Chapter 14
Mesoamerican Metallurgy: the Perspective from the West

Dorothy Hosler

Topic Overview

Mesoamerica provides an unusual and intellectually challenging case in the development of metallurgy when compared to other world areas we examine in this volume. The major challenge lies in complex events surrounding the introduction of this copper-based technology from South America to western Mesoamerica around 650 C.E. and its subsequent development there, long after state-level societies had become firmly established in the Central Highlands (Teotihuacan), the Southeastern Lowlands (Maya), and elsewhere. Here, we will synthesize our knowledge of Mesoamerican metallurgy at this point in time, focusing in particular on the west Mexican metalworking zone (Fig. 14.1) where the technology initially took root, developed, and flourished through 900 years, identifying those questions where answers are reasonably firmly established and those questions where the most productive work still lies ahead.

The earliest dates for metal artifacts in Mesoamerica come from the west Mexican metalworking zone, from sites along the west coast, in particular Tomatlán, Jalisco; Amapa, Nayarit; and from settlements located along the lower Balsas river between Michoacan and Guerrero in the Infiernillo region (Fig. 14.2), map showing Mesoamerica and site locations). They date to around 650–700 C.E. All objects are made from copper and represent two production traditions: some are lost-wax cast (bells and small ornaments) and others are cold-worked from an initial cast blank and comprise ornaments such as rings and small work tools (Hosler 1986, 1994). These sites are on the Pacific coast or have riverine access to the Pacific coast. This copper-based technology and/or its practitioners moved to the higher-elevation inland basins of Jalisco and Michoacan, where archaeologists recovered copper objects at sites such as Cojumatlan, Michoacan and Tizapan, Jalisco—both located on the shores of Jalisco's Lake Chapala (Hosler 1994).

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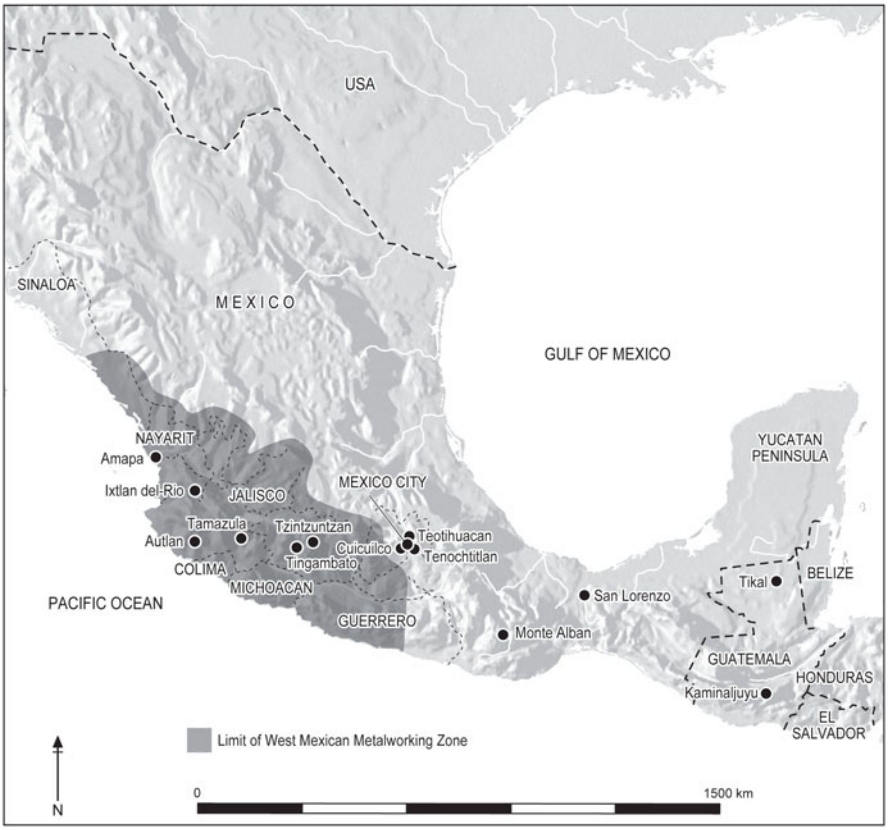

Fig. 14.1 Map showing major Mesoamerican archaeological sites and regions, the west Mexican metalworking zone, and archaeological sites within the metalworking zone

The copper artifacts from coastal and inland sites range from 650 to 1100/1200 C.E and comprise what Hosler has designated as Period 1 (Hosler 1994). At La Pena (Garcia 2007, 2008), a recently excavated site located in Cuenca de Sayula adjacent to Lake Chapala, copper objects date to between 800 and 1100 C.E (Garcia 2007). The La Peña artifacts also fit into the Period 1 types (Fig. 14.2), and consist of small cast copper bells, and copper objects shaped by cold work: open rings, pointed eye needles, and beam design tweezers. In fact, thus far, all artifacts analyzed from this period, except for one low-arsenic copper–arsenic figurine excavated from the Atetelco complex at Teotihuacan in 1998 (Hosler and Cabrera 2011), were made from copper. The artifact assemblages I have described provide the bulk of our earliest dated evidence. Unfortunately, the west Mexican metalworking zone, Mesoamerica's earliest locus for metalworking, still lacks studies of mining sites, smelting sites, and production-workshop sites dating to this period.

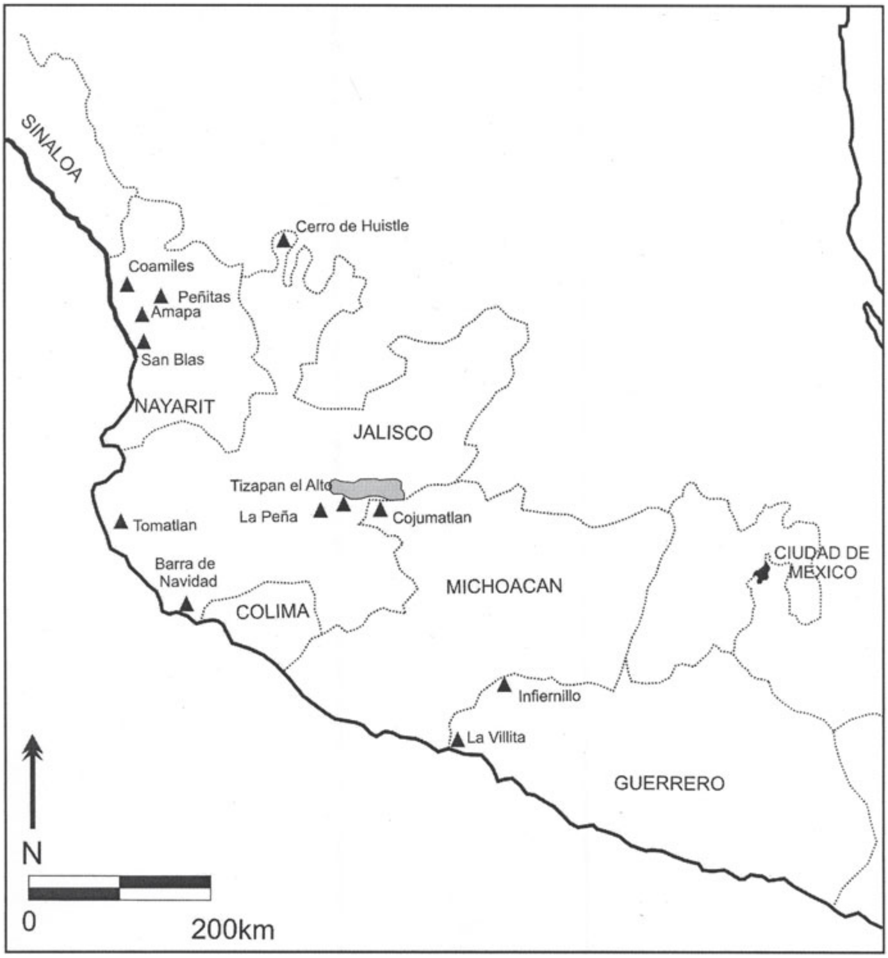

Fig. 14.2 Map showing locations of Period 1 archaeological sites where copper objects have been recovered

The Introduction of Metallurgy to Western Mexico and Period 1 Characteristics

There has been little argument concerning the origins of Mesoamerican metallurgy. Virtually all investigators since the pioneering research of Arsandaux and Rivet (1921, 1923) through the work in the 1960s and 1970s by Meighan (1969), Mountjoy (1969), Pendergast (1962), Willey (1966), Marcos (1978), and others have maintained that metallurgy was introduced to Mesoamerica either from Central America, South America, or from both regions most possibly via a maritime route. That hypothesis has been greatly strengthened and clarified in the last several decades by

