



Small gold bells and miniature keros: An approach to understanding the technologies and alloys employed in Pre-Columbian Andes

Maria Filomena Guerra, Soledad Fernandez, Irene Delaveris, José Oscar Encuentra, Juan Villanueva

► To cite this version:

Maria Filomena Guerra, Soledad Fernandez, Irene Delaveris, José Oscar Encuentra, Juan Villanueva. Small gold bells and miniature keros: An approach to understanding the technologies and alloys employed in Pre-Columbian Andes. *Journal of Archaeological Science: Reports*, 2019, 24, pp.967-977. 10.1016/j.jasrep.2019.03.002 . hal-02426496

HAL Id: hal-02426496

<https://hal.science/hal-02426496>

Submitted on 22 Oct 2021

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution - NonCommercial 4.0 International License

Small gold bells and miniature keros: an approach to understanding the technologies and alloys employed in Pre-Columbian Andes

Maria Filomena GUERRA¹, Soledad FERNANDEZ², Irene DELAVERIS³, José Oscar ENCUESTRA⁴, Juan VILLANUEVA²

¹ CNRS, UMR 8096, ArchAm, MAE, 21 allée de l'Université, 92023 Nanterre, France

² MUSEF, Calle Ingavi N 916, Esq. Jenaro Sanjinés Casilla 5817, La Paz, Bolivia

³ Delaveris Conservaciones, La Paz, Bolivia

⁴ Proyecto Titicaca, Université libre de Bruxelles, Belgium

Corresponding author:

Maria Filomena GUERRA, maria.guerra@cnrs.fr

Abstract

Fifteen gold miniatures in the collection of the MUSEF (La Paz) of types and dimensions consistent with bells and ceremonial cups (keros) produced during the Tiwanaku and Inca periods, were analysed in-situ using portable equipment to investigate the technologies and alloys employed. It was shown that at least two techniques of construction were used: one that is expected for Andean bells (by joining two gold sheets) and another that is expected for keros (by raising one gold sheet). One incomplete specimen was shown to be a broken miniature kero. Others, supposedly bells, with the same shapes, dimensions, and elemental compositions could have originally belonged to sets. The bodies and bases of the majority of the objects have different compositions, which are quite variable (10-63 wt% Ag and 0.5-5.5 wt% Cu), but within the range of alloys used by the Incas and of the few gold objects related to the Tiwanaku culture analysed so far. By comparison with gold grains from the Bolivian Cordillera mines, we suggest that the bells and keros containing more than 25 wt% Ag are made from artificial alloys. The others could have been made from either artificial or natural alloys, because only the Ag contents of some specimens match the fineness of gold grains from deposits situated in the Lake Titicaca area. Nevertheless, the Cu contents, being much higher in the objects than in the gold grains, could indicate that artificial alloys were more regularly produced.

Highlights

- First analytical approach to Bolivian small bells and miniature keros in gold
- Use of two techniques of manufacturing
- Gold alloys contain a wide range of Ag contents
- Artificial alloys were regularly produced
- Some alloys could be natural from Bolivian deposits

Keywords

Gold; alloys; technologies; miniatures; bells; keros; Andes

1. Introduction

Found in numerous archaeological sites associated to burials (Cabrero and Sil, 2013), sometimes still attached to a whole anklet brace (Portoni et al., 2012), frequently made in copper-base alloys, and occasionally made in silver (Medina-González et al., 2015) or in gold (López Lujan and Sil, 2015), small bells are the most abundant metal artefacts found in Mesoamerican sites (Paris, 2008). It has been suggested that they were worn in rites and dances around the waist or around the ankle, as their sounds should play a central role in agricultural and human fertility rites (Hosler, 2002). Even if some types have been related to productions from Colombia, Ecuador and Central America (Arsandaux and Rivet, 1921; Pendergast, 1962; Hosler, 1988, 1997), the most widespread examples are almost absent from Pre-Columbian sites excavated in the south-central Andes. Only a few specimens have been found in Argentina, for instance in the province of Jujuy (Debenedetti, 1921), in northern Chile (Latcham, 1936), and in the north coast of Peru (Gudemos, 2013).

Indeed, small metallic bells are only occasionally found in excavations in the Andean area, but they are sometimes found in groups (Gonzalez, 1979; Llagostera et al., 1988). Despite the scarcity of studies focusing on these objects, they were classified in four typological groups: pyramidal folded, truncated conical, truncated conical with oval section ("santamarianas"), and conical (Gudemos, 1998, 2013). Their chronological spread was not fully established. However, conical bells with oval section were assigned to late pre-Hispanic periods (Gonzalez, 2007) and small conical bells in copper base alloys have been assigned to the Incan period (Pérez de Arce, 1986). In fact, one of the child **mummies** – the maiden “La Doncella” – from the mountain sanctuary of Llullaillaco in Argentina (Reinhard and Cerruti, 2010; Gudemos, 2013) was ornamented with bells of this type, specimens that were also found along with miniature cups in Corral Redondo, an Incan site in Peru (King, 2016). Made by rolling a metal sheet, these bells seem typical of the south-central Andean ornaments, and may be feminine (Izikowitz, 1935), and produced by the Chancay, the Chimú and the Incas (Pérez de Arce, 1986). Under the Incas, they seem to be a specific typology of the region of Cusco and, from a broader point of view, of the Titicaca Lake area (Gudemos, 2013). Small conical bells are also among the metallic objects found in the site of Tiwanaku, located in the altiplano, near the southern shore of Lake Titicaca, in Bolivia (Uhle et al., 1889; Posnansky, 1957). Furthermore, small metallic bells were shown to be used in funerary rites in the large area of influence of the Tiwanaku culture (Stovel, 2001), and to be associated with the circulation between the important altiplano ceremonial site and the Argentinian northwest, the Atacama desert, Tarapacá and Arica (Pérez de Arce, 2001).

A few specimens of small bells found in archaeological context are in gold. They usually belong to the conical and to the truncated conical groups, but a few specimens belonging to the pyramidal folded group are also among the finds (Tarragó et al., 2010; Marsh, 2006; Izikowitz, 1935). Conical and truncated conical gold small bells were found in excavated sites related to the Tiwanaku and to the Inca cultures in Chile and Argentina. Similar bells are well represented in Bolivian collections, but they are frequently unprovenanced. **Along with small bells can be found ceremonial drinking cups, named keros, which were occasionally made in miniature. The shape and decoration of small bells and keros in precious metals (Carcedo, 2017; Carcedo et al., 2004) are frequently similar, which may lead to a misclassification. For example, one miniature kero in silver from Pucará de Rinconada (Boman, 1908) and some small bells from the Atacama region (Gudemos, 2013) have analogous shapes and decorations. The kero is, in addition, widely produced in the Andean area in various materials**

and forms (Cummins, 2015; Flores, 2015; Ramos Gómez, 2006; Villanueva and Korpisaari, 2013; Sagaseta, 1990). In his description of the New World (book six, chapter XXIII), the Inca Garcilaso de la Vega describes their use in many Incan ceremonies and refers to a production by pairs and in miniature, as follows: the drinking vessels are similar two by two, large and small, but each pair is similar in shape and size and made using the same material, gold, silver or wood (Garcilaso de la Vega, 1609).

Despite the difficulties raised by their typologies and therefore by their classification, the aim of this work is to make a first approach to understanding the technologies and alloys employed in the production of small gold bells. Fourteen unprovenanced gold miniatures in the collection of the National Museum of Ethnography and Folklore (MUSEF), La Paz, Bolivia, classified as bells, were studied using portable equipment. In order to provide further discussion on the analytical data obtained, the alloys employed in their production are compared to published data on Tiwanaku and Incan gold objects and on native gold from Andean deposits.

2. The gold miniatures in the MUSEF collection

Even if some specimens have been suggested to be female hair ornaments (Izikowitz, 1935), small bells found in the Andean area were supposedly sewn into the funerary textiles or into the costumes of dancers and participants to rites to produce sounds when clicking them together (Grebe, 1974). In fact, a few small bells were found in burials still attached to fragments of textiles or **sewn onto clothing**. These include, one in copper found with one miniature silver cup at Pucará de Rinconada in Argentina (Boman, 1908); some in gold from several burials at Larrache in Chile (Grebe, 1974); and one in silver found with a small silver tube in Ancón in the central coast of Peru (Reiss and Stubel, 1880). The presence in tombs of small bells in precious metals is certainly related to the symbolism of gold and silver and to the importance of the buried personage, but their function would then be merely decorative (Debenedetti, 1921). Small silver bells are much less frequent than gold ones, possibly due to accelerated corrosion processes during burial. The two specimens found with body 3 at the Casa Parroquial cemetery in Chile (Téllez and Murphy, 2007) are examples of such highly corroded silver specimens.

Pyramidal folded bells, already found in Early Period Ciénaga burials dated to phases II and III (González, 1979) are of various dimensions (González, 2008). They are certainly the most abundant type of bells in the Andean area, because specimens were found in Argentina, Bolivia, Chile and Peru (Gudemos, 2013). However, even though a few small specimens in gold were found in Chile, Argentina (Gudemos, 2013; Tarragó et al., 2010; Izikowitz, 1935) and Bolivia (Marsh, 2006), the most widespread typologies of small bells made from that metal are, as mentioned above, the conical and the truncated conical forms.

In the collection of the MUSEF are fourteen miniatures in gold with holed bases that can be classified as bells. The family Ballivian de Gutiérrez donated the group of miniatures in 2010 to the museum, along with other pieces in gold and silver. The pieces were acquired by several generations devoted to collecting since the early twentieth century. The donation records indicate that many of the pieces were obtained and then sold by residents of the altiplano, in the Titicaca Lake area, but none of them has an exact provenance.

The patterns on the bodies of the decorated gold bells in the collection of the MUSEF (Figure 1) form one or two bands. The miniature bells from different sites excavated in the province

of Jujuy in Argentina – Pucará de Tilcara, San José (Gudemos, 1998), Caspana (Ayala et al., 1999), Huayra Huasi (Ventura and Scambato, 2013) – and the seven specimens from tombs 356 and 359 excavated at Callejón de Larrache in Chile (Benavente et al., 1986) are decorated with several bands. The decoration of the Bolivian specimens and of keros from sites related to Tiwanaku are similar. We can cite the two specimens from Pucará de Volcán in Argentina (Gatto, 1946) and the miniature one from tomb PA6A at Pariti Island in the Titicaca Lake (Bennett, 1936) in gold, the one from Coyo Oriente in Chile (Uribe and Agüero, 2011) in black polished ceramics. Those with complex motifs from Larrache (Torres-Rouff et al., 2015), Casa Parroquial (Téllez and Murphy, 2015), and Pariti Island (Bennett, 1936; Korpisaari and Pärssinen, 2011) also have bands. Knowing that the keros can be found in miniature (Cummins, 2015) and in pairs (Ziólkowski, 1979; Cummins, 2002) – pairs in miniatures were found in the Incan *capacocha* contexts of Ampato in Peru and Llullaillaco in Argentina (Reinhard and Ceruti, 2010) – it is possible that some objects in the collections have been misclassified. However, we suggest that small gold bells should have a hole for sewing into the textile, such as those of our corpus.

Among the bells studied, 27459, 27460, 27461 and 27462 are undecorated specimens. Bell 27459, a little **larger** than the other three, could have originally been decorated with thin lines. Bells 27460 and 27461 have the same shape and dimensions. Originally, the latter could have been part of the same set or form a pair. Similarly, even if they do not form exact pairs, certain bells decorated with bands in our corpus are analogous: 27328 and 27329; 27217 and 27218; and 27268, 27274 and 27275.

The incomplete specimen 27256 was originally of greater height than all the studied objects. The round perforation at the base shown in Figure 2 could be modern indicating that this specimen might be a broken miniature kero. Two unprovenanced small effigy keros in gold (numbers 27219 and 27226, respectively 3.8 cm and 7.6 cm height) in the collection of the MUSEF are not perforated. Kero 27226 is published (Fernandez Murillo, 2016), but not kero 27219. This, the smallest one (Figure 1), with a damaged but not originally perforated base (the gold sheet that cracked is crooked half inside and half outside, as shown in Figure 2), was added to our corpus for comparison.

3. Methods of analysis

The gold bells and the miniature kero in the MUSEF collection were studied in-situ using non-invasive techniques and portable equipment (Guerra, 2008; Guerra and Tissot, 2016; Guerra and Rehren, 2009). The construction details were observed under a high-resolution Flexia video microscope with a zoom reaching x80, built-in LED illumination and Bersoft image measurement software. The composition of the alloys was determined with the handheld XRF spectrometer of the MUSEF, a Niton Thermo Scientific XL3t GOLDD, with 3 mm spot collimation, and with an Ag X-ray tube operating at 50 kV, 200 μ A. The objects were positioned on the fixed spectrometer table to ensure constant measurement conditions, and the integrated CCD camera was used for locating the area of interest in order to avoid irregular surfaces and select the flattest areas.

