Introduction

Metallography, the study of the microscopic structure of metals and alloys, has been used for more than a century to analyze metal objects from archaeological contexts. This poster demonstrates the use of metallography in examining the processing history of native copper artifacts and in distinguishing native copper from historic period smelted copper and copper alloys.

Native Copper

The use of native copper, i.e. copper found naturally in a pure metallic form (usually 99+ % copper), represents the earliest use of metals in both the Old and New Worlds. Metallography of native copper artifacts has provided evidence that shows that everywhere native copper was used in the past it was worked into shape using a combination of cold hammering and annealing. Due to its soft nature, native copper is malleable enough to be hammered into shape. However, as it is hammered it becomes harder, an effect known as work-hardening, and if hammered too much it becomes brittle and begins to crack. Work-hardening can be alleviated through the process of annealing, i.e. heating in order to cause recrystallization and hence softening. This can occur at temperatures as low as about 300°C, well below the melting point of copper (approx. 1084°C). Both annealing and cold hammering result in a columnar grain structure. Native copper is typically used in a work-hardened condition.

The image on the left (Sp. #2) shows a cold-hammered microstructure. The grain shapes, which were equiaxed before the hammering, have been thinned parallel to the hammering direction and elongated perpendicular to that direction so that each grain is now pancake-shaped. The image on the right (Sp. #3) shows the effect of annealing on a piece of work-hardened copper. During annealing the cold-worked flattened grains are replaced by a new set of equiaxed grains through the process of recrystallization. Note that melting is not involved; this process happens well below the melting temperature. The recrystallization of copper often results in parts of a grain that were equiaxed before the hammering, have been thinned parallel to the hammering direction and elongated perpendicular to that direction so that each grain is now pancake-shaped. The image below (Sp. #1) is of an archaeological specimen that displays an annealed microstructure.

These images show the difference between native copper that has been cold-hammered and that which has been annealed. This clear distinction allows researchers to make note of the use of annealing in the past and describe the condition in which native copper artifacts were left by artisans. In unweathered geological specimens of native copper there is often very little to see metallographically as the grain size can be quite large (on the scale of millimeters) leaving little defined structure.

Materials

Native Copper

Specimen #1: sheet fragment, Gulkana Site, Late Prehistoric Athapaskan (AD 1100-1500)
Specimen #2: nugget cold-hammered in the laboratory to replicate shaping process
Specimen #3: nugget treated as Specimen #1 and then annealed for 30 minutes at 450°C
Castle Hill, Silt, Alaska - Historic Russian (1820s-1840s)
Specimen #4: smelted copper droplet recovered from slag (99.5 Cu, 0.5% Zn, 1% Sn)
Specimen #5: copper alloy droplet (98% Cu, 7% Zn, 4% Sn, 1% Pb)

Description

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Methods

Samples were cut using a jeweller’s saw, embedded in epoxy mounts, and prepared using standard metallographic procedures: These involved grinding on 240, 320, 400 and 600 grit silicon carbide abrasive papers (water cooled and lubricated), followed by a two-stage polishing procedure: 6 µm diamond paste on nylon cloth with an oil-based coolant/lubricant, then 0.05 µm alumina suspension in water on short-napped cloth. The samples were etched with a 1:1 ammonium hydroxide/hydrogen peroxide etchant for 5 seconds and photographed using optical microscopy and digital imaging. Compositional analysis of the historic material was obtained using SEM-EDX.

Experimental Copper Working

A small nugget of native copper was hammered to reduce its thickness from approximately 10 to 6 mm, then cut in half using a jeweller’s saw. One half was then embedded in an epoxy mount and the other piece placed on an air furnace at 450°C for 30 minutes prior to being mounted. Both samples were prepared as described above.

Interpretation

It has been suggested that the value of a native copper artifact, i.e., whether it served a utilitarian or social/symbolic purpose, can be determined based upon whether it was left in an annealed or work-hardened condition. This argument contends that native copper artifacts are more effective (harder and sharper) when cold-hammered and that artifacts left in an annealed state could have served only a utilitarian function in the social realm. The sequence of a number of assumptions suggesting the use and value of native copper within a particular society. A total of 24 native copper artifacts from the Gulkana site have been examined metallographically. All of these artifacts are tools or manufactured debris and though cold-hammering was part of the manufacturing process, all were left in an annealed state. Furthermore, experimental work has demonstrated that annealed native copper tools can perform as well as work-hardened ones in some contexts. Interpreting the behavior behind a metal artifact’s microstructure is not straightforward. However, metallographic examination can identify types of metals and specific metallurgical techniques, both of which are important for understanding metal use in the past.

References