

Introduction

Archaeometallurgy and the University of Pennsylvania

VINCENT C. PIGOTT



1 Steel bracelet (I.55) with overlapping terminal from burial cave A4, Baq'ah Valley, Jordan. One of twenty or more early iron ornaments found in this cave. Photo by Nick Hartmann, MASCA.

In December 1982, the Archaeological Institute of America holds its annual meeting, in Philadelphia. Of the various scholarly issues to be discussed, a technological theme will receive particular emphasis: the role of metallurgy in ancient cultures. For the past several years scholars from a variety of disciplines at the University of Pennsylvania have directed their research towards this topic. The contributions in this issue of *Expedition* were prepared by some of these scholars whose disciplinary specialties include Anthropology, Near Eastern, Classical and Historical Archaeology, Ancient History and Metallurgy. Depicted on the cover of this issue are images which reflect the blend of disciplines which characterize archaeometallurgical research: the analysis of technologically derived materials and the

study of the cultural contexts of those who make use of the technology. It is the interdisciplinary nature of archaeometallurgical inquiry which furnishes the breadth of analytical and technological approaches evident in these articles and characteristic of much of the recent work in this field.

Current studies are frequently directed towards understanding the nature and significance of the development of metal technology within its cultural context. This broad focus is made possible in part by significant advances in the science of metallurgy, whose developed tools and improved understanding have facilitated metallographic and elemental analysis of artifacts, providing important clues to the degree of technological sophistication exercised by ancient metalworkers.

