments show good agreement, making possible to pool both dataset together (Figures 1-4). The differences observed here set the degree of uncertainty of these analysis and they will be taken into account when proposing similarities or differences between artefacts based on composition.

	MAC 1				MAC 2				MAC 3			
(wt%)	**Cu**	**Au**	**Ag**	**Sn**	**Cu**	**Au**	**Ag**	**Sn**	**Cu**	**Au**	**Ag**	**Sn**
pXRF 2015	1.0	94.3	4.3	0.5	4.9	75.4	18.6	1.1	8.7	59.4	29.9	2.0
pXRF 2016	1.1	94.1	4.3	0.5	5.3	74.8	18.8	1.1	9.4	58.7	29.9	2.0
Difference	-0.1	0.2	-0.05	-0.02	-0.4	0.6	-0.1	-0.03	-0.7	0.7	-0.04	0.05
δ relative (%)	**-9**	**0.2**	**-1**	**-4**	**-8**	**1**	**-1**	**-3**	**-8**	**1**	**-0.1**	**2**

	AGA 1									AGA 2								
(wt%)	**Cu**	**Pb**	**Au**	**Zn**	**Sn**	**Sb**	**Bi**	**Fe**	**Ag**	**Cu**	**Pb**	**Au**	**Zn**	**Sn**	**Sb**	**Bi**	**Fe**	**Ag**
pXRF 2015	18.6	0.2	1.6	0.2	<dl	<dl	0.2	<dl	78.7	9.7	1.3	0.6	0.5	0.6	0.2	0.1	<dl	87.1
pXRF 2016	19.4	0.2	1.5	0.3	<dl	<dl	0.2	<dl	78.0	9.7	1.1	0.5	0.5	0.4	0.1	0.1	<dl	87.5
Difference	-0.8	0.02	0.1	-0.1	-	-	0.01	-	0.7	-0.01	0.2	0.1	-0.1	0.2	0.02	0.01	-	-0.4
δ relative (%)	**-4**	**10**	**7**	**-44**	-	-	**5**	-	**1**	**0.1**	**14**	**10**	**-11**	**27**	**11**	**11**	-	**0.4**

Table 3: Comparison of the analytical results for pXRF2015 and pXRF2016 on gold (MAC1-3) and silver (AGA1-2) standards. The analytical results are averages of 17-21 measurements.

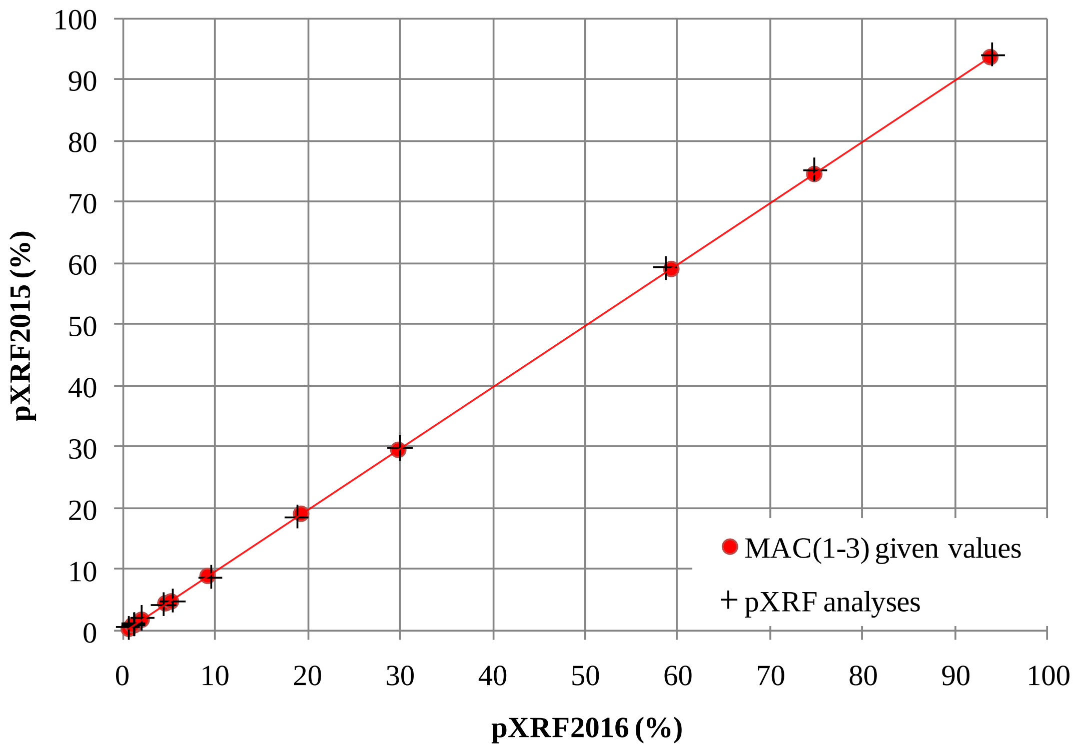


Figure 1: Scatter plot comparing the results of pXRF2015 and pXRF2016 (+), against the given values of the gold standards (red dots).The plot includes all the elements from MAC1-3: Au, Ag, Cu and Sn. The pXRF results are an average of 17 measures. Note the good agreement of both datasets.

