Gold and Tribute in Aztec Tlapa: An Ethnohistoric and Experimental Analysis

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Gold and Tribute in Aztec Tlapa:
An Ethnohistoric and Experimental Analysis

by

Esteban José Fernández

B.A., Florida State University, 2009

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Gold and Tribute in Aztec Tlapa: An Ethnohistoric and Experimental Analysis

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The final copy of this thesis has been examined by the signatories, and we find that both the content and the form meet acceptable presentation standards of scholarly work in anthropology
Though highly advanced and of remarkable sociopolitical importance, Mesoamerican metallurgy has been an understudied field. Recently the study of Archaeometallurgy has begun to establish itself within the region, and archaeologists are increasingly using metal artifacts to address a wide variety of inquiries. While this new emphasis on Mesoamerican metallurgy is seen as a welcomed shift, rarely any studies have focused on the production of gold artifacts. The study of goldwork in this region is laden obstacles, which include the lack of well-defined mining sites, as well as the limited amount of artifacts from provenienced contexts. In the face of these obstacles, I propose a multidisciplinary approach that combines ethnohistoric, and experimental evidence in order compensate for the lack of archaeological evidence of gold production. This thesis attempted to recreate and evaluate the efficiency of four metal casting techniques that could have been available to pre-Columbian goldsmiths for the manufacture of gold sheets that were used by the province of Tlapa as part of their tributary payments to the Aztec Empire. Along with assessing the efficiency of these metal-casting techniques, this thesis also analyzed the debris discarded from each of these techniques in order to identify potential archaeological markers of gold production in Mesoamerica.
For my Mother, whose strength never ceases to amaze me
Acknowledgements

This thesis represents the culmination of approximately three years of work. Throughout this process I have been incredibly fortunate to meet people whose advice and support proved to be invaluable. First, I would like to thank Karen Pierce, who took the time to teach me about the basics of metallurgy, and let me use her equipment for the experimental portion of this thesis. There is simply no way I could have completed this project without her.

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Chapter 1

Introduction

“This gold is perfection, the leader of all. It leads all riches on Earth. It is that which is sought, that which is desirable, that which deserves being guarded, that which deserves being stored.”

Bernardino de Sahagún (Anderson and Dibble 2012 V.11:234)

Gold, a precious metal revered by pre-Columbian peoples for its sheen was a major force behind one of the most momentous events in world history: the conquest of the Americas. Elliot (1996:180) estimates that approximately 185,000 kilograms of gold were extracted from the Americas and sent to Spain between the years of 1503 and 1660. With contemporary prices of 24 karat gold averaging $1,550 per ounce, this amount would have exceeded the 10 billion Dollar mark. While the significance of this precious metal in the shaping of the Americas is undeniable, archaeologists continue to have a fragmentary understanding of pre-Columbian goldwork, particularly in the region of Mesoamerica. Recently the study of Archaeometallurgy has begun to establish itself within the region, and archaeologists are increasingly using metal artifacts to address a wide variety of archaeological inquiries (Simmons and Shugar 2013:8). While this new emphasis on the study of Mesoamerican metallurgy is seen as a welcomed shift, the bulk of this research has been aimed at the study of copper mining, smelting and processing (see Hosler 2013:227), and considerably less work has focused on the production of gold artifacts.

The study of goldwork in this region is laden with a multitude of obstacles. These include the lack of well-defined mining sites, as well as the relatively small sample of artifacts from provenienced contexts. Additionally gold in Mesoamerica is
only found in its native state, which prevents archaeologists from identifying production sites through the presence of slag. These constraints have largely shaped the research on Mesoamerican goldwork, most of which has been aimed at the archaeometric analysis of artifacts, and interpretations of the symbolic value that these objects held in antiquity. While these analyses have been helpful in evaluating the composition of some artifacts, there are still numerous gaps of knowledge regarding the production of gold artifacts in Mesoamerica.

This thesis will attempt to deviate from this trend and will use a multidisciplinary approach that combines ethnohistoric, archaeological, and experimental evidence in order develop a more complete understanding of the manufacture of gold artifacts in Late Postclassic period (AD1350-1521) Central Mexico. When reviewing the literature of metallurgy in Mesoamerica, one can note that the lost wax casting method is almost exclusively cited as the casting method of choice for craftsmen in this region. While one cannot refute the popularity of this technique in the casting of metals, its ubiquity in the literature can also be partially attributed to a bias in the types of golden artifacts that have been found, and a reliance on colonial descriptions of this casting method.

In order to explore the possibility of other casting techniques being used by pre-Columbian smiths this thesis will attempt to recreate, and evaluate the efficiency of four casting techniques that could have been available to Aztec craftsmen to fabricate a number of thin gold sheets. According to Gutiérrez et al. (2009:73) these sheets comprised a major portion of the tributary payments made by the Province of Tlapa to the Aztec Empire. These sheets are unlike any other gold artifact found in
Mesoamerica, and their unique nature can give archaeologist an insight into the range of casting techniques employed by pre-Columbian goldsmiths.

The evaluation of each technique’s performance will be based on a combination of their respective labor investments, and an adaptation of Feinman et al.’s (1981:872) production step measure. Additionally, this thesis will also use the debris discarded by these production techniques in order to make inferences about potential archaeological markers of goldworking activities throughout Mesoamerica. One can hope that the analogies drawn from the experimental portion of this study, and from the analysis of archaeologically identifiable debris archaeologists will develop a more complete understanding of metalworking technology of Mesoamerica, and identify more efficient ways to recognize goldworking activities in the archaeological record.