For quantitative analysis, we used the method delivered by Thermo Scientific with the Niton XL3t GOLDD spectrometer, which was operated in precious metals mode. The XRF analyses were carried out with an acquisition time of 240 sec. The majority of the results reported below correspond to averages of 2-3 measurements.

A set of both standard reference materials certified for element contents and internal reference gold alloys were analysed with the same experimental conditions as the objects. The data obtained for these alloys, which cover a wide range of Au, Ag and Cu contents, was normalised to 100 wt% and is summarised in Table 1. The results were used to validate the measured amounts and to construct an adjustment curve to be fitted to the elemental data. The use of standard reference materials certified for element contents also allowed a check on any influence of the X-ray tube Ag anode on the Ag concentrations determined for the alloys. As shown in Table 1, the analysis of standard CLAL1 containing 50 wt% Au, 50 wt% Cu and no Ag has in fact indicated a very low error in the amount of silver (0.1 wt%).

When three results are excluded from Table 1, the accuracy of the data is typically better than 5% relative. Precision was checked by the repeated analysis of standard LA1, showing that it is better than 2% relative. The confidence level for data obtained using handheld XRF is in general good (Hull, 2017), in our case even for not entirely flat surfaces (see below section 4.2 and Table 3). However, XRF analyses only the surface layers of gold alloys (Troalen et al., 2014). When using a specific setup, the penetration depth varies for a particular incident energy according to the composition of the alloys and the energy of the X-ray lines used for elemental quantification (Troalen and Guerra, 2016). When using low energy X-ray lines the analysed layer might not be representative of the bulk. In our case, as shown below, the gold alloys mostly contain rather high amounts of Ag (see Table 2) and we were able to use the Cu and Ag K-lines and the Au L-lines. Therefore, the analysed layer is expected to be more than about 10 μm (Troalen et al., 2014).

4. Results and discussion

4.1. Technologies employed

All objects were observed under the stereomicroscope to search for details of fabrication. Decorated bells 27269, 27274, 27275, 27328, 27329, 27330 and 27331 have horizontal bands that seem to have been formed by chasing (the majority of the tool marks are indistinguishable). They can be assigned to a specific technological tradition, because they are all made by folding at one end of the gold sheet. Figure 4 shows the base hole and the visible seams related to the process of folding. The form of their base holes is very irregular.

At the base of a few specimens, seams and cracks suggest the use of a mounting process that consists of rolling a gold sheet and joining at one end a closing sheet (Figure 4a). In the Andean area, the Tehuelches employed this technique in the nineteenth century to produce truncated conical silver bells (Pérez de Arce, 1986). In addition, two among the four truncated conical small gold bells from the site of Huayra Huasi (Ventura and Scambato, 2013) could have been made using that technique, because their bases are missing. Bell 27328, shown in Figure 4, has a closing gold sheet, but the main gold sheet is folded at that end. Despite cracks in regions subject to higher mechanical stress, it was also possible to distinguish in the body of some specimens the seam corresponding to joining using the hard soldering process, as illustrated in Figure 4b for bell 27328. The presence of such seams indicates that the tube was completed by rolling and soldering a gold sheet. This technique was regularly employed in the production of conical bells (Pérez de Arce, 1986)

Bells 27217 and 27218 with larger borders than the others, but also decorated with horizontal lines, show regular round holes (Figure 5) and signs of wear-use. The undecorated specimens

(27459, 27460, 27461 and 27462) also show fairly regular round holes (Figure 5). The numerous cracks in the gold sheets make it difficult to suggest their construction technology, but it is possible that a gold sheet was added to form the base.

Interestingly, under low magnification, no signs of rolling, soldering, or folding could be found on the gold sheets of miniature kero 27219 and the incomplete specimen 27256. Therefore, they could have been made by raising a gold sheet, a technique regularly used in the production of keros (Easby, 1965; Carcedo, 1998).

4.2. The gold alloys

Data obtained by handheld XRF for the gold miniatures in the collection of the MUSEF are summarised in Table 2. The alloys are quite variable, containing 10-63 wt% Ag and 0.5-5.5 wt% Cu, but the undecorated specimens contain lower Ag contents than the decorated ones. For many specimens, data obtained for the body and the base are quite different but, despite the difficulties related to the elemental analysis of the tiny and not entirely flat bases, results obtained from triplicate analyses have shown comparable values, as shown in Table 3 for bell 27274, confirming the differences observed.

The two diagrams in Figure 6 show the Ag and Cu contents obtained for the bodies and the bases of the decorated and undecorated objects. Contrary to the other objects, incomplete specimen 27256, effigy kero 27219 and undecorated bell 27462 (the smallest specimen of our group that contains the highest Au contents) are homogeneous. Therefore, 27256 is certainly a miniature kero made by raising a gold sheet, and 27462 could have been made by employing the same technique. Also added to Figure 6a are two higher (7.6 cm and 14.5 cm height) unprovenanced anthropomorphic keros (references 27233 and 27226) in the MUSEF collection that were previously analysed (Fernández Murillo, 2016), but their composition does not match that of the miniature keros.

Undecorated bells 27460 and 27461, with the same shape and dimensions, could originate from one batch. Likewise, bells 27217 and 27218, bells 27268, 27274 and 27275, and bells 27328 and 27329, similar in shape and dimensions, are made from similar alloys. It is known that bells are often found in groups and keros in pairs. Some of the twenty-three miniature gold keros (2.6-3.7 cm height) from pit 6 of the excavations on Pariti island in the Titicaca Lake (Bennett, 1936) have forms that resemble bells and ten of them form five pairs. However, in our corpus specimens 27268, 27274 and 27275 form a group typologically and chemically, reinforcing their classification as bells.

The objects' bases show quite diverse compositions. In general, they have higher Ag contents than the bodies, which seems to reinforce the suggested addition of a base sheet to close the gold tube and perhaps indicate the presence of a solder alloy, indistinguishable under low magnification. It is difficult to provide further comments on the results obtained, due to lack of equipment with higher spatial resolution and of published data for comparison. In fact, to our knowledge, only one small gold bell was previously submitted to analytical study. It belongs to the group of six pyramidal folded bells found in grave 11 excavated at La Isla de Tilcara cemetery, in the province of Jujuy, Argentina (Tarragó et al., 2010). What should also be cited are two undetermined gold fragments from tombs excavated in San Pedro de Atacama related to the Tiwanaku culture and containing gold keros, that have shown the use of alloys containing 16-18 wt% Ag and low amounts of Cu (Theile, 2004). These objects are

plotted in the diagram of Figure 6a together with the four gold sheets (one in the form of a llama) also from tomb 11 at La Isla de Tilcara and three objects dated to the same period – one gold sheet in the form of a bird, one armband and one finger ring – from the site of Pueblo Viejo de La Cueva in the same region (Tarragó et al., 2010). The majority are within an area corresponding to gold alloys containing 15-20 wt% Ag which also includes the two keros and bells 27460, 27461, 27328 and 27329. Three published gold objects were not plotted in the diagram. One is a ‘T’ axe excavated in Casa Parroquial (containing 2.4 wt% Ag and 3.3 wt% Cu, Salazar et al., 2011) and the other two are anthropomorphic keros (about 10 cm height) found in Rio Doncellas, Argentina (a site in the province of Jujuy associated to Tiwanaku), made from Au-rich (10 wt% Au) silver alloys (Rolandi de Perrot, 1974)

Indeed, the majority of the objects analysed in this work contain Ag contents ranging from 25 wt% to 55 wt%. It is interesting to note that based on the analytical study of gold objects attributed to the southern coast of Peru in the Uhle Collection at the University of California, Root (1949a) stipulates chronological ranges of composition. The earliest objects, made by the early Paracas culture, contain 1-19 wt % Ag and 0-4 wt% Cu, whilst those made during the Middle Ica II period contain 25-48 wt% Ag, and those dated to the Inca period up to 40 wt% Ag. Recent data on anthropomorphic and zoomorphic miniature figurines of regular types produced in Incan times for ritual offerings are plotted in Figure 7 with our objects. Those figurines are in the collections of the Ethnologisches Museum in Berlin (Guerra et al., 2017), Museo de América (Rovira Lloréns and Gómez Ramos, 1995; Rovira, 2017) and musée du quai Branly (Núñez-Regueiro et al., 2017), to which were added a few provenanced specimens from the area of Cusco (Sierra Palomino and Guerra, 2017) and those from the Aconcagua (Bárcena, 2004) and El Plomo (Oberhauser et al. 1959) *capacocha* shrines.

It can be seen that our objects, as well as the finger ring and the armband from Pueblo Viejo de La Cueva, are within the range of alloys employed by the Incas, which mostly contain 25-50 wt% Ag. Data obtained for the Ica and Inca cultures by Root (1949a) match the data plotted in Figure 7, as well as the two objects (a third one contains 12.2 wt% Cu but no Ag) attributed to the Incan period excavated at Casa Morada de La Paya in Argentina that contain 4.9 wt% and 44.8 wt% Ag (González, 2003).

It is not our intention to relate the composition of our alloys to a supposed chronology of production. Nevertheless, Root (1949a) concludes that the alloys containing high Ag contents must be assumed to be artificial. Therefore we considered it important to compare our results with the composition of natural gold from the deposits located in the Lake Titicaca area, as proposed below. Moreover, we wish to point out that in the Andean area the colour of the alloys has important significance (Lechtman, 2007; 2014). Gold alloys containing Ag concentrations below and above 25 wt% (Cu is always present in low concentration in our objects) correspond to the use of either yellow or more or less pale green yellow gold alloys **in the ternary colour diagram Au-Ag-Cu** (Rapson, 1990), with a change in other alloy properties (solidus, hardness, tensile strength, etc., Grimwade, 2009). A subtle colour variation is perceptible. The alloy becomes whitish only when Ag is present above 50 wt%. However, in the case of ritual goldwork, more important than the colour is the reflectivity of gold-silver alloys (Guerra, 2019). The alloy appearances, depending on the lighting, contribute to the categorization of the objects (Fleming 2013). For gold-silver alloys, the reflectivity increases with increasing Ag contents (Roberts and Clarke, 1979). Therefore, the significantly higher Ag content in our objects greatly increases their surface reflectivity providing a singular

visual perception to objects of great significance. By their appearance, gold objects employed in rites are thus more easily related to the sun (Berthelot, 2009; Sauders, 1998), through both the employed material (gold) and the associated lustre.

4.3 Native gold alloys in Andean deposits

The gold alloys employed in La Isla de Tilcara and Pueblo Viejo de La Cueva were associated by Tarragó et al. (2010) with access to placer gold. Root (1949a) and Lechtman (1980) associated those employed in the southern Andes of Peru to either natural or artificial alloys depending on the amounts of Ag contained in the alloys. This suggestion is reinforced by the low Ag (3.6-4.6 wt%) and Cu (0.21-0.32 wt%) amounts contained in the earliest gold objects from the central Andes, a group of beads found in the Terminal Archaic burial context at Jiskairumoko, in the south-western Lake Titicaca basin in Peru (Aldenderfer et al., 2008).

The composition of natural gold from certain deposits in Argentina, Bolivia, Chile and Peru have been related to the production of ancient goldwork (Boman, 1908; Rivet and Arsandaux, 1946; Petersen, 1970), showing that Ag is frequently present in amounts below 10 wt%, attaining in a few cases 20 wt%. These natural alloys contain lower Ag contents than our objects and the Cu contents in native gold are below 1 wt% with the exception of two samples from Bolivia (Rivet and Arsandaux, 1946) and two samples from Peru (Petersen, 1970), that are also lower than the values shown in Figure 7. Only one sample from the river Tumbes in Peru contains 26 wt% Ag (Petersen, 1970). It is in fact in Colombia, in deposits localised far from the Titicaca Lake area, that Ag frequently attains 15-20 wt% in natural gold (Root, 1949b).