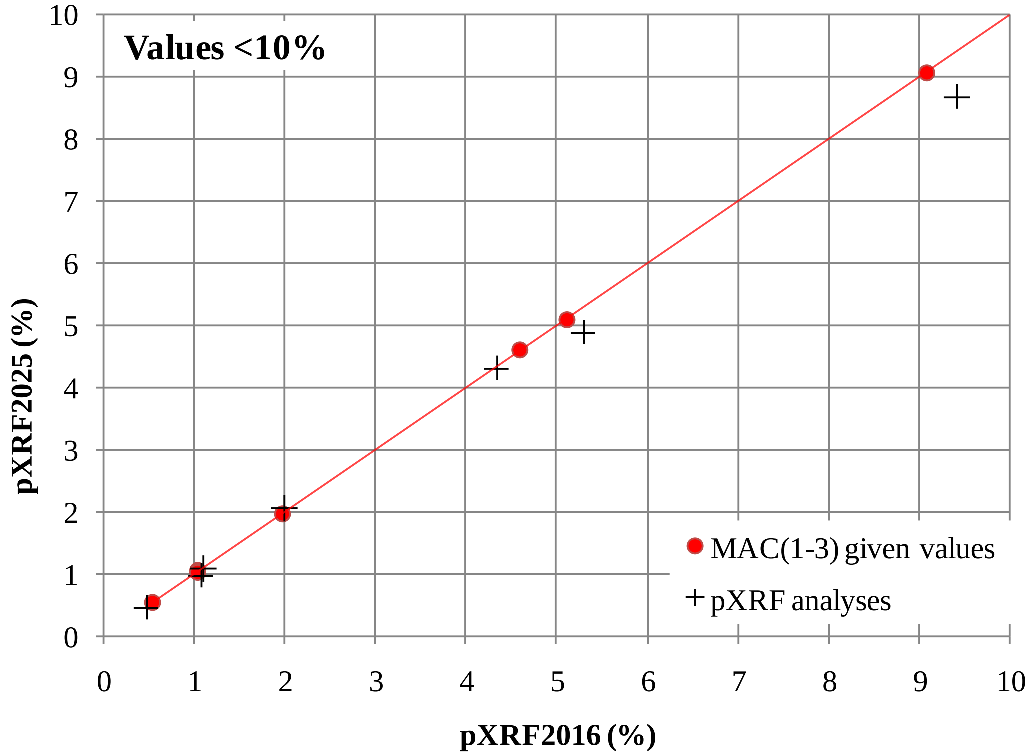


Figure 2: Detail of Figure 1 showing values below 10%.

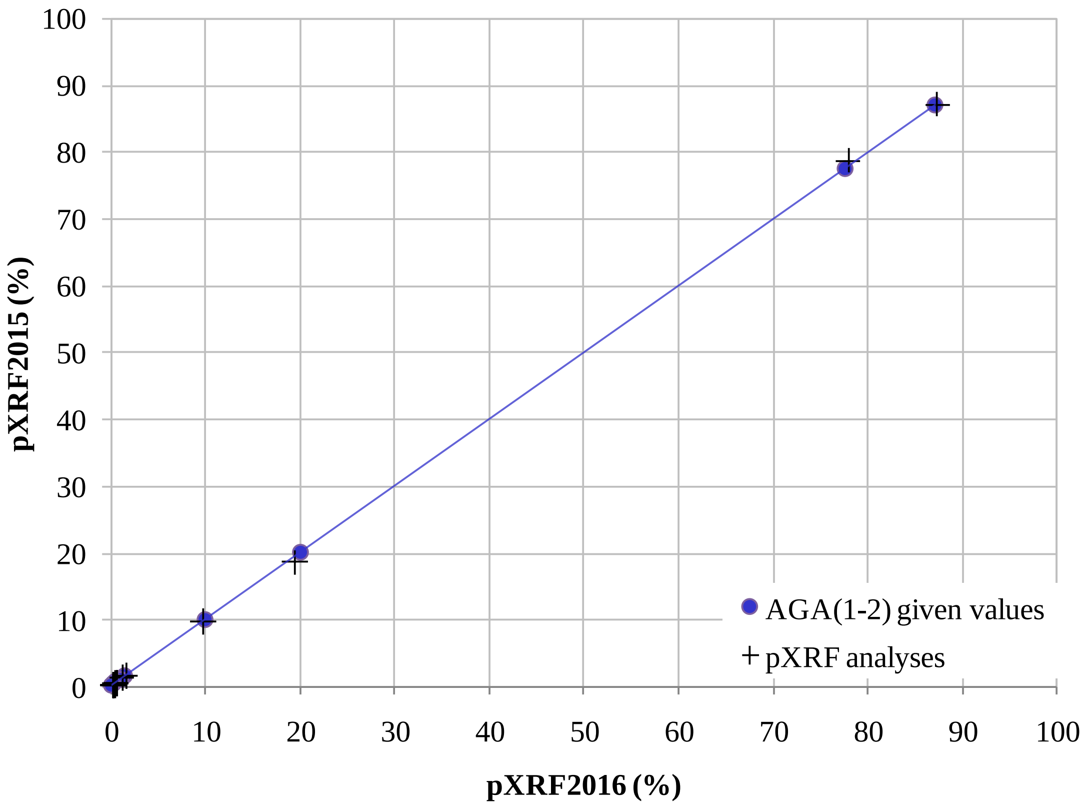


Figure 3: Scatter plot comparing the results of pXRF2015 and pXRF2016 (+), against the given values of the silver standards (blue dots).The plot includes all the elements from AGA1-2: Au, Ag, Cu, Sn, Pb, Zn, Sb, Bi and Fe. The pXRF results are an average of 21 measures.

