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Archaeometallurgy in Ancient Mesoamerica

Scott E. Simmons and Aaron N. Shugar

In recent decades there has been much discussion among archaeologists about the transformative roles material objects play in human societies. Various scholars have focused attention on the ways that material culture is an integral part of social and economic systems through time, with considerable discourse centered on the role of specialized crafting in ancient societies (Apel and Knutsson 2006; Arnold and Munns 1994; Brumfiel and Earle 1987; Clark and Parry 1990; Costin 1991, 2001; Earle 2002; Flad and Hruby 2007; Helms 1992, 1993; Henrich and Boyd 2008; Hirth 2009; Peregrine 1991; Roux 2003; Schortman and Urban 2004; Spielmann 2002; Sullivan 2006; Vaughn 2004; Wailes 1996). The investigation of ancient technologies has a long tradition in Mesoamerican archaeology. Stone, bone, ceramic, and a number of other materials have been analyzed by archaeologists and archaeological scientists working in this region of the Americas for many decades, and these studies have yielded valuable information on the myriad ways ancient Mesoamericans adapted to their dynamic physical and social environments. While it appears that metal never fully replaced stone, bone, or shell for utilitarian or other purposes, objects fashioned from this unique material and the technology used to create them had clearly been embraced by some groups as early as Classic times (ca. AD 300–900) and by even greater numbers of Mesoamerican peoples during the Postclassic Period (ca. AD 900–1521) (see Table 1.1).

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TABLE 1.1 Mesoamerican Chronology with Selected Sites Discussed in the Text

	Region			
Time Period	*Maya Lowlands*	*Maya Highlands*	*Basin of Mexico*	*West Mexico*
Colonial AD 1521–1800s			Tenochtitlán	
	Lamanai			
Postclassic AD 900–1521	Mayapán	Q'umarkaj		Jicalán el Viejo
	El Coyote	(Utatlán)		Itziparátzico
	Chichén Itzá			El Manchón
Classic AD 300–900				
Formative ca. 2000 BC–AD 300				

Throughout many parts of ancient Mesoamerica a wide range of metal objects, most of which were copper-base, were created during the centuries in which metallurgy was a part of the social fabric of ancient Mesoamerican life. Metal objects appear relatively late in this part of the Americas, by AD 600 (Dorothy Hosler 1994, 2009, and her Chapter 9 of this volume). The technology is believed to have been introduced to Mesoamericans by seagoing peoples from South America (Bray 1977; Hosler 2009; Lechtman, in press; Mountjoy 1969; Pendergast 1962; Strong 1935). Recent work in the Andes suggests that gold was the first metal to be manipulated by ancient South Americans (Aldenderfer et al. 2008). Specifically, nine cold-hammered native gold beads were found accompanying a roughly four-thousand-year-old burial in the southwest part of the Lake Titicaca basin at the site of Jiskairumoko in Peru (Aldenderfer et al. 2008, 5004). Such cold-hammered gold objects continued to be produced into the Early Horizon (1000–400 BC), and it was during this time that Andean peoples began to smelt gold and other nonferrous ores (Bruhns 1994; Cooke, Abbott, and Wolfe 2009; Ponce 1970). Later, Andean metallurgical traditions grew to become much more sophisticated, with smelting, hammering, and alloying of mostly status and ritual objects by highly skilled smiths, particularly in groups such as the Moche.

Although it is still not entirely clear why the diffusion of metallurgy from South America to Mesoamerica was "delayed" for some time (Bruhns 1989), it appears that the technology was introduced to West Mexicans living in coastal port towns by seagoing peoples from Ecuador by approximately AD 600 (Hosler 2009, 188–189). This belief is based on several lines of evidence,

FIGURE 1.1. Mesoamerica culture area, showing West Mexican metalworking zone as well as major archaeological sites discussed in the volume.

including comparative data derived from chemical compositional analyses as well as specific fabrication techniques and design characteristics of Central and South American metal artifacts. Also, recent experimental studies of the kinds of Ecuadorian balsa-wood sailing vessels reported by Spanish explorers suggest that such vessels were capable of making several round-trip voyages between coastal Ecuador and the West Mexican states of Guerrero and Michoacán before they were no longer serviceable (Dewan and Hosler 2008). The transmission of metallurgical technology between South and Central America probably took place over the course of several centuries, and would have required extended layovers in West Mexican communities by South American mariners (West 1961, 1994). It is likely that some of these travelers from the South were skilled metalsmiths who passed on their knowledge of metallurgy to some West Mexican peoples eager to learn this new technology. During these contacts West Mexican peoples would have acquired essential knowledge of the "transformative craft" of metallurgy, including identification of ores, mold production, smelting, casting, and a variety of other related activities (Miller 2007).

