Historical copper trapped in ice

February 8 2017, by Jan Berndorff

View of the Nevado Illimani glacier in Bolivia from La Paz. Credit: Paul Scherrer Institute/Theo Jenk

South America's mining industry supplies half the world with copper. The world's largest mines are located in the Andes. Yet just when copper production began there has remained unclear, until now. Very few artefacts from the early high cultures in Peru, Chile, and Bolivia have been preserved. Now, however, researchers of the Paul Scherrer Institute

PSI in Villigen, Switzerland, are on the trail of this mystery. Through analysis of ice from the Illimani glacier in the Bolivian Andes, they found out that by around 700 BC, copper was already being mined and smelted in South America. Their findings are published in *Scientific Reports*, an online journal of the Nature Publishing Group.

In South America, copper has been mined and smelted for around 2700 years. This has now been determined by researchers of the Laboratory of Environmental Chemistry at the Paul Scherrer Institute PSI in Villigen, Switzerland, through analyses of glacier ice from Bolivia. Copper mining in South America has enormous importance: Chile and Peru are the two largest copper producers in the world; Chile alone accounts for more than 30 percent of global copper production. Yet the beginnings of this essential industrial sector have remained obscure. The only certain evidence came from the time of the Moche culture, which flourished on the northern coast of Peru between 200 and 800 AD. Numerous copper objects from this culture, such as jewelry and ritual tools, have been found. From earlier times, however, there are few finds and no written records.

The ice of a glacier is, in principle, a kind of archive; in its layers, as in the growth rings of a tree, records of the region's climate development and air quality are stored away. Each year, a new layer of frozen precipitation is deposited on top. And every time, dust particles that were floating in the air at the time are embedded in the new layer. After drilling deep into the glacier and extracting a long column of ice, scientists can bring it—with great care and under refrigeration—into a laboratory for analysis. In just this way the team of Anja Eichler, the study's first author, and project leader Margit Schwikowski took a 139 m-long ice core that had been drilled during a 1999 expedition, at an altitude of around 6,300 m on the Illimani glacier in Bolivia, and analysed the deposits of metallic dust in particular.

The PSI researchers Anja Eichler (left) and Margit Schwikowski, two authors of the study, in the cold room, where the ice core from Illimani was cut. Credit: Paul Scherrer Institute/Markus Fischer

In a cold room of the PSI, the researchers continuously melted the ice core layer by layer, with a device they had developed themselves, and analysed the meltwater with a mass spectrometer. This instrument can separate different chemical elements from each other and determine their respective mass. Thus we worked our way back in time to roughly 4500 BC— the ice corresponding to this time was at a depth of around 134 m, Anja Eichler reports. And we determined that the first elevated copper concentrations that must trace back to human activity occurred around 700 BC. Living to the northwest of the glacier at that time were

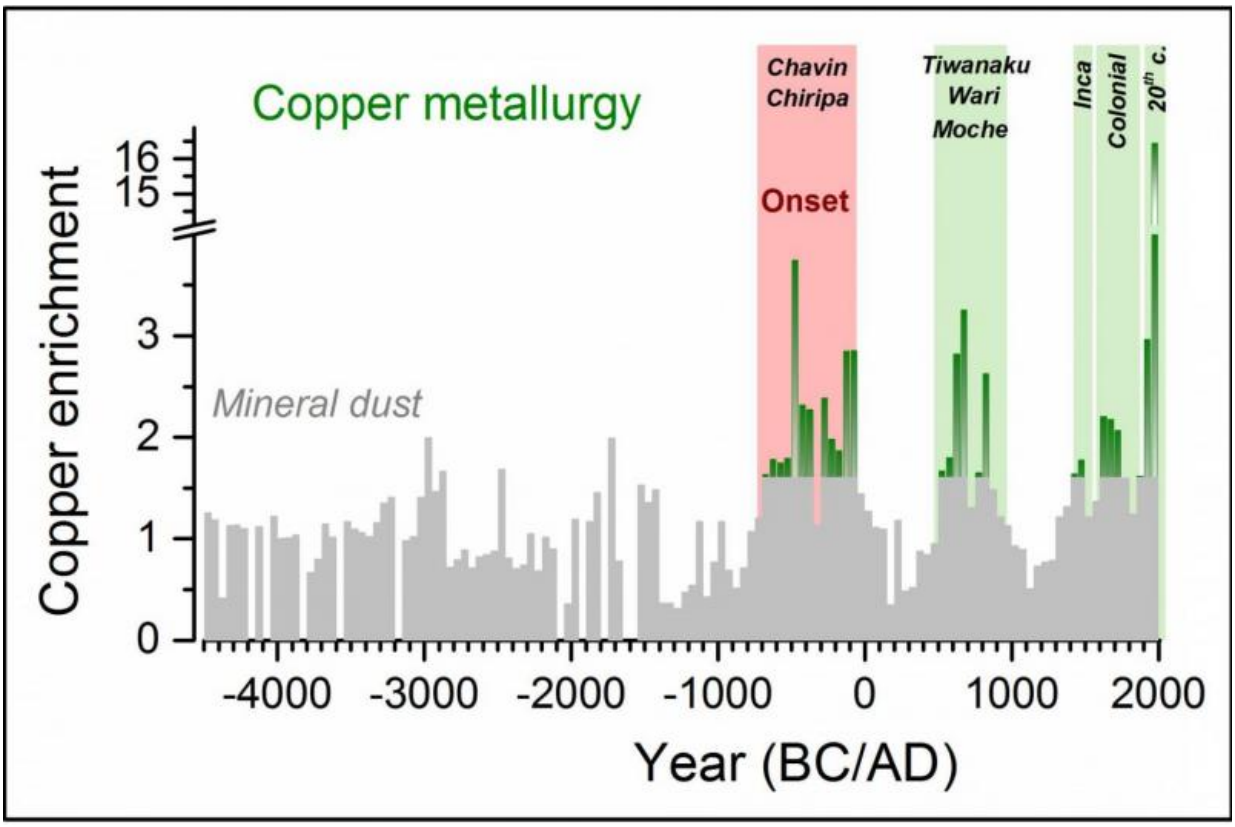
people of the Chavin culture, the first civilisation in the Peruvian Andes, while the Chiripa culture, a relatively simple society, lived in the immediate vicinity of Lake Titicaca. This is known from archaeological excavations. Hence it is possible that both practiced copper metallurgy, smelting copper ore to obtain pure copper for the production of artefacts. Copper particles emitted during this process made their way, on the wind, up to the glacier and were deposited there in the corresponding ice layers, says Margit Schwikowski. These particles added to the natural copper from mineral dust and thus produced the particularly high copper concentrations.