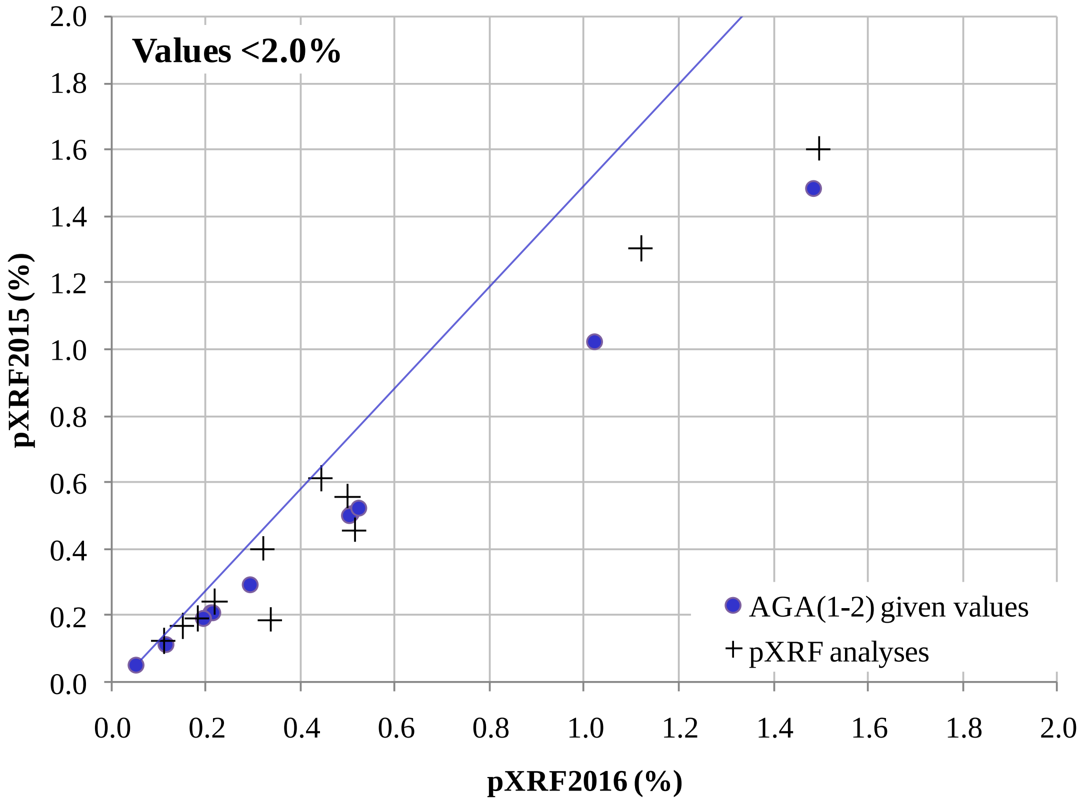


Figure 4: Detail of Figure 3 showing values below 2.0%. Note that at lower concentrations, values are less accurate.

Appendix nº11. Metallography supplementary data

Etchant	Components	Time	Results
Positive results			
Aqueous ferric chloride	12ml Ionised water 3ml Chlorhydric acid 1gr Ferric chloride aqueous	65 seg	Popm27: revealed banding (Cu-high). Did not react with the other samples
Aqua regia concentrated	40 Nitric acid (65%) 60 Chlorhydric acid (37%)	5 seg	Popm30: partially revealed some grains and banding. The remaining samples with >30%Ag were burnt; samples with <30%Ag were not affected, only developed a minor pitting.
Hydrogen peroxide / iron (III) chloride (fresh)	3.2gr Ferric chloride aqueous 10ml Hydrogen peroxide 10ml Distilled water	5 seg	Popm10, 15, 24, 25, 32, 34, 35, 37: revealed grains and twin bands in some samples with silver ~30%Ag. The remaining samples were burnt (Ag-rich) or not attacked at all (Au-rich).
Negative results			
Hydrogen peroxide / iron (III) chloride (one day old, reactivated)	3.2gr Ferric chloride aqueous 15ml Hydrogen peroxide 10ml Distilled water	5 seg	Did not attacked Au-rich samples, it burnt Ag-rich alloys. It revealed some banding in Ag-rich alloys, but not grains.
Hydrogen peroxide / iron (III) chloride (one day old, reactivated)	3.2gr Ferric chloride aqueous 15ml Hydrogen peroxide 20ml Distilled water	60 seg	Did not attacked Au-rich samples, it burnt Ag-rich alloys.
Aqua regia diluted	40 Nitric Acid (5N) 60 Chlorhydric Acid (5N)	10 min	Revealed banding. Ag-rich phases were attached with pitting. Grains were not revealed.
Amonnia hydrogen peroxide	8.3ml Distilled water 8.3ml Ammonium hydroxide 1.7ml Hydrogen peroxide	95 seg	Did not attacked the samples
Amonnia hydrogen peroxide	8.3ml Distilled water 8.3ml Ammonium hydroxide 5ml Hydrogen peroxide	60 seg	Did not attacked the samples
Nitric acid (5N)		25 seg	Did not attacked the samples

Table 1: List of etchants used to reveal the microstructure of the samples, taken from Scott (1991). Only 10 samples were positively attacked.

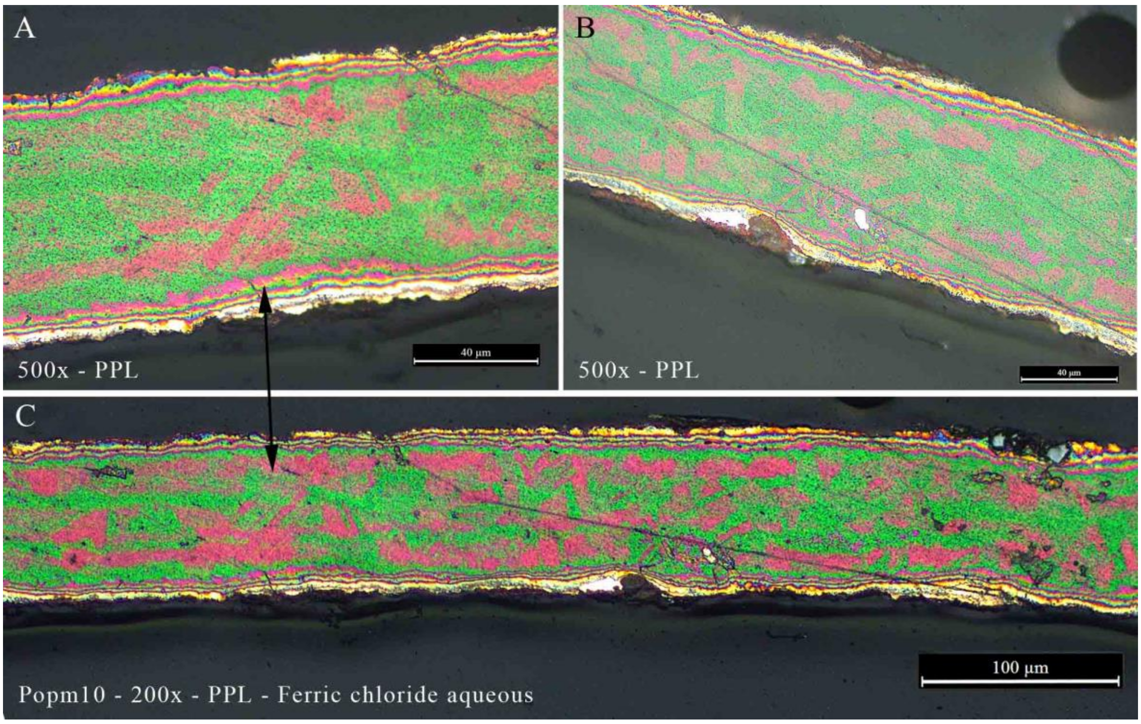


Figure 1: Optical microscope images under PPL of sample popm10. Note the equi-axed hexagonal grains and lightly twinned bands; the average grain size is ~25μm.