*Metallurgy and Mesoamerica*

In comparison to the rest of the Americas, Mesoamerica was late in developing a metallurgical tradition. Some of the earliest metals have been found in the Andean region of South America, and recent excavations in the Lake Titicaca Basin have uncovered a set of nine gold beads that date between 2155-1936 BC, making them the oldest golden artifacts in the Americas (*Figure 1.1*) (Aldenderfer et al. 2008:5004). The diffusion of metallurgy spread from the Andean region throughout the rest of South America, and by the seventh century BC archaeologists have identified evidence of metalworking in Colombia (Habashi 2008:92). This technological tradition continued to spread, and by AD 500 gold began to replace Jade as the most valued status good in some regions of Costa Rica and Panama (Quilter 2003:8).
Metallurgy did not reach Mesoamerica until approximately AD 650 (Simmons and Shugar 2013:2). Unlike the distribution of other artifacts, it has been somewhat difficult to pinpoint a single point of introduction, which has led some archaeologists such as Pendergast (1962:534) to argue that this technology may have been introduced to various places at the same time. Simmons and Shugar (2013:4) and Hosler (1994:28) have proposed that there is a distinct Southeastern Mesoamerican metalworking tradition that extends through Chiapas, Belize, Guatemala, and Honduras (Figure 1.2). However, much more research is necessary to understand the nature of this tradition.

Along with this proposed Southeastern tradition, Hosler (1988:832 et passim, 1994:16 et passim, 2009:187 et passim) has also argued that a second metallurgical tradition was introduced into what she has denominated as the West Mexican Metalworking Zone. Including the Mexican states of Michoacán, Guerrero, Jalisco,
Sinaloa, and Nayarit, this region shows the most evidence of being the major entry point and hub of most metallurgical developments in Mesoamerica. These early metal artifacts were found in both domestic and ritual contexts and were mainly composed of breastplates, diadems, pendants, tweezers, awls, and bells. The latter appear to have been overwhelmingly favored, and an approximate 60% of all metal artifacts found in this region consist of copper bells (Hosler 1994:42 et passim.). These artifacts were crafted using the lost wax casting method, and cold hammering. Along with these techniques, early metalsmiths also had knowledge of embossing, soldering, annealing, and gilding (Easby 1956:403 et passim).

![Figure 1.2 Map of West Mexican Metalworking Zone and proposed Southeastern Metalworking Zone](image-url)
Given the chronological track of the development of metals, as well as many stylistic and technical similarities, archaeologists have largely agreed that metallurgy was introduced to Mesoamerica from Central and South America (Meighan 1969: 11 et passim; Pendergast 1962: 534). Nevertheless, the exact process by which this new technology was introduced has been a point of contention. Hosler (2009: 188) has widely suggested that knowledge of metalworking techniques, along with a number of prototypes, were introduced by Ecuadorian sea voyagers who were sailing up the Pacific coast and exchanging metal artifacts for Spondylus shells. Her comparative analyses of Andean and Mesoamerican copper artifacts indicate that those objects from the West Mexican Metalworking Zone are almost identical in design parameters and production techniques to South American artifacts.

Furthermore, Dewan and Hosler’s (2008: 19 et passim) engineering analyses and mathematical simulations of balsa wood rafts found in Ecuador have indicated that these vessels could have successfully travelled between coastal Ecuador and the western Mexican coast. This journey would have taken approximately six to eight weeks to complete, and the seafaring traders would have been forced to remain in Mexico for approximately six months until climactic conditions were favorable for their return (Dewan and Hosler 2008: 36; Hosler 2009: 188). Along with the similarities in artifacts, and mathematical simulations, ethnohistoric sources have also reinforced this notion. In a 1525 document written in Zacatula, Mexico the royal accountant Rodrigo de Albornóz describes indigenous accounts from western Mexico of Indians who arrived by boat from certain lands to the south and exchanged their
exquisite goods for locally made products. These merchants then remained in Mexico for several months until the weather was adequate for their return (West 1961:133).

At approximately AD 1200 there was fluorescence in metallurgical developments in the West Mexican Metalworking Zone, as well as a widespread dissemination of metal artifacts throughout Mesoamerica. Despite continuing to craft similar artifact types, Mesoamerican metalsmiths began experimenting with a number of alloys including copper/tin, copper/arsenic, copper/gold, and copper/silver/gold (Hosler 1988:843). These alloys allowed for a greater variety of colors in metal artifacts, and a preference for golden and silver tones appears to have developed. Aside from this preference for silver and golden tones, the advancements of alloying technology in Mesoamerica surely were also linked with an improvement in the malleability and durability of metals. Some have even interpreted the improvement on metalworking techniques as a religious service that was done by craft specialists (Salas et al. 2006:45). Along with this expansion in alloying technology, a few artifact types such as axe-monies were introduced (Appendix A). Axe-monies appear to have served as standardized units of payment, not just for provincial tribute, but also for everyday market exchanges (Easby et al. 1967:107 et passim; Hosler et al. 1990:39 et passim).

Whereas copper appears to have been the metal of preference within the West Mexican Metalworking Zone, the southern portions of Guerrero and much of Oaxaca had a higher affinity for gold. In fact, the latter state boasts approximately 80% of all gold artifacts found within Mesoamerica (Ruvulcaba et al. 2000’s:7). Rivaling this high concentration of golden artifacts is a ritual cache of excavated from the Cenote
Sagrado in Chichén Itzá that included zoomorphic figurines, bells, gilded copper plates and pendants. Though found in Mesoamerica, these artifacts do not conform to the style and production technique of other artifacts from this region. Rather, they seem to correspond to the golden artifacts from the regions of Diquis and Veraguas of Costa Rica and Panama (Ruvulcaba et al. ca. 2000’s:4; Cooke et al. 2003:111). Moreover, analyses on the gilded copper plates recovered from the Cenote Sagrado indicate that they were gilded by an electrochemical replacement plating process consistent with the metalworking techniques of the Andean region (Lechtman et al. 1982:17).