The first metal objects produced in Mesoamerica are found at archaeological sites located in the West Mexican states of Michoacán, Guerrero, Jalisco, Colima, and Nayarit. West Mexico is one of only a few areas in Mesoamerica where copper and other metallic minerals are present in appreciable quantities (Figure 1.1). A distinctive metallurgical tradition flourished there for nearly a millennium before Spanish Contact (Hosler 1994, 2009). Copper artifacts, and later copper-base artifacts—mainly those made of copper alloyed with tin and arsenic—are found throughout much of Mesoamerica by Early Postclassic times, having been distributed via a well-developed trade network that was part of a larger "Mesoamerican world system" (Smith and Berdan 2003, 4).

The other principal metalworking tradition that is presently known in this part of the Americas is represented by artifacts having distinctive design elements and chemical signatures that are part of what has been called a "southeastern Mesoamerican" metalworking tradition (Hosler 1994, 208). Metallurgy in this region of Mesoamerica, which likely emerged by the end of the Classic Period, is not as well understood as its West Mexican counterpart, however, since much less research has been carried out in the Southeast. Nevertheless, it appears likely that ore sources in Chiapas, Mexico; southern Guatemala; and western Honduras provided the copper, tin, and arsenic from which bronze objects were created and then distributed throughout much of the Maya area and beyond (as suggested by Bray 1977). In certain places, including West Mexico and the Maya area, once metal objects appeared their production and use continued through the Postclassic Period and, in a few cases at least, up to and probably beyond the time of initial Spanish Contact. This may have been the case in other parts of Mesoamerica as well, such as in the valley of Oaxaca or along the gulf coast. Unfortunately, little research on mining, metals, or metallurgical technologies has been undertaken in these and certain other areas of Mesoamerica as yet, so our understanding of the ways metal objects were used in some areas of the region is at this time limited.

With their unique aural and visual qualities, objects made of metal seem to have been highly regarded by a great number of Mesoamerican peoples, serving a variety of social, religious, and economic needs. But in contrast to their counterparts in the Old World, the peoples of ancient Mesoamerica were not as interested in the utilitarian functions of metal objects as they were in their more esoteric properties, particularly those of sound and color (Hosler 1994, 2009). This inclination is reflected in the assemblages of metal artifacts recovered archaeologically at Mesoamerican sites, where weaponry and armor are not found and comparatively small numbers of utilitarian objects—such as needles, pins, axes, and fishhooks—are present (Figures 1.2 and 1.7, p. 16). As mentioned, most metal objects made in ancient Mesoamerica were primarily copper-base, with far fewer numbers of gold or silver objects found. Ferrous-base metal technologies were never developed by the pre-Columbian peoples of the region. These findings also stand in contrast somewhat to the Old World, where gold and silver objects were more common and ironworking was later an important metallurgical tradition (see Tylecote 1992 for a historical approach to metal development in the Old World).

FIGURE 1.2. Various copper axes from Lamanai, Belize.

The value metal objects held in this part of the Americas was firmly grounded in certain social realities that had been part of ancient Mesoamerican life for many centuries. In Classic times one of the ways Mesoamerican rulers, nobles, and other elites communicated their wealth, power, and social status was by means of a variety of symbolically charged, highly valued materials, especially jade, quetzal feathers, Spondylus shell, and jaguar pelts, among others. It is also clear that Mesoamerican elites, particularly rulers but also religious specialists, sometimes created and often manipulated a range of complex symbols that functioned as material expressions of group ideology (Evans 2008). Public displays of bells, tweezers, finger rings, and elaborate clothing ornaments (Figure 1.3)—with their shimmering metallic colors and, in the case of bells, their utterly unique sounds—were meant to impress those who saw and heard them. Such displays, which probably included some kinds of public performances, likely helped to reinforce the elevated power and social status of Postclassic Mesoamerican elites in much the same ways that jade, Spondylus, and other high-value materials had for their Classic Period predecessors.

Objects made of metal had powerful sacred connotations for Mesoamerican peoples; often they were associated with the creation of humankind, certain deity cults, or distant, exotic realms (Hosler 1994). For example, the Aztecs considered one of their most powerful deities, Xochiquetzal, to be the patroness of metalsmiths and other luxury arts and crafts (Holmer 2005, 66). Among the Maya, the strong connection of metal with the gleaming rays of the sun, represented by a deity known as K’inich Ajaw or God G (Miller

FIGURE 1.3. S-scroll clothing ornaments (LA 69-9a–g) from Lamanai, Belize.

and Taube 1993), suggests they believed metal possessed animate characteristics and had divine associations.