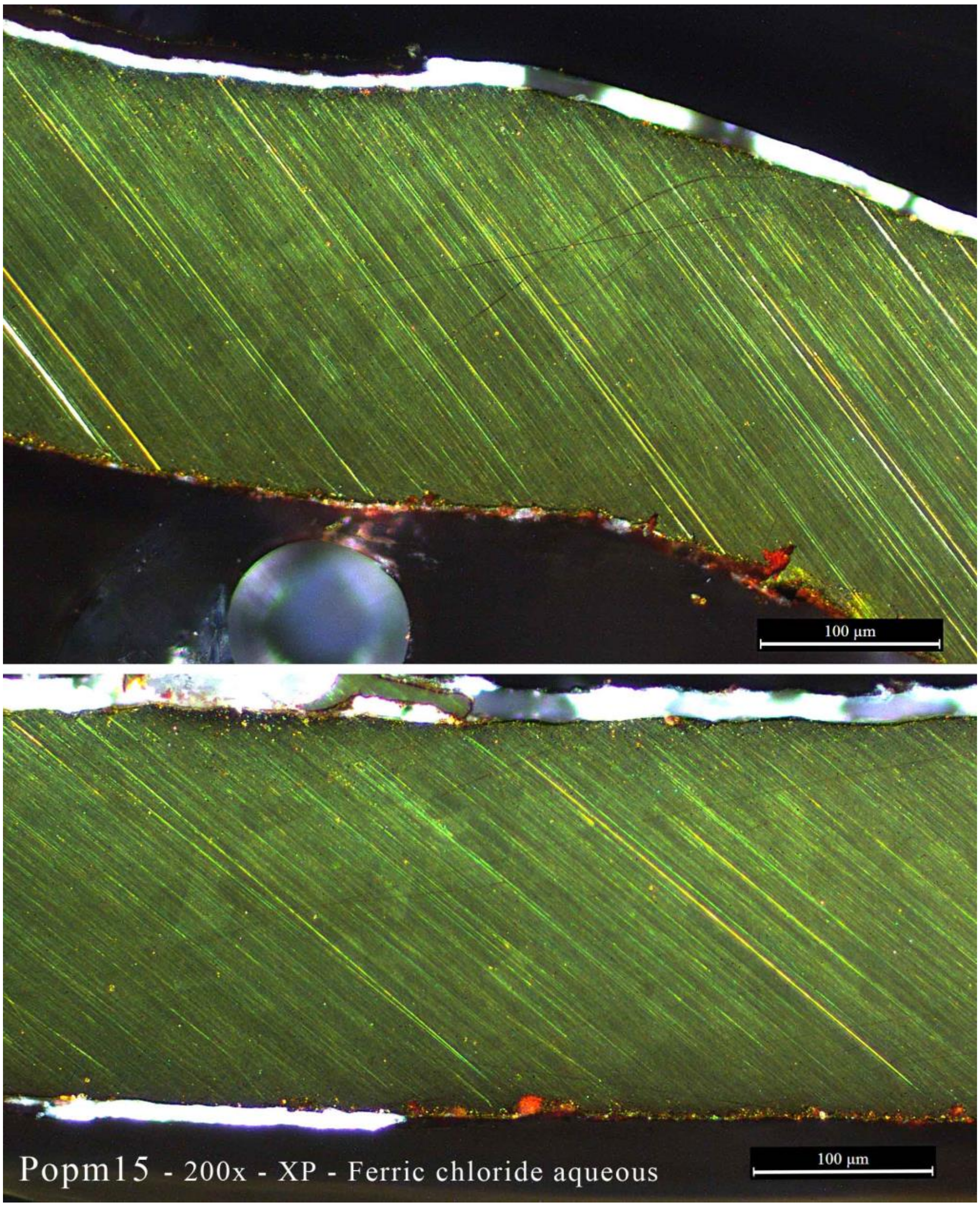


Figure 2 Optical microscope images under XP of sample popm15. Note the subtle equi-axed hexagonal grains; the average grain size is ~31μm.

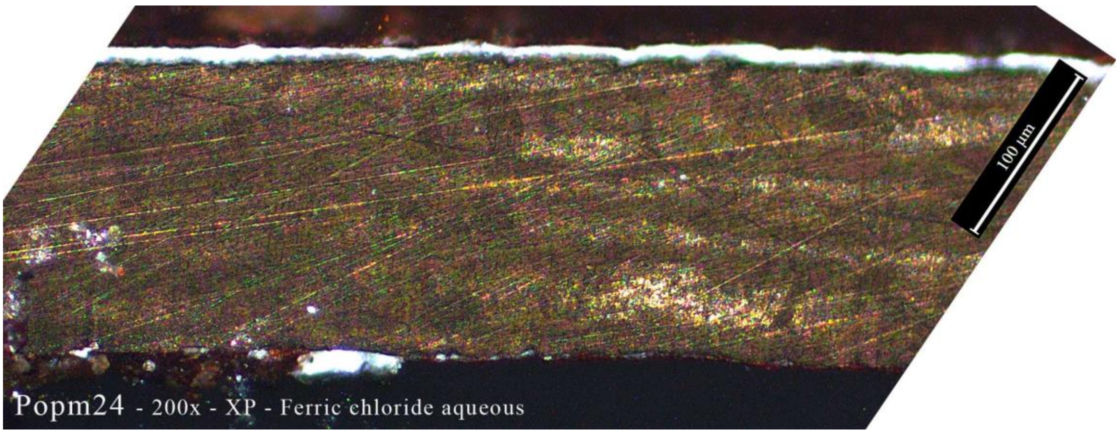


Figure 3: Optical microscope images under XP of sample popm24. Note the equi-axed hexagonal grains, twinned bands are not visible; the average grain size is ~30μm.