The gold resources in the Titicaca Lake area have been suggested to be sufficient to cover the production needs in the area (Núñez, 1987). In fact, the rich Andean resources (Burger, 2013) also include access to gold-bearing quartz veins and placer deposits (Cuadra and Dunkerly, 1991; Soler et al., 1986; Alarcón and Fornari, 1994; Fontboté et al., 1990; Berthelot, 2009). Although the majority of the published work focusing on the composition of gold grains from the Andean area considers the grains fineness only, some data is however available. Even if a few grains contain 85-90 wt% Au, Au contents range essentially between 90 wt% and 100 wt% for deposits at the north of La Paz, such as Consata Mapiri, Tipuani, Mariapu, Cangalli, Yani, La Rinconada, and other deposits in the Eastern Cordillera (Hérail et al., 1988, 1990; Fornari and Hérail, 1991; Miranda Angles et al., 1991). This confirms that natural alloys in the Titicaca Lake area contain lower Ag contents than many of our objects. The same situation is demonstrated for gold deposits in the Eastern Bolivian Cordillera situated south of La Paz, some of them said to be exploited since the Incan period (Alarcón and Fornari, 1994), including the Vilander and Guadalupe deposits in the south Lípez (Fornari et al., 1991; Ramos and Fornari, 1994). In fact, the gold grains have been shown to contain Ag contents varying from 1 wt% to 30 wt%. Once more, the Cu contents, always below 0.1 wt%, do not match the composition of our objects. Identical values were obtained for gold grains from deposits situated further away. Those from the south-eastern Andes of Peru (Fornari et al., 1988) and from Cerro Casales (Palacios et al., 2001; Townley et al., 2003) and San Pedro de Cachiyuyo (Hérail et al., 1999) in the Atacama region in Chile have shown Ag contents below 21 wt% and Cu contents up to 0.6 wt%, respectively: 2-10 wt% Ag and 0.1-0.5 wt% Cu; 5-21 wt% Ag and 0.01-0.2 wt% Cu (a few containing up to 28 wt% Ag and 0.35 wt% Cu); and up to 10 wt% Ag and 0.6% Cu.

The Ag contents of our objects and of the gold grains were plotted in Figure 8, showing that only some of our objects could have been produced with natural alloys. In fact, only gold grains from deposits located far from the Titicaca Lake area contain high Ag contents. Examples are the quartz veins of the Pataz deposits in the north of Peru exploited since pre-Columbian times (Schreiber et al., 1990) and the placer deposits at San Luis Range in Argentina (Márquez-Zavalía et al., 2004). The gold grains contain respectively up to 40 wt% Ag and 0.1 wt% Cu and up to 47 wt% Ag and 0.06 wt% Cu. Although it is tempting to affirm that the alloys employed in the manufacture of our objects are mostly natural, it has to be considered that only a small number of gold grains from these two deposits contain more than 30 wt% Ag, and therefore match our objects (Figure 8), except the miniature keros 27219 and 27256. It has also to be considered the low probability associated with the use of gold from sources situated far from the rich Titicaca Lake area when the same type of alloy can be obtained by adding silver to natural gold. The fact that the Cu contents in the objects are always higher than in natural gold reinforces the suggestion of the production of artificial alloys.

5. Conclusion

The study of a group of unprovenanced miniatures in gold in the collection of the MUSEF, one effigy kero and fourteen specimens classified as small bells, provided a first approach to understanding the techniques of manufacture and to the alloys employed in their production. The small bells have shapes and dimensions consistent with bells and keros, produced in areas under the influence of the Tiwanaku culture and the Incas. Despite the analytical difficulties raised by the in-situ study using portable equipment with low magnification and low spatial resolution, we were able to demonstrate the use of two techniques of construction. One is the expected technique for the production of bells in the Andean area, specifically by rolling a gold sheet and adding at one end a closing sheet, and another is the expected technique for the production of keros, specifically by raising a gold sheet. We were however unable to confirm whether a process of hard-soldering was employed to form the base of some specimens.

The alloys used in the manufacture of our objects are quite variable, containing 10-63 wt% Ag and 0.5-5.5 wt% Cu, but they match very well with the alloys employed by the Incas to produce goldwork as well as the gold objects related to the Tiwanaku culture analysed so far. By comparing our results with data published for gold grains from Andean deposits situated in the Lake Titicaca area, we would suggest that the alloys used in the production of our objects are certainly only partially natural. In fact, the Ag amounts in the natural gold alloys from the Eastern Bolivian Cordillera deposits are always below 30 wt%, with a large majority under 20 wt%. The use of artificial alloys is reinforced by the systematic presence of Cu contents in the objects that are higher than those published for gold grains

Some of the miniatures classified as small bells are analogous in shape and decoration to miniature keros. Based on the composition of the bodies and bases of the objects we were able to suggest that the incomplete specimen 27256 should be a broken miniature kero made by raising one gold sheet. Only this specimen, the smallest bell in our corpus, and miniature kero 27219 show such homogeneous compositions. The bodies and bases of the other specimens show the use of different alloys for these components. By considering their shape, dimensions, decoration and elemental composition we were able to suggest that some specimens form groups and could therefore be originally part of a set. Thus, specimens 27268,

27274, and 27275 form a group, typologically and chemically, reinforcing the classification of our objects as bells as the miniature keros are found either alone or in pairs.

The typological similarities of miniature keros and bells may lead to the misclassification of some specimens in the collections, but other pieces might also be misclassified. One gold cap from an inhalation tube found inside a bag in tomb 107 at cemetery Solcor 3 (Llagostera et al., 1988) and some bells from the Atacama region (Gudemos, 2013) are possible examples of this. In this area, the relationship between musical instruments and rites using hallucinogens is well-known (Fernández, 1993) and both inhalation tube caps and small bells should be perforated to accomplish their functions. The misclassification of bells is certainly accentuated by their systematization still in progress. Regrettably, only certain specimens are well contextualised. Among them are the bells excavated in Huayra Huasi found along with one of the Incan bronze plaques that widely circulated “in the Puna of Jujuy and in the valleys of the southern Bolivia, reaching Catarpe in Chile and Sacsahuaman in Peru” (Ventura and Scambato, 2013). **Analysis of contextualised specimens would shed new light on Andean gold productions.**

Acknowledgements

The authors gratefully acknowledge Alfredo C. Basagoitia and Primitivo A. Calcina at the MUSEF for support with the XRF equipment and Proyecto Titicaca at Université libre de Bruxelles, in particular Dr. Christophe Delaere, for support during this work. We are also grateful to Mike Cowell, who made valuable suggestions on the manuscript, and to the anonymous reviewers, whose comments improved the quality of this manuscript.

References

- Alarcón, B.H., Fornari, M., 1994. Análisis de oro por microsonda (E.P.M.A.) en depósitos primarios de oro de la provincia metalogenética andina de Bolivia y su significado genético, in: *Memorias del 11 congreso geológico de Bolivia*, Sociedad Geológica Boliviana, La Paz, 304–312. <http://www.documentation.ird.fr/hor/fdi:010021839>
- Aldenderfer, M., Craig, N.M., Speakman, R.J., Popelka-Filcoff, R., 2008. Four-thousand-year-old gold artifacts from the Lake Titicaca basin, southern Peru. *PNAS* 105(13), 5002–5005. <https://doi.org/10.1073/pnas.0710937105>
- Arsandaux, H., Rivet, P., 1921. Contribution à l'étude de la métallurgie mexicaine. *JSA* 13(2), 261–280. <https://doi.org/10.3406/jsa.1921.2922>
- Ayala, P., Reyes, O., Uribe, M., 1999. El cementerio de los abuelos de Caspana: El espacio mortuario local durante el dominio del Tawantinsuyu. *Estudios Atacameños* 18, 35–54. <http://dx.doi.org/10.22199/S07181043.1999.0018.00005>
- Bárcena, J.R., 2004. Las piezas metálicas de la ofrenda ritual del Cerro Aconcagua. Mendoza, República Argentina, in: Perea, A., Montero Ruiz, I., García Vuelta, Ó. (Eds.), *Tecnología del oro antiguo: Europa y América*, *Anejos de Archivo español de arqueología* 32, Madrid, 157–172.
- Benavente A., M.A., Massone Mezzano, C., Winter, C.T., 1986. Larrache, evidencias atípicas. ¿Tiahuanaco en San Pedro de Atacama?, *Rev. Chungara* 16-17, 67–73. <http://repositorio.uchile.cl/handle/2250/122020>

- Bennett, W.C., 1936. Excavations in Bolivia. *Anthropological papers of the American Museum of Natural History* 35(4), 329–507. <http://hdl.handle.net/2246/120>
- Berthelot J., 2009. The extraction of precious metals at the time of the Inka, in: Murray, J.V., Wachtel, N., Revel, J. (Eds.), *Anthropological history of Andean polities*, Cambridge University Press, 69–88.
- Boman, E., 1908. *Antiquités de la région andine de la République argentine et du désert d'Atacama*, vol. 2, Imprimerie Nationale, Librairie H. Le Soudier, Paris.
- Burger, R.L., 2013. Some thoughts on mining and quarrying in the ancient Andes, in: Tripcevich, N., Vaughn K.J. (Eds.), *Mining and quarrying in the ancient Andes*, Springer Science and Business Media, New York, 325–334. https://doi.org/10.1007/978-1-4614-5200-3_15
- Cabrero, M.T., Ruvalcaba Sil, J.L., 2013. Copper Bells in the Bolaños Culture, Jalisco. *Arqueol. Iberoam.* 19, 24–36. <https://doi.org/10.5281/zenodo.1311231>
- Carcedo, P., 1998. Instrumentos líticos y de metal utilizados en la manufactura de piezas metálicas conservadas en los museos. *Boletín Museo del Oro* 44-45, 241–270. <https://publicaciones.banrepcultural.org/index.php/bmo/article/view/6901>
- Carcedo, P., 2017. Reflection on the Sicán and Chimú silver production of *kero*-type beakers and disks: their iconography and its relationship to Chimú miniatures, *Bull. Inst. Fr. Etudes Andin.* 46(1), 37–75. <http://journals.openedition.org/bifea/8428>
- Carcedo, P., Vetter, L., Diez Canseco, M., 2004. Los vasos-efigie antropomorfos: un ejemplo de la orfebrería de la costa central durante el Periodo Intermedio Tardío y el Horizonte Tardío. *Bol. Arqueol. PUCP* 8, 151–189. <http://revistas.pucp.edu.pe/index.php/boletindeferqueologia/article/view/2004>
- Cuadra, W.A., Dunkerley, P.M., 1991. A history of gold in Chile. *Econ. Geol.* 86(6), 1155–1173. <https://doi.org/10.2113/gsecongeo.86.6.1155>
- Cummins, T., 2002. *Toasts with the Inca: Andean abstraction and colonial images on kero vessels*, University of Michigan Press.
- Cummins, T., 2015. Inka art, in: Shimada I. (Ed.), *The Inka empire: a multidisciplinary approach*, University of Texas Press, Austin, 165–195.
- Debenedetti, S., 1921. La influencia hispánica en los yacimientos arqueológicos de Caspinchango (provincia de Catamarca). *Revista de la Universidad de Buenos Aires* 46, 745–788.
- Easby, D.T., 1965. Pre-Hispanic metallurgy and metalworking in the New World. *Proc. Am. Phil. Soc.* 109(2), 89–98.
- Fernández Murillo, M.S., 2016. *Alianzas del metal. La colección de minería y metales del Museo Nacional de Etnografía y Folklore, según la cadena de producción*, MUSEF, La Paz.
- Fleming, R.W., 2014. Visual perception of materials and their properties, *Vision Research* 94, 62–75. <http://dx.doi.org/10.1016/j.visres.2013.11.004>
- Flores, E.V.C., 2015. From Colonial kero to Republican kero. *La vida y la historia* 4, 7–18. <http://revistas.unjbg.edu.pe/index.php/vyh/article/view/463>
- Fontboté, L., Amstutz, G.C., Cardozo, M., Cedillo, E., Frutos, J. (Eds.), 1990. *Stratabound ore deposits in the Andes*, Springer-Verlag, Berlin-Heidelberg.
- Fornari, M., Hérail, G., 1991. Lower Paleozoic gold occurrences in the Eastern Cordillera of southern Peru and northern Bolivia; a genetic model, in: Ladeira, E.A. (Ed.), *The economics, geology, geochemistry and genesis of gold deposits*, Balkema, Rotterdam,