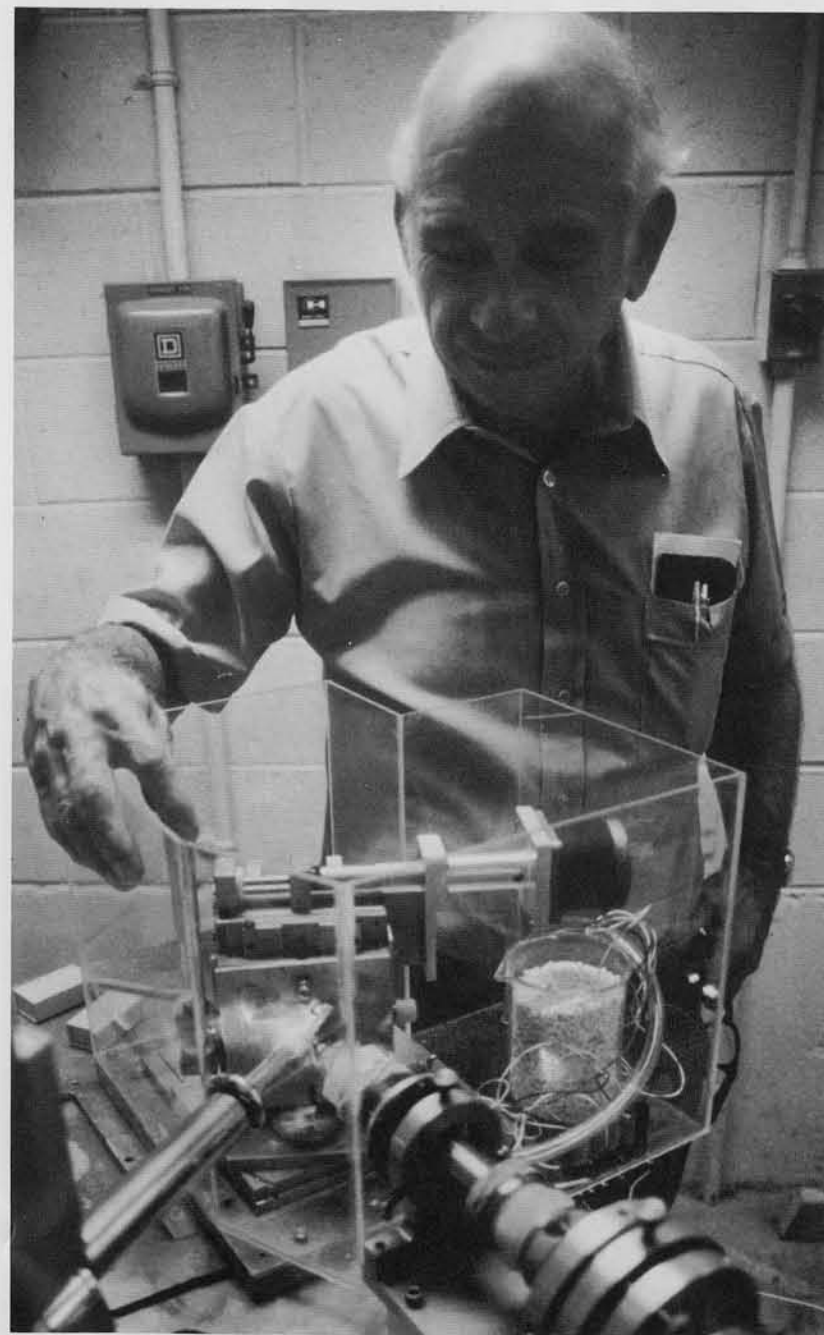
The background image on the cover of



2 Deborah Ricketts, Research Specialist at the University of Pennsylvania's Laboratory for Research on the Structure of Matter (LRSM), is shown operating a Phillips 500 scanning electron microscope capable of 80,000x direct magnification. It is equipped with an ECON energy dispersive windowless spectrometer capable of detecting the presence of the traditional range of elements as well as a number of those with lower atomic numbers, including carbon, nitrogen, oxygen and fluorine. Photo courtesy of Alex Vaskelis and Robert White, LRSM.

3 Dr. Charles P. Swann shown here with the proton induced x-ray emission device (PIXE) designed by him at the Bartol Research Foundation at the University of Delaware. The PIXE is an important tool in the quantitative elemental analysis of ancient metals.

this issue shows a scanning electron microscope (SEM) photomicrograph, at 3000 magnifications, of an early iron artifact (12th-11th centuries B.C.) from the Near East: a bracelet of true steel excavated by P. E. McGovern in a burial cave in the Baq'ah Valley, Jordan. The SEM permits the detailed investigation of the crystalline microstructure of metals as well as of non-



metallic inclusions (slag) which ancient metals often contain. When utilized in conjunction with semi-quantitative, analytical, energy dispersive x-ray devices, the SEM is an even more powerful tool to the metallurgist who is investigating the composition of an artifact. Such devices permit elemental analyses at the microstructural level. For example, the much more precise information gained about the alloying ingredients used to produce a metal provides important clues concerning the ability of ancient smiths to control the outcome of pyrotechnological processes.

Another significant new device providing specific quantitative information on the elemental composition of an artifact is proton induced x-ray emission (PIXE). It is currently being utilized in the study of ancient metals by Dr. Stuart Fleming, director of the University Museum's Applied Science Center for Archaeology (MASCA), in collaboration with Dr. Charles P. Swann of the Bartol Research Foundation at the University of Delaware. One of the most significant advances of this and other new techniques is that the damage to the metal artifact being studied is much less than with the traditional techniques of emission spectroscopy and atomic absorption.

Another newly developed technique of interest in archaeometallurgy is lead isotope analysis. This process yields the proportion of isotopes of lead in a metal artifact or ore, a ratio which remains unchanged by smelting or corrosion. The isotopic ratio detected in the metal artifact is directly comparable to that present in the original ore from which the artifact under analysis was smelted. Lead and silver ores, fortunately, all differ according to their own isotopic 'fingerprint.' Thus this technique is the most promising analytical tool yet available by which metal artifacts bearing similar isotopic 'fingerprints' may be clustered, and by which lead-bearing metal artifacts may be traced to their original ore source.