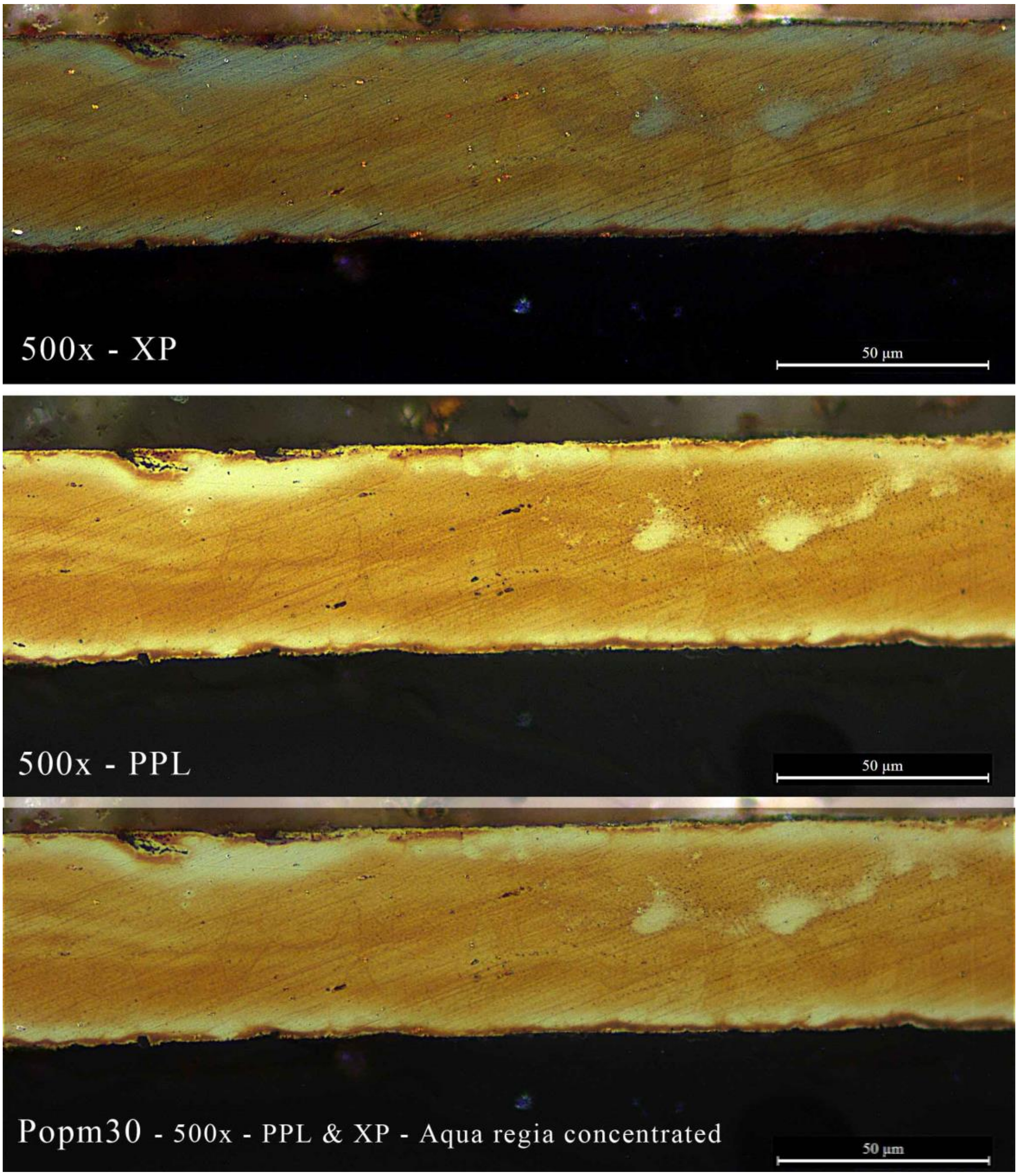


Figure 4: Optical microscope images under XP and PPL of sample popm30. Note the equi-axed hexagonal grains and lightly twinned bands; the average grain size is ~14µm.