Within the Basin of Mexico, the bulk of the gold artifacts recovered have originated from the Templo Mayor excavations (Matos Moctezuma and Solis 2003:447 et passim). Since there are no known gold sources in the Basin of Mexico, both the raw material and artifacts had to be imported (Emmerich 1965:148). The goldsmiths of the Mixteca region were highly revered by the Aztec, and together with raw materials, it seems that these goldsmiths were also brought into the Aztec heartland to work as craft specialists (Easby 1956:402).

Given the intricacies of metallurgical techniques, it is impossible to examine Mesoamerican metallurgy without first considering craft specialization. Costin (1991:4) defines specialization as the “differentiated, regularized, permanent, and perhaps institutionalized production system in which producers depend on extra-household exchange relationships at least in part for their livelihood and consumers depend on them for acquisition of goods they don’t produce themselves”. There has been widespread discussion of ways to qualify the degree of specialization and many
archaeologists have applied a dichotomy of independent versus attached specialists. (Costin1991:4 et passim; Costin and Hagstrum 1995:620; D’altroy and Earle 1985:188). Independent specialists produce goods or services for an unspecified demand crowd that may vary according to socioeconomic or political conditions. Attached specialists, on the other hand, provide services to a patron, oftentimes an elite individual or the state itself (Brumfiel and Earle 1987:2 et passim).

Seeing this bipartite distinction as one-dimensional, Costin (1991:3 et passim) uses the four variables of context, concentration, scale, and intensity in order to create a continuum of degrees of specialization that range from autonomous individual specialists to full time retainer workshops sponsored by an elite or governing institution. Similarly, Hassig (1985:117 et passim) has suggested that there is a semi dependent class of specialization in which independent producers rely on the distribution networks that were likely controlled by the ruling class. In the case of the Aztec these distribution networks appear to have been managed by elites and the pochteca, a group of powerful long distance traders who specialized on the long distance exchange of sumptuous goods. Hassig’s model is particularly attractive for the distribution of metalworkers in Mesoamerica, where both ethnohistoric and archaeological evidence shows extensive trade networks where some of the raw materials needed by metallurgists were exchanged with varying degrees of state influence (Smith and Berdan 2000:284 et passim, 2009:7 et passim).

Despite recent developments in the identification of metal-producing sites in Mesoamerica (See Roskamp and Rétiz 2013; Maldonado2013; Maldonado and Rehren 2009 Urban et al. 2013; Paris 2008) the evidence of workshops associated
with the production of metal artifacts in Mesoamerica is sparse. Maldonado et al. (2009:227 et passim) points to the possibility that the crafting of some metal products could have taken place at a household level. According to this model the production of metals was naturally dispersed throughout the Tarascan territory. While mines were exploited through the tribute system, some of the production of metals could have taken place at the household level, or in dispersed workshops. In a manner similar to the way in which Aztec women produced textiles in their households (see Brumfiel 1991), Maldonado et al. (2009:209 et passim) suggest that metal production could have taken place at the household level or in dispersed workshops for tributary demands. This notion is supported by the finding of two crucibles in two households at the site of Mayapan (Paris 2008:50). These crucibles consisted of tecomates, each made out of local ceramic types: Navula Unslipped and Mama Red. Both of these artifacts had solidified metal drippings along the walls, casting sprues, and a portion of a bell along the bottom. This dispersed production of metals for tributary demands is an attractive alternative to rigid dichotomies of attached vs. independent production, and will be discussed in later portions of this thesis.

**Geographic and Cultural Setting of the Province of Tlapa**

The province of Tlapa lies in what is now the Mexican state of Guerrero (Figure 1.3). The topography is highly variable and the elevations in this province can range somewhere between sea level up to almost 10,000 feet above sea level. Due to these marked changes in elevation, Tlapa can be divided into three main regions according to the Köppen climate classification: two very similar tropical regions that can experience summer showers and the temperature ranges between 22°Celsius and
18°Celsius, and one temperate area of intermediate humidity where the annual temperature can range between 18°Celsius and 3°Celsius. The annual rainfall in this state lies between 1000 and 2000 millimeters annually, and the vegetation can vary between tropical deciduous forest, oak forests, and oak and pine forests (Gutiérrez 2010:18).

Figure 1.3. Map of the Aztec Empire with Tlapa being shaded in gray (Modified from Berdan and Anawalt 1992 V.2:85)

The archaeological evidence in the territory that encompasses the province of Tlapa dates back to the Late Archaic Period (3500-2000BC) (Gutiérrez 2010:12 et passim). However, there is a markedly disparate relationship between the archaeological richness of this area and the startlingly small amount of research that has been done there (Gutiérrez et al. 2011:15). For over a decade research by Gerardo
Gutiérrez has begun to remedy this lack of research in the region, and he has
identified Olmec influences, some type of Teotihuacano presence in the area, as well
as the development of a myriad of local polities (Gutiérrez and Pye 2010:27 et
passim). Perhaps the most successful of these polities was the kingdom of Tlapa-
Tlachinollan. Headed by the city of Tlapa, it became the largest and most prominent
polity in the region from the mid-1300s to 1486 (Gutiérrez 2002:4 et passim). It is
estimated that at its apex of political expansion Tlapa may have controlled a
population of approximately 80,000 people distributed over an area of 6,000 square
kilometers (Gutiérrez 2010:14). It was not until Ahuizotl’s conquest in 1486, that
Tlapa and its subjugated polities were annexed into the Aztec Empire as the province
of Tlapa (Gutiérrez 2002:4).

