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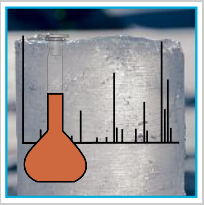

Highlights of Analytical Sciences in Switzerland

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Ice-Core Evidence of Earliest Extensive Copper Metallurgy in the Andes 2700 Years ago

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Access to metal is considered as a main driving force for the socioeconomic development of cultures and countries. Advances in agriculture, warfare, transport, cookery, and the entire Industrial Revolution would have been impossible without metal. Historically, Andean copper (Cu) in particular was an essential resource of wealth for pre- and post-colonial societies and still plays a central economic role in many South American countries today. Despite of this importance the onset of extensive Cu metallurgy in South America is still debated. Comprehensive archaeological findings point to first sophisticated Cu metallurgy during the Moche culture ~200–800 AD.

In 1999, a 138.7 m long ice core was retrieved from Nevado Illimani, the highest mountain of the eastern Bolivian Andes. In the −20 °C cold room at PSI, inner core sections (~2.2 × 2.2 × 70 cm) were cut out using a stainless steel band saw. Trace element concentrations were determined in the inner sections with continuous ice melting inductively coupled plasma-sector field-mass spectrometry (CIM-ICP-SF-MS). Based on the resulting highly time-resolved ice-core data from Illimani glacier, we reconstructed a 6500-years Cu emission history for the Andes, providing the first complete record of large-scale Cu smelting activities in South America.

Ice-core Cu originates from two different sources, namely wind erosion of Cu-containing mineral dust and anthropogenic emissions from mining and metallurgical processing. Cu enrichment factors above the natural dust background were derived by normalizing the Cu concentration with the concentration of cerium (Ce), a geogenic element present in mineral dust.

We find earliest anthropogenic Cu pollution during the Early Horizon period ~700–50 BC, and attribute the onset of intensified Cu smelting in South America to the activities of the central Andean Chiripa and Chavin cultures about 2700 years ago. Maxima in Cu enrichment factors were similarly observed during the times of later South American high cultures such as the Moche, Tiwanaku, Wari, and Inca, as well as during the colonial period and in the 20th century, matching the archaeologically known periods of increased metal production during the last two millennia. **Our study is the first one to provide substantial evidence for extensive Cu metallurgy in the Andes starting already 2700 years ago**.

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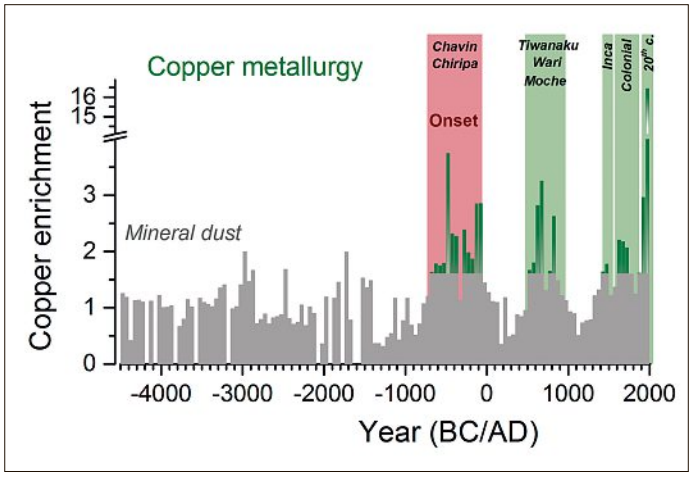
Earliest extensive Cu artefacts are known so far from the Moche culture in South America. Shown is a Moche belt ornament (Peru, 2nd–7th century AD), Credit: The Metropolitan Museum of Art, *www.metmuseum.org*, bequest of Jane Costello Goldberg, from the Collection of Arnold I. Goldberg, 1986.



Illimani ice-core record of anthropogenic Cu emissions over the past 6,500 years in the Bolivian Altiplano. Shown are Cu enrichment factors (green) above the natural background from mineral dust (grey) during the flourishing of the pre-Columbian Chavin/Chiripa cultures (onset of Cu metallurgy), Tiwanaku/Wari/Moche cultures, the Inca, colonial times, and the 20th century.

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