Plain-walled bells, as well as more elaborately crafted ones, were perhaps the most ubiquitous metal artifacts produced in ancient Mesoamerica (Figure 1.4). Only copper axes—used throughout Mesoamerica for cutting purposes and in certain areas, such as West Mexico, as money (Hosler 2003; Hosler, Lechtman, and Olaf Holm 1990)—may have been more common. In terms of their sacred associations copper and bronze bells, with their unique sonority, tones and resonance, were used extensively by religious practitioners in a variety of ritual performances, many involving dance. Pohl notes that "the value of wealth acquired from distant lands was amplified through artistic transformation" (2003, 176). The ability to transform rock into beautifully crafted metal objects, with their unique sounds, lustrous colors, and divine associations, was very likely considered by ancient Mesoamericans to be quite a remarkable, perhaps even magical, transformation. The value of such objects was amplified in part by the sometimes great distances involved in their acquisition and the technical challenges required of their production. As the sources for metals were restricted to only certain parts of Mesoamerica and the materials themselves had such unique colors, sounds, and divine associations, Postclassic Mesoamerican elites and religious functionaries who possessed such highly valued objects were able to effectively manipulate them as potent material expressions of ideology and social

FIGURE 1.4. Copper bell from Tlacotepec, Toluca Valley, Mexico. 88720.000, National Museum of the American Indian (NMAI) Collections.

power, thereby demonstrating connectedness to distant physical and spiritual realms and continuing the legacy of their Classic Period predecessors.

Metal objects also were an important economic commodity during Postclassic times and, at least in several parts of Mesoamerica, their value in this regard continued into the Spanish Colonial Period. In the seventeenth century the Spanish friar Diego López de Cogolludo provided explicit information regarding how copper bells were used and perceived by the Maya in Yucatán. He noted that "the money that they used was little bells, and bells of copper that had value, according to their size" (López de Cogolludo 1688, 181). The writings of Diego Quijada, a sixteenth-century *alcalde mayor*, also include references to the value ascribed to copper bells during the Spanish Colonial Period. In discussing fines levied on Mayas convicted of idolatry, Quijada noted that cacao, red stones and beads, and "small bells and bells of copper that they had from the time of their infidelity" were required for payment to Spanish authorities (Scholes and Adams 1938, 214). Indeed, by Postclassic times copper objects were regarded as some of the most highly valued "key commodities" throughout this region of the ancient Americas (Smith 2003).

ARCHAEOMETALLURGY AS A FIELD OF INQUIRY

Today the study of such key commodities is quite often carried out as part of a burgeoning field of inquiry that combines traditional archaeological research with materials science applied to the study of metals. The field of archaeometallurgy has a relatively long and rich history, yet only in recent years has it truly extended itself into Mesoamerica. Its establishment can be found in the advancement of microscopy and the resulting metallurgical analysis that quickly followed, allowing for early publications of the analysis of archaeological metal artifacts (see Smith 1988 for details on this progress). The earliest reports of the analysis of metallurgical artifacts from archaeological sites date to the late eighteenth century, when interested metallurgists, such as Pearson (1796), published the results of his research on ancient metallic arms and utensils (see Caley 1951 and Pollard and Heron 2008 for reviews of and more details on early archaeological chemists). By the mid-nineteenth century, Percy had published his accounts of metallurgical investigations of artifacts from Nineveh and Babylon as an appendix to a related archaeological publication (Layard 1853, appendix 3: 670–672). Similar appendices continued to appear for three-quarters of a century, while the research undertaken slowly incorporated new experimental models and scientific methodologies. Research tended to focus on the technology behind the metal artifacts in question, in particular their manufacturing techniques based on the understood principles of "modern" metallurgy. This research into archaeological metal production broadened to include the investigation of furnace design, furnace efficiency, and the raw products from the smelt.

While all these early works fall under the purview of "metallurgical analysis of archaeological finds," which are today considered archaeometallurgical studies, the term *archaeometallurgy* is said to have been coined by Beno Rothenberg in the early 1970s (Goodway 1991). Rothenberg wanted to shift the focus of study away from strictly describing and assessing artifact formation and from the extractive metallurgical process of ancient cultures. Rather, he hoped to provide more relevant information to archaeologists by investigating what these processes left in the archaeological record. Rothenberg's approach was a clear shift in thinking, moving from the metallurgist-investigating technology and processes involved in the manufacture of individual artifacts (which were separated from their archaeological context) toward working in conjunction with archaeologists and in tandem with archaeological excavations. The ultimate goal was to gain a more holistic vision of the level and development pyrotechnology held during a specific culture or time period (Tylecote [1992] follows this path, and his book is broken down into a chronological view of the advancement of metallurgy).

The realization that the value of archaeometallurgy lay in the larger global perspective of archaeological theory can be considered a paradigm shift by some, and it has prompted archaeometallurgical studies to develop into a valuable tool for the archaeologist who wishes to better understand the complex position that metals held in human societies (Chirikure 2007; Ehrhardt 2009). Even with this shift in thinking, the field of archaeometallurgy had to develop further in order to grow into a more substantial, accepted field that could fit into modern archaeological theory. Ehrenreich (1991a) recognized this divide between archaeological theory and the descriptive nature of early archaeometallurgical research. He noted that "[t]he objectives of archaeometallurgy should be to augment our understanding of the rise of craft specialization, the organization and importance of prehistoric industries, the effects of new technologies on societies, the extent and limits of cultural contacts, and the impetus and alterations required to change rudiments of societal infrastructure" (1991a, 55).