*Ethnohistory*

When comparing the amounts of documentary evidence to the archaeological
research aimed at the Aztec Empire, it is clear that the archaeology is vastly
overshadowed by the documents. The continuous expansion of Mexico City has
limited the amount of excavations that archaeologists can do in the Aztec capital of
Tenochtitlan, and pushed much of the research to other smaller sites throughout the
edges of the empire. Nevertheless, early colonial administrative records, and other
documents aimed to inform the Spanish Crown about the indigenous poulation of
Mexico such as the *Florentine Codex* and the *Codex Mendoza* have helped
counterbalance the fragmented archaeological information. This documentary wealth
has allowed for the widespread application of ethnohistory to Aztec society.
Ethnohistory merges history and anthropology and is defined as “the use of historical and ethnological methods and materials to gain knowledge of the nature and causes of change in a culture defined by ethnological concepts and categories” (Axtell 1979:2). The methodology uses a number of media such as material culture, native texts, oral stories, place names, and paintings in order to present the effects of the interaction between two cultures rather than the one sided story of the inevitable triumph of the Western world (Harkin 2010:116). This thesis has embraced this methodology and much of the interpretations that will be presented henceforth will be largely based on Mesoamerican ethnohistoric record.

Compiled by Friar Bernardino de Sahagún between the years of 1547 and 1562 the General History of the Things of New Spain or the Florentine Codex is a compilation of 12 books that document a multitude of aspects of Aztec culture, ranging from their cosmology, to economics, to even natural history. Rather than a single integrated work, the Florentine Codex can be divided into three major parts: a Nahuatl encyclopedia, a picture manuscript, and a Spanish ethnography (Edmonson 1974:8). Most relevant to this study are chapters 15 and 16 of the 9th book in which Sahagún describes some of the techniques used by Aztec craftsmen to manufacture gold artifacts. In chapter 15, Sahagún describes a division of labor between metallurgists in which some craftsmen specialized in the hammering and polishing of gold artifacts, while the others cast artifacts.

Unfortunately Sahagún does not expand on the role of the smiths in this chapter. Instead he describes the festival during the month of Tlacaxipeualiztli in which the patron god of goldsmiths, Xipe Totec, was celebrated through a number of ritual
sacrifices and parades (Anderson and Dibble 2012 V.9:69). Commonly depicted as wearing the flayed skin of a sacrificial victim, this deity was associated with fertility and regeneration. Gold’s yellow tone was seen as the color of the earth before the rainy season, which creates the nexus between gold, Xipe Totec, and renewal (Falchetti 2003:356). While chapter 15 is predominantly a description of this religious celebration, chapter 16 consists of a detailed technical description of the entire lost wax casting process starting with the mixing of charcoal and clay for the inner mold to the polishing of the final product with a blend of minerals the Aztec referred to as gold medicine (See Easby 1955 for a detailed step by step description of this process).

Lastly, the *Tribute Record of Tlapa* is the combination of the *Codex Azoyú 2-Reverse* and the *Codex Humboldt Fragment 1* (Gutiérrez 2013:144). When the two latter documents are combined, they depict the political history and tributary obligations of the Aztec province of Tlapa. During the 36-year period illustrated *Tribute Record of Tlapa* it appears that gold comprised a major portion of this province’s tributary obligations (Gutiérrez et al. 2009:73 ). Gold was paid in two major forms: gourds of gold dust and thinly hammered sheets of gold.

Pictographically depicted by long rectangles these sheets measured 62.5 centimeters long, seven centimeters wide, and had the approximate thickness of one and a half millimeters (Gutiérrez et al. 2009:75).

Along with these rectangles, this document also illustrates triangles and squares (*Figure* 1.4). Gutiérrez et al. (2009:76) suggest that triangles are used to represent half of a gold tributary sheet. According to them, drawing a rectangle that is half as
large as the full tablet would be problematic for the reader once the scale of the images changes when the scribe attempts to fit more articles in a cell. Tributary obligations steadily rose and it would have been difficult to distinguish between half of a table and one that was drawn to a smaller scale. As for the squares, they have been interpreted as representing one fifth of a complete tributary sheet. In the *Tribute Record of Tlapa* whenever five squares were represented, they were linked by a solid line. This is likely associated with the Mesoamerican system of writing numerals in which bars were used to describe units of five and dots units of one (Gutiérrez et al. 2009:80). Individually, the pieces represented by the squares in this document would have measured 12.5 centimeters in length, by seven centimeters in width, and had the same thickness of one and a half millimeters (Gutiérrez et al. 2009:80). Due to their smaller size, it is these squares that this actualistic study will attempt to manufacture.
Figure 1.4. Folio 22 from the facsimile of the *Tribute Record of Tlapa* showing the three sizes of tributary sheets and gourds of gold dust (Gutiérrez et al. 2009).

*Structure of the Thesis*

Five chapters follow this introduction. Chapter 2 will review some of the principal variables that helped dictate the kinds and amounts of goods that provinces were forced to pay to the Aztec Empire, and briefly compare the tributary payments of the eight provinces whose tributary obligations included gold items. Chapter 3
consists of an evaluation of the ways in which pre-Columbian smiths manufactured gold artifacts in Mesoamerica, the Intermediate Area, and the Andean region. The fragmentary understanding of pre-Columbian goldwork necessitates the creation of analogies from each of these regions in order to paint a more complete picture of the ways in which gold artifacts were produced.

