Chapter 1
Archaeometallurgy

Patricia Silvana Carrizo

It is useful to think each of the objects that comes to us from the past must have a story to tell; a story that, if read and interpreted correctly, can contribute to our general understanding and even some of this information can be recovered and applied to the development of new metal alloys, studies related to corrosion, and development of material conservation processes.

In this way, archaeometallurgy is an interdisciplinary and international field of study that examines all aspects of the production, use, and consumption of metals from approximately 8000 BC until now, although, in general, this review is limited to mining and metallurgy in pre-industrial societies.

Most of this literature was not written with an anthropological reading in mind, but many of its central themes are relevant to some current debates in anthropology.

Since the 1970s, studies in archaeometallurgy have been explicitly concerned with the materiality of metals and with the highly variable value of precious metals in time and space. Exact criteria have been developed to distinguish transfers of transmitted technologies from generation to generation from independent inventions. Archaeometallurgists have also done important work in the social construction of technology in precapitalist economies.

Among the new approaches that encompass archaeological and metallurgical research is the study of technological change, conceived from a double orientation: internal and external. The internal one explains the change from the technological system itself, that is, considering what changes and how it changes, based on pre-existing knowledge and innovation. This part of the research has been strongly linked to the Technology History approach. The second orientation, that is, the external one, tries to answer the question: why does technology change?

From the scientific point of view, we can highlight a trend that is gaining greater weight: interdisciplinarity, an unavoidable challenge for any successful scientific

P. S. Carrizo (✉)
Archaeometallurgy Area/Metallurgy Laboratory, National Technological University, Mendoza, Argentina

P. S. Carrizo (ed.), *Reverse Engineering of Ancient Metals*,
https://doi.org/10.1007/978-3-030-72842-7_1

approach. The archaeometallurgist scientist no longer works alone and in isolation but has to be understood and coordinated with all kinds of specialists and specialties; this fact produces a positive effect, not only from the methodological point of view but also the theoretical, as the prospects for teamwork are expanded.

In summary, archaeometallurgy offers a lot of interest for the anthropological and social sciences that study growth, the dissemination of knowledge, and value systems, before the capitalist era.

Archaeometallurgy: Studies of Invention, Innovation, and Dissemination

Archeometallurgy, in its advancement, has benefited in some way due to technological development, either in laboratory equipment or in portable equipment that greatly facilitate the task of the archaeometallurgical researcher and in this way archeometallurgy has taken giant steps in recent decades in the advancement of knowledge and this accompanied by the application of the scientific method to approach each investigation, which often resembles a forensic expertise, with the difference that the pieces of the historical heritage are prohibitive to be cut unless expressly authorized by the authorities competent. Despite these limitations mentioned, the archeometallurgy that uses metallographic techniques for research as a means, has made it possible to carry out the reverse path, that is, through applied techniques it is possible to do the reverse path in the manufacture of the pieces in question and obtain information on the raw material used, on how was its manufacturing process, whether or not there was presence of an incipient heat treatment, or study the characteristics of its state of conservation to this day, since the findings in this type of research are really exciting and incredibly surprising and at the same time that they relate to all the historical information of the object or piece and it is so in these instances, due to the interaction shown, is that the researcher always needs to transmit his new and useful discoveries as contributions to the knowledge to the field.

In fact, archaeometallurgy offers us, among its applications, studies of invention, innovation, and dissemination in modern times, as if there were no fundamental differences in the processes of creation between industrial and pre-industrial societies.

General Information About the Applied Techniques

Archaeometallurgy studies all the processes derived from obtaining old metal parts. These can come from mining, reduction and smelting furnaces, mold processes, cold or hot forging processes, and finishing processes (decoration, patina,

cementation, etc.). This research field is also interested in the current state of these metal parts, studying:

- The geochemical environment of the soil in which they have been found.
- The characterization of the corrosion layer.
- The observation of the structural aging of the metal or alloy.
- The variation of mechanical properties over time.

Studies Involved in Each Archaeometallurgy Research

- Metallographic study (optical microscopy, scanning electron microscopy, high resolution scanning electron microscopy, transmission electron microscopy, electron microscopy).
- Chemical composition with portable X-ray diffraction spectrometer for non-ferrous materials.
- X-ray diffraction in laboratory equipment.
- Mechanical tests (mechanical traction, bending, compression, hardness, micro hardness, impact Charpy); obviously, these tests are performed only when they are previously authorized by the competent authority.
- Non-destructive tests (radiography, ultrasound, penetrating inks).