- 135–142. http://horizon.documentation.ird.fr/exl-doc/pleins_textes/pleins_textes_6/b_fdi_39-40/43409.pdf
- Fornari, M., Hérail, G., Laubacher, G., Delaune, M., 1988. Les gisements d'or des Andes sud-orientales du Pérou. *Géodynamique* 3(1,2), 139–161.
<http://www.documentation.ird.fr/hor/fdi:26024>
- Fornari, M., Hérail, G., Ramos Collorana, W., 1991. Le placer de Vilader, modèle génétique, in: Hérail, G., Fornari, M. (Eds.), *Gisements alluviaux d'or*, ORSTOM, La Paz, 159–173.
<http://www.documentation.ird.fr/hor/fdi:36205>
- Garcilaso de la Vega, E.I., 1609. Historia de la conquista del Nuevo Mundo, Primera parte de los Comentarios Reales, T II, Oficina de Pedro Crasbeeck, Lisbon.**
- Gatto, S., 1946. Exploraciones arqueológicas en el Pucará de Volcán. *Revista del Museo de La Plata* 4(18), 1–91. <https://publicaciones.fcnym.unlp.edu.ar/rmlp/article/view/1723>
- Gluzman, G., 2013. Tradiciones metalúrgicas en el noroeste argentino. *Relaciones de la Sociedad Argentina de Antropología* 38(2), 321–350.
<http://sedici.unlp.edu.ar/handle/10915/33990>
- González, A.R., 1979. Pre-Columbian metallurgy of Northwest Argentina: historical development and cultural process, in: Benson, E. (Ed.), *Pre-Columbian metallurgy of South America*, *Dumbarton Oaks Research Library and Collections*, Washington, 133–202.
- González, L.R., 2008. La rebelion de los bronce. Estudios sobre metalurgia prehispánica en el noroeste argentino, in: Cruz, P.J., Vacher, J.J. (Eds.), *Mina y metalurgia en los Andes del Sur desde la época prehispánica hasta el siglo XVII*, Instituto Francés de Estudios Andinos, Lima, 57–89. <http://www.documentation.ird.fr/hor/fdi:010047369>
- González, L.R. 2007. Tradición tecnológica y tradición expresiva en la metalurgia prehispánica del Noroeste argentino. *Bol. Mus. Chil. Arte Precolomb.* 12(2), 33–48.
<http://www.redalyc.org/articulo.oa?id=359933356003>
- González, L.R. 2003. El oro en el noroeste argentino prehispánico. Estudios técnicos sobre dos objetos de la Casa Morada de La Paya. *Relaciones* 28, 75–99.
<http://www.saanropologia.com.ar/textos/el-oro-en-el-noroeste-argentino-prehispanico-estudios-tecnicos-sobre-dos-objetos-de-la-casa-morada-de-la-paya/>
- Grebe, M.E., 1974. Instrumentos musicales precolombinos de Chile. *Rev. Music. Chil.* 28(128), 5–55.
<https://revistamusicalchilena.uchile.cl/index.php/RMCH/article/view/11966/12326>
- Grimwade, M., 2009. Introduction to precious metals. *Metallurgy for jewelers and silversmiths*, A&C Black Publishers Ltd., London.
- Gudemos, M., 1998. Campanas arqueológicas de metal del Noroeste argentino. Entre el poder y los dioses. *Anales Museo de América* 6, 111–135.
<https://dialnet.unirioja.es/servlet/articulo?codigo=1455849>
- Gudemos, M., 2013. Mapa cultural de los instrumentos musicales y objetos sonoros de metal arqueológicos: idiófonos (Área Andina centro–meridional). *Rev. Esp. Antropol. Am.* 43(2), 579–597. <http://revistas.ucm.es/index.php/REAA/article/view/44024>
- Guerra, M.F., 2008. An overview on the ancient goldsmith's skill and the circulation of gold in the past: the role of X-ray based techniques. *X-ray Spectrom.* 37(4), 317–327.
<https://doi.org/10.1002/xrs.1013>

- Guerra, M.F., 2019. Physicochemical approaches to gold and silver work, an overview: Searching for technologies, tracing routes, attempting to preserve. *Physical Sciences Reviews* 4(2), 1–15. <https://doi.org/10.1515/psr-2018-0015>
- Guerra, M.F., Rehren, T., 2009. In-situ examination and analysis of the gold jewellery from the Phoenician tomb of Kition (Cyprus). *ArcheoSciences* 33, 151–158. <http://journals.openedition.org/archeosciences/2148>
- Guerra, M.F., Tissot, I., 2016. Bronze Age and Iron Age gold torcs and earrings from the Iberian Atlantic façade: a non-invasive multi-analytical approach to the characterisation of the alloys and the corrosion. *X-Ray Spectrom.* 45(1), 5–13. <https://doi.org/10.1002/xrs.2628>
- Guerra, M.F., Fischer, M., Radtke, M., Reinholz, U., 2017. Inca figurines from the Ethnologisches Museum in Berlin: an analytical study of some typical and atypical productions. *Bull. Inst. Fr. Etudes Andin.* 46(1), 221–251. <http://journals.openedition.org/bifea/8232>
- Guerra, M.F., Radtke, M., Reiche, I., Riesemeier, H., Strub, E., 2008. Analysis of trace elements in gold alloys by SR-XRF at high energy at the BAMline. *Nucl. Instrum. Methods Phys. Res. B* 266, 2334–2338. <https://doi.org/10.1016/j.nimb.2008.03.008>
- Hérail, G., Fornari, M., Viscarra, G., Miranda, V., 1988. Evolución de las partículas de oro en el transcurso de la formación de un placer fluvial: el caso de los placeres de Tipuani (Andes, Bolivia), in: *Anais do Congresso 7 Latino-Americano de Geologia*, Sociedade Brasileira de Geologia, Belém, 127–138. http://horizon.documentation.ird.fr/exl-doc/pleins_textes/pleins_textes_6/b_fdi_39-40/43388.pdf
- Hérail, G., Fornari, M., Viscarra, G., Miranda, V., 1990. Morphological and chemical evolution of gold grains during the formation of a polygenic fluvial placer: the Mio-Pleistocene Tipuani placer example (Andes, Bolivia), *Chron. Rech. Min.* 500, 41–49. http://horizon.documentation.ird.fr/exl-doc/pleins_textes/pleins_textes_5/b_fdi_30-30/31921.pdf
- Hérail, G., Lagos, J., Vivallo, W., 1999. Gold dispersion in Andean desertic environment (Atacama, Chile). *J. Geochem. Explor.* 66, 427–439. [https://doi.org/10.1016/S0375-6742\(99\)00045-X](https://doi.org/10.1016/S0375-6742(99)00045-X)
- Hosler, D., 1988. Ancient West Mexican Metallurgy: A Technological Chronology, *J. Field Archaeol.* 15(2), 191–217. <https://doi.org/10.1179/009346988791974475>
- Hosler, D., 1997. Los orígenes andinos de la metalurgia del occidente de México. *Boletín Museo del Oro* 42, 3–25. <https://publicaciones.banrepcultural.org/index.php/bmo/article/view/6905/7150>
- Hosler, D., 2002. The sounds and colors of power: the sacred metallurgical technology of ancient West Mexico, The MIT Press, Cambridge, Massachusetts.
- Hull, M.V., 2017. Accuracy, precision, and confidence in X-ray Fluorescence for positive material identification. *TNT* 16(1), 1–11. <https://ndtlibrary.asnt.org/2017/AccuracyPrecisionandConfidenceinXrayFluorescenceforPositiveMaterialIdentification>
- Izikowitz, K.G., 1935. Musical and other sound instruments of the South American Indians. A comparative ethnographical study, Elanders Boktryckeri Aktiebolag, Göteborg.
- King, H., 2016. Further notes on Corral Redondo, Churunga Valley. *Ñawpa Pacha* 36(2), 95–109. <https://doi.org/10.1080/00776297.2016.1239802>

- Korpisaari, A., Pärssinen, M., 2011. Pariti: the ceremonial Tiwanaku pottery of an island in Lake Titicaca. *Academia Scientiarum Fennica*, Helsinki.
- Latcham, R., 1936. Metalurgia atacameña. *Bol. Mus. Nac. Hist. Nat.* 15, 107–151.
<http://publicaciones.mnhn.cl/668/w3-article-63491.html>
- Lechtman, H., 1980. The Central Andes: metallurgy without iron, in: Wertime, T., Muhly, J. (Eds.), *The coming of the Age of Iron*, Yale University Press, New Haven, 267–334.
- Lechtman, H., 2007. Inka, and Andean metallurgical tradition, in: Burger, L.R., Morris, C., Matos Mendieta, R. (Eds.), *Variations in the expression of Inka power*. *Dumbarton Oaks, Trustees for Harvard University*, Washington D.C., 313–355.
- Lechtman, H., 2014. Andean metallurgy in Prehistory, in: Roberts, B.W., Thornton, C. (Eds.), *Archaeometallurgy in global perspective*. Springer-Verlag, New York, 361–422.
<https://doi.org/10.1007/978-1-4614-9017-3>
- Llagostera, A., Torres, M.C., Costa, M.A., 1988. El complejo psicotrópico en Solcor-3 (San Pedro de Atacama). *Estudios Atacameños* 9, 67–106.
<https://doi.org/10.22199/S07181043.1988.0009.00004>
- Lopéz Lujan, L., Ruvalcaba Sil, J.L., 2015. Tenochtitlan's Gold: the Archaeological Collection of the Great Temple Project, *Estudios de Cultura Náhuatl* 49, 7–57.
http://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S0071-16752015000100002
- Marsh, E., 2006. Excavaciones en Sector 7, Compuesto K3, in: Janusek, J.W., Plaza Martínez V. (Eds.), *Khonko Wankane: segundo informe preliminar del proyecto arqueológico Jach'a Machaca*, Ministerio de Cultura de Bolivia, 142–160.
- Marqu岸-Zavalía, M.F., Southam, G., Craig, J.R., Galliski, M.A., 2004. Morphological and chemical study of placer gold from the San Luis Range, Argentina. *Can. Min.* 42, 169–182.
<https://doi.org/10.2113/gscanmin.42.1.169>
- Medina González, I., Espinosa Pesqueira, M., Pereira, G., 2015. Metalurgia proto-tarasca del Occidente mesoamericano: una aproximación científica a la materia y tecnología de artefactos metálicos de sitio arqueológico de Malpaís Prieto, cultura uacúsecha, Michoacán, México, in: Cano, E., Barrio, J. (Eds.), *Proceedings of MetalEspaña 2015*, Universidad Autónoma de Madrid, 59–72, <http://hdl.handle.net/10261/132099>.
- Miranda Angles, V., Fornari, M., Hérail, G., 1991. Los placeres de oro de la región de Mapiri (Bolivia) y sus fuentes primarias, in: Hérail, G., Fornari, M. (Eds.), *Gisements alluviaux d'or*, ORSTOM, La Paz, Bolivia, 175–185. <http://www.documentation.ird.fr/hor/fdi:36206>
- Núñez A., L. 1987. Tráfico de metales en el área centro-sur andina: factos y expectativas. *Cuadernos del INAPL* 12, 73–105.
<https://revistas.inapl.gob.ar/index.php/cuadernos/article/view/414>
- Núñez-Regueiro, P., Moulhéat, C., Guerra, M.F., 2017. The Inca figurines of the musée du quai Branly - Jacques Chirac: typological variety and production chronology. *Bull. Inst. Fr. Etudes Andin.* 46(1), 193–219. <http://journals.openedition.org/bifea/8198>
- Oberhauser, F., Fuhrmann, P., Gaillard, M., 1959. Estudio metalúrgico, in: Mostny, G. (Ed.), *La momia del Cerro El Plomo*, *Bol. Mus. Nac. Hist. Nat.* 27, 78–81.
<http://publicaciones.mnhn.cl/668/w3-article-64207.html>
- Palácios, C., Hérail, G., Townley, B., Maksaev, V., Sepulveda, F., Parseval, P., Rivas, P., Lahsen, A., Parada, M.A., 2001. The composition of gold in the Cerro Casale gold-rich porphyry deposit, Maricunga belt, Northern Chile. *Can. Min.* 39, 907–915.
<https://doi.org/10.2113/gscanmin.39.3.907>