Chapter 4 will introduce the materials and methods that I will use in order to assess the efficacy of four production methods available to Aztec goldsmiths for the manufacture of the tributary gold sheets. After a brief discussion on the use of experimental archaeology to construct analogues about the past, I will note the ways in which efficacy will be evaluated in this study. The following section will describe materials used for these replicative exercises. Subsequently, I will detail all of the steps taken in the recreation of each of the four methods assessed.

The data gathered from the previous chapter will be analyzed in Chapter 5. After a short introduction, this chapter will discuss the length of these replicative exercises, as well as the amounts of charcoal necessary to successfully complete them. The following section will discuss the results of each of the techniques assessed at length, and make considerations about the efficiency and the archaeological footprints of each of the methods assessed. This method will end with a discussion regarding the viability of each of the techniques examined. Also, considerations are taken regarding the nature of the manufacture of tributary sheets in the province of Tlapa.

Chapter 6 will synthesize the information presented in this thesis. Each of the methods assessed in it will be discussed, as well as the methodological contributions
of this thesis. Additionally, this chapter will also make suggestions about potential avenues of research for the future, particularly the addition of more experimental projects aimed at understanding pre-Columbian metalworking techniques, and suggestions of sites that have the largest probabilities of producing evidence for metalworking.
Chapter 2

Tribute and Gold in the Aztec Empire

Since the gold sheets analyzed in this theses were a significant portion of Tlapa’s tributary payments (see Gutiérrez 2013), it is imperative to review some of the major features of Aztec tributary obligations. Additionally, Tlapa was only one of eight provinces whose tributary obligations included gold. In order to have a more thorough insight on the relationship between gold and tribute the second portion of this chapter will provide a brief comparison of the amounts and types of gold artifacts each of these provinces was forced to tribute.

Aztec Tribute and Imperial Strategies

The collection of tribute is a long-standing practice in Mesoamerica and it refers to the revenue collected by a militarily dominant state from its conquered regions (Berdan 1992 V.1:55). Not all tribute was exacted equally and the amounts and kinds of goods paid as tribute were the result of the interaction between numerous variables. The combination of the time of conquest and the distance from the capital are some of the factors that helped determined the extent of tributary demands. When analyzing the quantities and types of commodities that were collected as tribute it is apparent that those provinces around the imperial core provided a higher quantity of foodstuffs, while those located on the outskirts of the empire tended to tribute luxury goods (Hassig 1985:108). This pattern is likely attributed to the difficulties of transporting vast amounts of staple goods through long distances, and the accessibility of those provinces on the periphery of the empire to exotic goods. In a similar vein, the availability of certain goods in a region would have only partly
dictated some of the tributary obligations. In some cases provinces were forced to
tribute goods that were not available locally. Such was the case for many provinces
whose obligations included textiles and warrior suits, yet the cotton and feathers to
craft them had to be imported from distant regions (Berdan 1996:125 et passim).

Together with the availability of materials and the time of conquest, another
variable in the tributary requirements was local resistance. Oftentimes those
provinces that did not resist their inclusion into the empire were given lesser tributary
obligations. Conversely, those who resisted and/or rebelled were punished with
extensive obligations (Gutiérrez 2013:148 et passim). This was the case with the
province of Cuetlaxtlan, who under the influence of Tlaxcalan elites refused the
Aztec request for marine goods. As a result the Aztec sent troops to reconquer the
province and dramatically raised tributary demands (Berdan and Anawalt 1992
V.2:122).

Gutiérrez’s (2013:142 et passim) analysis of Aztec tributary patterns indicates
that rather than a fixed system, Aztec tribute was highly dynamic and flexible.
Shortly after being conquered by the Aztec, polities engaged in surrendering
ceremonies in which the losoing parties would accept the Aztec tribal deity as
supreme and agreed to pay tribute to their new overlords (Gutiérrez 2013:148). A
combination of local rulers, local tribute collectors (calpixque), and imperial

*calpixque* would then negotiate the amounts of goods to be collected (Gutiérrez
2013:148). It appears that, when necessary, the quantities of certain commodities
could have been exchanged for their equivalencies in others, which would have likely
proven beneficial for market systems (Gutiérrez 2013:163).
Throughout the 93 year period following the Tepanec War and formation of the Triple Alliance, there was a general increase in goods required as tribute. This increase is likely concomitant to population rises within the Basin of Mexico, and the growing requirements of the Aztec state and its burgeoning elite class. One can also associate this growth in the Aztec elite class with the upsurge in exotic raw materials and other sumptuous goods that were demanded by the state (Berdan 1996:124 et passim).

Along with textiles, foodstuffs, raw materials, sumptuous goods and warrior suits tributary obligations also included a rotation of communal labor (coatequitl). These services included activities such as participating in construction projects, providing maintenance to public structures, or even amassing warriors for military campaigns. Divided among individual calpolli within an altepetl these duties have been interpreted as being the lifeline of the empire as whole (Lockhart 1992:14 et passim). For some polities such as the Otomi and Matlazinca who bordered the Tarrascan Empire, their tributary obligations mainly consisted of military actions against their hostile neighbors (Pollard and Smith 2003:89). Along with the military engagements with enemy states, these border polities also provided indirect aide such as constructing garrisons, and providing some necessary supplies for Mexica armies (Smith 1996:137 et passim).

Another approach that was attractive for those provinces located among contested borders was the use of gift giving as a euphemism for tribute (Smith
This tactic attempted to soften the relationship between the empire and those altepeme located in locations as strategic as the borders of enemy polities. In some cases these gifts were given in regular intervals. Additionally these were also given during special occasions such as the crowning of a tlatoani, or the funeral of elite individuals (Townsend 2000:24).