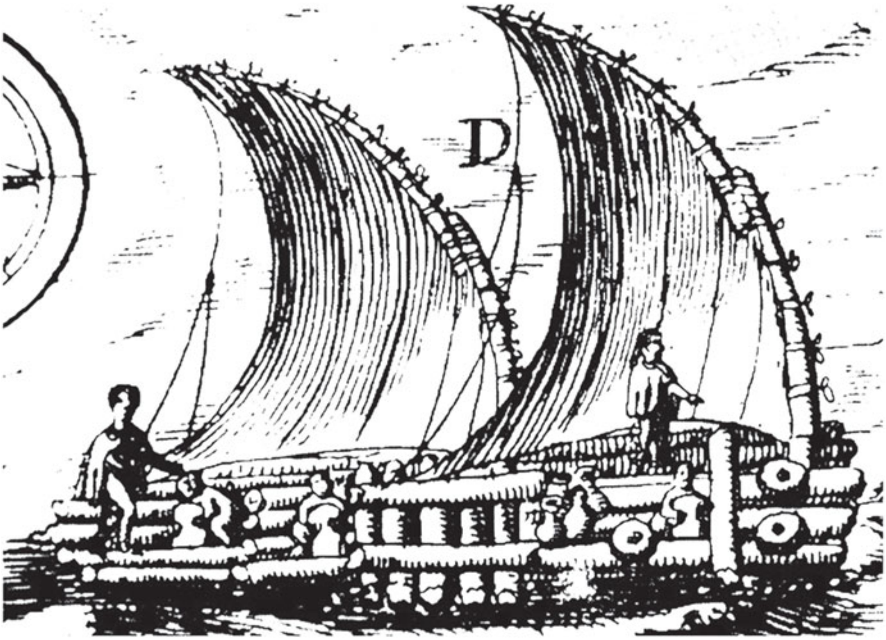

Fig. 14.3 Drawing of sixteenth-century balsa-wood watercraft drawn from Joris Van Spilbergen. (from Edwards 1965)

Hosler (1988a, b, 1994) and Dewan and Hosler (2008), whose research strongly supports the idea that knowledge of metallurgy was introduced by Ecuadorian voyagers to peoples living in west Mexican ports. The support for these conclusions derives from Hosler's comparative analyses of lower Central American and South American artifact chemistries, fabrication techniques, and design characteristics, with those of artifacts from west Mexico (Hosler 1986, 1988b, 1994, 1996) and from recent engineering studies of the design and performance of Ecuadorian balsawood sailing rafts (Dewan and Hosler 2008). Both lines of evidence strongly suggest that knowledge of metalworking techniques and a few prototype artifacts was carried to the shores of western Mexico by the seagoing maritime peoples of coastal Ecuador, whose balsawood trading rafts were still in evidence at the time of the European invasion (Hosler 1988b, 1994; Dewan and Hosler 2008). The comparative metallurgical studies, facets of which I discuss in subsequent sections, have identified specific Andean metallurgical traditions from which certain west Mexican artifact design types/fabrication methods and alloy systems originated (Hosler 1986, 1988b, 1994).

To reassess whether such seagoing voyages were feasible given Ecuadorian sailing technology, Dewan and Hosler (2008) carried out engineering studies of ancient Ecuadorian balsa-wood rafts. The engineering models were based on drawings of the sixteenth-century Ecuadorian watercraft (Fig. 14.3). The models reveal that these vessels, to navigate successfully, could measure between 6 and 11 m in length and would require two masts, measuring between 5 and 7.5 m in height. The cargo

Fig. 14.4 Spondylus oyster. (photo courtesy of HenryDomke.com)

capacity of balsa rafts in this size range varied between 10 and 30 metric tons, which replicates the cargo capacity of nineteenth-century Erie Canal barges. Further, these balsa rafts were capable of making two round-trip voyages between coastal Ecuador to the coasts of west Mexico (Guerrero or Michoacan) before deteriorating sufficiently to become inoperable. Dewan and Hosler (2011, p. 36) calculated that the raft could make the 3,000-km voyage between these two regions in 6–8 weeks, when traveling 12 h per day at 4 knots/h with eight crewmembers aboard. Analysis of Pacific weather conditions and currents suggests that these rafts could have most easily launched from coastal Ecuador in December and arrive in west Mexican ports in late January. The return trip could have been undertaken in March, at the earliest. At least one document, written by the royal accountant Rodrigo de Albornoz, describes native accounts from western Mexico of "Indians from certain islands to the south [who] brought exquisite things which they would trade for local products [and] those who had come would stay for 5 or 6 months until good weather occurred" (Dewan and Hosler 2008).

Hosler (1988b) has argued that long layovers were essential to the process of introducing this complex technology, metallurgy, to peoples who were unfamiliar with it. That enterprise requires that local west Mexican peoples at some point during these contacts—which probably occurred sporadically over hundreds of years—learn to identify key copper ore types (malachite, azurite, and chalcopyrite), tin (cassiterite), ores of arsenic (arsenopyrite), arsenic-bearing copper ores (tennantite and others), and the other parent materials Hosler has identified in previous studies of ore types used in the west Mexican metalworking zone (Hosler 1994, Chap. 2).

If Ecuadorian sailing technology indeed allowed these long-distance, round-trip voyages, another fundamental question has concerned what Ecuadorian voyagers were seeking in west Mexican coastal settlements. We have no new data since the last discussion of this particular topic (Hosler 1994), but those data merit recapitulation in view of the objectives of this special issue of this journal. Various authors, but most notably Jorge Marcos (1978), have posited that seagoing traders voyaged north from Ecuador along the Pacific coast to harvest sypondylus oysters which live in dispersed deep-water pockets from coastal Ecuador to southern Sinaloa, Mexico (Fig. 14.4). Spondylus' shell was sacred to Central and Southern Andean peoples.

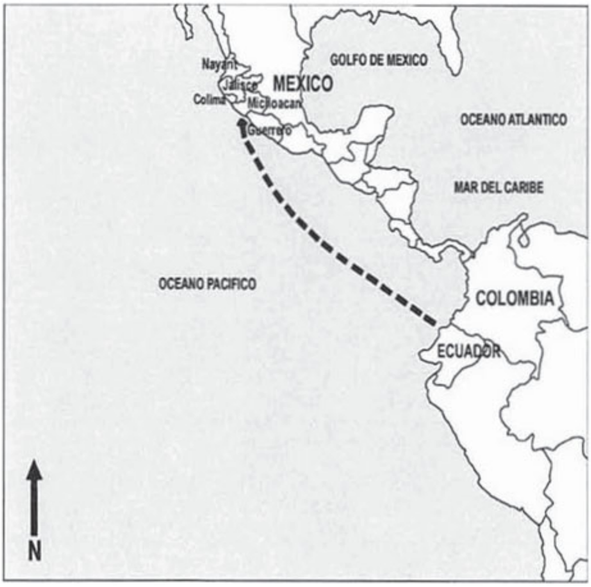

Fig. 14.5 Map showing possible maritime route from coastal Ecuador to west Mexico

Since spondylus oyster requires a warm-water habitat and cannot survive in the cold waters of the Chile–Peru current, the shell became an item of critical value in the Ecuador-based maritime trade along the coast of Peru. The observations of Bartolemé Ruíz de Estrada, Francisco Pizarro's chief pilot who captured one of these rafts as it sailed northward along the Ecuadorian coast (Hosler citing Samano Xerez 1937, pp. 66–67) are particularly germane to this discussion. Ruíz describes a raft with 20 men aboard carrying trade goods that included metal (silver) objects: tiaras, crowns, bands, tweezers and bells—all of which, he reports, they brought to exchange for some shells (Hosler 1994, p. 103 citing Samano Xerez 1937, pp. 65–66). These Ecuador-based traders thus also voyaged north. I have argued elsewhere (Hosler 1988b, 1994) that they offered metal objects, and metalworking knowledge and techniques to their west Mexican partners in exchange for spondylus shell (Fig. 14.4), which grows and was harvested along the west coast of Mexico (Fig. 14.5).

The argument that west Mexican metallurgy was introduced from the south becomes particularly convincing when we assess the laboratory and archaeological data comparing lower Central American and South American metallurgy to the metal objects excavated in the west Mexican metalworking zone. Those data show that copper objects recovered at the west Mexican metalworking zone sites mentioned previously—lost–wax-cast bells and cold worked needles, tweezers, and rings—are virtually identical in design parameters and fabrication techniques to Colombian and to Ecuadorian/Northern Peruvian artifacts (Hosler 1986, 1988a, 1994). Colombian and Ecuadorian/Peruvian peoples treated metal in very different ways. In Colombia, metal was treated as a liquid and objects were cast in open molds, in one- or two-piece molds or by the lost-wax method. Bells, cast using the lost-wax method,

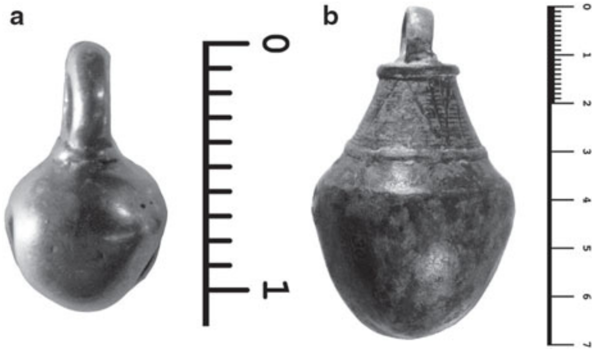

Fig. 14.6 **a** Costa Rican lost-wax-cast bell. **b** West Mexican lost-wax-cast bell

occur in Colombia and Costa Rica by 100 C.E. (Hosler 1994, p. 99) predating their appearance in the west Mexican metalworking zone by at least 500 years (Figs. 14.6 and 14.7. In Ecuador, Peru, and parts of the south-central Andes, metal was treated as a solid, and objects were formed by hammering them to shape from an original cast blank. Counterparts of the cold-worked Period 1 west Mexican items—copper-pointed eye needles, beam design tweezers, open rings, and small chisels—have been excavated in Ecuador and Northern Peru, and date to between 100 and 500 C.E. or earlier (Hosler 1994, Chap. 4), hundreds of years earlier than the west Mexican examples. (Hosler 1986, 1988b, 1994) (Figs. 14.8 and 14.9). In both Ecuador and west Mexico, the objects are made from copper, and the design parameters, fabrication techniques, and even burial contexts in some cases (the rings) are the same.