Applications

- The metallographic and mechanical studies of the archaeological pieces examined provide valuable information on mining forms, old extractive metallurgy, casting and casting processes, hot or cold forging, thermo mechanical treatments applied, surface finishing treatments, provenance, and the age of the piece itself is achieved indirectly through the timeline of the metallurgy evolution and its techniques processes.

Metallurgy, Ways to See and Value

The claim that technologies are socially constructed has become axiomatic among historians and sociologists of technology since the early 1990s [1]. Heather Lechtman (archaeologist and materials engineer) was one of the first advocates of this view [2]. She argued that in different regions of the world distinctly different technological trajectories could be recognized, so she coined the term “technological styles.” The essentially identical concept of “technological choices” was developed independently in France [3–5].

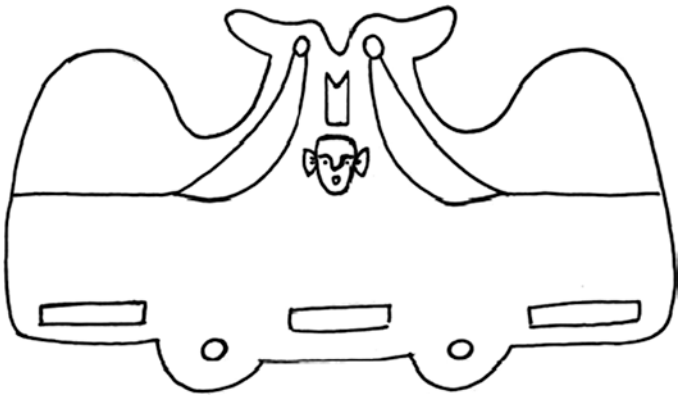
Archaeometallurgy provides some of the best examples of precapitalist technological styles. For example, historical documents and ethno-archaeological field research show that in many African societies iron smelting was understood exactly as equivalent to gestation and birth, illustrating the symbolic appropriation by men of the generative powers of women. The oven was a woman, the iron flower that grew in the oven was the fetus, and her male assistants were simultaneously husbands and midwives. In some cases, this equivalence was explicit, with furnaces modeled as women's bodies or bellows as male genitals. More commonly, it was implicit in the behavior of ironworkers, who were often forbidden to have sex during the process and were often isolated in the foundry fields to ensure compliance [6, 7].

Another example of this is given by the *Mapuche* people in South America who, through the jewels of their well-known *Mapuche* Silverware, sought a link with the Universe, how human life and other philosophical ideas are generated, and embodied them in the making of their jewels. The *Mapuche* people, similar to any other people since time immemorial, tried to understand where life came from, how it was generated, who made life possible here, who generated the *Mapuche* human life, the relationship between the *Mapuche* being and the other elements of nature, who administers and controls the human race in all their spiritual movements.

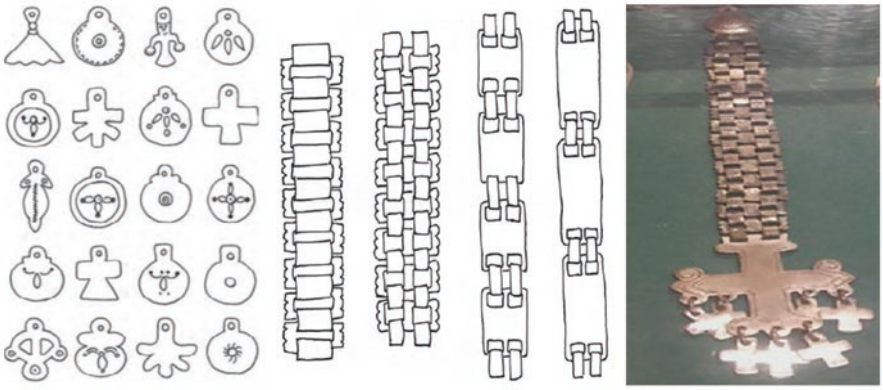
For the First idea of how life was generated, the ancients say that there was a moment in time when the universe was in complete disorder and chaos. Large explosions followed each other, the stars collided, until a great *newen* (spiritual force) appeared, imposed itself on other *newenes* in the cosmos and ordered it, also resulting in the generation of life in the *Wajontu mapu* (earth globe). This great *newen* that can generate life has a dual duality: it has the two energies—the positive and the negative—these are not opposed, but on the contrary they are complementary; they are in reciprocity and in balance. It also has both sexes, the masculine and the feminine, which is the only way to generate life; this aspect is of real importance because it supports the *Mapuche* religious structure in terms of its authorities.