**Gold-Tributing Aztec Provinces**

Though this thesis is focused on the gold items from the province of Tlapa, according to the *Codex Mendoza*, there were also seven other provinces that were required to include gold as part of their tributary payments (Figure 2.1). These payments were made in three ways: gourds of gold dust, semi-prepared materials, and jewelry. The gourds were said to contain two almozadas of gold dust. According to the *Diccionario de Autoridades* (2002:236) that is the measurement of a non-liquid loose material that can fit into two hands cupped together with the palms facing up. The semi-prepared materials refer to those items that required some crafting, yet cannot be described as items of self-adornment such as jewelry. These came in two kinds: disks and the aforementioned rectangular tributary sheets. While the dimensions of the latter were described by Gutiérrez et al. (2009:75 et passim), the disks were described as being the size of a Host served during Catholic mass, and having the thickness of a finger (Berdan and Anawalt 1992 V.4:84). Unfortunately this text does not provide a more complete description of these disks.
One of the eight provinces whose tributary payments included gold was Coayxtlahuacan. Following its initial conquests this polity allegedly assassinated 160 pochteca traders as an act of defiance against Aztec authority. Soon after hearing about this massacre, Moctezuma Ilhuicamina dispatched a number of warriors to reconquer the town in retaliation for those killings (Berdan and Anawalt 1992 V.2:102). Following the reconquest of this polity, hefty tributary obligations were placed upon them. Along with a variety of warrior costumes, Coayxtlahuacan was also required to pay some exotic goods such as hundreds of handfuls of quetzal feathers, bags of cochineal pigments, and twenty gourds of gold dust annually (Figure 2.2).
Located in the Mixteca Alta, the province of Tlachquiavco appears to be the last province conquered by the Aztec armies (Berdan and Anawalt 1992V.2:110). It has been interpreted as being a major trading center, thus making it a very attractive addition to the empire. Similar to Coayxtlahuacan, the province of Tlachquiavco’s tributary obligations included hundreds of handful of quetzal feathers, bags of cochineal dye, and twenty gourds full of gold dust (Figure 2.3) (Berdan and Anawalt 1992V.2:110).
To the west of the province of Tlachquiavco and encompassed by the modern day state of Guerrero is the province of Tlapa. It was headed by the kingdom of Tlapa Tlachinollan, which was conquered by Ahuizotl in 1486. It took several decades of fighting between Mexica and Tlapanec armies, partly due to the mountainous terrain and the numerous fortified hilltop sites that are distributed throughout the province (Gutiérrez 2002). According to the Codex Mendoza, this province was obliged to pay ten golden sheets and twenty gourds of gold dust annually to the Aztec empire (Figure 2.4).
When comparing this section of the *Codex Mendoza* to the *Tribute Record of Tlapa*, a local tributary document depicting 36 years of tributary payments to the Aztec, one can note discrepancies between the amounts of gold that had to be paid yearly (Gutiérrez et al. 2009: 103 et passim; Gutiérrez 2013:142 et passim). The divergences between both tributary documents may be rooted in the fact that the *Codex Mendoza* provides a static picture of a very dynamic Aztec tributary system.
(Gutiérrez et al. 2009:103 et passim). According to the *Tribute Record of Tlapa*
payments took place four times per year during the festivals of *Etzaqualiztli*,
*Ochpaniztli*, *Panquetzliztli*, and *Tlacaxipehualiztli*, and created a cyclical pattern of
tributary payments that alternated between 100 day and 80 day periods (Gutiérrez et

Bordering the northwest of the province of Tlapa, Yoaltepec’s tributary
obligations also included gold. This province was located in the Mixteca Baja, and
was the only province recorded in the *Codex Mendoza* to have occupied this region
(Berdan and Anawalt 1992 V.2:92). Instead of the rectangular sheets paid by Tlapa,
Yoaltepec’s gold tribute came in the form of gold disks. Annually, the Aztec required
a payment of 40 disks (Figure 2.5) (Berdan and Anawalt 1992 V.4:85).

![Figure 2.5. Tributary obligations of Yoaltepec with gold items highlighted (Modified from Berdan and Anawalt 1992 V.4:85)](image)

Located in and around the Valley of Oaxaca and bordering the kingdom of
Tututepec is the province of Coyolapan. While Coyolapan was the head town of this
tributary province, it seems that the administration and tribute collection took place in the town of Huaxcac, where the Aztec built a garrison. Besides protecting tribute, this garrison also likely assured the safety of merchants likely traveling to Central America for luxury goods (Berdan and Anawalt 1992 V.2:107). Like Yoaltepec, this province also paid their gold tribute in disk form and annually they had to pay a total of 20 disks (Figure 2.6) Berdan and Anawalt 1992 V.4:93)
Alongside these provinces whose tribute included gold in raw material and semi-prepared form, there were three other provinces that were crafting artifacts out of gold and paying in the form of finished products. The province of Tochtepec was located along the major riverine systems that flow into the Gulf of Mexico. This location diversified their available resources via effective trade routes, was a plentiful source of fish and gold. The latter was most commonly found along the southwestern edge of the province, which bordered with Coayxtlahuacan and an unconquered Chinantec territory. Among the substantial demands that were exacted annually there was a gold diadem, one gold headband, a necklace of gold beads, and another necklace of gold beads and bells (Figure 2.7) (Berdan and Anawalt 1992 V.2:112). Furthermore, their tributary obligations included twenty lip plugs of clear amber and gold decorations, and twenty lip plugs of crystals set in gold. The headband was specified to be the width of a hand and as thick as a piece of parchment, while the beads on necklace were described as oblong and larger than those necklaces made out of other materials (Berdan and Anawalt 1992 V.2:114).