Following up on this, Anja Eichler looked into the archives of numerous museums and was able to find at least two copper artefacts from that time. One was a bent needle of the Chiripa culture, found in 1934 and kept since then in the American Museum of Natural History in New York. The second was a bracelet, which was found in Bolivia and is on exhibition but cannot be clearly assigned to any culture. In fact there are also copper objects from the time between 1400 and 1100 BC—much earlier. There, though, what you're dealing with is hammered metal made from native copper, Margit Schwikowski explains. That is elementary copper, which also occurs naturally in this form. It is quite rare, though. For copper in larger quantities, ore must be mined and the pure copper must be extracted through smelting.

The image shows the schematic extension of the Chavin and Chiripa cultures in Southern America around 500 BC and the location of the Illiman site in the Bolivian Andes (red star). Credit: Paul Scherrer Institute/Anja Eichler

The earliest evidence of smelting furnaces comes from the later Moche culture for which, likewise, elevated copper concentrations can be detected in glacier ice. Moche people evidently used a type of ceramic oven, Anja Eichler says. This had several holes where air could be injected through blow-tubes to heat the fire to well over 1,000 degrees C. When exactly such ovens were used for the first time, however, is not known, adds archaeometallurgist Thilo Rehren of University College London (UCL), who took part in the study. But it is also possible that the smiths of the earlier cultures threw copper ore into simple pit furnaces dug into the ground. In these fires small cakes of metal were formed, which could be processed further in crucibles.

With their study, the researchers are correcting a picture that stems from another, earlier study. In this, a different research group postulated that copper metallurgy in South America might have begun still earlier, by around 2000 BC. That group had done a similar analysis on a peat bog drilled at Tierra del Fuego and detected a strong increase, already for this early period, in copper concentrations. Like ice, peat forms layers over the years and centuries, which preserve records of environmental pollution in past times. Tierra del Fuego lies around 3,000 km south of the centres of metallurgy in the Andes, says Anja Eichler. Besides that, the peat bog record only reaches a little farther back than 2000 BC—our ice core, in contrast, goes back beyond 4500 BC. That puts us in the position to quantify the natural fluctuations in the deposition of copper dust before the onset of metallurgy. And our results indicate that the increase at Tierra del Fuego at that time was a natural regional fluctuation.



Record of anthropogenic copper emissions over the past 6,500 years in the Bolivian Altiplano, reconstructed using an ice core from Illimani. Shown are copper enrichment factors compared to the natural background from mineral dust (grey) during the flourishing of the pre-Columbian Chavin/Chiripa cultures (onset of copper metallurgy), Tiwanaku/Wari/Moche cultures, the Inca, colonial times, and the 20th century (green). Credit: Paul Scherrer Institute/Anja Eichler

More information: A. Eichler et al. Ice-core evidence of earliest extensive copper metallurgy in the Andes 2700 years ago, *Scientific Reports* (2017). DOI: 10.1038/srep41855

Provided by Paul Scherrer Institute