At MASCA, Stuart Fleming is currently involved in the application of this technique to ancient Egyptian copper artifacts with detectable lead content. He is working in association with Noël Gale and Zofia Stos-Gale at Oxford, whose studies of Eastern Mediterranean lead and silver artifacts and ores have shown this technique to

be very successful for both clustering and identifying proveniences of these materials. This investigation, plus a number of archaeometallurgical problems of current interest, is discussed in a special issue of the University Museum's *MASCA Journal* (Vol. 2, no. 2). The articles included in this issue of *Expedition*, on the other hand, are of a more general nature and reflect wider issues in the study of archaeometallurgy: each article treats in some fashion an aspect of metallurgical innovation, innovations which account for major technological transitions of crucial socio-cultural significance to the communities involved.

In the first article, Lee Horne discusses production of the ancient metalworker's fuel, namely charcoal. Lee, whose training is in archaeology and ethnography, has conducted extensive ethnoarchaeological field work in north-central Iran. Her contribution evaluates the social and ecological implications of charcoal production, particularly the significance of deforestation to both ancient and modern populations.

The adoption of bronze in the ancient

E 14293 Isis and Horus Group

Cu	Sn	Fe	Hg	Pb
75.0	7.00	≤1.24	≤0.06	17.7
Ni	Ag	As	Zn	Sb
≤0.08	≤0.0005	0.27	0.064	≤0.009

world is an innovation which has long been a focus of archaeometallurgical research, particularly by the University of Pennsylvania's research team of Tamara Stech, Robert Maddin, and James D. Muhly. Bronze is an alloy of copper and tin and, despite the great popularity of this metal during the Bronze Age, tin does not appear to have been readily available in many of the areas where it was used, most notably in Southwest Asia, so argument has raged for many years about the source(s) of the tin used in that area in antiquity. Included in this issue of *Expedition* is an account of major tin fields recently identified in Afghanistan which could have been exploited during the Bronze Age and later by peoples in Southwest Asia. The documentation of these fields for the archaeological community is largely the accomplishment of Thierry Berthoud, a physicist, and Serge Cleuziou, a Near Eastern archaeologist, presently associated, respectively, with the French atomic energy commission (CEA) and the Centre National de la Recherche Scientifique (CNRS) in France.

Following the discussion of Bronze Age issues comes a brief discussion of the development of metallurgical technology (in this instance that of iron) as a continuum of change fueled by the dual processes of innovation and adoption. An evaluation of the nature and significance of these processes within socio-cultural/technological contexts has been espoused by such scholars as the cultural anthropologist

4 An Egyptian tin-bronze statuette with high lead content, ca. 575 B.C., depicting the goddess Isis nursing her son Horus. This statuette (27 cm. high) (E 14293) is part of a group of University Museum metal artifacts investigated in the lead isotope analysis project at MASCA conducted by Stuart Fleming and Bernard Fishman.

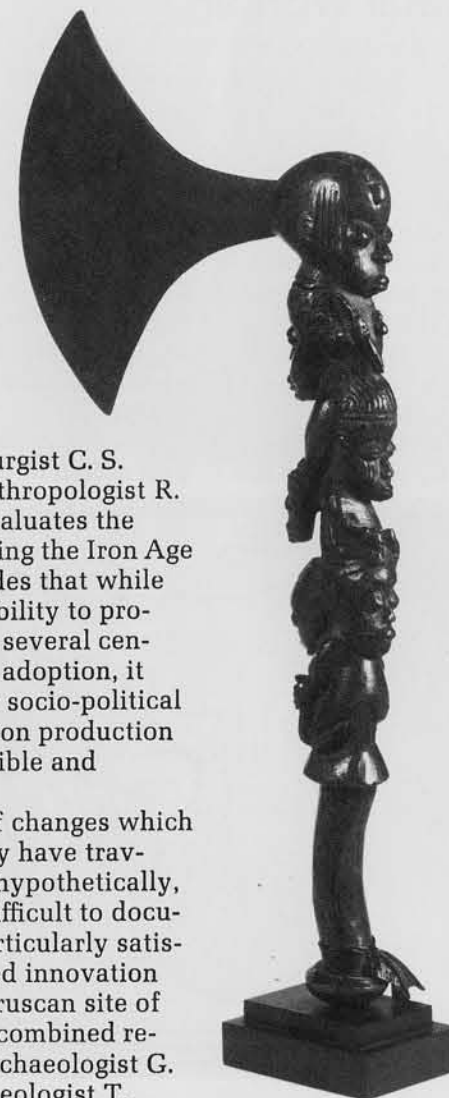


Analysis by PIXE courtesy of C. P. Swann and S. Fleming.