To the north of Tochtepec is the province of Cuetlaxtlan, which lies in the coastal lowlands of the Gulf of Mexico. This province proved to be quite unruly and led a number of rebellions under the influence of Tlaxcallan elites. These rebellious acts resulted in their extensive tributary obligations, which mark a stark contrast to the province’s small size (Berdan and Anawalt 1992 V.2:123). Together with numerous textiles, feathers and loads of cacao, they were also obliged to pay 20 lip
plugs of crystal set in gold, and 20 of amber set in gold in similar form as those from Tochtepec (Figure 2.8) (Berdan and Anawalt 1992 V.2:122).

Figure 2.7. Tributary obligations of Tochtepec with gold items highlighted (Modified from Berdan and Anawalt 1992 V.4:97).
Lastly, the distant province of Xoconochco also was required to pay for gold jewelry as part of their annual tribute. Their obligations consisted of just two amber lip plugs set in gold. When compared to the other provinces, the tribute from this province is mainly composed of luxuries such as jadeite, quetzal feathers, jaguar skins, and cacao (Figure 2.9). Their location in the southern portion of the modern state of Chiapas made this province a successful trade center with those centers.
throughout Guatemala and the rest of Central America. According to some documentary sources, local attacks on pochteca traders had prompted the conquest of Xoconochco. However it is likely that these attacks may have been a pretense, and the true reason for the Aztec conquest was more related to the region’s valuable products (Gasco 2003:287). Aside from the large availability of luxuries, the role of Xoconochco as an important trade center is also reflected in the presence of gold jewelry in their tributary obligations (Berdan and Anawalt 1992 V.2:116).

Figure 2.9. Tributary obligations of Xoconochco with gold items highlighted (Modified from Berdan and Anawalt 1992 V.4:99)
Summary

The Aztec tributary was characterized by its dynamic nature and flexibility in the way that commodities were chosen by imperial and local officials. Variables such as the province’s distance from the Basin of Mexico, time of the conquest, availability of goods, and local resistance helped dictate the kinds and amounts of goods that each province was forced to pay to the empire. Moreover, evidence suggests that individual provinces were able to negotiate these payments and pay replace some items for their equivalencies in other commodities. In regards to gold, Tlapa was one of eight other provinces whose obligations included this precious metal. While five of these provinces made these payments with raw and semi-prepared materials, three other ones paid with gold jewelry. The next chapter will review some of the major techniques by which these items were manufactured in Mesoamerica.
Chapter 3

Gold Production Through the Americas

This chapter will provide the necessary background for understanding the most important facets of the manufacture of gold artifacts through Mesoamerica, the Intermediate Area, and the Andes. As it was mentioned in Chapter 1, the metallurgical techniques of the Andean region appear to have influenced the other two regions. Additionally, due to the paucity of archaeological evidence of goldwork in Mesoamerica this thesis will draw analogies from the Intermediate Area and the Andes, thus it is essential to recognize how each of these individual regions adapted this technical knowledge prior to delving into the experimental portion of this thesis. This chapter will review the major production techniques of these three regions by using a combination of archaeological and ethnohistoric evidence.

Production Techniques

The indigenous peoples of the Americas had a wide repertoire of techniques by which they crafted artifacts of gold (Figure 3.1). While there is a degree of variability in the preferences that goldsmiths had in each of the three different regions, there are also major areas of overlap. Throughout these regions, native metalsmiths built upon techniques such as hammering and developed numerous alloys, and methods to cast gold artifacts. These methodological developments in the production of golden artifacts depend on much more than the availability of metals in a region. These advances are also tied to a stable social structure where surplus production can be used to support specialized craftsmen and complementary developments in ceramics in order to create molds, furnaces, crucibles necessary for the smelting of metals (Lechtman 1976:1).
Figure 3.1. Gold pieces from three regions surveyed: a) zoomorphic lip plug with bells from Mesoamerica (Ruvulcaba et al. ca. 2000s:20), b) anthropomorphic figurine from Costa Rica (Quilter 2000:188), c) Gold diadem, ear-spools, shoulder straps and pectoral from Peru (O’Day 2000:63).

The roots of the development of alloying techniques are still subject to some debate. Nonetheless, it is likely that the first alloys were discovered accidentally by using the same crucible for smelting various materials (Daumas 1969:405). Though the alloys found throughout the Americas were highly variable, and somewhat dependent on the purity of the source where the gold was acquired, on average they contained a significantly higher amount of copper than gold alloys from other parts of the world. While copper traces can go up to five percent in classic Greece, some gold-copper alloys from the Americas had up to 60 percent copper (La Niece and Meeks 2000:221). Throughout all regions, metalworkers differed in cultural and social affiliation as well as language. However, they managed to share the highly specialized metallurgical knowledge of ores, smelting regimes, fabrication methods, and designs (Hossler 2009:209).
As it was previously mentioned, some of the earliest known, and most frequently found metal artifacts in Mesoamerica were bells made by using the lost wax casting method. Ethnohistoric evidence suggests that Mesoamerican goldsmiths were using small kilns and blowpipes for the casting of gold artifacts, which is likely one of the reasons why metal production has proven to be so elusive for the Mesoamerican archaeological record (Figure 3.2). In his 1517 account of pre-Columbian goldwork along the Gulf Coast Father Juan Díaz wrote “These indians melted [gold] in a vessel wherever the found it and for bellows the used cane tubes, with which they lighted the fire. We saw it done this way in our presence” (De Fuentes 1963:12). A comparable image was also drawn in the Codex Mendoza where a goldsmith is depicted teaching his son his craft as he uses a blowpipe to raise the temperature of the coals on a tripod kiln with a metal object resting on the coals (Berdan and Anawalt 1992:). Lastly the Florentine Codex also illustrates several images of goldsmiths working on these small portable kilns.

