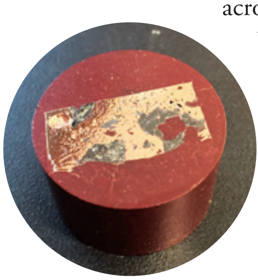
# Investigating Metallurgical Knowledge in the Iron Age Eastern Mediterranean

BY OLIVIA HAYDEN

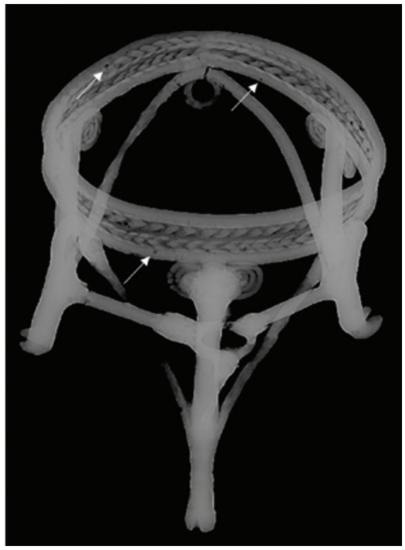
The transformation of raw metal into finished objects consists of an intense cycle of heating, cooling, and hammering, and, when all is said and done, the finished objects contain few visible traces of this grueling ordeal. Fortunately, archaeologists can use scientific techniques to reveal these otherwise imperceptible steps of production and to learn about the craftspeople who performed them.

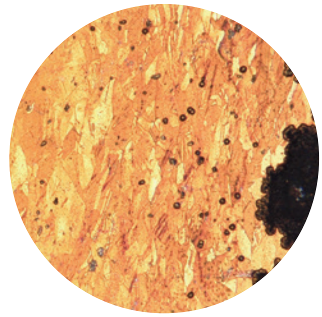
AS PART OF MY DISSERTATION RESEARCH, I am working with CAAM experts to apply a range of analytical techniques to metal objects from the Penn Museum collection in order to reveal traces of their production. I investigate the metalworking techniques used to produce bronze and iron objects from Early Iron Age sites at Kourion and Lapithos in Cyprus and Vrokastro on Crete. By understanding the techniques craftspeople used to form objects and the decisions they made, I can begin to investigate how these individuals were trained and how metalworking techniques spread between communities of metalsmiths. During the Early Iron Age, influential advancements in metalworking spread across the Mediterranean world, but the exact ways that these advancements were taught by one smith to another are not well understood.



LEFT: A piece of metal embedded in epoxy is polished to investigate the microstructure.

ABOVE: The author arranges metal objects onto trays in the Collections Study Room.





CENTER AND FAR LFET: This x-ray image of a tripod stand shows many large porosities, which indicate the stand was cast. ABOVE: A metallographic image displays recrystallized and flattened grains, indicating that the object was annealed and hammered.

After metal ore has been transformed into raw metal through the process of smelting, several raw metals can be combined to form metal alloys. (For example, bronze is an alloy of copper and tin or arsenic.) The proportion of metals used in the alloy impacts many properties of the final metal, including aspects of workability (i.e. melting point and malleability), function (i.e. hardness), and aesthetics (i.e. color). An Energy Dispersive Spectroscopy (EDS) detector attached to a Scanning Electron Microscope (SEM) to investigate alloying practices will shed light on the properties that might have been important to ancient craftspeople.

Once a metal or its alloy has the desired chemical properties, it can then be formed into a shape, and there were two main methods used to shape metal in the ancient Mediterranean. First, an object could be formed by heating metal until it was molten and pouring it into a pre-shaped mold (this technique is called casting). Second, metal could be heated to below its melting point and then cooled down slowly (called annealing). Annealing makes metal more malleable and ductile so that it could be worked by hammering. Casting and annealing are not mutually exclusive, and often objects were cast and then subjected to successive rounds of annealing and working.

Archaeologists use the techniques of X-radiography and microscopy to investigate this formation process. X-ray images, taken in the CAAM labs with the help of CAAM Laboratory Coordinator Dr. Marie-Claude Boileau and Project Conservator Tessa Alarcon Martin, can be used to identify working methods such as casting and hammering. For example, cast objects sometimes contain porosities, places where the molten metal did not completely fill the mold. They appear like tiny holes on a radiograph.

I am also investigating samples from some of the metal objects with a reflective light microscope under the supervision of CAAM Teaching Specialist for Archaeometallurgy Moritz Jansen. This process, known as metallography, reveals further information about object formation. For example, if an object was annealed, the internal structure of the metal will resemble hexagonal grains under the microscope. If it was hammered after annealing, the grains will be flattened and deformed from the impact of the hammer.

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