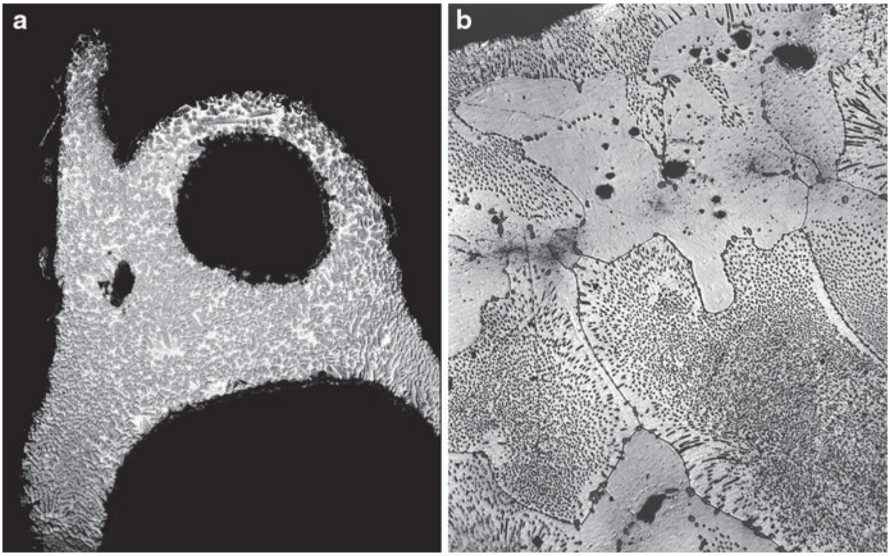

Fig. 14.7 **a** Cast microstructure of Costa Rican bell. **b** Cast microstructure of west Mexican bell

Fig. 14.8 **a** Ecuadorian pointed-eye needle. **b** West Mexican pointed-eye needle

Minor differences in the presence and concentrations of trace elements, and in the ratios of certain artifact dimensions to one another, distinguish the Andean material from the west Mexican objects. Thus, the objects excavated at Amapa and other sites were not imports from Colombia/Ecuador but were second-generation items, made

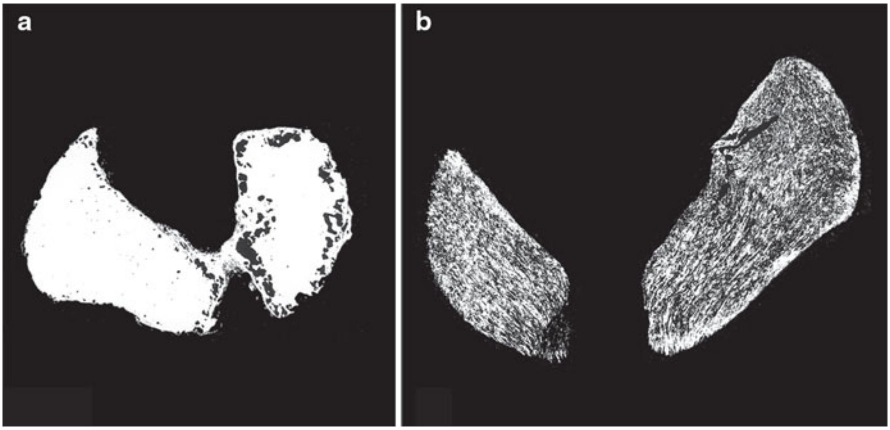

Fig. 14.9 **a** As-polished section through eye of Ecuadorian pointed-eye needle. **b** Etched section of west Mexican pointed-eye needle

from prototype exchange items introduced by seagoing Ecuadorian traders (Hosler 1988b, 1994) (Figs. 14.5, 14.6 and 14.7).

A significant piece of evidence supporting the introduction of these metalworking techniques through maritime contact is that the geographical distribution of these assemblages of cold-worked and cast objects is discontinuous. They are absent in the Intermediate area (Southern Mexico to Nicaragua) between 200 and 600 C.E, the time period we are discussing (Figs. 14.8 and 14.9).

The west Mexican metalworking zone contains the largest copper deposits in Mesoamerica (Hosler 1994). The metalworking zone (Fig. 14.1) comprises the area encompassed by the modern states of Guerrero, Michoacan, the southern part of the state of Mexico, Jalisco, Colima, and Nayarit. The Mexican copper belt runs through Michoacan and Guerrero and exhibits a series of massive sulfide deposits and innumerable smaller copper outcrops. The most common copper ores are chalcopyrite, malachite, and azurite (Fig. 14.10). Arsenopyrite is the major ore of arsenic; deposits of tennantite and enargite also appear, as well as deposits of gold (not shown) metallic silver, argentite, and silver sulfosalts. Small deposits of cassiterite, the oxide ore of tin, are dispersed sporadically in the metalworking zone particularly along the northeastern boundary, but most cassiterite occurs along the eastern edge of the Sierra Madre Occidental. That region is known as the Zacatecas tin belt.

People living in the metalworking zone thus had access to the raw materials for metal extraction and production, and in many cases lived in complex village settlements by 600–700 C.E, when the technology was introduced. In Guerrero's and Michoacan's middle Balsas region, for example, these settlements, which date to this and later periods, display residential sectors as well as extensive public and ceremonial architecture (Hosler 2000; Meanwell 2001, 2008; Moguel and Pulido 2005; Reyna 1997). Similar polities flourished in Michoacan, Jalisco, Colima, and Nayarit. Archaeological data show that peoples living in these areas understood and had been managing the properties of stone, clay, and other materials for hundreds of years and that they also were at least familiar with certain copper ore minerals such as malachite, which they polished and used for ornaments. It is not surprising that people living in these settlements could have learned and incorporated the techniques and practices required by the copper-based technologies introduced from the South (Fig. 14.10).

Evidence for Mining, Extractive Metallurgy (Smelting), and Object Fabrication

The laboratory analyses of artifacts show that, during the period between about 650 C.E. and 1100–1200 C.E., metalworkers across this broad geographical region were making the same kinds of objects from similar materials and using the same techniques. As I mentioned, no significant evidence exists for mining smelting and metal production. At Amapa several small objects appear which William Root, the chemist who analyzed them, has identified as slag (Root in Meighan 1976). Archaeologists

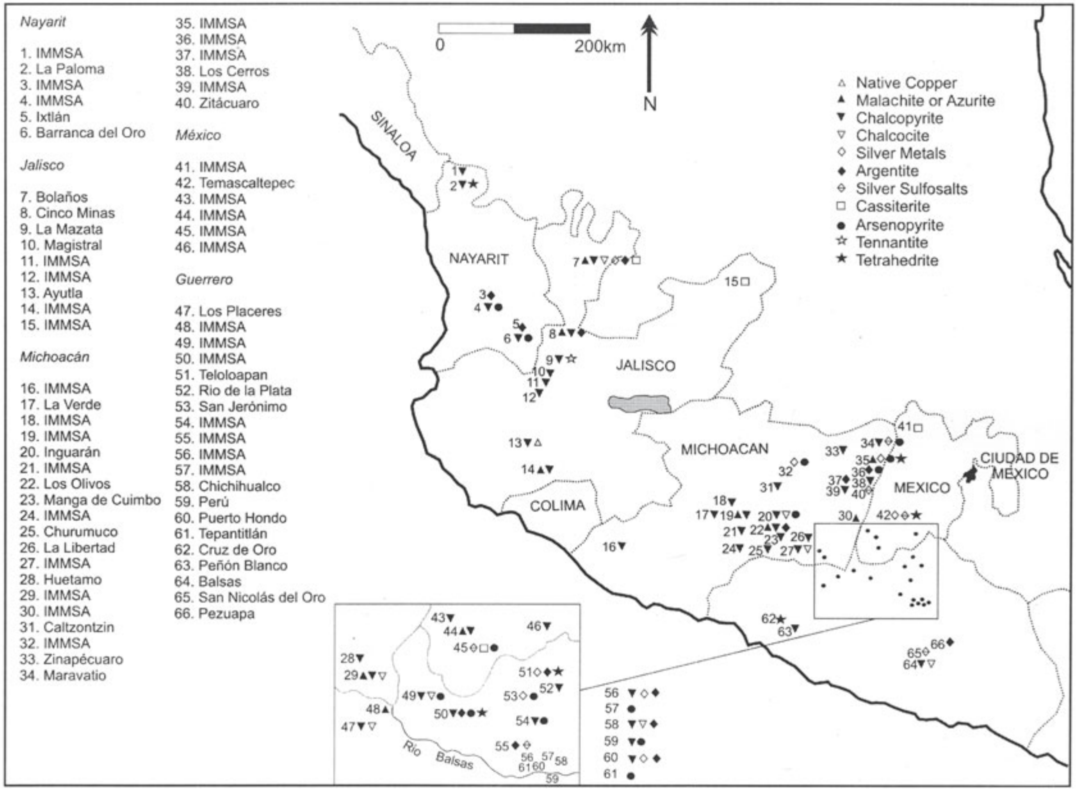

Fig. 14.10 Map showing the location of metallic ore deposits in the west Mexican metalworking zone. IMMSA represents unpublished archival data; the place names are taken from geological reports. (see Hosler 1994, 2003, Chap. 2)

report slag-like materials adhering to a potsherd at Peñitas, Nayarit (Carriveau 1978) but do not provide analyses of those materials. The strongest evidence comes from Ruben Cabrera, who identified amorphous metal adhering to stone-crucible fragments where he argues melting or smelting took place (Cabrera 1976, Hosler 1994). Joseph Mountjoy reported what he believes are metalworkers' tools at Tomatlan Jalisco. At Cojumatlán, Meighan and Foot (1968) excavated what they call "slugs" of metal: these, they think, were ingots (Hosler 1994, 2003) (Fig. 14.2). It is likely that some facet of metal production occurred at at least some of the Period 1 sites where copper artifacts were excavated but the data so far remain sparse.

