# Early copper metallurgy in Northern Chile

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## Abstract

The Central Andean region of South America has a long tradition of mining and metallurgy. Such activities were fundamental to the economic, socio-political and ideological dynamics of the pre-Columbian cultures that inhabited this area. In spite of their importance, few archaeological investigations of metallurgy have been carried out in the Central Andes in general, and in current Chilean territory in particular. The present project investigates archaeometallurgical sites in Northern Chile using scientific analysis, as a first step towards a large-scale map of prehistoric copper production and exchange across South America. This research involves documentation and sampling of already excavated archaeological materials from a number of copper-producing sites located in the Atacama District. Preliminary results of X-ray fluorescence analysis of artefacts from the collection of the R.P. Gustavo Le Paige Archaeological Museum, San Pedro de Atacama, have been obtained and enabled us to characterise the different elements present in the metal objects. These results might provide information on the nature of the raw materials used.

## Introduction

The Andes is a rich metallic ore-bearing region, which, to this day, provides a variety of minerals for the production of gold, silver, copper, and tin. From the standpoint of the pre-Columbian peoples, however, copper was the most important metal, and played a prominent role in the early metallurgy of the area. Copper was not only the predominant metal, but the most extensively used base material. Andean metalworkers produced an assortment of copper-based alloys, including copper-arsenic and tin bronze, which were fashioned mainly as ornaments used in religious ceremonies and for the enhancement of elite cultural status.

At present, details of prehistoric copper smelting in South America are mostly known from a few sites in Peru (Shimada *et al*., 1982, 1983; Shimada and Merkel, 1991). Archaeological evidence, however, indicates a much wider distribution of ancient smelting sites into northern Chile and Argentina. Numerous metal artefacts, most of them from mortuary contexts, have been recovered in the Atacama Desert of northern Chile. Nevertheless, the technological, social and economic processes involved in the production and distribution of these objects remains virtually unknown. Developed jointly with the UCL Institute of Archaeology, the *Curt-Engelhorn-Zentrum Archäometrie* (CEZA), and the mining company Codelco, the present project investigates archaeometallurgical sites in the Atacama Desert, using scientific analysis as a first step towards a large-scale map of prehistoric copper production and exchange across South America.

So far, no systematic work has been conducted on smelting technology which would allow a comparative analysis of technological styles or cultural traditions among the various peoples who inhabited this region. This research involves documentation and sampling of already-excavated archaeological materials from a number of copper-producing sites located in the Atacama area. The aim is to technologically and isotopically characterise at least two different copper production sites, and analyse several dozen copper artefacts from the wider region for their chemical and isotopic composition. This will involve neutron activation analysis (NAA) and multi-collector inductively coupled plasma mass spectrometry (MC-ICPMS), as the two most powerful analytical techniques for this kind of research. The resulting data will first be processed using statistical models to identify different compositional groups among both the technical and artefactual samples. The characteristic data for these groups will then be compared to the geological literature on lead isotope ratios in the Andean copper belt, and to trace element data on copper-based artefacts from the wider region. Taken together, this will form the basis for a collection of reference data, possibly enabling the first tentative allocations of artefacts to specific regions of provenance.

In addition, samples from residual ore and waste metal from the sites will be analysed for trace elements and lead isotopes, in preparation for the study of copper and bronze artefacts from collections and excavations in the wider vicinity, particularly into modern Peru. This will enable to link regional artefact groups with potential production places. A combination of typological and archaeological methods will be used to date the different material groups, in order to distinguish between Inca- and pre-Inca contexts. In the long run, it is anticipated that through this kind of analysis we can increase our understanding of the impact that the Inca Empire had on the regional economy of the Andean world.

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## Materials and Methods

A total of 495 metal artefacts from the Le Paige collection were recorded during this initial phase of the project. Most of these objects had been recovered from funerary contexts in the San Pedro de Atacama region. Saw-cut samples and drill samples were obtained from 80 of these objects, coming from different archaeological sites in the area. Sampling was performed using a portable drill equipped with a diamond cutting wheel. In an effort to obtain a relatively representative sample, the selection of the pieces was made based mainly on their formal category and provenience (site and context, if known), but also considering their preservation state (degree of corrosion