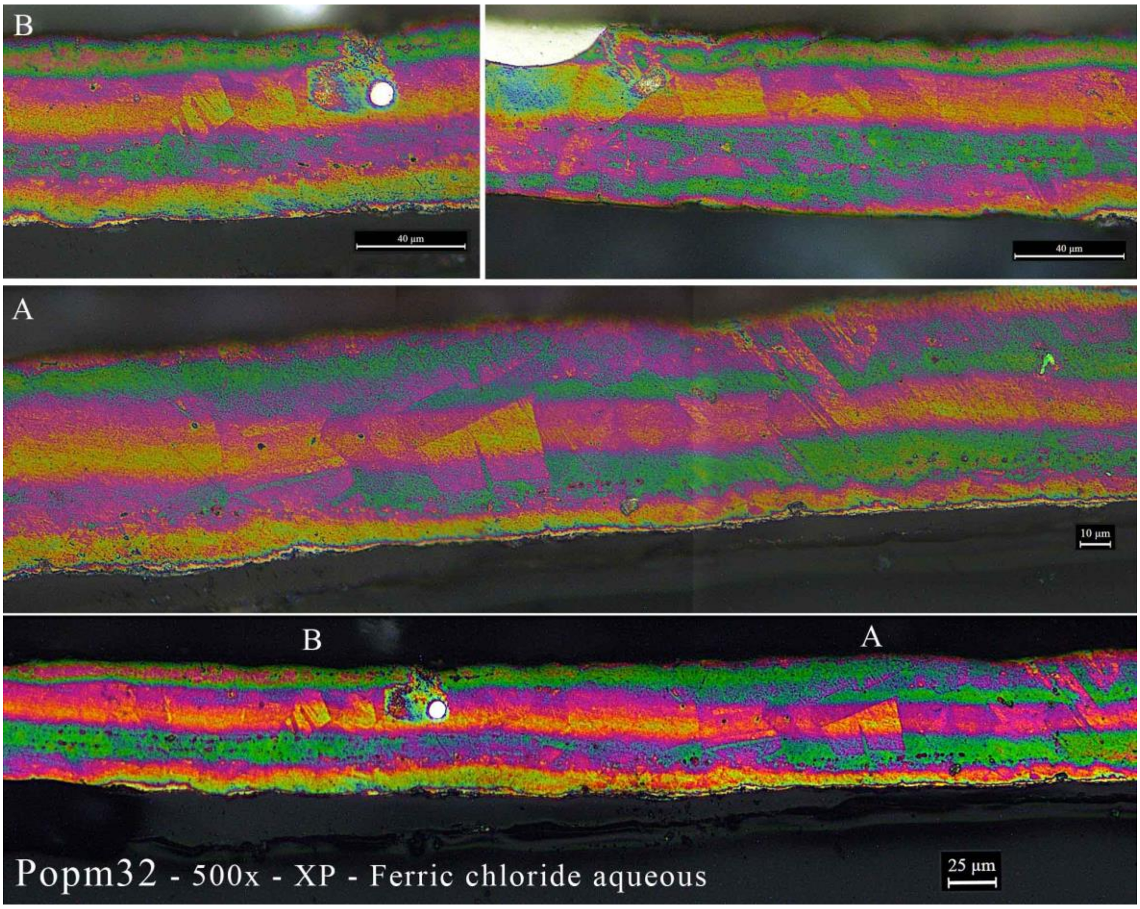


Figure 5: Optical microscope images under XP of sample popm32. Note the equi-axed hexagonal grains and lightly twinned bands; the average grain size is ~26μm.

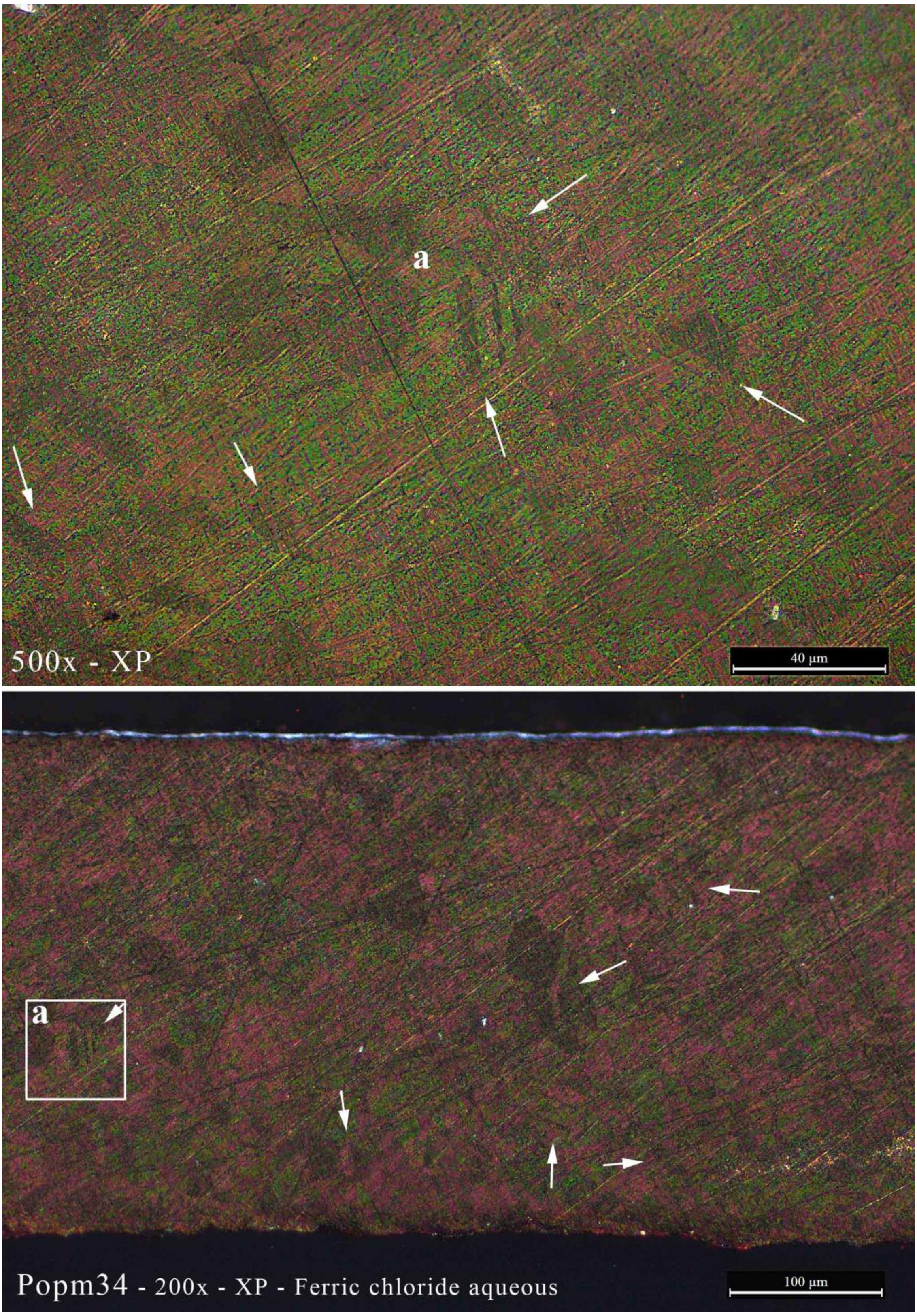


Figure 6: Optical microscope images under XP of sample popm34. Note the equi-axed hexagonal grains and twinned bands (white arrows); the average grain size is ~26µm.