Thus, the sum total of the direct evidence of production activities is small. However, the data indicate strongly that artifacts recovered from sites in this zone were produced somewhere within the region. Artifact distribution is confined to the metalworking zone during this period. Further, this region is one of Mexico's richest in copper ore minerals, and it also displayed the social prerequisites of metal production: the existence of complex societies (Hosler 1996). What is more, the lead isotope ratios of west Mexican artifacts match those of west Mexican copper ores we have sampled and distinguish those ores from other (i.e., eastern Mexican) copper sources (Hosler 2003, Hosler and Macfarlane 1996).

The paucity of archaeological information concerning extraction and smelting activities illustrates one of the major gaps in our understanding of west Mexican metallurgy and Mesoamerican metallurgy as a whole. This leaves another major question unanswered. What social entities participated in the incorporation of the technology from South America and initiated mining, ore processing, and metal production in the west Mexican metalworking zone? What are the dates? How did they organize extraction and production activities?

Pottery Clues

We do have evidence, while unrelated to processing, which may be useful from some (but not all) Period 1 sites concerning the social affiliations of the groups using these copper artifacts. A polychrome pottery type known as Aztatlan appears at Tomatlan, Amapa, Cojumatlan, and Tizapan associated with the copper artifacts excavated at those sites. Hosler (1994) reviewed this evidence and commented that the meaning of these associations is unclear but worth noting.Garcia (2007, 2008) found this same pottery type at La Peña (Fig. 14.11), which dates to approximately the same period. Unfortunately, the origins and social affiliations of peoples associated with this pottery complex are one of most contentious issues in Mesoamerican archaeology (Smith and Heath Smith 1980; Mountjoy 1990; Nicholson and Quiñones Keber 1994; Kelley 2000), and its discussion is far beyond the scope of this paper. This pottery cannot be associated with a particular social or ethnic group or region, and temporal controls are far from established. The data for the association of copper objects and Aztatlan pottery nonetheless continue to accumulate and at some point should provide some insights into the incorporation and dissemination of metal technology and/or of objects during Period 1.

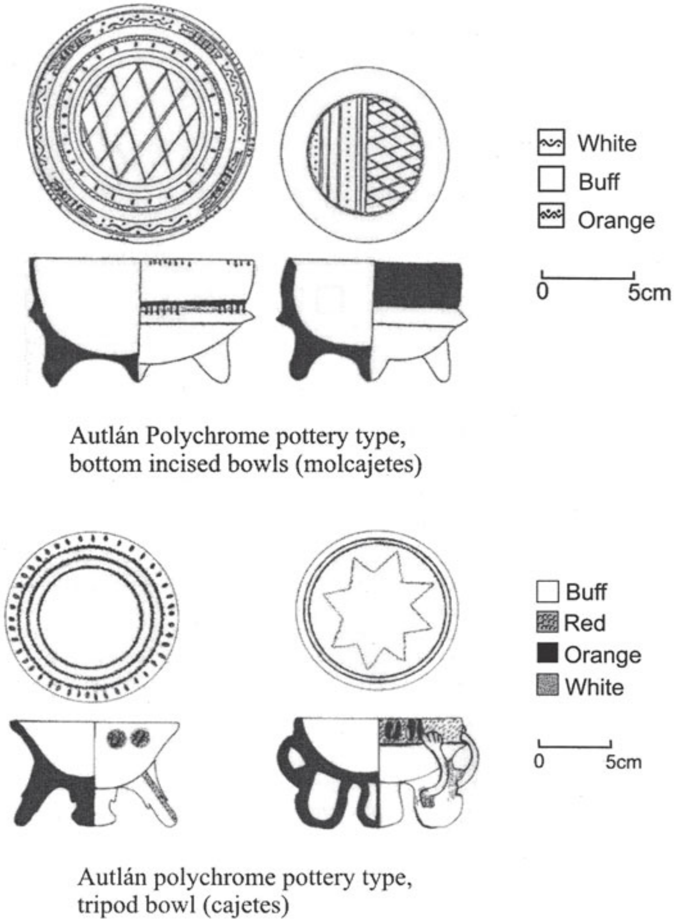

Fig. 14.11 Autlan pottery recovered at la Peña

Sound and Cosmology

Apart from the origins and characteristics of this new technology, one of the broad issues that we have been able to confront concerns the vital question of what people living in complex societies, who have already solved problems of daily and ritual life using other materials, choose to do with metal, a completely new material. Copper, when cold worked, lends itself to a variety of applications which, in some cases (for example, needles) produces an implement whose physical and mechanical properties (strength and toughness) are far superior to those of bone needles that Mesoamerican peoples produced in large quantities (Hosler 1994). Yet, the primary concern of these metalworkers was metal's acoustical properties, its sound. Bells, cast using the lost-wax method, by far outnumber any other artifact class. Bells comprise some 60 % of all items made from metal in the west Mexican repertoire. These peoples were particularly interested in producing a range of pitches, casting bells that varied in those design parameters (internal volume and width of resonator opening) crucial to pitch. Data from burials show that different-sized bells (i.e., bells whose pitches varied) were worn together on the wrists or ankles, attached to waistbands, and sewn onto clothing. (Hosler 1994, 1995).

Linguistic, lexical, ethnohistoric, and ethnographic evidence (Hosler 1994) reveals that metallic bell sounds and the sounds of composite instruments containing bells were highly significant in Mesoamerican cosmology. Bells and bell instruments were essential in rainmaking ceremonies: they reproduced the sounds of thunder, rain, and the roar of the jaguar, a progenitor of Mesoamerican peoples. Bell sounds also engendered agricultural and human fertility. Bell sounds could precipitate trance, in ritual, drawing the participants into altered states of consciousness, in which they directly experienced the supernatural (Hosler 1994).[1] In the metalworking zone, metal bells came to replace the seed pods, gourd rattles, and rattles made from other materials traditionally used in shamanistic curing ceremonies, in rainmaking ceremonies, and dance (Hosler 1994). As I discuss elsewhere (Hosler 1994), lexical evidence from several Mesoamerican languages indicates that the words for "metal" and for "bell" are the same, so that metal and bells can be considered culturally synonymous. Thus, the sounds of metal in bells and in composite bell instruments was the property of this new material that most interested these west Mexican people and which, from the outset, guided their production choices.

Metal bells and their sounds were also significant in Colombia, where bells were lost-wax cast, and in Ecuador where they were cold worked to shape. However, metal bells constituted minor elements in the technologies of those two Andean regions.

I have argued previously that metalworkers' interest in fashioning objects evoking sacred and supernatural spheres of experience through sound may respond to the particular circumstances surrounding the introduction of metallurgy from Andean South America. This foreign material and the sounds that it made may have been especially compelling to chiefs and other elites in consolidating power and attracting followers through associations with the supernatural (Hosler 1994). The timing $\sim$ 700 C.E. coincides was the collapse of Teotihuacan, Mesoamerica's most powerful state, and with the formation of smaller polities in many Mesoamerican areas. These events reconfigured loyalties, alliances, and trade networks and may have provided a particularly propitious moment for the introduction of a new and exotic material.

The Florescence of West Mexican Metallurgy: Period 2

Around or somewhat before 1100–1200 C.E,[2] the technical expertise of metalsmiths in the metalworking zone expanded greatly. They developed copper–tin and

[1] There has been some ethnographic work documenting trance states brought on by the repetitive sounds of rattles and bells.

[2] Garcia (2007) dates a copper–arsenic alloy bell to 1040 C.E. from Caseta where the numerous copper–tin and copper–arsenic bronze artifacts recovered fall between 1040 and 1300 C.E., making

copper–arsenic bronze and copper–silver alloys, which they primarily used—with the alloying element present in the bronzes to 23 weight percent—for the color of these alloys in elite status objects and in ritual paraphernalia. These objects consist of bells and other sounding instruments, rings, pendants, assorted body ornaments, ornamental tweezers, sheet metal breastplates, large disks, ornamental shields, and crowns. What is so striking about the trajectory of this metallurgy is that metalworkers took advantage of the increased strength, ductility, fluidity, and other properties of copper–tin bronze, copper–arsenic bronze, and sometimes copper–silver alloys, to refine, redesign, and sometimes alter the color of the same artifact classes they had previously made in copper.

These artifacts also include new tools and implement designs in which metalworkers capitalized on the increased hardness and toughness of the bronze alloys to improve functionality (Hosler 1994, 2003). In tools, they added the alloying element, tin or arsenic, only in concentrations (2–5 wgt %) sufficient when cold-worked to produce thinner and harder chisels, punches, axes, and awls. They produced these items in relatively small numbers when compared to status and ritual objects (Hosler 1994, 2003). These west Mexican peoples elected to define tin and arsenic bronze as sacred materials, particularly appropriate for elite and status purposes, rather than to use them either for the utilitarian ends common to other world metallurgies (for armor and weapons) or to undertake production of bronze tools and work implements on a large scale, thus altering the course of this technology.