This integration has been one of the more difficult tasks for the archaeometallurgist—extrapolating social and cultural information from scientific technical studies of material culture. Archaeometallurgical investigations still tend to focus on the technical aspects of object production and use. The relationship between the production, fabrication, and handling aspects and how the artifacts themselves fit into a larger cultural schema is sometimes difficult to ascertain. This can be witnessed in many archaeological site reports that still include archaeometallurgical data and reports as appendices, hardly incorporating the results into the broader construct of the archaeological interpretations.

Crossing this divide was a major problem for earlier archaeometallurgists when they investigated metal artifacts and is still something that needs to be fully overcome. Analytical studies can, for example, determine if metal was cast, cold worked, drawn, or quenched, and chemical composition can be ascertained. But too often information about an isolated artifact's technical and material properties is not articulated clearly with discussions of a given culture as a whole. While this lack of connectivity is likely more true for the investigation of a single artifact, the study of an assemblage of artifacts offers the potential for extrapolating a broader vision of the social and cultural roles metals can play; studying assemblages has been the path most current archaeometallurgists have taken to solve the problem (Dobres and Hoffman 1999; Doonan 1999, 72; Ehrenreich 1991b; Lemonnier 1986, 1993; Lubar 1996; Pfaffenberger 1992, 2001; Pigott 1991, 81; Rehren et al. 2007; Schiffer 2001; Thornton and Roberts 2009; Wells 1991). Information gleaned from such metallurgical inquiries provides valuable insights into experimental aspects of metalworking, the technological expertise craftspeople possessed, and the material properties and performance of the materials with which they worked. This information can then enrich our understanding of the technological choices people made in materials selection, processing, and manipulation as well as in artifact design, production, and use (Pryce et al. 2007; Roberts 2011; Sillar and Tite 2000). When interpreted within larger cultural, social, and geographical contexts and associations, information derived from archaeometallurgical research can strengthen our inferences concerning larger anthropological questions about social organization and development; craft specialization; the dynamics of hierarchy; power relations; trade, barter, and other exchange interactions; and the organization of labor along gender, class, or ethnic lines (Ehrhardt 2002, 2005; Lechtman 1999, 223–224).

In recent years, archaeometallurgy has developed into a field of investigation that has provided invaluable information for archaeologists and anthropologists committed to gaining a more comprehensive understanding of the critical roles metals can play in the structure, organization, and development of societies. This research has been increasingly recognized by scholars as vital to our overall understanding of the ways ancient social groups use material culture through time, including metal objects (Carozza and Mille 2008; Ehrenreich 1991b; Shugar and Gohm 2011; Thornton and Roberts 2009; Young et al. 1999).

Archaeometallurgy is not only relevant but highly contributory to larger issues in anthropology, archaeology, and particularly our understanding of human technological innovation through time (Dobres and Hoffman 1999; Doonan 1999, 72; Ehrenreich 1991b; Ehrhardt 2002; Lechtman 1999; Lemonnier 1986, 1993; Lubar 1996; Pfaffenberger 1992, 2001; Pigott 1991, 81; Pollard and Bray 2007; Roberts 2011; Schiffer 2001; Shimada et al. 1999, 301; Sillar and Tite 2000; Wells 1991). A wide range of anthropological questions can be addressed through archaeometallurgical studies. These include the varied ways in which people developed, extracted, manipulated, and transformed raw materials into finished products; how metal objects were integrated into their respective cultural systems; the nature, extent, and contexts of social interaction, bartering, and exchange; the dynamic processes of the control, transfer, and maintenance of technological knowledge; the social and political controls of technology and artifact production, use, and dissemination; the development of craft specialization; and the intensification of production and its role in cultural complexity.

To fully extract information from the metallurgical process that can aid in addressing these questions, it is necessary to understand that the production and use of metal objects can be broken down into two general spheres of study. The first deals with the technological manufacturing of a metal object. This includes all processes, from mining through final finishing or polishing of an object (i.e., the collection and beneficiation of ore, smelting, remelting for casting, alloying, possibly further working and annealing of the metal, and final finishing [polish and adornment]). Each stage leaves not only characteristic waste materials in the archaeological record (refractory materials, mold material, slag, etc.), but recognizable features in the resulting metal artifact that can be revealed through scientific analyses. The second sphere deals with the social aspects of the use of metals by the individuals within a particular society who made or used metal objects. In this view, archaeometallurgical research can provide information concerning how materials were acquired (making determinations about established trade networks, exchange interactions, and provenance), the physical nature of the object (typology), the physical uses of the object (utilitarian and other), and disposal or recycling. But it is the combination of these two spheres of research that can impart the most relevant information concerning the roles of metal objects within a culture and their implementation therein.