**Table 1. Chemical composition of the samples analysed by X-ray fluorescence.**

| Sample | Cu (%) | Sn DL Sn <0.005 (%) | Fe DL Fe <0.02 (%) | As DL As <0.01 (%) | Ag DL Ag <0.002 (%) | Co DL Co <0.005 (%) | Ni DL Sn <0.01 (%) | Sb DL Sb <0.005 (%) |
|---|---|---|---|---|---|---|---|---|
| AMC-16467 | 91.1 | 0.013 | <0.02 | 5.13 | 0.016 | <0.005 | 3.58 | 0.087 |
| AMC-18408 | 93.6 | 0.007 | <0.02 | 4.27 | 0.019 | 0.005 | 1.95 | 0.100 |
| AMC-18385 | 92.3 | <0.005 | <0.02 | 4.03 | 0.015 | 0.012 | 3.50 | 0.098 |
| AMC-16475 | 92.9 | <0.005 | <0.02 | 3.77 | 0.003 | 0.005 | 3.16 | 0.059 |
| AMC-0233 | 93.5 | <0.005 | <0.02 | 3.71 | 0.003 | 0.025 | 2.56 | 0.126 |
| AMC-16409 | 92.7 | 0.015 | <0.02 | 3.70 | 0.023 | <0.005 | 3.30 | 0.054 |
| AMC-16519 | 93.8 | 0.010 | 0.04 | 3.48 | 0.015 | <0.005 | 2.39 | 0.044 |
| AMC-16487 | 95.8 | 0.085 | <0.02 | 2.40 | 0.181 | 0.007 | 1.31 | 0.060 |
| AMC-16474 | 95.8 | 0.201 | 0.50 | 1.56 | 0.007 | <0.005 | 1.83 | 0.021 |
| AMC-19406 | 92.3 | 4.646 | 0.05 | 1.32 | 0.008 | 0.005 | 1.55 | 0.114 |
| AMC-18378 | 93.1 | 5.932 | 0.33 | 0.41 | 0.096 | <0.005 | 0.01 | 0.032 |
| AMC-19401 | 97.6 | 0.928 | 0.34 | 0.29 | 0.010 | 0.008 | 0.17 | 0.614 |
| AMC-16794 | 92.8 | 6.749 | 0.29 | 0.05 | 0.005 | 0.005 | 0.07 | 0.036 |
| AMC-16399 | 96.0 | <0.005 | <0.02 | 0.04 | 0.012 | 0.000 | 0.05 | 3.869 |
| AMC-18428 | 99.9 | <0.005 | <0.02 | 0.02 | 0.015 | <0.005 | 0.01 | 0.000 |
| AMC-16305 | 95.7 | 4.098 | 0.07 | 0.02 | 0.011 | <0.005 | 0.01 | 0.020 |
| AMC-19442 | 96.5 | 3.391 | 0.05 | 0.01 | 0.013 | <0.005 | 0.01 | <0.005 |

Results have been sorted by decreasing arsenic content.

and fragmentation). All the samples have at this point been analysed by energy-dispersive X-ray fluorescence (XRF). The saw-cut samples have in addition been examined by metallography, and some of them by scanning electron microscopy using energy dispersive analysis (SEM-EDS), and are currently being characterised chemically by electron microprobe. Twenty samples, including both shavings and fragments, have been further selected for lead isotope analysis and the results will be available shortly. The present work reports the results of XRF analysis of 18 drill samples which were sub-selected to identify their elemental composition. The examined samples correspond to different categories of artefacts, including implements such as axes, maces, chisels, and tweezers, as well as adornments which include pins and metal discs (Figure 1). Two different measurements were performed in consecutive sessions, and the results were then averaged, normalised to 100%, and rounded (Table 1). One of the samples (not included in the table) was determined to consist of 99.7% lead, with only traces of other elements like antimony and copper.

## Results and Discussion

Most of the analysed samples are associated with sites that appear to date to the Middle Period in the region (AD 600-900), which is characterised by an outstanding influence from Tiwanaku. Interestingly, about half of


**Figure 1. Different categories of artefacts from the collection of the Archaeological Museum in San Pedro de Atacama: a) axe; b) tumi; c) chisel; d) tweezer; e) metal disc; f) pin.**

them consist of an alloy of copper with about equal amounts of arsenic and nickel, reaching up to 5 wt% As and nearly 4 wt% Ni. Neither antimony nor silver appear correlated with arsenic. The use of a ternary Cu-As-Ni alloy has been regarded as a cultural and technological marker of the Middle Period in the Bolivian Altiplano and in northern Chile. So far, artefacts manufactured from this unusual alloy have been excavated in Tiwanaku and San Pedro de Atacama (Lechtman, 1997, 2003a, 2003b). Lead isotope analysis of bronze artefacts recovered at these two places (Lechtman and MacFarlane, 2004) and of a number of metallic ores sampled from deposits in Northern Chile and Bolivia, indicates that the ore sources for most of the objects were located in the Puna and high sierra of Bolivia – about 60 km from San Pedro de Atacama. The sample also includes one example of a Cu-Sn-As-Ni alloy. Copper-tin bronze with tin concentrations around 5 wt% occurs frequently among the artefacts analysed, while some samples consist of technically pure copper or copper with elevated levels of antimony. Such results raise questions about the movement of ore, of copper and bronze ingots, and of manufactured goods of various alloys. The presence of workshop debris, primarily casting waste, among the finds excavated in the Atacama region points to an active engagement in metallurgy; further work is necessary to more fully characterise the nature and extent of this activity.

## Conclusions

Although preliminary, the results obtained from the analysis of samples from San Pedro de Atacama provide important direction for future research.

Firstly, we will expand the analysis to cover all artefacts in order to detect possible correlations between alloy choice and object type, origin or date.

Further investigation will aim to cover the entire sequence of Precolumbian copper production in Chile and the South Central Andes. Slag samples will be analysed to link specific production or workshop sites to alloy types, and to characterise the nature of the ores selected for copper production.

The next sampling will focus on production debris, and more lead isotope analyses will be performed on artefacts, slags and ores from the northern Chilean region.

The presence of a lead object raises the issue of local lead and possibly silver production, in the context of regional silver metallurgy (Gordon and Knopf, 2007; Schultze *et al*., 2009).

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