Metalworking zone artisans cast vast numbers of bells of different sizes from these bronze alloys. By doing so, they were able to greatly expand the range of pitches the bells could produce. The physical and mechanical properties of tin and arsenic bronze alloys facilitate larger bell castings, and pitch, as noted, is a function of the internal volume of the bell resonator chamber. Their concern with metallic sound persisted, resulting in technical choices which disallowed the use of metal for other cultural objectives. They also became intensely interested in metallic colors, most notably of silver and gold. In the west Mexican case, metalworkers used the bronze alloys, especially copper–tin and sometimes copper–arsenic in concentrations to 23 % by weight in lost-wax castings to produce golden and silvery colors in objects, such as certain intricate thin-walled bell designs (Fig. 14.12) whose design parameters precluded the use of gold or silver metal. These bronze alloys are highly fluid; they flow easily into an extremely thin-walled mold cavity, and they do not solidify or freeze at a single temperature but over a range of temperatures, which allows time for the liquid metal to fill in design detail. These alloy concentrations are far higher than necessary to produce the fluidity and strength required by the design of the casting. High-tin bronze bells look golden. High-arsenic bronze bells look silvery. Gold and silver colors are associated in the Mesoamerican pantheon with the solar and lunar deities, respectively (Hosler 1994, 1995).

dates for the copper–tin and copper–arsenic alloys earlier than the (very general) 1200–1300 C.E. dates available previously (see Hosler 1994). Some Milpillas bronze artifacts dated lightly earlier than 1200 C.E., which is why Garcia's findings make the earliest dates about 100 years earlier than previously estimated.

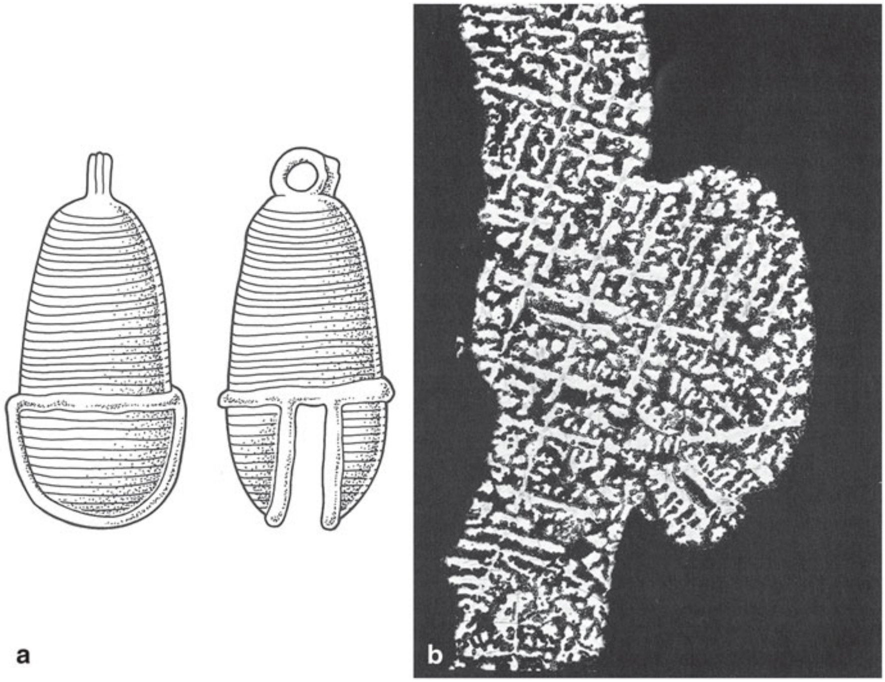

Fig. 14.12 **a** Copper arsenic bell. **b** Photomicrograph of longitudinal section of bell wall. The bell contains 23 % arsenic by weight

West Mexican smiths also used copper–tin bronze, and sometimes, copper–silver alloys, for worked objects. They crafted large, elaborate, thin, shell-shaped golden and silvery looking tweezers through cold and hot work (Fig. 14.13) (Hosler 1994). These tweezers became symbols of the state in the Tarascan empire (Hosler 1986, 1994). Tarascan priests donned large multispiralled versions of these tweezers as symbols of office. Ethnographic accounts concerning the meaning of body hair in Amerindian cultures (Hosler 1994) are useful in explaining how this pedestrian Andean and Period 1 west Mexican copper implement used to remove facial hair, became transformed in the Tarascan zone into a symbol of power. Body hair among indigenous American groups is identified with the animal realm rather than with socialized human groups. Hosler (1994) has argued that these large Tarascan tweezers symbolically separated the priests who wore them from that animal realm, reinforcing the priest's social and supernatural power and moral authority (Figs. 14.12 and 14.13).

Our studies have shown that the tweezer design itself, which in mechanical engineering parlance is known as a shell, can be realized only by using these bronze alloys due to their toughness and strength. Tin regularly appears in Period 2 shell tweezers in concentrations up to 10 % by weight, giving the metal a golden color that identified the priests and elites who wore them with the solar deities.

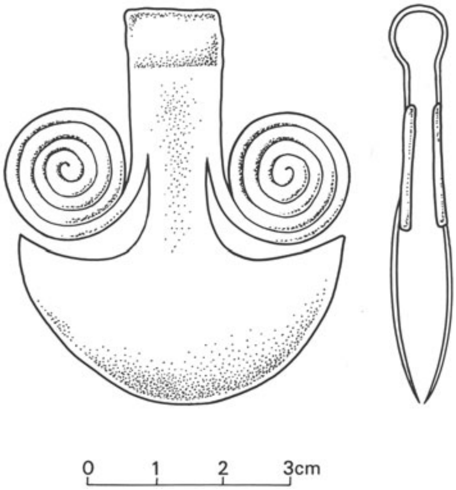

Fig. 14.13 West Mexican spiral tweezer design. These tweezers frequently contain to 10 % tin by weight

Other Period 2 object classes, such as the worked circular rings worn as earrings or hair braid holders, contain up to 18 % tin by weight (Hosler 1986, 1994), again giving the metal a golden color. Cold-hammered copper–silver alloys, which are extremely ductile, were shaped into the large pieces of silvery looking, highly reflective, sheet-metal ritual objects—for example, the breast plates, disks and shields, and other items just mentioned. Documentary and pictoral sources from the Tarascan state indicate that these items were worn and used by elites and nobility.

In other publications, I have assessed the extent to which aspects of this Period 2 technology, particularly the use of copper–tin, and copper–arsenic bronze and copper–silver alloys, were stimulated by the metallurgies of Ecuador and Peru where these alloys and some artifact classes (needle designs, certain tweezer designs) were also developed, but earlier. The similarities and differences in the use of these alloys in Ecuador and Peru and western Mexico are documented in Hosler 1994 (Chap. 6). In some cases, the object classes and alloy systems are identical: copper–silver alloy rings, for example, have a long, early history in Ecuador. The copper–silver alloy (and copper–silver rings) was so common in the State of Michoacan that the Spaniards called this alloy "the metal of Michoacan" (Hosler 1994). Although beyond the geographical scope of this paper, copper–arsenic alloy axe monies (Hosler 1986; Hosler et al. 1990) abound on the coast and in inland areas of Ecuador and these same items—thin, stackable, T- shaped Cu–As objects—were used as a medium of exchange in Guerrero and Oaxaca, located on the southern border of the west Mexican metalworking zone.

I have maintained that knowledge of the Cu–Sn, Cu–As, and Cu–Ag alloy systems and some prototype artifacts were introduced to western Mexico through the same Ecuador-based maritime trading system responsible for introducing knowledge and techniques that stimulated the initial development of metallurgy in the metalworking zone. Yet what stands out, as we compare these Mesoamerican and Andean metallurgical traditions, are the original and innovative ways in which west Mexican

Fig. 14.14 Map showing large west Mexican mines and/or archaeological sites, and the smelting sites referred to in the text

metalworkers reinterpreted and transformed the bronze alloys for their own social objectives. They principally were interested in these alloys for large golden and silvery looking bells they could cast, in keeping with their cultural interest in sound, and for the golden and silvery colors they could produce in the other elite and status items they fashioned that associated the wearers with the supernatural, particularly the solar and lunar deities.

These new artifact designs, made using tin-bronze, arsenic-bronze, and copper–silver alloys, have been recovered in burials and household debris at sites throughout the metalworking zone (Figs. 14.14 and 14.15). Ethnic affiliations are clear in only two cases: in Jalisco's Cuenca de Sayula and in the highland areas of the State of

Fig. 14.15 Map showing Period 2 archaeological sites where metal artifacts were recovered

Michoacan. The powerful Tarascan state dominated Michoacan between 1350 C.E. and the Spanish invasion in 1530 C.E. (Pollard 1994). The dates from excavations in the Cuenca de Sayula are earlier, and I will treat them first.

The Cuenca de Sayula project in Jalisco provides the single most significant new contribution to our understanding of the social affiliations of the peoples using objects made from copper–tin and copper–arsenic bronze in the metalworking zone. The Sayula project sites are located within 50 km of each other in a highland basin of Jalisco. This region lacks significant ore mineral deposits although such deposits are abundant to the south, in the Ayutla and Ayutlan area, and were exploited at the time of the Spanish invasion (Hosler and Macfarlane 1996) (Fig. 14.14).