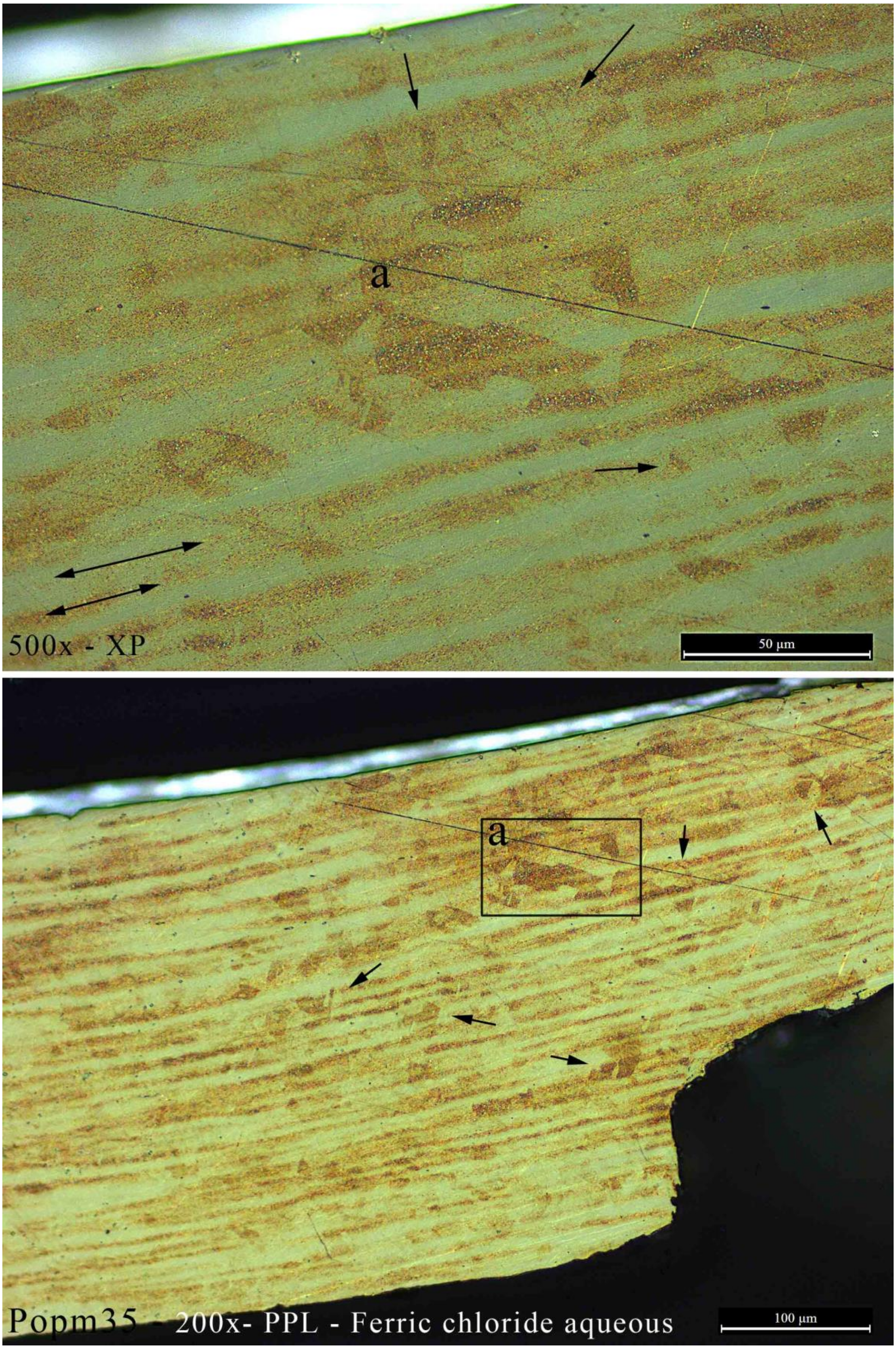


Figure 7: Optical microscope images under XP and PPL of sample popm35. Note the equi-axed hexagonal grains and lightly twinned bands; the average grain size is ~24μm.

Appendix nº12. Analysis on alluvial gold from NW Argentina

Five gold grains from an alluvial deposit in Rinconada, Argentinean *puna* (Figure 1, coordinates: 22º26'58.42'' S and 66º8'57.91'' W), were observed and analysed using SEM-EDS (Figure 2). The analysis in this case is qualitative, because the grains were not prepared or mounted. Their surfaces are very irregular and their shapes are volumetric, therefore the results presented here are only broad references. Moreover, the SEM-EDS analysis only gives the composition of the surface which is usually purer than the core (Chapman et al., 2002; 2006; Hough et al., 2009), therefore these results do not represent the bulk composition of the gold grain if this is eventually melted. Nevertheless, their analysis is useful to have a reference of the range of composition that alluvial may have.

The results show interesting patterns. First, silver content vary between grains (Table 1). For instance some grains contain between 2.1-4.7%Ag (grain n°2), others contain ~10%Ag (grain n°5) and even up to 27.2%Ag (grain n°1). The mean of all the analysis in the five grains gave ~11.9%Ag content. Second, copper was not detected as expected when analysing the core of a grain. Third, some impurities and inclusions were detected when analysing small areas, such as Si, Al, K and Ca. The two minute inclusions identified were silica (Si and O) and titania (Ti and O).

