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Electrons, X-rays and Archaeometallurgy

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The reasons for the scientific examination of an archaeological metal object include: the determination of its chemistry or alloy composition, its fabrication methodology, its location of origin, and its authenticity. The development and application of the wide array of electron imaging and analytical techniques has enabled the study of the microstructure and microchemistry of such objects and has had enormous impact on the field of archaeometallurgy. In this paper we would like to discuss appropriate examples including: precipitation in a steel bracelet from Jordan; corrosion of ancient steel objects; metallography of Japanese swords; patina formed on the Japanese alloy *Shakudo*; fabrication of the Japanese composite *Mokume*; silver shekels from Tyre; a copper smelting crucible and copper axe from Israel; and joining technology in Pre-Columbian copper, silver and gold objects.

As an example of Pre-Columbian gold joining technology, we show here a nose filigree from the Vicus culture (FIG. 1). This sample has small gold granules decorating the edges. Our investigation of this object focused specifically on the granulation technique used by this early culture. A small sample of the granulation (FIG. 2) was removed for SEM investigation.

There were three granulation techniques believed to be used by the Vicus culture: solder, copper salts, and unaided fusion [1]. EDS provided an initial observation that the composition of the joints was slightly copper rich, suggesting that it was likely that copper salts were used. LISPIX [2] compositional maps indicated higher concentrations of copper at the joint, confirming the initial EDS spectra. The results shown here in Figures 3 and 4 indicate that the granulation on the filigree was produced with copper salts. LISPIX revealed almost 10 % copper at the joint, which corresponds to a low point in the melting temperature of copper- gold alloys.

In this technique, copper salts were mixed with an organic glue. This glue was then used to bind the spheres together before melting them together. The presence of the copper salts allowed for a lower melting temperature isolated at the joint. The phase diagram for the copper gold system predicts this drop in melting temperature. The depressed melting temperature due to localized composition difference, would have allowed for enough local melting for fusion and soldering, without liquefying the entire piece.

These results show how advances in electron microscopy can aid in the detailed investigation and analysis of artifacts such as these and exemplify the technological skill and knowledge employed by ancient metal smiths.

References

[1] C. McEwan. ed. Pre-Columbian Gold: Technology, Style and Iconography. Fitzroy Dearborn Publishers: Chicago, (2000) 229.

[2] D.S. Bright. Journal of Microscopy. 148 (1987) 51-87.

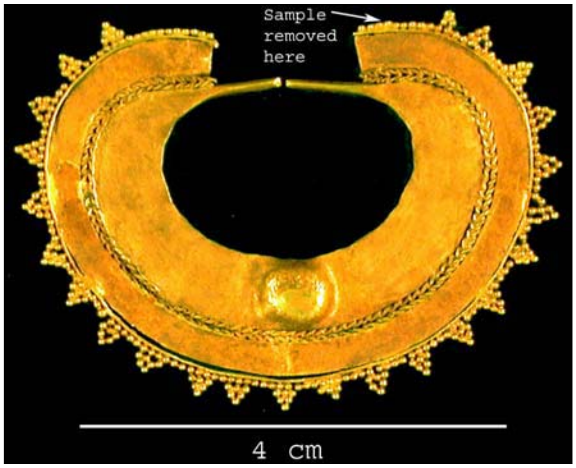

FIG. 1: Vicus culture nose ring.
Note the granulation around the edges.

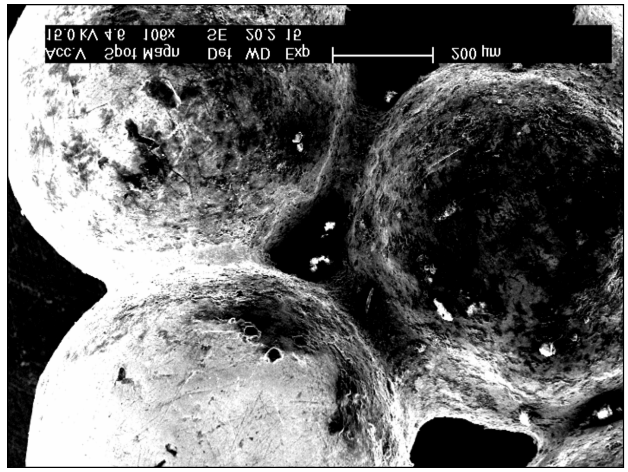

FIG. 2: SEM image of the gold granulated joint.

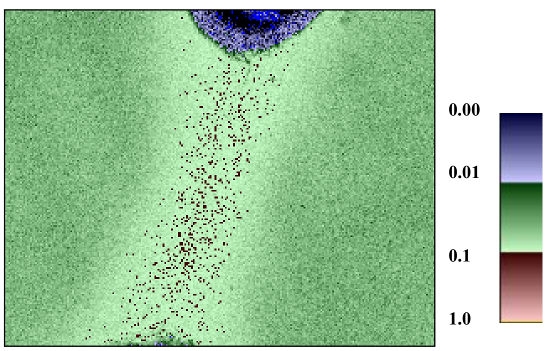

FIG. 3: LISPIX compositional map showing showing
almost 10% Cu at the granulation joint.

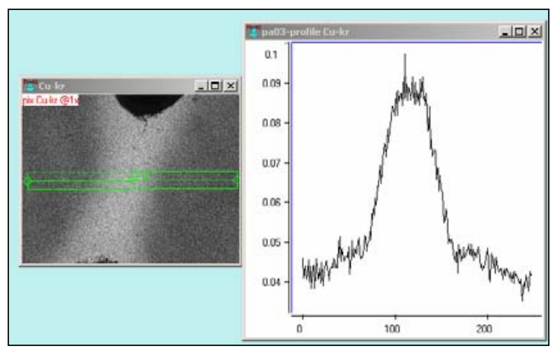

FIG. 4: EDS line scan across the joint

an increase to 10 % Cu in the vicinity of the joint, values on a log scale. SEM photo taken with LISPIX.

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