Johan Garcia's research has focused on metal objects from Sayula sites (Garcia 2007, 2008). Since the investigation is multiyear and multidisciplinary, many other researchers have made signal contributions as well (for example, Acosta Nieva 1994; Valdez et al. 2005; Acosta Nieva et al. 1996; Liot et al. 2006). I have already commented on Garcia's work at La Peña (800–1100 C.E.), where archaeologists excavated Period 1 copper objects. Metal objects from the other three sites, Tasajillo, Caseta, and Atoyac, provide new insights into the dates for the bronze alloys in the metalworking zone and, on the basis of the associated pottery, about the social affiliations of the peoples using these metal objects. All data come from well-dated artifacts excavated chiefly from burials.

One significant contribution made by Garcia's work concerns the social affiliations of the metal-using groups in the metalworking zone. Several authors have argued that the Tarascan state (1350 C.E. through the Spanish conquest) controlled metal production over a broad area, and that, in fact, control of metal production was a critical element in the rise of the state (Pollard 1987, 1994; Maldonado 2006[3]) (Fig. 14.15). At the site of Caseta, in the Sayula basin, Garcia and others recovered 30 objects, 28 of which were from burial contexts. All are made from copper–tin and copper–arsenic alloys and the artifact designs (shell tweezers, for example) conform to the artifact designs Hosler has identified as Period 2. What is most compelling is that these copper–tin and copper–arsenic bronze artifacts date to between 1040 and 1300 C.E., prior to the emergence of the Tarascan state (1350 C.E.). On the basis of the pottery, and other material remains, they show no affiliations with that political entity. In fact, based on pottery (Autlan polychrome), these Caseta peoples are linked to groups in the Autlan area of southern Jalisco (Garcia 2007, 2008) where, as mentioned previously, copper deposits are plentiful. Garcia's work definitively puts the argument to rest concerning the control of metal production by the Tarascan state in this area of the metalworking zone. Hosler had long argued on the basis of artifact distribution and artifact chemical compositions that there is no evidence for the standardization implied by such state-level control of metallurgy in west Mexico (see, for example, Hosler 2002, p. 166).

The Cuenca de Sayula dates for the bronze alloys are also highly significant, because they make clear that the first use of these alloys in the west Mexican metalworking zone is earlier (Garcia 2007, 2008) by about 100 years than previous data allowed. The earlier dates also make sense. West Mexican bronze alloy objects have been identified outside of the metalworking zone dating to 1200–1300 C.E. (Hosler 1994, Chap. 7). Bronze production within the zone logically should have taken place earlier, but until Garcia's studies, we lacked the data to demonstrate this. Although we do not yet know who (what peoples) were first responsible for ore extraction, processing, and producing the bronze alloy objects excavated at Caseta, the pottery data from the site (Garcia 2007, 2008) (Figs. 14.14 and 14.15) indicate that archaeologists should be looking south to the Autlan area of Jalisco.

Atoyac (1350 C.E. to the Spanish invasion) also located in the Sayula basin (Fig. 14.15) produced approximately 200 artifacts, all from burials. Chemical analyses of 30 of these show copper–tin, copper–arsenic, and copper–silver alloys. The

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[3] I was able to read the abstract of Dr. Maldonado's thesis (2006) but did not have access to the text at the time of the writing of this paper.

lower levels of the deposit contain some 50 metal artifacts (Garcia, personal communication 2008) associated with local pottery (Amacueca) produced by people living in the Sayula basin. Archaeologists recovered copper–tin and copper–arsenic bronze artifacts from these levels. The artifact types correspond to Hosler's Period 2. According to Garcia (2007), local Sayula (Amacueca) elites had been wearing and using these bronze objects prior to their contacts with the Tarascan traders who settled there. The later occupational phases of Atoyac display a distinct Tarascan presence based on pottery and other items. Copper–tin, copper–arsenic, and copper–silver objects were recovered, including examples of the Tarascan symbol of state, the spiral tweezer. Garcia maintains that (2007, 2008), the archaeological data indicate that Amacueca and Tarascan people were engaged in commercial rather than bellicose interactions, in which Amacueca and Tarascan elites were intermarrying and interacting. There are no data indicating a Tarascan conquest of these Amacueca people.

The only other area in the metalworking zone where there is clear evidence of the social affiliations of people using copper–tin, copper–arsenic, and copper–silver objects are sites in the modern state of Michoacan (Fig. 14.1), which was dominated by the Tarascan state from 1350 C.E. up to the Spanish invasion. Tin and arsenic bronze artifacts and copper–silver alloys have been excavated at the Tarascan capital, Tzintzuntzan in Michoacan (Cabrera 1988; Grinberg 1989; Hosler 1986; Rubin de la Borbolla 1944), and at Huandacareo, Tres Cerritos (Macias Goytia 1990; Hosler 1994), Orichu (Hosler and Macfarlane 1996), and Huetamo (Hosler 1986).

Unlike the clear-cut situation in the Cuenca de Sayula and in highland Michoacan, these bronze artifact types also appear at metalworking zone sites where the social affiliations of the people using these objects are problematic. At Apatzingan, Michoacan, Kelly (1947) recovered archaeological material she argues is unrelated to the Tarascan state, and this includes some of the metal artifact designs that characterize Period 1 (Cu, Cu–As alloys). Cultural affiliations are similarly unclear at Milpillas, Michoacan (Hosler 1994), at lo Arado, Jalisco (Hosler n. d.), at El Chanal, Colima (Kelly 1985; Hosler 1986 and field notes), at San Miguel Ixtapan in the state of Mexico (Ruben Nieto, personal communication 2000), and at Bernard in coastal Guerrero (Brush 1962); but copper–tin bronze artifacts are common at all of these sites. Moreover, hundreds of high-tin, tin-bronze artifacts (open rings) were recovered in the salvage operation in the Infiernillo region of the Rio Balsas, and social affiliations in these cases are likewise uncertain (Hosler 2002).

Discussion

Taken as a whole, we can point to significant contributions to understanding the South and Central American origins of west Mexican metallurgy, the characteristics of that technology, its chronological trajectory, and the ways in which west Mexican peoples incorporated, transformed, and defined the new material, using it for their own cultural objectives. The feasibility studies of the success of the Ecuadorian seagoing rafts in introducing the technology to western Mexico greatly strengthen that argument. Garcia's work at the Cuenca de Sayula has refined Hosler's chronology (1994) for the first use of the Cu–As and Cu–Sn alloys in the metalworking zone. By identifying the social affiliations of the Sayula groups' first use of these Cu–Sn and Cu–As alloys through the pottery analysis (Autlan polychrome), Garcia's work also makes southern Jalisco a key area for future studies of extraction, and perhaps initial production of these bronze alloys. The Sayula project also provides the first recent data allowing us to identify the social affiliations, interactions, and relations of two metal-using groups: the Amacueca and Tarascan peoples.

The most fundamental and serious lacunae in our data concern extractive technologies—identifying mines, smelting sites, and smelting regimes—and centers of production and distribution together with the social affiliations of the groups that did produce the Cu–As, Cu–Sn, and Cu–Ag alloys that developed in the west Mexican metalworking zone after 1100 C.E. I address this issue in the subsequent section.

Archaeological, Chemical Analytical, and Historical Evidence for Mining, Extractive Metallurgy, and Object Fabrication

Data for mining and ore processing in the metalworking zone are scant during and after the bronze and copper–silver alloys were introduced. Archaeologists have reported occasional evidence for metal production activities at widely dispersed sites and regions in Colima, Jalisco, Michoacan, and Guerrero (Hosler 1994). Only two possible prehispanic metal smelting sites, at la Barranca de Las Fundiciones de El Manchon, Guerrero (Hosler 2002, 2003) and Itziparatzico, Michoacan (Maldonado et al. 2005; Maldonado 2006[4]), have been systematically excavated (Fig. 14.14). La Barranca de Las Fundiciones was identified in a metallurgical site survey of the *tierra caliente* area of Guerrero and the adjacent Sierra Madre del Sur (Hosler 2000). Substantial evidence exists for preconquest and Colonial mining, ore processing, and metal production in this area of Guerrero. Thirty-two archaeological sites were located: all but two are situated within 1 km of a copper mine. Six of these sites display evidence for some facet of extractive metallurgy and metal production (e.g., ore, furnaces, processing tools, and slag) (Hosler 2002). Well-defined smelting areas distinguish five of these sites, all containing substantial slag accumulations. Three sites (La Barranca de Las Fundiciones, Cerro del Chivo, and Agua Fria) seemed the most promising for excavation (Hosler 2000, 2002, 2003). I elected to work at La Barranca de las Fundiciones, the largest of the three and the only site that did not exhibit some evidence[5] of Colonial or subsequent occupation.

[4] See footnote 3.

[5] Agua Fria was identified in a document referring to eighteenth century and subsequent mining activities, and thus was exploited after the conquest and from the pottery and prehispanic house mounds and house foundations likely before (Personal communication, RocuiColegio Mexiquense 2006).

La Barranca de las Fundiciones de El Manchon is located in the Sierra Madre del Sur in the State of Guerrero at 1,400 m (Hosler 2002, 2003). The site, which is badly eroded, consists of three distinct subareas distributed linearly across approximately 1 km—two of the three areas are habitation sites, marked by long, rectangular, house foundations. The surface collections of all three areas produced prehispanic potsherds and obsidian and both materials appear in the excavations of the two habitation areas. Pottery types have not been identified definitively, but the pottery is made from local clays (Reitzel 2007) and shows no particular association with the well-defined pottery traditions in other Mesoamerican areas (Aztec, Tarascan, Oaxaca, and Jalisco). Some of the potsherds have been provisionally linked to Yestla-Naranjo and Cuitlateca peoples, who were living in the State of Guerrero at the time of the Spanish invasion. Between the two habitation areas, and separated by a year-round arroyo, is a smelting area containing large volumes of slag and extremely disturbed and destroyed furnace structures (Hosler 2003).