Ottaway (2001, 88) recognizes this social connection when looking at the cyclical nature of copper production and clearly defined the effective potential for social influences on the lifespan of a metal. The process of extractive metallurgy, which is often separated from its social and cultural aspects, can best be understood when viewed holistically. In the general category of extractive and formative metallurgy, it appears that there would be little to no social input affecting the process, but this is not entirely true. By incorporating information obtained from additional sources—including historical documentation and ethnographic studies—and by expanding research to include a larger assemblage of artifacts, much can be gleaned from the extractive and formative processes of metals. Political control of mining and raw materials; social pressures to obtain and produce metal; the role of elites in production, procurement, and distribution; and the craft specialists' role in training, running, and developing the technology: all these elements can be explored.

Chaîne opératoire, originally described by André Leroi-Gourhan for Paleolithic research, has been extensively used to develop these ideas and has become invaluable for archaeometallurgical studies. Application of the operational sequence of production can best be seen in the use of flowcharts explaining the process of metallurgy within a society based on the archaeological remains, providing information about the technical abilities and formation skills involved in the process, and its social ramifications (see Bachmann 1982; Craddock 1995; Merkel et al. 1994; Shugar 2001; Tylecote 1992). It provides a framework capable of linking materials with social practices, extending beyond the technological process itself to include the social forces that may have a direct impact on the technological choices made. This would include the barter and exchange of finished objects, their functionality, their utilitarian or ritual use, their use or wear during their functional life, and their purposeful or unintentional loss or deposition.

Much more needs to be explored, investigated, and learned, and much more comparative work done to answer questions about innovation as a social and a material process, changes in manufacturing technology over time, and the evolving contexts of metal use in particular regions. It is certain that archaeometallurgical studies, and the results obtained from materials science inquiries, have already proven quite useful, even indispensable, in authenticating, dating, and conserving material objects housed in museums, in establishing the provenance of artifacts, and in understanding ancient and historical technologies. It is equally certain that the field of archaeometallurgy will continue to improve and advance over time, offering new insights into the social and cultural aspects of the role metals played within ancient societies.

METALS IN ANCIENT MESOAMERICA

Metal artifacts are not nearly as abundant at Mesoamerican archaeological sites as those made of stone, clay, or shell. There are several reasons for this, including the relatively late date by which metal objects began to be widely distributed and used, the very limited number of metal-bearing areas in the region, and the comparatively small number of people who knew how to work the material successfully. As a result, few studies have been conducted on metallurgy in ancient Mesoamerica, although there are some notable exceptions (see also Hosler, Chapter 9 of this volume). Information about the distribution and stylistic typologies of metal artifacts in Mesoamerica can be found in works by Pendergast (1962, Mesoamerica); Bray (1971, Mesoamerica); Castillo Tejero (1980, Mexico); Flores de Aguirrezabal, M. D. López, and Quijada López (1980, Mexico); and Hosler (1988b, Mesoamerica). Only a small percentage of the metal artifacts that have been found up to this time have been analyzed chemically, and studies of manufacturing techniques have been rare (see Bergsøe 1938; McLeod 1937, 1945, 1949; Root 1943, 1947, 1952, 1953, 1962, 1969, 1976 for examples).

To date, the most comprehensive archaeometallurgical investigations in Mesoamerica have been undertaken by Dorothy Hosler (1985, 1986a, 1986b, 1988a, 1988b, 1988c, 1994, 2003, 2009). Her seminal work, *The Sounds and Colors of Power* (Hosler 1994), is a landmark publication in which she reports on the results of her investigations, to that point in time, of the metallurgical tradition that arose in West Mexico. Her sustained work in this region over the past two and a half decades has proven pivotal in understanding the development of metallurgy, and we consider her synopsis of the past, present, and future of Mesoamerican archaeometallurgy to be an invaluable contribution to this volume (see Chapter 9 of this volume). Hosler's research clearly illustrates the importance of investigating not only the empirically valuable data that can be collected from technical analyses, but also the more anthropologically relevant data on the use, design, coloration, and social importance of the artifacts within Mesoamerican cultures.

Metallurgy in Mexico developed in two main stages and is represented by changes in the stylistic elements and chemical signatures of copper-base objects produced in the West Mexican states mentioned above. The objects produced during the earliest phase, beginning around AD 600, consist mostly of small bells and pins made of pure copper. The second expansion phase was not until approximately AD 1200, at which time it became possible to create a wide range of silvery- and gold-colored bronze objects with unique properties of sound by alloying copper with tin and arsenic (Hosler 1986a, 1994). It was during this latter phase that greater numbers of metal objects began to flow into eastern Mesoamerica, particularly the Maya lowland area, from both West Mexico and the still poorly defined southeastern Mesoamerican metalworking zone.