This great *newen* is called *El Mapun* and is a great cosmic energy. The generation of life in the *Wajmapu* is carried out considering three elements: the energies of the cosmos in particular that of the *ahtü* (sun), the energies of *ko* (seas, lakes, and rivers), and the energies of the plain earth or *Naüq Mapu*. Also, these three energies must be in balance, complement, and reciprocity, so that these conditions are maintained over time; it is essential to develop religious spiritual activities that the *Mapuche* human being carries out such as prayers and thanks. Thus, the life of nature appears in the *Wajontu mapu*: time and years, day and night, moon, thunder, lightning, rivers, lakes, mountains, snow, wind, rains, heat, trees, plants, animals, fish, insects, and birds also appear. Each and every one of them with energies and sexes for their multiplication, all distributed in the plain of the *Wajontu mapu* (globe) with defined spaces and with owners, the g*eh* [8] (Graphic 1.1).

- **The *Mapuche* philosophy and spirituality are condensed in the *Keltatuwe*.**



Graphic 1.1 How life was generated



Graphic 1.2 Diagrams of various known pins in the *keltatuwe*, chains of different types used in *keltatuwe*. *Photo 1* K*eltatuwe* belonging to the Aboriginal collection of La Pampa and Patagonia from La Plata National Museum of Natural History, Buenos Aires Province, Argentina

When we see the different jewels of the *Mapuche* Silverware, we must stop to analyze the *Keltatuwe* (pin) because the contents of the idea of how life in general appears in nature are expressed in its upper plate (Graphic 1.2).

The *Mapuche* authorities: *Fücha Chaw, Kushe Ñuke, Mür* (parity), and *xürgen* (symmetry) are principles of life, not just opposite or complementary, intrinsically necessary and the origin in themselves. *Meli Newen, Weche,* and *Üjcha* express experience, wisdom, youth, strength, vigor, fertility, and fertile creation, all of which give the *Mapuche* religious basis for the construction of future jewels. The *rüxafe* managed to define a design that considered these elements as duality and determined that it was a bird's body with two heads, which are sometimes facing each other and other times they are looking in opposite directions. The reason why

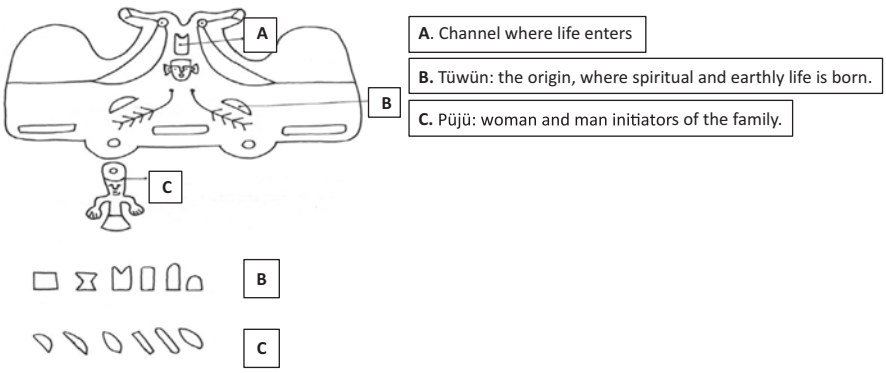
sometimes it is represented as a bird and other times as a large fly is determined to be because they are the only ones that can fly so high into the cosmos and that can disappear from our view demonstrating the infinity of the universe.

The *Mapuche* ancestors created the design of the top plate of the *Keltatuwe* based on harmony, on balance (it is a symmetrical piece); sometimes it has the figure of a face with human forms, which represents *Elmapun* (sometimes he has big ears). It is noteworthy that although the *Mapuche* jewelry is best known for their work in silver, this was not the only material that they worked with. Various studies indicate that they started working with copper and that although they went through various stages of development and improvements in their silver works, they never abandoned copper [9]. (See Chap. 12: Case Studies on Reverse Engineering of Ancient Metals, "Border Archaeometallurgy: Pieces Found in the *Mapuche* Cemetery of Cerro Mesa, Malargüe, Mendoza.")