Project members were able to recover copper ore and metallurgical slags from excavations of several of these furnace structures, and the ore and slag samples were extensively analyzed by Rachael Sharp (2003) in her comprehensive, laboratory-based, undergraduate thesis work. Sharp determined that metalworkers were smelting copper oxides and carbonates such as cuprite and malachite to produce copper metal. The ore originated from a weathered complex copper sulfide–iron sulfide deposit. The ore contains copper and iron oxides and, as a result, was self-fluxing. Sharp concludes that the furnaces did not have to operate at temperatures higher than 1,150 °C to smelt effectively. Most of the copper was consolidated within the furnace; only about 2 % of the copper was retained in the slag in the form of prills (Sharp 2003). We are not sure how metalworkers achieved these temperatures, but Sharp speculates that the furnaces may have operated through a natural draft mechanism. Unfortunately, the project has not yet located an intact furnace. Copper deposits are common throughout the area and one potential candidate, located approximately 1 km to the south of the site, has been completely exhausted. We recovered only three pieces of smelted copper metal from our excavations of the smelting area. I suspect that the copper metal may have been exported as ingots to the large, adjacent site of Los Cimientos, although we have no direct evidence for this contention. Local people do report occasionally recovering copper rings and a few other copper items from Los Cimientos. Social conflict and violence related to drug trafficking in this highland Guerrero area have precluded continued work at this site during the last several years.

Dates for La Barranca de las Fundiciones are problematic. The two habitation areas have produced calibrated radiocarbon dates ranging from 1250 to 1650 C.E.

The Spanish invasion took place around 1530 C.E. in this area. Although no evidence exists for Colonial or recent occupation in any portion of the site (no pottery, iron artifacts, etc.), radiocarbon dates from wood charcoal from the smelting area are equivocal and range from 1350–1850 C.E. and later. These dates are perplexing. I am currently working with geochemists to try to determine what may have contributed to these disparate results. Sixteenth-century documents referring to this area of Guerrero provide another line of investigation to determine whether this particular mine and smelting area may have been exploited after the invasion by the Spainards. For now, I suspect that Las Fundiciones peoples were smelting copper shortly before the Spanish invasion and that these activities continued after the invasion—perhaps by indigenous peoples under Spanish control or perhaps by Spanish miners themselves. To reiterate, our most confounding observation from this site is that virtually no colonial artifacts or artifacts representing later periods have been recovered either at the site of Las Fundiciones, or at the adjacent sites of La Nueva and Los Cimientos.

Blanca Maldonado has undertaken a study of the slags at the highland Tarascan site of Itziparatzico Michoacan (Maldonado et al. 2005). The authors have identified chalcopyrite as the copper ore that was smelted, present in a silica-rich matrix. They found that furnace temperatures must have been about 1,100 °C. Maldonado speculates that the copper ore was brought to Itziparatzico for smelting, then exported as ingots. She was unable to determine definitively whether the smelting activities represented prehispanic- or later-conquest period activities.

Archaeologists working in the metalworking zone have reported evidence for processing at various other sites in Jalisco, Michoacan, and Guerrero. Isabel Kelly (1949) identified slag in the Autlan area of Jalisco, and she also recovered copper ore as well as artifacts (already noted) at Apatzingan in Michoacan. Apatzingan lies in the Mexican copper belt and is very close to La Verde, one of Mexico's very large copper-belt mines. Grinberg (1989) has identified slag at Churumuco and at the La Verde (Michoacan) mines, but the slag was not associated with archaeological material and thus may correspond to more recent mining activities. These two mines have been subject to small-scale and commercial exploitation from the Spanish invasion into the twentieth century. Brush (1962) excavated slag at Bernard, Guerrero, which, from his description, may be a by-product of tin smelting. This is especially significant because he also identified tin-bronze alloys at that site. Weitlaner (1947) identified slag at Naranjo, Guerrero. Two ingots were excavated at El Chanal, Colima, neither of which has been analyzed.

Chemical analytical data also support the archaeological evidence (albeit scant) that metal processing and production were carried out in many regions of the metalworking zone. The hundreds of artifacts analyzed dating to Period 2 when the bronze alloys were used show little evidence for standardization in alloy composition or design (Hosler 2003). Metalworkers did not follow strict technical recipes; that is, they did not adhere to strict norms for alloy compositions. Artifact chemical compositions, whose suite of trace elements varies greatly, suggest that metal was smelted from quite different parent materials.

Perhaps most crucial to this argument are the results of our most recent lead isotope analyses of copper ores from the *tierra caliente* area and Sierra Madre del Sur in Guerrero (Lopez et al. 1999), which greatly expand the number of potential artifact ore sources we analyzed and published in *Science* (Hosler and Macfarlane 1996). At that time, the ore and artifact data pointed to several large Michoacan mines (Inguaran and Bastan) as major sources of copper ore for some 170 artifacts analyzed from sites in Jalisco, Michoacan, Morelos, Chiapas, Belize, and Tamaulipas. The Guerrero lead isotope ratios (from 21 mines) overlap with those of Michoacan (Inguaran and Bastan mines) and occasionally with ore lead isotope ratios from Jalisco deposits. These data and data gained from other geochemical studies of Mexican ores now indicate convincingly that ore lead isotopic values alone will not allow us to distinguish copper ore fields that are located along a north–south axis (for example, among the states of Jalisco, Michoacan, and Guerrero). We can sometimes make positive identifications when the lead isotope ratios for the deposits and the artifacts coincide precisely. Nevertheless, the data do confirm the evidence presented in the article published in *Science* that Mexico exhibits a west–east trend in lead isotopic ratios, making it possible to distinguish, for example, artifacts made from Jalisco ores from those made from copper deposits to the east, from San Luis Potosi or Veracruz. The lead isotope evidence from Guerrero, coupled with archaeological evidence for processing in the *tierra caliente* area, suggests that a variety of ore sources were exploited during Period 2.

Ethnohistoric sources from many Mesoamerican regions also have provided insights concerning metal production prior to the Spanish invasion. The Relaciones Geograficas report copper and silver deposits in the modern State of Jalisco in the province of Tenazmatlan, Jalisco (Acuña 1988, p. 290), where, in the last several decades, many copper artifacts have been recovered by looters. The region is classified as a mining district by Mexico's Instituto Nacional de Geografía e Estadistica (INEGI). In Michoacan, the Relaciones Geograficas also describe a copper mine at Sinagua (Acuña 1987, p. 254). Sinagua is located in Michoacan's *tierra caliente* region and is within about 25 km of the Inguaran, Churumuco, and Cocian mines, three of Mesoamerica's richest copper deposits. The historian Elinore Barrett (1981) argues that all three mines were subject to Sinagua prior to the invasion and were mined by local peoples. She cites *Legajo 1204*, a document written in 1533 C.E. and first published by J. Warren (1968) to support this contention, but she relies on other sources as well. Apart from identifying these mines, the *Legajo* reports that half of the metal was rendered as tribute to the Spanish Crown. It also describes copper smelting, but fails to do so in sufficient detail to facilitate useful reconstructions (Hosler 1986). In Guerrero, the Relaciones Geograficas from Tetela del Rio (Hosler 1986, 2003; Paso y Troncoso 1905, p. 36) mention two copper deposits and note that they had been mined prior to the invasion.

Technical Choices: Color, Sound, and Cosmology

Thus, the metalworking zone object designs that characterize the period after 1100–1200 C.E. have been recovered at many sites throughout the area. The properties of bronze facilitate a range of new applications. In general, rather than expanding the range of artifact classes, and for example, using bronze for tools weapons or armor, artisans continued to produce sacred and status items altering and refining design to take advantage of alloy properties. It is clear that the sound and color of this material were the two key physical properties that shaped the technical choices concerning objects they designed and the metals and alloys they used. Metalworkers used high tin and high arsenic bronzes for large, thin-walled, golden and silvery looking bells cast with intricate, complex, external zigzag design motifs. They redesigned their tweezers, making them thinner and wider, cold- and hot-working the blade portion into delicate concave shapes. From copper–silver alloys, they produced highly reflective silvery looking metal sheet, crafting it into ornamental shields and other items. I have observed elsewhere (Hosler 1994, 1995) that Tarascan nobility and the other elites in the metalworking zone wore and used these objects, as well as objects made from gold and copper–gold alloys, in ritual and by doing so affiliated themselves with the solar (gold) and lunar (silver) deities. The metallurgy that emerged in western Mexico functioned as a visual and auditory system that symbolically defined elite and sacred spheres of activity.

The central question to consider again concerns why metalworkers elected to develop these two properties of metal: its sound in bells and its golden and silvery colors in bells and an array of other objects. In previous discussions, I have pointed to sixteenth-century Nahuatl texts and linguistic evidence in which bell sounds and rattling sounds are related to song and associated with speech. Nahuatl texts and lexical and linguistic evidence (Hosler 1995) disclose that bell sounds regenerate, protect, and metaphorically create the Aztec sacred garden or paradise described by Louise Burkhart (1992) and treated subsequently. Bells and composite instruments containing them are associated particularly with three Mesoamerican deities in sixteenth-century Aztec texts and illustrations, all connected to ideas of fertility and regeneration: Tlaloc, the god of rain, Xipe Totec the god of the metalsmiths, regeneration, and new vegetation (Hosler 1994, 1995), and Quetzalcoatl who represents aspects of the wind and storm deity (Broda 1971). Quetzalcoatl (the plumed serpent) is often depicted as a rattlesnake, and in some illustrations the rattles are replaced by metal bells (Hosler 1995).