A variety of metal tools, as well as status and ritual objects, traveled around the Yucatán Peninsula via a well-developed, circumpeninsular exchange system that was facilitated by canoe travel along both the coast and within the extensive river systems that are found in this part of Mesoamerica. During Postclassic times finished metal objects, raw materials including ingots (Figure 1.5), and tools used in metal production moved through ports of trade from Xicalango and Chetumal to those along the Ulúa River and areas around Naco on the Gulf of Honduras (Bray 1971, 39). In 1502 Christopher Columbus reported encountering several large canoes off the Bay Islands of Honduras during his fourth voyage to the New World (Keen 1959). Among the items of their cargo, the traders carried "hatchets resembling the stone hatchets used by the other Indians, but made of good copper; and hawks bells of copper, and crucibles to melt it" (Keen 1959, 231–232). Again, the ability of such large seagoing vessels to make extended open-ocean voyages has been recently documented; the results of these studies, along with ethnohistorical reports such as the one by Keen, indicate that such voyages were likely quite common in the centuries prior to Spanish Contact (Chandler 2009; Dewan and Hosler 2008; and Hosler, Chapter 9 of this volume).

It appears that metal objects were produced in Mesoamerican communities by highly skilled specialists who had an intimate understanding of both the mechanical properties of the medium they worked and the deeper underlying cultural meanings of the colors, forms, and sounds of the objects they created. In analyzing the ceramic crucibles and molds from Calchaquí metalworking sites in northwestern Argentina, Hagstrum (1992, 1993) developed the concept of *intersecting technologies*. Essentially this concept states that craft specialists working primarily in one medium, such as metal, were likely knowledgeable and proficient in the use of other ancillary materials, such as

FIGURE 1.5. Copper ingot, Chamelecón River Valley, Honduras. 040342.000, NMAI Collections.

clay and wax. As lost-wax casting was such a prominent part of the metallurgical tradition of this region of the Americas, this was almost certainly the case with Mesoamerican metalsmiths, who may have developed their craft as part of some sort of apprenticeship arrangement with master smiths. Judging by the high level of craftsmanship seen in so many of the metal artifacts that have been recovered archaeologically throughout Mesoamerica in the past decade (see Figure 1.6), such master smiths clearly understood not only the mechanical properties of metal but also those of associated materials needed to create metal objects. Whether metalsmiths operated on an itinerant basis, as Bray (1977) has suggested, or resided in certain metalworking communities (see Hosler, Chapter 9 of this volume), it is clear that an intimate knowledge of the properties of various materials, as well as the technical proficiency necessary to work them, had to have been acquired over what may have been a lengthy period of time in some areas of Mesoamerica.

In terms of metal consumption, it appears that both commoners and elites had access to certain kinds of metal objects. At Lamanai, Belize, for instance, utilitarian objects such as axes, wedges, fishhooks, pins, and needles are most commonly recovered in domestic contexts (Figure 1.7). Nonutilitarian objects, the great majority of which are plain-walled bells, however, dominate these assemblages. In contrast, more intricately designed bells, filigree rings, and various beautifully crafted ornaments are recovered in elite contexts at the site, specifically in tombs and other burial contexts (Simmons,

FIGURE 1.6. Copper ring, Veracruz, Mexico. 011195.000, NMAI Collections.

Pendergast, and Graham 2009). There is good evidence at Lamanai as well as at Mayapán (see Simmons and Shugar, Chapter 6, and Elizabeth H. Paris and Carlos Peraza Lope, Chapter 7 of this volume) that Maya elites were influential in, if not held control over, the production and possibly the distribution of metal objects, and this may be the case in other areas of Mesoamerica as well. At least by the Postclassic Period, metal objects appear to have taken their place alongside those made of other valuable materials. Both status and utilitarian metal objects were regarded highly by the Maya, as well as by a number of Mesoamerican peoples, regardless of the particular status these people held in their society or the specific manner in which they used their metal objects.

Despite calls that began decades ago for more intensive study of ancient Mesoamerican metallurgy (Bray 1971, 1977; Pendergast 1962), it has only been in recent years that archaeometallurgical research has been conducted in this part of the Americas in earnest. This situation, however, is beginning to change; in the last decade or so, a number of researchers have begun to address various social, economic, and technological aspects of metallurgy in ancient Mesoamerican societies.