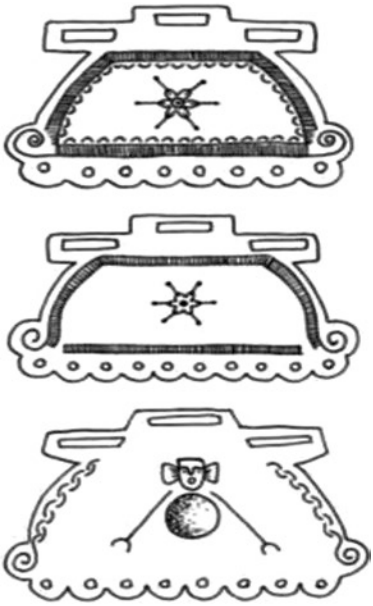
For the Second idea of how the *Mapuche* human life was generated, the ancients said that a long time passed and in the sky there was a very sad star who cried because she was alone, *Elchen* (who is a cosmic spiritual force) takes the sad star in his hands, and transforms her into a woman and deposits her on the *naüq* (surface), then takes another star, transforms it into a man and places him next to the woman to accompany her, so *Elchen* deposited several couples in different places where the sun rises.

These spiritual places are called *tuwün* (the origin); there the spirits recreate, reproduce, and define the roles and functions. The channel of human life comes through women, and when all *Mapuches* are born they have a duality: an organic-biological part and a spiritual part; the spirit in life is called *püjü*. In the top plate of the *Keltatuwe* (pin) all these contents of the *Mapuche* philosophy are expressed. The various incisions have shown this, the channel of life in general has different forms (see Graphic 1.3).

The incision that represents the *tuwün* has several lines that join them to another line that has a beginning and ends in two holes in which hang figures called *püjü*



Graphic 1.3 Family founders' distribution and their spirits



Graphic 1.4 Diverse designs of the bottom plate of a *keltatuwe*

that represent the initiators or founders of the families in the *Naüq Mapu* (the plain of the *Wajmapu*); these family founders remain in the collective memory and their spirits are represented on this top plate of the *Keltatuwe* (Graphic 1.4).

Archaeometallurgists have long been aware of spatial and chronological differences in the value of metals and have often tried to link this with their colors [10–12]. The Eurasian obsession with gold and silver began in the Balkans around 5000 BC and was gradually adopted throughout the continent, except in the central plain of China, where these metals were ignored in favor of tin bronze [13]. Gold and silver were also highly valued in Egypt, Nubia, and Carthage, but neither gold (Au) nor silver (Ag) was used south of the Sahara (except in Nubia and Eritrea pre-axumite/axumite, which had commercial ties with the Mediterranean) until the Islamic era, when sub-Saharan Africa became the main source of gold for Eurasia. At this point, African elites that emerged to control the gold trade adopted the use of gold as a marker of distinction [14–17]. The absence of gold from previous archaeological sites cannot be attributed to ignorance because trajectories or currents could be analyzed with little effort, and Iron Age Africans certainly had the technology to melt it. However, as [7] has so convincingly demonstrated, they largely preferred the red color of unalloyed copper, which they largely reserved for ornaments, using iron for weapons and tools.

Gold was the first metal used in South America, and subsequently elaborate chemical treatments were invented to develop a variety of surface colors in the *tumbaga* bodies (copper, gold, and silver alloy) [18–20]. The symbolic meaning of these colors in prehistoric contexts is unknown, but there is an ethnographic link

between metallurgy and cosmology in Colombia, where the symbolism of the *Tukanoan* color has approximately 30 shades between yellow-white (the sun, male power) and copper red (the waning moon, female generativity defined as the ability of the adult to commit to the establishment and guidance of the next generation). Ideally, "the sun fertilizes a bright new moon, which then passes through a sequence of yellowish, reddish and coppery phases that are compared to the embryonic development process" [21]. The triad of silver, copper, and gold metallurgy was extended by sea from Ecuador to Mexico [12] where metals were used almost exclusively for ornaments.

One of the most suggestive features of pre-Hispanic Andean metallurgy is that the technical procedures that were developed and the gradual increase in production over the centuries were not driven by practical considerations. It was not the intention of the ancient artisans to obtain more efficient and lasting tools or more powerful weapons but rather to put forth effort, inventiveness, and focused creativity for the achievement of pieces with certain aesthetic qualities, while paying close attention to certain cultural norms—not only physical and chemical—for the transformation of materials. The processing of the raw materials involved cultural principles that the original peoples used to order and structure their reality in a similar way to what they did with language, achieving a connection between heaven and earth.