In the west Mexican metalworking zone, particularly in the Tarascan state, the evidence shows that deities responsible for these same forces and events exist, but in different guises. Tarascan ideology shares basic principles with other Mesoamerican groups, including autosacrifice, the ball game, flaying, and heart sacrifice (Pollard 1993). Xaranga the moon deity, was the wife of Curicaueri, the sky god, and the sun's messenger. Xaranga was the daughter of Cuerauperi. Cuerauperi controlled birth, death, rain, and fertility. Flaying rites were dedicated to her, and she, like Xipe Totec, was also associated with renewal (fertility) and regeneration. Xaratanga, the moon deity, is depicted in various ways, of which one is a snake. Xaratanga was associated with childbirth and also with fertility. The association between snakes, which make rattling sounds, and fertility seems also to prevail among Tarascan peoples. Linguistic evidence, while limited, suggests that the terms for copper and rattlesnakes are related (Prof. Kenneth Hale personal communication 1994). In addition, the Tarascan word *Tiamu* translates both as *Hierro* (iron or metal) and as *Campana* (bell), which, as I have emphasized elsewhere (Hosler 1994, Chap. 8), indicates that for these peoples the purpose of metal was to make bells: "bell" and "metal" became cultural synonyms. Stanford (1966) has observed that the musical cultures of the Aztec, Tarascan, and Mixtec cultures are fundamentally similar, so that sounding instruments, including bells and the meanings ascribed to them, should also resemble one another.

Documentary evidence from the Tarascan state is particularly helpful concerning the meaning of metals and of metallic color. Tarascan peoples considered golden and silvery objects divine, they associated them with the sun and with the moon deities, and nobility wore them to reify their status. One of the three brothers, Hiripan, who participated in the Tarascan state expansion expresses the following in declaring his intent to recover gold, silver, and other items from conquered peoples:

"The people in the villages run away and carry off the plumes and jewels which made them nobles in the villages we have conquered. Go get them so the gods (the golden and silvery objects} come back to their villages." Seeing that yellow gold and white silver Hiripan said: "Look brothers, this yellow metal must be the substances the sun excretes and that white metal must be the substances excreted by the moon." (Tudela 1977, p. 152)

The citation makes explicit that the nobility defined itself by possessing golden and silvery plumes and jewels. The association of gold with the sun is reinforced by linguistic data: the root *titipeti* means gold in Tarascan and Tiripiti was also the name of gods who were individual manifestations of the sun (Brand 1951). State treasuries stored golden diadems and disks in chests to honor the sun and disks of silver to honor the moon (Hosler 1994). The information from Central Mexican (Aztec) sources for similar associations, of gold with the sun and silver with the moon, are equally strong and have been cited elsewhere (Hosler 1994, 1995).

Perhaps the key to west Mexican and Mesoamerican interest in the golden and silvery colors of metal, whether achieved by alloying or by other means, is in the quality of brilliance that defined the Aztec paradise. Termed a "cult of brilliance" by Burkhart (1992) in Nahuatl devotional literature, this paradise is conceived as a shimmering sacred garden:

> In this symbolic garden one came into direct contact with the creative life-giving forces of the universe and with the timeless world of deities and ancestors. The garden is a shimmering place filled with divine fire, the light of the sun reflects from the petals of flowers and the iridescent feathers of birds—human beings the souls the dead or the ritually transformed living are themselves flowers, birds and shimmering gems [this garden] is a metaphor for life on earth, a metaphor that ritual transforms into reality by asserting that in fact this is the way that the world is. (Burkhart 1992, p. 89)

We presume that the concept of a brilliant, shimmering garden may also have existed in the Tarascan ideas of paradise, particularly given the quantities of copper–silver metal artifacts, gold and silver artifacts, and artifacts that looked golden or silvery produced by using the bronze alloys. The concept of a brilliant shimmering garden was probably held by other Uto-Aztecan speakers and possibly also by the Maya (Burkhart, personal communication 1993). Some evidence exists that these same concepts were held in Andean South America as well.

Stanzas from *Cantares Mexicanos* (Biehorst 1985)[6] show that a shimmering iridescent garden is created through song, represented by bell sounds, bird sounds, and the sounds of human voices singing, and that the Aztec paradise is replete with birds, flowers, trees, and golden colors (Hosler 1994, p. 241, 242). The idea that metallic sound can create metallic color also appears in these texts. As the following stanza

[6] Cantares Mexicanos was composed in Nahuatl between 1550 and 1580 C.E. and deals with the conquest and its aftermath.

from *Cantares Mexicanos* shows, it is precisely through sound and song that the sacred shimmering garden comes into being:

> As colors I devise them, I strew them in the Palace of Good Song. As jewel maps shot with jade and emerald sunray the Green Place flower songs are radiating green. A flower incense flaming all around spreads sky aroma filled with sunshot mist as I, the singer in this gentle rain of flowers sing before the ever present ever near. (Bierhorst 1985, p. 141)

Other metaphors in this poetry present the same idea. What is most compelling however is that sound and metallic colors can come into being through a metallurgical process:

> I drill my songs as though they were jades, I smelt them as gold. I mount these songs of mine as if they were jades. (Bierhorst 1985, p. 207)

This links sound, singing, smelting, and metallic colors. Producing song is analogous to the process of producing metal. Songs are smelted, a process of transformation from musical thought to musical production. Metal is smelted from the rocky ore to produce the liquid metal. This extraordinary conception of creative activity reveals that in Aztec thought, the processing technologies devised for creating objects, and including metal objects, and the cognitive processes involved in creating song require precisely the same coordination of thought and activity.

These sounds and colors helped define the Aztec paradise (Hosler 1994) described by Burkhart (1992) as a realm populated by deceased warriors and deified ancestors, and conceived as a shimmering, iridescent, golden and silvery garden filled with the creative, generative sounds and songs of bells, birds, and human voices singing.

The cultural interest in bell sounds arose from their association with thunder, rain, fertility, and regeneration, and that these sounds and the sounds of human voices singing could create the sacred paradise. This may explain the lexical evidence which indicates that "metal" and "bells" were cultural synonyms in three Mesoamerican languages. The experience of hearing metallic sounds for the first time, also must have deeply affected the west Mexican peoples. The highly reflective metallic colors were also a new, powerful, visual experience for these people, particularly the golden and silvery colors of metal sheet whose closest counterparts were in the silvery colors of the moon and the golden colors of the rays of the sun, reflecting off of lakes and streams. The sounds of metal bells and the golden and silvery metallic colors became fundamental to and integrated into these peoples' concepts of the sacred, and were associated with supernatural forces. The paradise was a garden filled with shimmering beings, reflective dewdrops, and the iridescent colors of insects, butterflies, dragonflies, and the feathers of certain multicolored birds that populated the tropical paradise. These conceptions of divinity and paradise may already have been in place when metal was first introduced to western Mexico. If this was so it helps explain the technical choices that resulted in the focus on lost-wax-cast bells. Pottery bells preceded them. If the idea of a shimmering paradise also holds for South America, the South American concern with producing the reflective colors through the production of golden and silvery sheet metal may also become explicable.

These topics merit further research, and one the most fruitful means of doing so in the Mesoamerican case may be through lexical and linguistic studies of the Tarascan and Nahuatl languages, and the meticulous exploration of Colonial-period religious texts.

The most interesting aspect of the information presented here is that metalworking zone smiths from across a very broad region, and representing many social groups, elected to use these new materials to produce religious and status-bearing paraphernalia to strengthen, consolidate, and reify religious and social power, and to express the cosmological precepts just discussed. This ritual use of metal distinguishes the technology of this metalworking zone. Linguistic and other evidence indicates that the metalworking zone peoples shared beliefs concerning the meaning of bell sounds and of golden and silvery metallic colors with other Mesoamerican groups. The remarkable implication of these findings is that although metalworkers differed in cultural affiliations (based on other aspects of their material repertoire, pottery, for example) and thus probably social affiliations and language, they nonetheless shared the highly specialized metallurgical knowledge of ores, smelting regimes, fabrication methods, and design options. We know nothing about how this information was transmitted from one generation to another or how it was disseminated to other metalworking zone peoples. What is clear is that the level of technical expertise required for smelting the complex ores used to produce the high arsenic copper–arsenic alloys, the specialized knowledge required to produce lost-wax castings, and the expertise required for many other facets of this extraordinary metallurgical tradition can only be compared to those of other highly skilled specialists: for example, individuals in the Maya realm who could write and read hieroglyphic script. Another implication of these findings is that metalworkers in the large and socially diverse west Mexican metalworking zone shared fundamental cosmological precepts regarding the sacred nature and the meaning of this new material.

What makes the West Mexican development of metallurgy so challenging to archaeologists is to determine how we identify the social mechanisms through which this highly specialized technical knowledge was initially transmitted and subsequently transformed by west Mexican peoples for their own social objectives. The larger question, that of documenting "technology transfer" or the introduction of technology by one non-literate ancient people to another, has to be one of the most complex issues an archaeologist can face.

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