ORGANIZATION OF THE VOLUME

Metallurgy is one of a great many human creative endeavors; as such, it reflects certain values that are embodied within cultures. It is for this reason

FIGURE 1.7. Copper fishhook and miscast bell from Progresso Lagoon, Belize. Image courtesy of Maxine Oland.

that the chapters in this volume take a decidedly anthropological approach in their discussions of ancient Mesoamerican archaeometallurgy. A central theme in this volume is exploration of the varied social contexts in which metallurgical traditions developed in ancient Mesoamerica and how metallurgy as specialized crafting, along with the metal objects themselves, was regarded and used by its peoples. Specifically, the authors in this volume examine the ways metallurgy and metal objects were integrated into the multifaceted social and cultural realms of different ancient Mesoamerican peoples. Using various theoretical, methodological, and interdisciplinary perspectives, the chapters here focus on archaeometallurgical investigations that are currently being conducted throughout Mesoamerica. While perspectives may differ, the work of each of the volume's authors is firmly grounded in an anthropologically informed understanding of the past.

The way in which scientific technical studies provide detailed and useful information on metallurgical technologies, activities, and use was acknowledged some time ago. Bray predicted decades ago that "chemical analysis may one day allow the definition of metal 'groups' each with its own diagnostic compositions" (1971, 38). Although scientific studies of the properties of metal artifacts are invaluable and research on the technological aspects of mining and metal production are also an important part of archaeometallurgical research in Mesoamerica today, the results of such studies are not considered by the authors in this volume as an end in themselves; instead, they are seen as contributing to a larger discourse on the social significance of ancient Mesoamerican metallurgy. The authors use information derived from scientific and technical analyses as one method to enhance our understanding of the roles that metal objects played in the larger complex social milieu of ancient Mesoamerican life. They also use a variety of alternative sources to inform their perspectives on the ways metal objects were regarded and used in the multilayered sacred and material worlds of ancient Mesoamericans. Data obtained from archaeological investigations, ethnohistoric sources, and ethnographic studies, along with materials science analyses, are brought to bear on questions related to the integration of metallurgy into local and regional economies; the sacred connotations of copper objects; metallurgy as specialized crafting; and the nature of mining, alloy technology, and metal fabrication, among others.

In this volume we present current approaches to the study of archaeometallurgy in Mesoamerica as well as new perspectives on the significance metallurgy and metal objects had in the lives of its ancient peoples. The chapters in the volume were presented in a Society for American Archaeology symposium held on March 28, 2008, in Vancouver, British Columbia, entitled "Current Archaeometallurgical Research in Mesoamerica: New Approaches, Discoveries and Perspectives." All of the volume's principal authors attended the symposium with the exception of John Weeks and Dorothy Hosler, who accepted our invitation to contribute papers at a later time. It is important that the majority of researchers actively engaged in archaeometallurgical investigations in Mesoamerica today have contributed to this volume, and they have done so using a multidisciplinary, anthropologically grounded approach. The chapters are organized to follow the cyclical nature of metals, starting from the extraction and mining of ore, followed by smelting, casting, recycling, and finally deposition of finished objects.

Combining ethnohistorical information with the results of archaeological survey and preliminary field investigations, Hans Roskamp and Mario Rétiz present the results of their recent work in Michoacán, Mexico, in Chapter 2. Much of their research includes a careful reading of the *Lienzo de Jicalán*, an important pictographic document that is rich in information on life in Michoacán and that was used in the second half of the sixteenth century by Nahuatl-speaking peoples as proof of their rights to several key mineral deposits in Michoacán's Hotland region. Roskamp and Rétiz have identified the archaeological remains of Jicalán el Viejo, which is located some distance from the nearest copper mines, challenging the notion that smelting centers were consistently situated relatively close to mines. The identification of large amounts of slag on the surface of the site, combined with detailed information included in the *lienzo*, leads the authors to conclude that Jicalán holds great potential for providing a wealth of information on indigenous metal processing during Spanish Colonial times.

In Chapter 3 Blanca Maldonado also focuses much of her discussion on work recently conducted in Michoacán. Like others who have contributed to this volume, she utilizes multiple lines of evidence in her discussion of ancient Mesoamerican metallurgy, including archaeological, geological, ethnohistorical, and experimental information. In addition, instead of focusing solely on Michoacán, she uses these multiple lines of information to provide a more general overview of recent archaeometallurgical research in West Mexico, thereby advancing our current state of knowledge of the developmental trajectory of metallurgical technology in this important Mesoamerican region. Her work also points to the great utility of the concept of chaîne opératoire in providing a conceptual framework for understanding the sequence of technical processes used in creating metal objects, the ultimate outcomes of such processes, and the social choices behind them.

Patricia Urban, Aaron N. Shugar, Laura Richardson, and Edward Schortman, in Chapter 4, explore the nature of copper production at the site of El Coyote in western Honduras. Evidence for smelting and the processing of the resulting copper slag to extract copper prills is presented along with information on fairly well-preserved production features that are the first of their kind to be reported in this part of Mesoamerica. While dating of the features and metal production as a whole at the site needs to be refined, the archaeological data link features from the smelting area to physically discrete Epiclassic and Early Postclassic architectural features, and it is very likely that metal production predates this period. The research at El Coyote is particularly welcome, as it is providing us with a better understanding of the nature of metallurgical activities in a region where so much more work is needed.