The Symbolic Power of Metals

In the last part of this chapter—Archaeometallurgy—special reference is made to the Andean metallurgy because this work focuses on the metallurgy developed by native Latin American peoples and also refers to the precapitalist infrastructure.

The appreciation for metal goods not only resided in the energy of work and the technical knowledge applied to production but also in the connections that metallurgical activities and their products maintained with the rich Andean mythical universe, many of whose elements remain current to the present day. In Los Andes, nature was conceived as an integrating totality in which men connected with these entities following the principles of reciprocity that prevailed in everyday relationships.

Respectful activities with them and offerings were the way to win their will and collaboration in personal or community ventures. Thus, the products of nature can only be used by applying the appropriate techniques and rituals. Nature, rather than exploiting itself, was cultivated in all its aspects and man acted as a midwife of its fruits.

For example, in Inca times, the mountains that housed metal deposits were especially revered and received sacrifices and offerings. The mines were considered *huacas*, (see Chap. 12: Case Studies on Reverse Engineering of Ancient Metals: "Gold Artifact Production During the Central Andean Formative Period: New Evidence from Chavín de Huántar and Caballete, Perú"), that is to say sacred places, and with the arrival of the Spaniards, this term became synonymous with hidden

treasure. The miner was linked intimately with the land "*Pachamama,*" the mineral was treated as another lively element of nature, which was reproduced, raised, and harvested just like crops. Even today, ceremonial procedures continue to be practiced, considering the miners responsible for the life of the mine and its products.

The ethnographic and archaeological information available from Los Andes related to ceremonial activities around metallurgical production is unfortunately very scarce; however, the creative process required the consent of supernatural powers and that played a very important role in several areas [22]. According to elements of the Andean worldview and the information of societies from other continents, they give rise to the idea that in pre-Hispanic times, smelting events were surrounded by significance and mysticism that brought them closer to the supernatural spheres. Today's traditional goldsmiths retain behaviors that have nothing to do with technical procedures but are fundamentally linked to deep conceptions rooted in the past. In San Pablo, department of Cuzco-Peru, the goldsmiths refuse to recast old pieces because they contain the souls of their previous owners and could punish them, and because Tuesdays and Fridays are considered evil days for metals, they should not face foundry tasks on these days [23].

With the arrival of the industrial society, the idea triumphed that the metalworking industry should be motivated by the desire for progress and that it was governed by the criteria of efficiency and utility. Then, the metallurgical work of yesteryear was reduced to a long process of experimentation and mastery of techniques and materials, from the simple to the complex determined by the laws of physics and chemistry and totally separated from the social context. However, Andean events are far from responding to a natural evolution of metallurgy, but they respond precisely to deeper imperatives, intimately linked to culture and in a particular way to the future of the cosmos. Although in their jewels the original Andean peoples unknowingly complied with the laws of physics and chemistry known to everyone today, in their creations this important fact was implicit. Adding to our delight and utmost admiration for the abilities of the ancient metal craftsmen, in the *Mapuche* language: the *rüxafe*.

It was the structural elements of societies that established the requirements to which the qualities of metal objects should be adjusted and the ways in which they should be processed. Andean metallurgy could be said to place both the technical and the symbolic on an equal footing, giving rise to goods full of meaning that transcends its apparent functionality.

At this stage, copper represents the material that enabled not only developing a technology with its own characteristics in the ancient world but also allowed expressing the most intimate foundations of the Andean universe [24, 25].

Conclusion

In the past 50 years, archaeometallurgy has become a well-integrated and highly productive interdisciplinary field of study, but archaeometallurgists have not yet managed to convince most archaeologists of the relevance of their work, perhaps due to the existing separation between what are social sciences and exact or hard sciences where precisely it is framed: engineering. Many of the leading figures in the field of archaeometallurgy today were trained in disciplines such as geology, chemistry, and materials science and have tended to focus on the technical problems of reconstruction and provenance. Another reason, of no less importance, is that archaeometallurgy is now large enough to support a series of specialized conferences, with the consequence that much of these works tend to be presented there or at specialized meetings of archaeological scientists. A third important reason is that some of the most interesting work has been done in East Asia, Africa, and Latin America and is rarely summarized for academics who are not specialists in those areas.