- Paris, E. (2008). Metallurgy, Mayapan, and the Postclassic Mesoamerican world system. *Ancient Mesoamerica*, 19(1), 43–66. <https://doi.org/10.1017/S0956536108000291>
- Pendergast, D.M., 1962. Metal Artifacts in Prehispanic Mesoamerica. *Am. Ant.* 27(4), 520–545. <https://doi.org/10.2307/277677>
- Pérez de Arce, 1986. Cronología de los instrumentos sonoros del Área extremo sur Andina. *Rev. Music. Chil.* 40(166), 68–124. <https://revistamusicalchilena.uchile.cl/index.php/RMCH/article/view/12654>
- Pérez de Arce, J., 2001. Campanas metálicas santamarianas. *Rev. Music. Chil.* 196, 59–74. <http://dx.doi.org/10.4067/S0716-27902001019600004>
- Petersen, G.G., 1970. Minería y metalurgia en el antiguo Perú (Mining and metallurgy in ancient Perú, translated by W.E. Brooks), The Geological Society of America Inc., Colorado.
- Posnansky, A., 1957. Tihuanacu, the Cradle of American Man, vol. 3, translated by J.F. Sheaver, Ministerio de Educación, La Paz, Bolivia, and J.J. Augustin, New York.
- Portoni F.G., Martínez, D.M., Serafín, H.P.S., 2012. Estudio, conservación y montaje de dos tobilleras de cascabeles provenientes del sitio arqueológico Teteles de Santo, Intervención 3(6), 55–62. <https://dialnet.unirioja.es/servlet/articulo?codigo=4947351>
- Ramos, W., Fornari, M., 1994. Problemática de la presencia de oro en los Lípez. *Bol. Soc. Geol. Bol.* 28, 248–259. http://horizon.documentation.ird.fr/exl-doc/pleins_textes/pleins_textes_7/b_fdi_55-56/010021835.pdf
- Ramos Gómez, L., 2006. Las vasijas de madera ornamentadas con laca utilizadas por los dirigentes andinos de la época colonial: función y tipología de sus formas. *Rev. Esp. Antropol. Am.* 36, 83–117. <http://revistas.ucm.es/index.php/REAA/article/view/REAA0606120083A>
- Rapson, W.S., 1990. The metallurgy of the coloured carat gold alloys, *Gold Bull.* 23(4), 125–133. <https://doi.org/10.1007/BF03214713>
- Reinhard, J., Ceruti, M.C., 2010. Rituals and sacred mountains. A study of the world's highest archaeological sites, The Cotsen Institute of Archaeology Press, Los Angeles.
- Reiss, W., Stubel, A., 1880-87. The necropolis of Ancon in Peru: A contribution to our knowledge of the culture and industries of the empire of the Incas, vol. 3, A. Asher and Co, Berlin.
- Rivet, P., Arsandaux, H., 1946. La métallurgie en Amérique précolombienne, *Travaux et mémoires de l'Institut d'Ethnologie* 34, Paris.
- Roberts, E.F.I., Clarke, K.M., 1979. The colour characteristics of gold alloys. *Gold Bull.* 12(1), 9–19. <https://doi.org/10.1007/BF03215099>
- Rolandi de Perrot, D.S., 1974. Un hallazgo de objetos metálicos en el área del Río Doncellas (Pcias. de Jujuy). *Relaciones* 8, 153–160. <http://sedici.unlp.edu.ar/handle/10915/25365>
- Root, W.C., 1949a. The metallurgy of the southern coast of Peru. *American Antiquity* 15(1), 10–37. <https://doi.org/10.2307/276954>
- Root, W.C., 1949b. Metallurgy, in: Steward, J.H. (Ed.), *Handbook of South American Indians*, vol. 5, Bureau of American Ethnology Bulletin 143, Smithsonian Institution Press, Washington, 205–225.
- Rovira Lloréns, S., Gómez Ramos, P., 1995. Los objetos de metal de la colección Juan Larrea: un estudio arqueometalúrgico. *Anales del Museo de América* 3, 21–33. <https://dialnet.unirioja.es/servlet/articulo?codigo=1012232>

- Rovira, S., 2017. Inca metallurgy: a study based on the collections of the Museo de America in Madrid. *Bull. Inst. Fr. Etudes Andin.* 46(1), 97–131.
<http://journals.openedition.org/bifea/8155>
- Sagaseta, A.A., 1990. El kero: vaso ritual de los incas. *Revista Espacio, Tiempo y Forma* 3, 11–30. <http://revistas.uned.es/index.php/ETFVII/article/view/2156>
- Sauders, N.J. 1998. Stealers of light, traders in brilliance: Amerindian metaphysics in the mirror of conquest. *Anthropology and Aesthetics* 33, 225–52.
<https://doi.org/10.1086/RESv33n1ms20167010>
- Salazar, D., Figueroa, V., Morata, D., Mille, B., Manríquez, G., Cifuentes, A., 2011. Metal production during the Middle Period in San Pedro de Atacama: new data, new questions. *Rev. Antropol.* 23, 123–148. <http://repositorio.uchile.cl/handle/2250/122145>
- Schreiber, D.W., Fontboté, L., Lochmann, D., 1990. Geologic setting, paragenesis, and physicochemistry of gold quartz veins hosted by plutonic rocks in the Pataz region. *Econ. Geol.* 85, 1328–1347. <https://doi.org/10.2113/gsecongeo.85.7.1328>
- Sierra Palomino, J., Guerra, M.F., 2017. Technological study of the anthropomorphic statuettes and miniature tupus from a discovery in Paucartambo (Cusco, Peru). *Bull. Inst. Fr. Etudes Andin.* 46(1), 151–170. <http://journals.openedition.org/bifea/8387>
- Soler, P., Grandin, G., Fornari, M., 1986. Essai de synthèse sur la métallogénie du Pérou. *Géodynamique* 1(1), 33–68. http://horizon.documentation.ird.fr/exl-doc/pleins_textes/cahiers/geodyn/23610.pdf
- Stovel, E., 2001. Patrones funerarios de San Pedro de Atacama y el problema de la presencia de los contextos tiwanaku, *Bol. Arqueol. PUCP* 5, 375–395.
<http://revistas.pucp.edu.pe/index.php/boletindeferqueologia/article/view/2511>
- Tarragó, M.N., González, L.R., Ávalos, G., Lamamí, M., 2010. Oro de los señores. La Tumba 11 de La Isla de Tilcara (Jujuy, Noroeste Argentino). *Bol. Mus. Chil. Arte Precolomb.* 15(2), 47–63. <http://dx.doi.org/10.4067/S0718-68942010000200004>
- Téllez, F.C., Murphy, M., 2007. El cementerio “Casa Parroquial”; un rescate afortunado. San Pedro de Atacama, Chile., in: Lleras, R. (Ed.), *Metalurgia en la América Antigua. Teoría, arqueología, simbología y tecnología de los metales prehispánicos*, Instituto Francés de Estudios Andinos and Fundación de Investigaciones Arqueológicas Nacionales, Banco de la República, Bogotá, 53–82.
- Téllez, F.C., Murphy, M., 2015. El Cementerio “Casa Parroquial”; un rescate afortunado. San Pedro de Atacama, Chile. *Nuestro Norte: Revista de Historia y Ciencias Sociales del Museo Regional de Iquique* 1, 50–83.
- Theile, J.M., Tellez F., Dinator Ramírez, M.I., Guidi, G.F., 2004. Conservación y análisis de los vasos de oro del Museo Arqueológico Gustavo Le Paige de San Pedro de Atacama, *Proceedings of the International Conference on Metals Conservation. Metal 2001*, Western Australian Museum, Perth, Australia, 248–259.
- Torres-Rouff, C., Knudson, K.J., Pestle, W.J., Stovel, E.M., 2015. Tiwanaku influence and social inequality: A bioarchaeological, biogeochemical, and contextual analysis of the Larache cemetery, San Pedro de Atacama, Northern Chile. *Am. J. Phys. Anthropol.* 158(4), 592–606. <https://doi.org/10.1002/ajpa.22828>
- Townley, B., Hérail, G., Makshev, V., Palácios, C., de Parseval, P., Sepulveda, F., Orellana, R., Rivas, Pa., Ulloa, C., 2003. Gold grain morphology and composition as an exploration tool: Application to gold exploration in covered areas. *Geochem. Explor. Env. A.* 3, 29–38. <https://doi.org/10.1144/1467-787302-042>

- Troalen, L.G., Guerra, M.F., Tate, J., 2014. Goldwork in Ancient Egypt. Workshop practices at Qurneh in the 2nd Intermediate Period. *J. Archaeol. Sci.* 50, 219–226.
<https://doi.org/10.1016/j.jas.2014.07.010>
- Troalen, L.G., Guerra, M.F., 2016. Gold from the tomb of Scribe Beri: a comparative analytical approach to the New Kingdom gold grave goods from Riqqa (Egypt). *Appl Phys A*. 122, 210–222. <https://doi.org/10.1007/s00339-016-9699-1>
- Uhle, M., Stübel, A., Reiss, W., Koppel, B., 1889. *Kultur und Industrie südamerikanischer Völker*, vol. 1, A. Asher & Co, Berlin.
- Uribe M., Agüeron C., 2001. Alfarería, textiles y la integración del Norte Grande de Chile a Tiwanaku. *Bol. Arqueol. PUCP* 5, 397–426.
<http://revistas.pucp.edu.pe/index.php/boletindeferqueologia/article/view/2512>
- Ventura, B., Scambato, A.C., 2013. La metalurgia de los valles orientales del norte de Salta, Argentina. *Boletín del Museo Chileno de Arte Precolombino* 18(1), 85–106.
<http://dx.doi.org/10.4067/S0718-68942013000100006>
- Villanueva, J., Korpisaari, A., 2013. La cerámica Tiwanaku de la isla Pariti como recipiente: performances y narrativas. *Estudios Atacameños* 46, 83–108.
<http://revistas.ucn.cl/index.php/estudios-atacamenos/article/view/10>
- Ziólkowski, M., 1979. Acerca de algunas funciones de los keros y los akillas en el Tawantinsuyu incaico y en el Perú colonial. *Estudios Latinoamericanos* 5, 11–2.
<http://www.estudios-online.org/pl/strona-glowna/79-numery-czasopisma/numery-archiwalne/81-estudios-latinoamericanos-vol-5-1979.html>

Figure captions

Figure 1 – The fifteen gold miniature objects in the collection of the MUSEF at the same scale. At the top, those that are decorated with bands, in the middle the undecorated ones, and at the bottom the incomplete piece and the effigy kero.

Figure 2 – The bases of (a) incomplete piece 27256 and (b) kero 27219, under the stereomicroscope.

Figure 3 – The base of bell 27275 under the stereomicroscope showing (a) the hole and (b) the folding of the gold sheet.

Figure 4 – Details of bell 27328 joining seams under the stereomicroscope at (a) the base and (b) the body.

Figure 5 – The base holes of bells 27227 (a) and 27460 (b) under the stereomicroscope.

Figure 6 – Diagrams representing the Ag and Cu contents in the alloys of the bodies (a) and bases (b) of the analysed objects. In the diagram representing the bodies were added the alloys published for keros 27233 and 27226 in the MUSEF collection (Fernández Murillo, 2016), the gold fragments from San Pedro de Atacama (Theile, 2004) and the gold objects from La Isla de Tilcara and Pueblo Viejo de La Cueva (Tarragó et al., 2010).

Figure 7 – Diagram representing the Ag and Cu contents in the objects plotted in Figure 6a to which were added the anthropomorphic and zoomorphic miniature figurines produced in Incan times for ritual offerings from several collections and archaeological contexts (Guerra et al., 2017; Rovira Lloréns and Gómez Ramos, 1995; Rovira, 2017; Núñez-Regueiro et al., 2017; Sierra Palomino and Guerra, 2017; Bárcena, 2004; Oberhauser et al. 1959).

Figure 8 – Diagram representing the Ag amounts determined for the objects in the MUSEF and for natural gold grains from diverse Bolivian deposits (Alarcón and Fornari, 1994), included some in the Lípez (Fornari et al., 1991; Ramos and Fornari, 1994), from the Patata deposits in Peru (Schreiber et al. 1990), from the San Luis Range deposits in Argentina (Márquez-Zavalía et al., 2004), and from the Cerro Casales deposits in the Atacama region in Chile (Palacios et al., 2001). The many gold grains from other deposits in the Eastern Cordillera of Bolivia (Hérail et al., 1988, 1990; Fornari and Hérail, 1991; Miranda Angles et al., 1991) and in the south-eastern Andes of Peru (Fornari et al., 1988) published by several authors are all under 20 wt% Ag, represented by the thick line.

Table captions

Table 1 – Certified values (CV) and measured values (MV) obtained for the standard reference materials and internal reference gold alloys at the analytical conditions to verify the accuracy of the quantitative results. Data was normalised to 100 wt%. Comptoir Lyon-Alemand, Louyot et Cie (CLAL) and Goodfellow (GD). The two coins were analysed by other techniques (Guerra et al., 2008), and LA and LE were fabricated by European project Authentico (Guerra and Rehren, 2009).

Table 2 – Data obtained by two or three-repeated XRF analysis of the base and body of the analysed gold miniatures in the collection of the MUSEF. Data was normalised to 100 wt%.

Table 3 – Data obtained by three-repeated XRF analysis of the base and body of bell 27274. Data was normalised to 100 wt%.