Compelling evidence for onsite copper production is presented by John M. Weeks in Chapter 5, who summarizes the results of work conducted at the K'iche' Maya site of Utatlán (Q'umarkaj) in highland Guatemala. Most notable are the casting molds and mold fragments, numbering over 100, that have been recovered from several structure groups at the site. Rectangular in shape and made of volcanic pumice, these molds contain small deposits of copper oxide and copper carbonate. Preliminary examination of these unique artifacts suggests that they were probably not used for smelting but were instead designed for casting copper into small rectangular bars. They are the only known casting molds that have been identified thus far in the Maya area.

In Chapter 6 Simmons and Shugar present a summary of the kinds of metal objects that have been recovered archaeologically from the ancient Maya site of Lamanai, Belize. More metal objects have been recovered at this site than at any other in the southern lowland area, and there is quite compelling evidence for onsite production there, specifically lost-wax casting of bells and possibly other objects. It appears that metal objects were first imported to Lamanai from West Mexico and southeastern Mesoamerica during Early Middle Postclassic times (twelfth and thirteenth centuries). In the centuries just prior to and likely during Spanish colonization in the southern lowland area, Lamanai's metalsmiths engaged in melting and casting plain-walled bells and other objects onsite using metal from ingots or pigs as well as from recycled objects. The authors also present the results of analytical and contextual studies and offer their thoughts on the meanings metal objects may have had for the Postclassic Maya.

Elizabeth H. Paris and Carlos Peraza Lope present the results of recent work in the northern Maya lowlands in Chapter 7 of this volume. Solid evidence for onsite production at Mayapán, Yucatán, Mexico, is seen at two discrete locales at this important Late Postclassic site. One of these is a burial that includes two miniature *tecomates* (neckless ceramic jars) that may have been used as crucibles. If these indeed served as crucibles, they would be the first of their kind recorded in the Maya area. Discarded sprues from lost-wax casting, along with failed bells and a cache containing nearly 300 bells, have recently been recovered at the site. Mayapán's place as an important player in the Postclassic Mesoamerican world system has already been established, particularly with regard to the movement of a variety of both luxury and utilitarian commodities (Masson, Peraza Lope, and Hare n.d.). The archaeometallurgical research of Paris and Peraza Lope at this site is beginning to illuminate the role copper objects may have played in both the Postclassic Maya and larger Mesoamerican world systems.

In Chapter 8 Niklas Schulze presents data and interpretations derived from materials analyses, including geochemical composition and fabrication methods, of copper bells recovered from the Templo Mayor in the Aztec capital of Tenochtitlán. Nearly 3,400 alloyed copper bells were deposited in 48 separate offerings during successive construction phases of this important Late Postclassic structure. Schulze reports on the results of archaeometric analyses, specifically X-Ray Fluorescence (XRF), examining the alloy composition of the Templo Mayor bells and the utility of XRF analyses under certain circumstances of artifact preparation. He found that the Templo Mayor bells are quite homogenous in composition but different from other Mesoamerican bells, which he interprets as possible evidence for local production. This idea is supported by ethnohistorical sources stating that some raw materials that reached Tenochtitlán as tribute or trade items were redistributed to local artisans, who sometimes produced ritual objects intended as offerings in buildings. Interestingly, a number of the bells Schulze examined still retained their casting cores and therefore could not emit any sounds; they were produced expressly as offerings.

Finally, in Chapter 9 of this volume Dorothy Hosler remarks on the contributions current research efforts have had in illuminating the nature of metallurgical traditions in ancient Mesoamerican societies. She briefly summarizes the origins and early history of archaeometallurgical research in Mesoamerica and continues with a discussion of the state of this research today, as well as directions for future work in the field. Hosler outlines some of the successes, along with the various challenges, encountered by researchers studying metallurgy in ancient Mesoamerica and how these challenges might be met in the future. One such challenge is reliable dating of metal extraction and production sites and features. This is obviously an important issue to resolve if we wish to continue making strides in understanding the development of this ancient technology through time. Another challenge is identifying specific sources for copper and other ores in southeastern Mesoamerica, and better defining the nature of the metallurgical tradition that appears to have developed there. But in looking back at where archaeometallurgy in this region of the Americas has come from, and how rapidly it has matured in the past decade, Hosler expresses overall optimism for the continued growth and development of the field. In this final chapter she offers words of encouragement for the new generation of researchers, many of whom have been profoundly influenced by her pioneering work in the region, to continue broadening their understanding of the ways metals and metallurgy were integrated into the lives of ancient Mesoamerican peoples. To paraphrase her, in short, the future of archaeometallurgical research in Mesoamerica looks very bright, indeed.

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