5 Close-up photo of copper smelting slag excavated from the mid-3rd millennium B.C. "Craftsmen's Quarter" at South Hill on the site of Tepe Hissar in north-central Iran. In the upper right portion of the photo a black charcoal fragment (1 cm. across) can be seen entrapped in the slag. Below and slightly to the left, impressions of more wood charcoal were left in the slag as it cooled from a molten state. Heat released from the charcoal fuel permitted copper to be extracted from the ore charged into the prehistoric smelting furnace. Photo by Nick Hartmann, MASCA, courtesy of the Tepe Hissar Restudy Project.

6 Ekiti Yoruba, Nigeria. Wood and iron Ogun ceremonial axe. The importance of weaponry in West African cultures is reflected in their transformation into ceremonial objects. H. 18 1/2". Private collection. Photograph courtesy Pace Gallery, New York.



A. F. C. Wallace, the metallurgist C. S. Smith, and archaeologist/anthropologist R. McC. Adams. This article evaluates the appearance of early iron during the Iron Age of the Near East and concludes that while knowledge of iron and the ability to produce it intentionally existed several centuries before its widespread adoption, it was only after certain major socio-political changes had occurred that iron production on a large scale became feasible and desirable.

Although the sequences of changes which a developing technology may have traversed can often be deduced hypothetically, these transitions are often difficult to document archaeologically. A particularly satisfying example of documented innovation has been identified at the Etruscan site of Poggio Civitate through the combined research efforts of Classical archaeologist G. Warden, Near Eastern archaeologist T. Stech, ancient historian/archaeologist J. D. Muhly, and metallurgist R. Maddin. This evidence, described in the fourth article, is significant in that it documents the probable early smelting of iron from iron-rich copper slag, a by-product of the copper smelting processes. This technique was long thought possible but until now never identified in the archaeological record.

The development of iron working can be seen as a series of technological innovations over numerous centuries, and in the final article Helen Schenck discusses the archaeological evidence for the rise of iron making in the eastern United States, a part of this process. Her contribution presents a brief historical overview of iron making from the Colonial period to the 19th century, outlines 19th century advances in

technology, and stresses the archaeological evidence from which our current understanding of this technological phenomenon in the United States has developed.

While this issue of *Expedition* deals primarily with archaeological evidence for the development of ancient metallurgy within its cultural context, the contribution of Lee Horne illustrates the relevance of modern ethnographic data. In a similar vein, the Winter issue of *Expedition* will include an article by University of Pennsylvania scholars Sandra Barnes (Anthropologist) and Paula Ben-Amos (Art Historian) on the West African cult of Ogun, the god of iron, a cult known as early as the 18th century and which has a modern counterpart in the Caribbean. This article illustrates the fundamental interconnection between technology and culture.

It is hoped that studies such as those described above will continue to expand the scope of our understanding of technological development as a phenomenon of complex social, cultural and environmental significance.



Vincent C. Pigott, a Near Eastern archaeologist trained in the Department of Anthropology at the University of Pennsylvania, is presently a Research Specialist at the University Museum's Applied Science Center for Archaeology. In conjunction with a long standing research interest in the origins of metalworking in Southwest Asia, a current research project in which he is participating along with a group of scholars at Pennsylvania, is the investiga-

tion of the development of copper-base metallurgy in Mesopotamia. The University Museum's substantial Mesopotamian collection (from Ur and Tepe Gawra in particular) is lending itself well to the variety of analytical techniques being applied. The other major focus of this investigation concerns the identification of the cultural dynamics of technological innovation and change potentially discernible via an anthropological research design.