Figure 1



Figure 2a

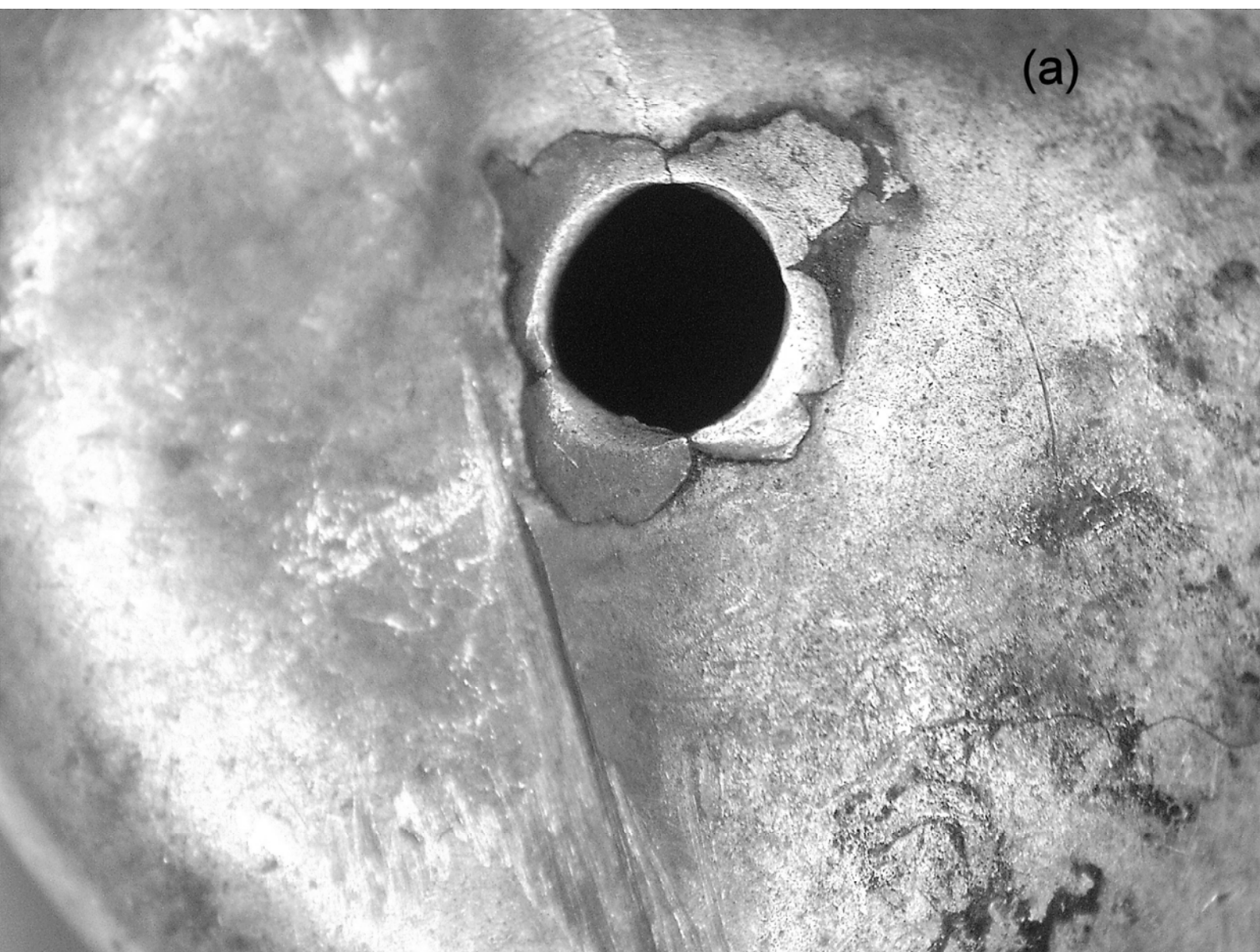


Figure 2b

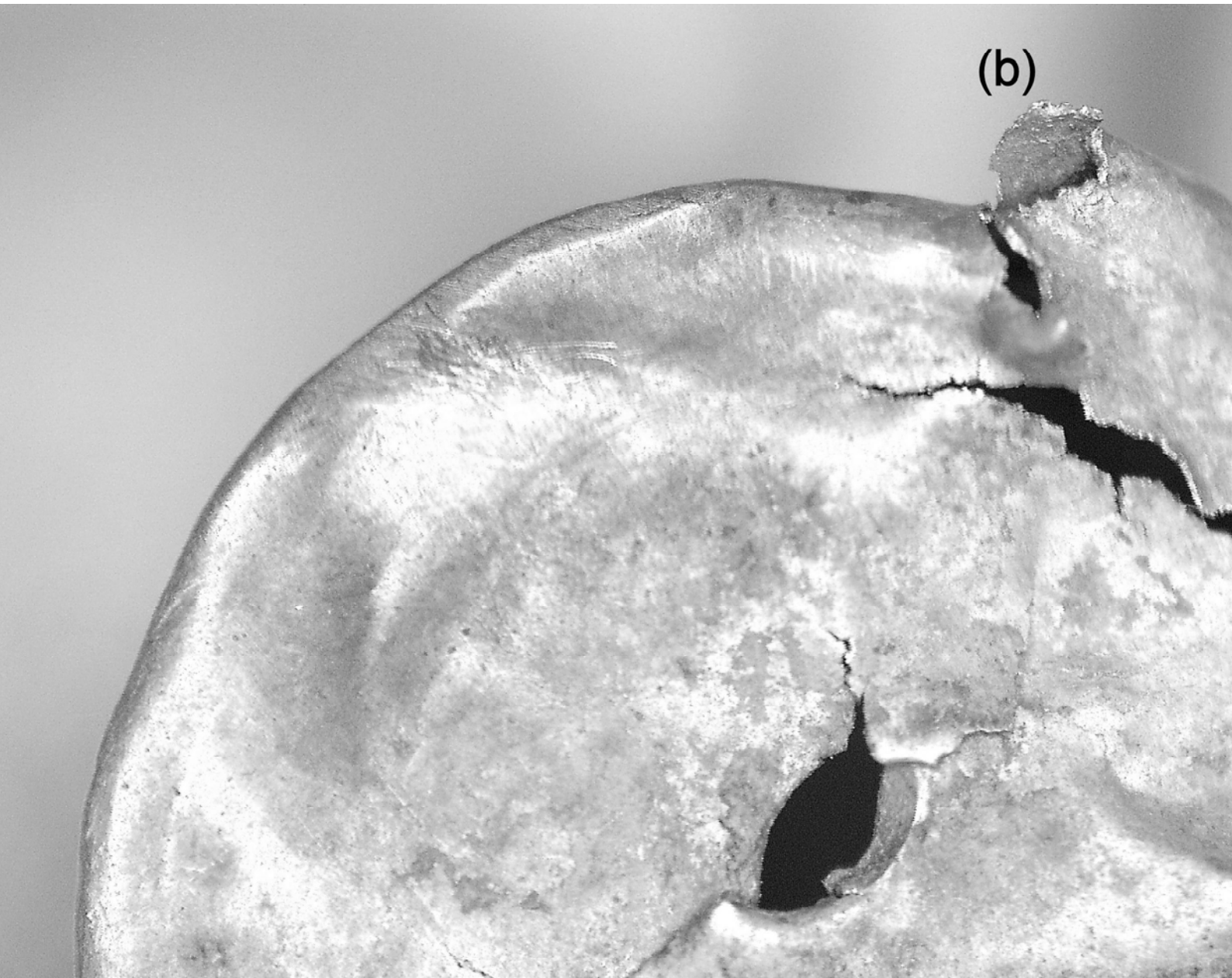


Figure 3a

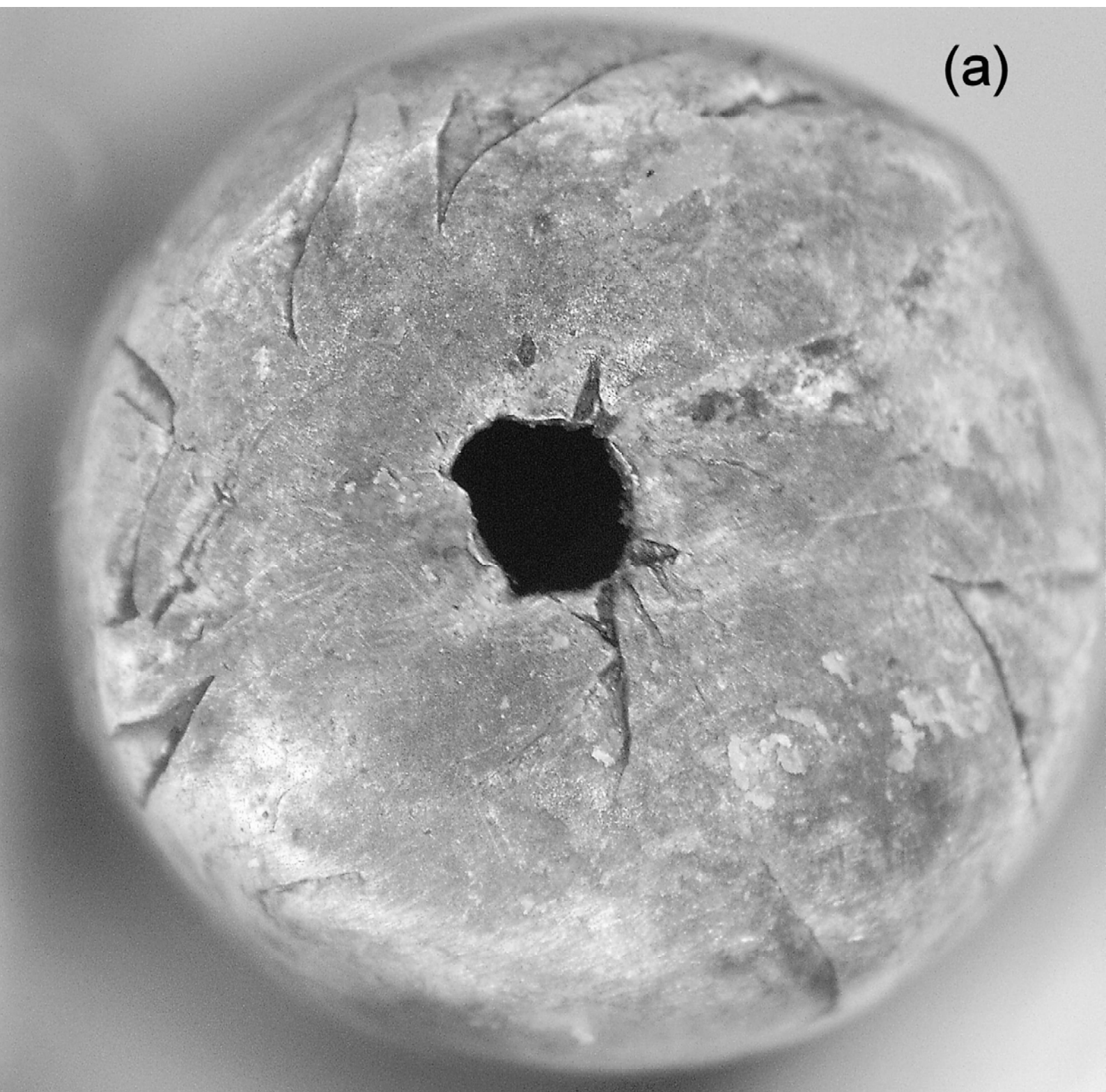


Figure 3b



Figure 4a

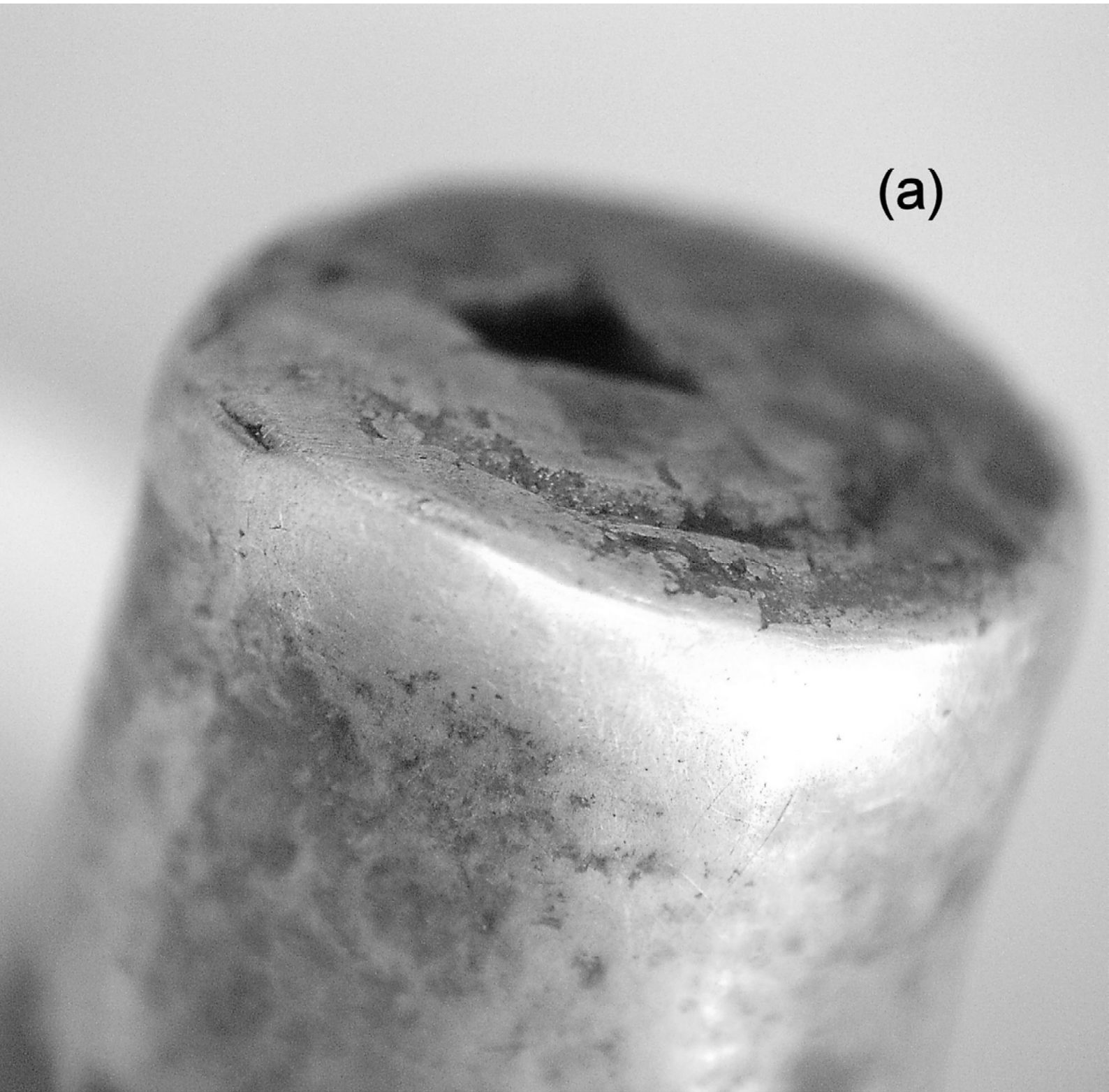


Figure 4b

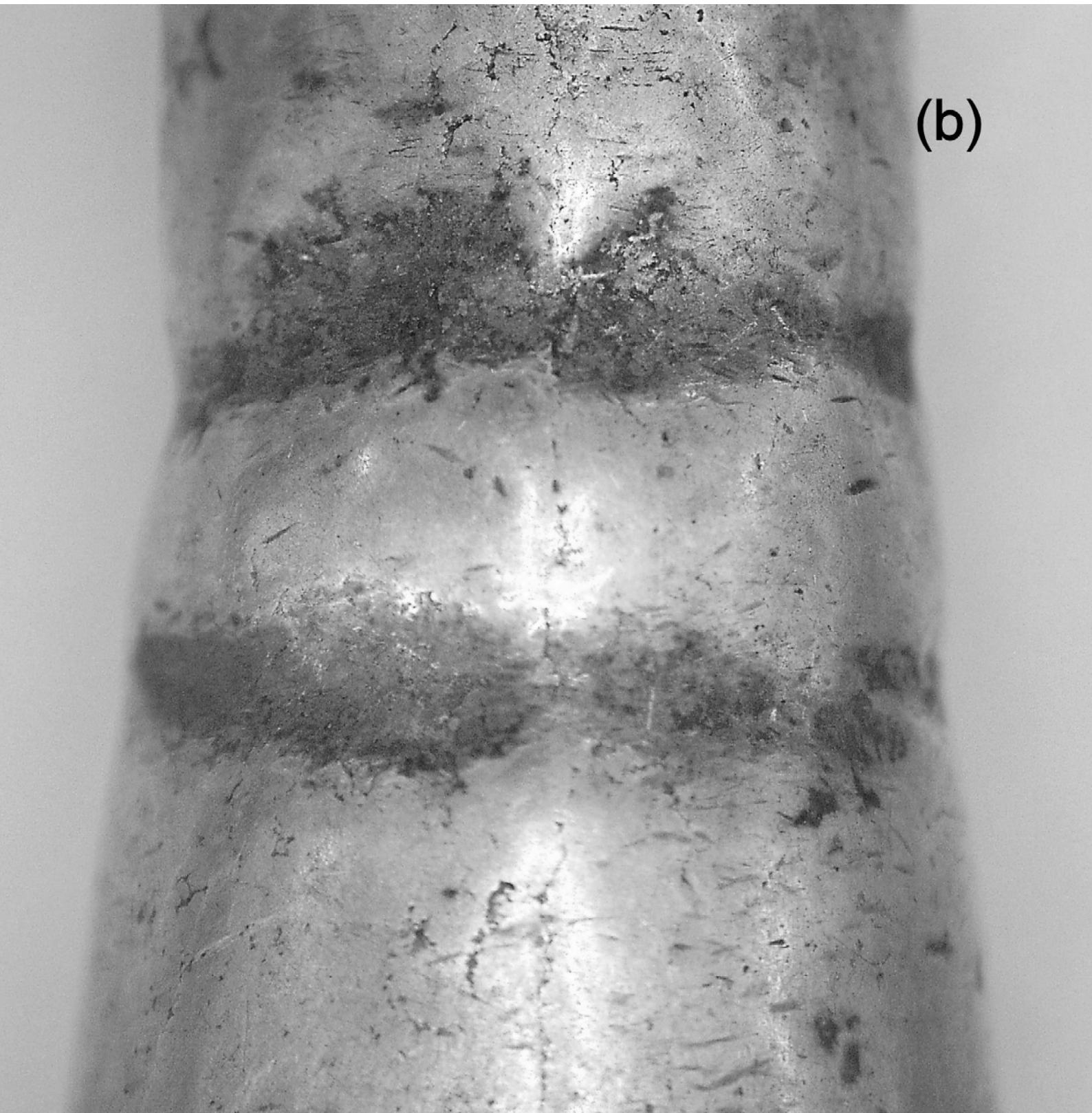


Figure 5a



Figure 5b

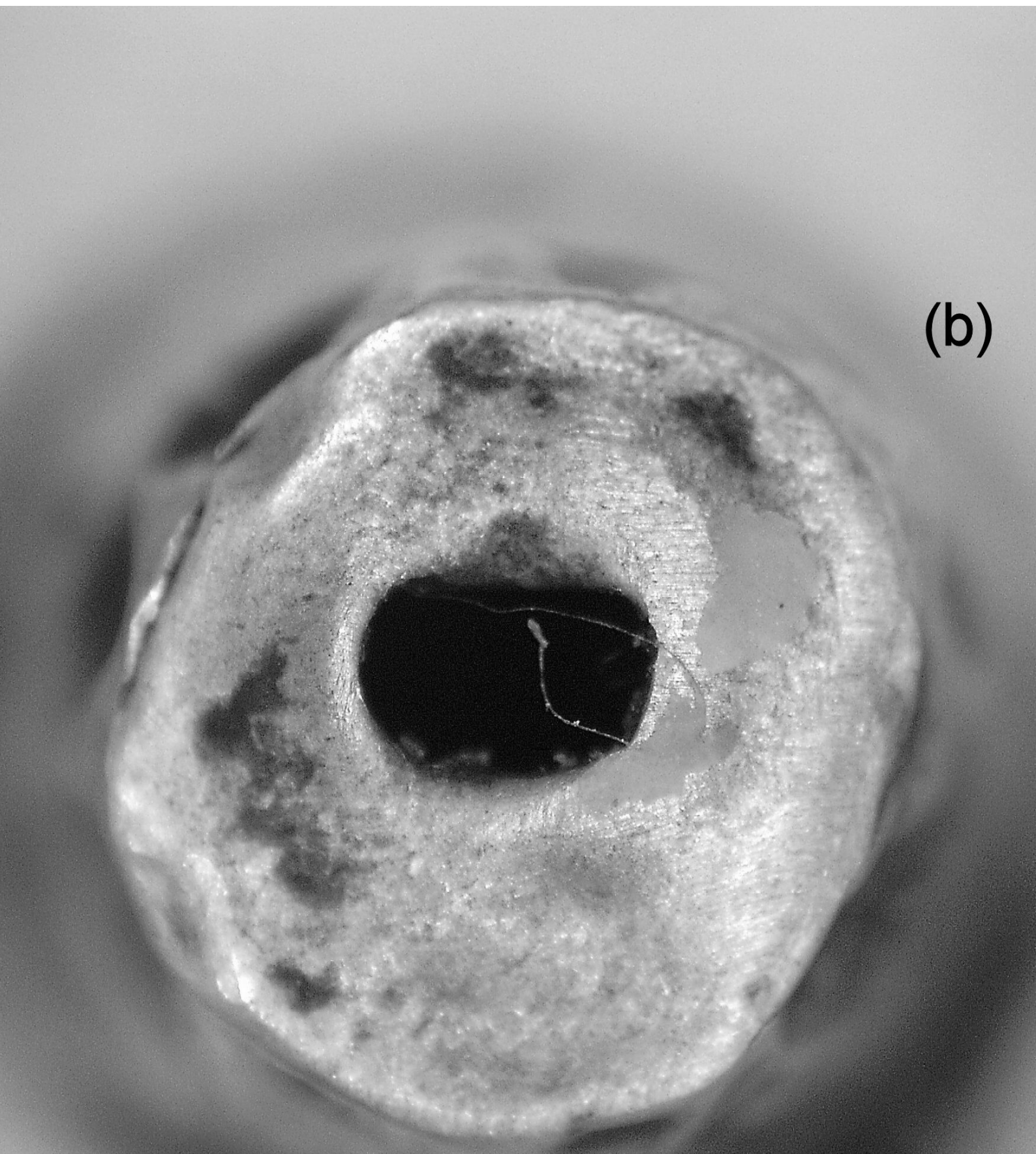


Figure 6

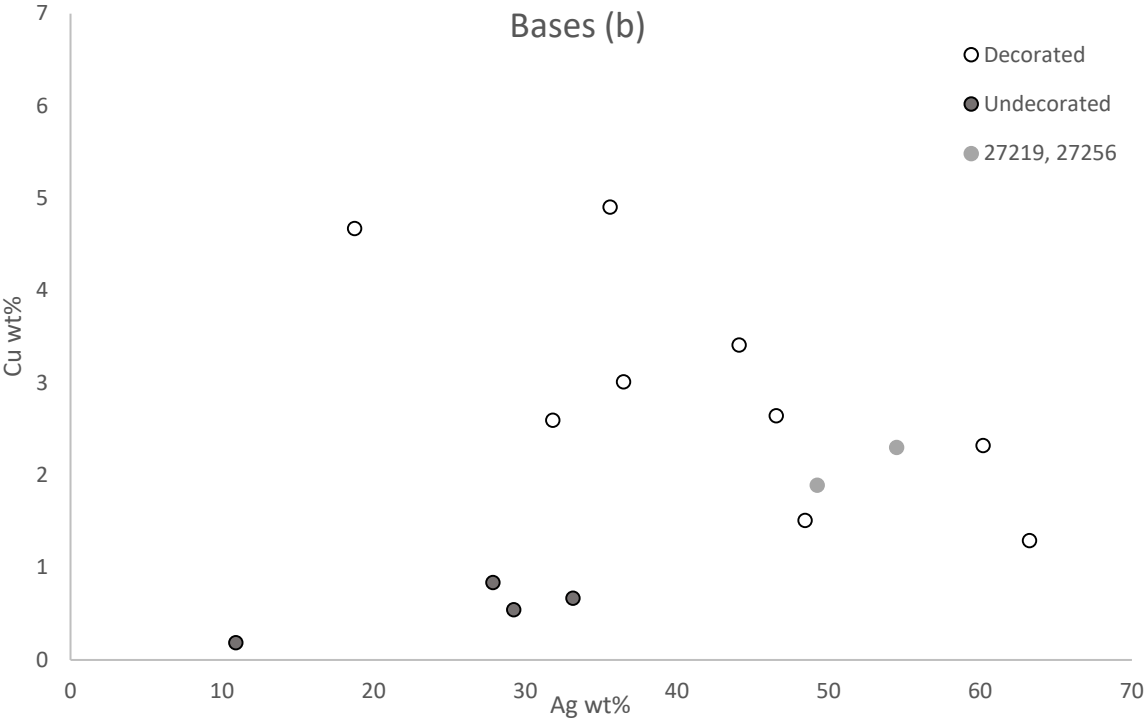
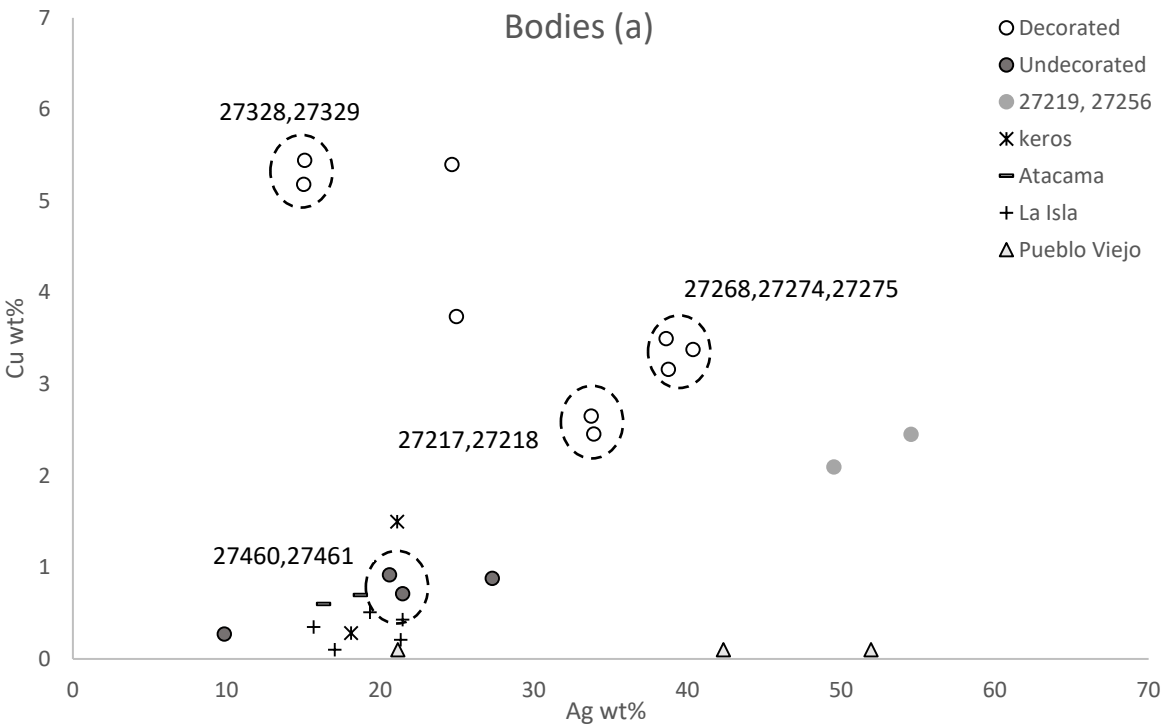


Figure 7

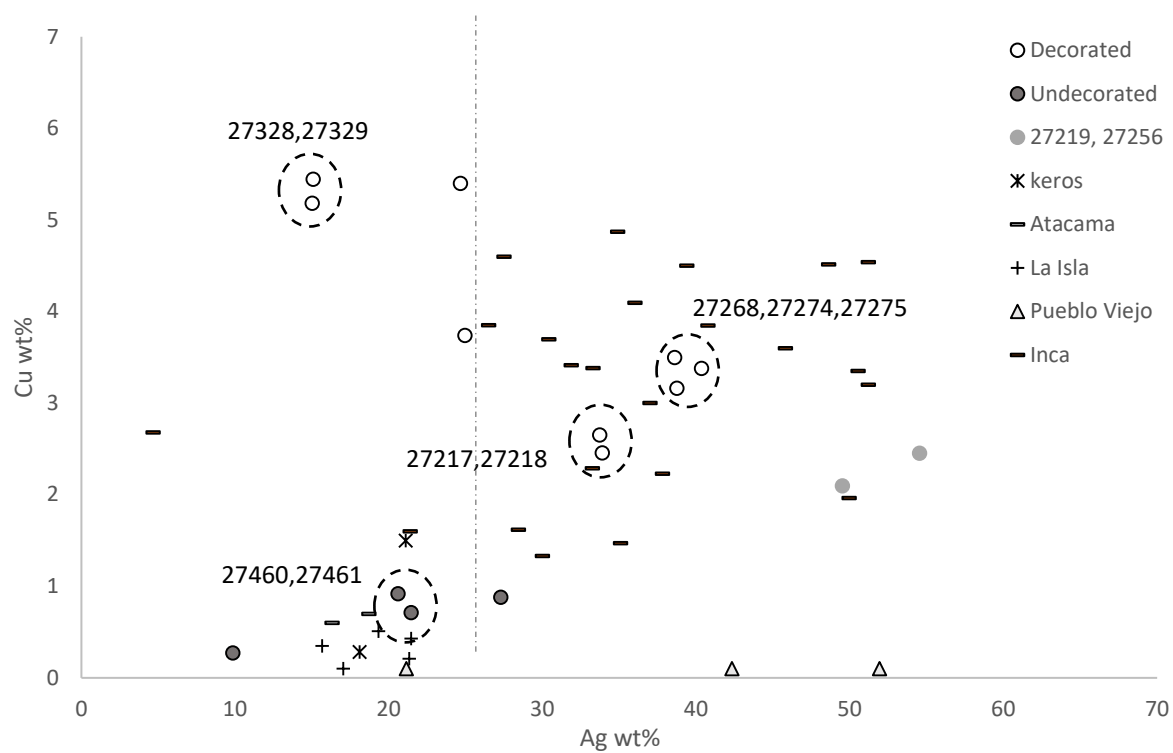
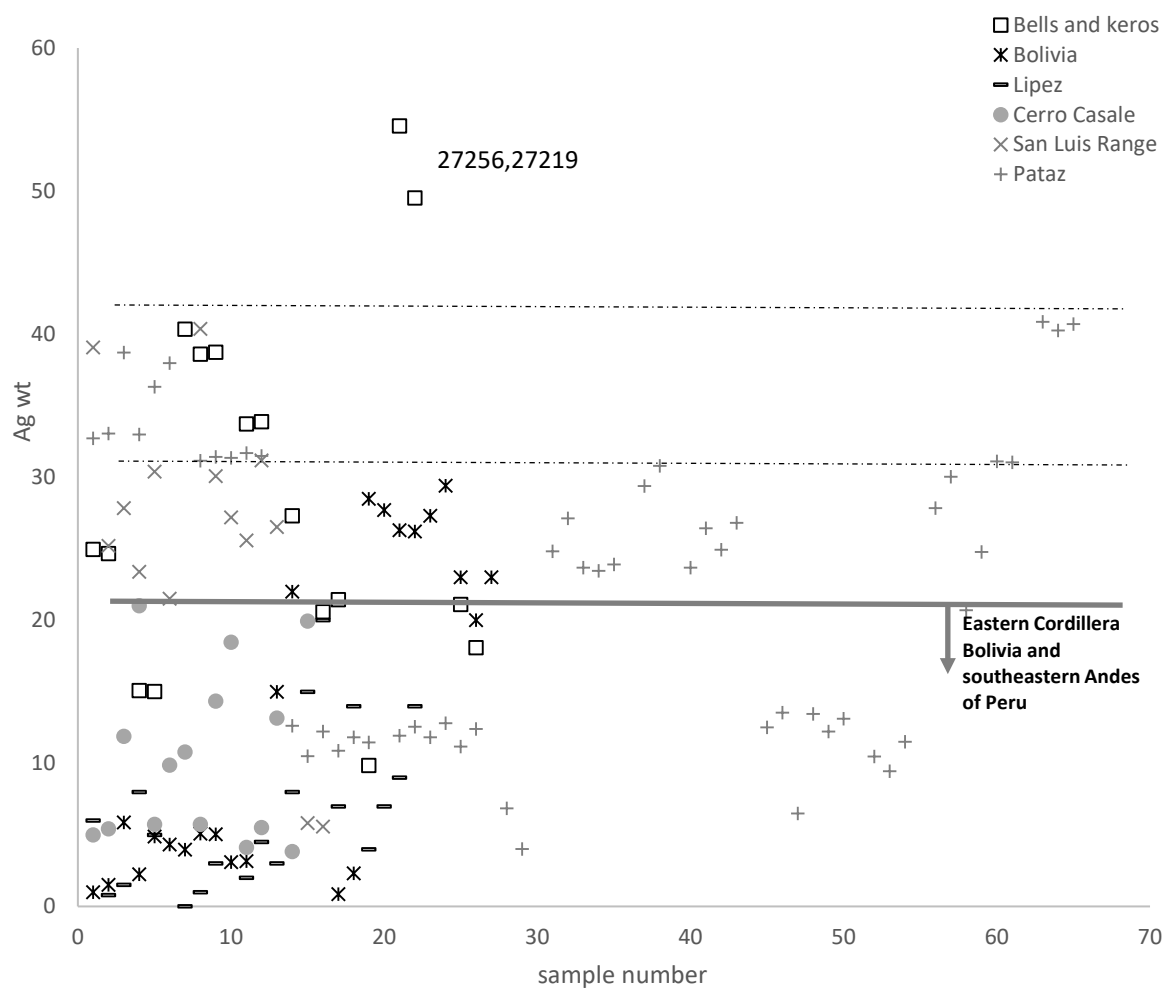


Figure 8



Reference		Au wt%	Ag wt%	Cu wt%
LA1	CV	92.4	6.5	1.1
	MV	92.5	6.4	1.1
	MV	92.5	6.3	1.2