Chemical composition of gold grains by SEM-EDS (wt%)													
Grain n°	**Grain dimension (µm)**	**Area analysed**	**N° of analyses**	**O**	**Al**	**Si**	**K**	**Ca**	**Ti**	**Ag**	**Au**	**Total**	**Analytical total**
2	266.1x191.9	Area	3							2.1	99.3		79.4
2		Spot	6							4.7	97.7		97.7
4	170.8x131.8	Area	3	≤11.5	≤0.8	≤1.1				3.8	88.4		74.2
4		Spot	6							6.3	93.7		94.6
5	146.7x143.4	Area	3	≤6.5	≤0.6	≤0.4		≤0.8		10.3	85.1		86.5
5		Spot	6							10.1	89.9		93.3
3	155.0x85.3	Area	3	≤22.1	≤2.3	≤3.7	≤0.9		≤1.6	12.9	73.3		103.6
3		Spot	6							17.2	82.8		101.0
3	10.6x3.3	Inclusion	1	37.5	0.4	1.1			53.4	0.8	6.7	100.0	95.5
1	184.5x98.0	Area	3							27.2	72.8		102.5
1		Spot	6							24.6	75.4		101.8
1	5.1x3.6	Inclusion	1	39.1	0.6	22.1		0.8		4.6	33.0	100.0	108.7
General mean (excluding inclusions)				**≤22.1**	**≤2.3**	**≤3.7**	**≤0.9**	**≤0.8**		**11.9**	**85.8**		

Table 1: Chemical composition of five alluvial gold grains from the NWA, by SEM-EDS. Small areas and spot analysis were performed. Results are qualitative because the analysis were analysed applied on unprepared surfaces.

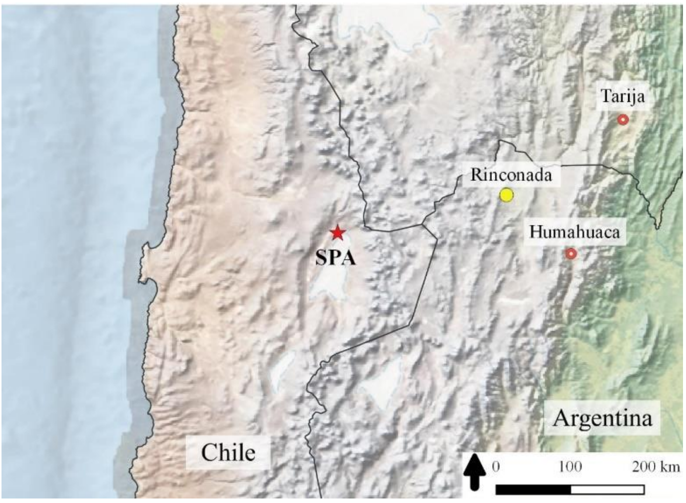


Figure 1: Map with the location of the Rinconada placer where the grains were collected and SPA.

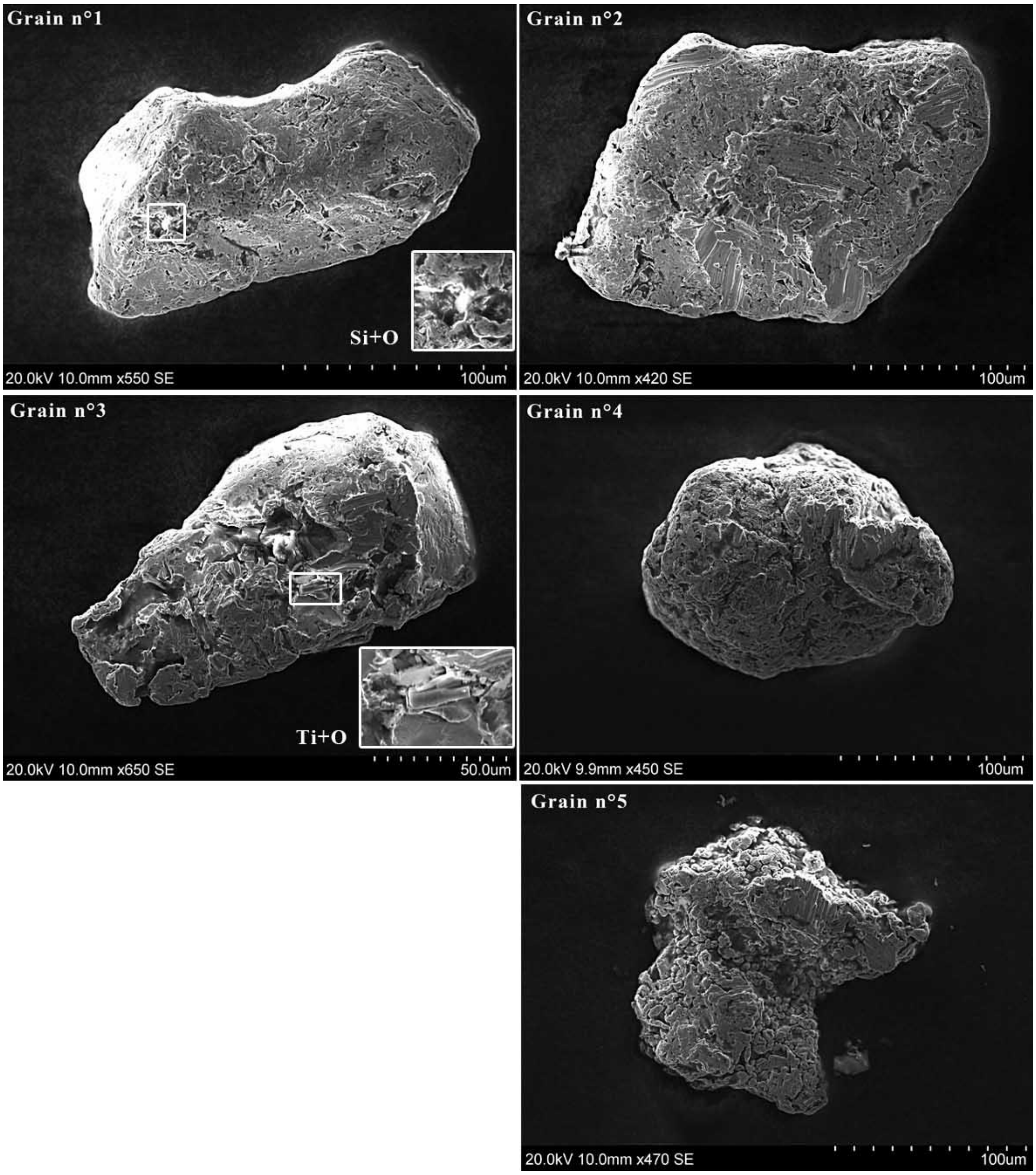


Figure 2: SE images of gold grains from the NWA.