Thus, stemming from engineering and materials science, the great development in increasingly sophisticated laboratory equipment, including portable ones, obviously put in the forefront those who have been trained in the branches of engineering, generating an extraordinary development niche and future knowledge to unveil.

References

1. MacKenzie, D., Wajcman, J.: The Social Shaping of Technology, 2nd edn. Open University Press, Buckingham (1999)
2. Lechtman, H.: Style in technology—some early thoughts. In: Lechtman, H., Merrill, R. (eds.) Material Culture: Styles, Organization and Dynamics of Technology, pp. 3–20. West, New York (1977)
3. Cresswell, R.: Transferts de techniques et chaînes opératoires. Tech. Cult. **2**, 143–163 (1983)
4. Lemonnier, P.: Elements for Anthropology of Technology. Museum of Anthropology, University of Michigan, Ann Arbor (1992)
5. Lemonnier, P.: Technological Choices: Transformation in Material Cultures Since the Neolithic. Routledge, New York (1993)
6. Childs, S.T.: Style, technology and iron smelting furnaces in Bantu-speaking Africa. J. Anthropol. Archaeol. **10**, 332–359 (1991)
7. Herbert, E.: Iron, Gender and Power: Rituals of Transformation in African Societies. Indiana University Press, Bloomington (1994)
8. Antinao, J.P.: Sociedad y Cosmovisión en la Platería Mapuche. Universidad Católica de Temuco, Temuco (2010)
9. Campbell, R.: Entre el Vergel y la Platería Mapuche: El trabajo de los metales en la araucanía poscontacto (1550-1850 D.C.) (2004)
10. Herbert, E.: Red Gold of Africa: Copper in Precolonial History and Culture. University of Wisconsin Press, Madison (1984)
11. Hosler, D.: The Sounds and Colors of Power. MIT Press, Cambridge (1994)
12. Hosler, D.: West Mexican metallurgy: revisited and revised. J. World Prehist. **22**, 185–212 (2009)

13. Linduff, K., Mei, J.: Metallurgy in ancient Eastern Asia: retrospect and prospect. J. World Prehist. **22**, 265–281 (2009)
14. Austen, R.: Trans-Saharan Africa in World History. Oxford University Press, New York (2010)
15. Huffman, T.: Mapungubwe and Great Zimbabwe: the origin and spread of social complexity in southern Africa. J. Anthropol. Archaeol. **28**, 37–54 (2009)
16. Killick, D.: Cairo to Cape: the spread of metallurgy through Eastern and Southern Africa. J. World Prehist. **22**, 399–414 (2009)
17. Killick, D., Fenn, T.: Archaeometallurgy: The Study of Preindustrial Mining and Metallurgy. Annu. Rev. Anthropol. **2012**, 559–575 (2009)
18. Lechtman, H.: A pre-Columbian technique for electrochemical replacement plating of gold and silver on objects of copper. JOM. **31**, 154–160 (1979)
19. Lechtman, H.: Andean value systems and the development of prehistoric metallurgy. Technol. Cult. **25**, 1–36 (1984)
20. Lechtman, H.: Technologies of power: the Andean case. In: Henderson, J.S., Netherly, P. (eds.) Configurations of Power, pp. 244–280. Cornell University Press, Ithaca (1993)
21. Reichel-Dolmatoff, G.: Things of beauty replete with meaning metals and crystals in Colombian Indian cosmology. In: Furst, P.T. (ed.) Sweat of the Sun, Tears of the Moon: Gold and Emerald Treasures of Colombia, pp. 17–33. Natural History Museum of Los Angeles County, Los Angeles (1981)
22. Shimada, I.: Aspectos tecnológicos y productivos de la cultura Sicán, costa norte del Perú. Gaceta Arqueológica Andina **13**, 15–21 Lima (1987)
23. Valencia, A.: La platería tradicional en un pueblo del sur del Perú. In: Ravinés, R. (ed.) En Tecnología Andina, pp. 535–554. Instituto de Estudios Peruanos, Lima (1978)
24. González, L.: Recuerdos de bronce. La metalurgia prehispánica tardía en el noroeste argentino, in *Ponencia a 51° Congreso Internacional de Americanistas*, Santiago (2003)
25. González, L.: De texto catálogo "El arte del cobre en el mundo andino", in *El arte del cobre en los Andes Prehispánicos: Historias de poder, brillos y colores* (2004)