	MV	92.5	6.3	1.2
	<i>average</i>	<i>92.5±0.03</i>	<i>6.3±0.03</i>	<i>1.2±0.02</i>
LA2	CV	73.5	22.8	3.7
	MV	74.2	22.8	3.1
LE1	CV	49.8	50.2	
	MV	50.6	49.4	
LE2	CV	54.9	44.7	0.4
	MV	55.8	43.8	0.4
Coin 1	CV	91.3	4.6	4.1
	MV	90.9	4.6	4.6
Coin 2	CV	90.2	6.3	2.9
	MV	90.2	6.7	3.1
CLAL 1	CV	50		50
	MV	49.9	0.1	49.9
CLAL 2	CV	92	4	4
	MV	92.2	3.9	4.0
GD	CV	20	80	
	MV	19.7	80.2	

Reference	Analysis	Au wt%	Ag wt%	Cu wt%
MUSEF 27217	body	63.6	33.7	2.7
	base	37.5	60.2	2.3
MUSEF 27218	body	63.7	33.9	2.5
	base	50.0	48.5	1.5
MUSEF 27268	body	56.3	40.4	3.4
	base	52.5	44.1	3.4
MUSEF 27274	body	57.9	38.6	3.5
	base	35.4	63.2	1.3
MUSEF 27275	body	58.1	38.7	3.2
	base	50.8	46.5	2.6
MUSEF 27328	body	79.8	15.0	5.2
	base	76.6	18.7	4.7
MUSEF 27329	body	79.5	15.1	5.4
	base	65.6	31.8	2.6
MUSEF 27330	body	69.9	24.7	5.4
	base	59.5	35.6	4.9
MUSEF 27331	body	71.3	24.9	3.7
	base	60.5	36.5	3.0
MUSEF 27459	body	71.8	27.3	0.9
	base	66.2	33.1	0.7
MUSEF 27460	body	78.5	20.6	0.9
	base	71.3	27.9	0.8
MUSEF 27461	body	77.8	21.5	0.7
	base	70.2	29.2	0.5
MUSEF 27462	body	89.9	9.8	0.3
	base	88.9	10.9	0.2
MUSEF 27256	body	43.0	54.5	2.5
	base	43.2	54.5	2.3
MUSEF 27219	body	48.4	49.5	2.1
	base	48.9	49.2	1.9

Bell 27274	Au wt%	Ag wt%	Cu wt%
base	38.4	57.8	3.8
	39.2	57.5	3.3
	38.2	58.5	3.3
body	62.9	35.8	1.3
	63.6	35.2	1.2
	63.3	35.3	1.4