The alloys that were cast by Mesoamerican smiths varied by region, though they generally were composed of 60 to 85 percent gold, up to 20 percent silver, and between 10 to 40 percent copper (Ruvulcaba et al. ca. 2000’s:12). Sahagún describes the last step in the lost wax casting process as the treatment of the final piece with a pebble and a combination of salts and sulfur that the Aztec referred to as gold medicine to maximize its sheen. Lechtman (1979:155 et passim) suggests that those minerals were strongly corrosive and Aztec smiths were using the technique of depletion gilding, or *mise en couleur*, to remove the base metal from the surface of a gold alloy object, thus giving the finished appearance of high purity of gold. Depletion gilding has been documented ethnohistorically and through archaeometric analyses of gold artifacts from the Intermediate Area and the Andes. Depending on the mineral deposit, placer gold can come with medium to high amounts of silver. Due to these high traces of silver, pre-Columbian smiths required depletion gilding to achieve the vibrant golden tones that marveled European explorers (La Niece and Meeks 2000:221 et passim).

Despite their clear Spanish influences, such the use of Spanish styled ovens and casting of European looking artifacts (Figure 3.3), the *Florentine Codex* has some of the most comprehensive pictographic depictions of the manufacture of gold artifacts in Mesoamerica. Chapter 16 of Book 9 illustrates each of the steps taken by artisans to produce an artifact by using the lost wax casting method (Figure 3.4). In a similar vein, an image found in Chapter 9 of Book 11 depicts a somewhat stylized image of a metalsmith casting an axe (Figure 3.5). Though, this image appears to have some inaccuracies such as the lack of a crucible during the melting and pouring process one cannot argue that it depicts the use of an open mold for the manufacture of an axe.
Figure 3.3. European styled gold artifacts depicted in the *Florentine Codex* (Anderson and Dibble 2012:59)
Recent evidence from the site of Utatlán in Guatemala is highly indicative that Mesoamerican metalsmiths were using some type of molds. Excavations by Weeks (2013:119) recovered fragments of what appear to have been open molds used for the casting of ingots. These molds were carved out of volcanic pumice, and when whole would have measured 72 millimeters long, 29 millimeters wide, and 35 millimeters high (Weeks 2013:120). Though these molds appear to have been used for...
the casting of copper, they suggest that Mesoamerican metalsmiths used a greater variety of casting techniques than previously discussed.

Figure 3.5. Stylized image of a goldsmith using an open mold to cast an axe (Anderson and Dibble 2012 V.11:796).

Another way that Mesoamerican goldsmiths crafted their goods was through the process of hammering. First gold was cast into ingots and then hammered into thin sheets. Once the surface was even, it was burnished with a stone and designs were drawn with particular stones that left a black trace. These designs were then cut with a flint knife (Anderson and Dibble 2012 V.9:76). Once the sheet was cut into the appropriate shape, the craftsman could use a hammer and stamp it in order to decorate it with a design in low relief, through a technique also known as repoussé (Figure 3.6). An advantage of this method is the quickness by which smiths could produce a large number of thin metal objects with the same designs. In order to create these hammered goods, Mesoamerican goldsmiths needed a degree of knowledge in annealing techniques to prevent the sheets from cracking as they were hammered into shape (Daumas 1969:406). During the hammering process the particles of the metal piece being hammered align and harden the metal. The annealing process consists of reheating the metal in order to allow its particles
to take their original form, thus making the metal malleable again (McCreight 1986:110; Emmerich 1965:158).

![Figure 3.6](image)

**Figure 3.6.** Goldsmith applying a *repoussé* on a gold disk (Anderson and Dibble 2012:54).

There are abundant similarities between the goldworking techniques of Mesoamerican craftsmen, and those in the Intermediate Area. Looting operations have proven to be a major issue with the archaeological analyses of golden artifacts in this region, and despite the abundance of artifacts displayed in museums and other private collections, only one archeological site has yielded a significant amount of gold artifacts. This rare site is Sitio Conte in Panama, and approximately 1,149 gold artifacts have been recovered from it. These artifacts include figurines, pieces of jewelry, and amorphous metal clusters that have been interpreted to be ingots (Cooke et al. 2003:106 et passim). Among the most popular gold artifacts in these region are anthropomorphic and zoomorphic figurines (**Figure 3.7**), and other pieces with spiral ornaments (Ibarra 2003:389 et passim).
Metalsmiths in the Intermediate Area had a propensity of alloying copper and gold in order to create *tumbaga*, a gold and copper alloy. In spite of the frequent references to *tumbaga* in the ethnohistoric records, its specific composition was never described, and it could have ranged from having as much as 90 percent gold, to being composed of 85 percent copper (Ferrero 2000:261 La Niece and Meeks 2000:234 et passim). The addition of copper into the alloy both strengthened the artifact as well as lowered its melting temperature to 800° Celsius (Habashi 2008:96). *Tumbaga* artifacts were so common throughout this region that the gold producing portions of southern Costa Rica and northern Panama has been referred to as the *Tumbaga* isthmus (Ibarra 2003:385).

The peoples of this region developed a highly advanced technique of depletion gilding in which the finished alloyed artifact was heated in an open hearth until becoming oxidized. Subsequently, this artifact was dipped in a highly acid solution made out of a combination of plants and minerals (La Niece and Meeks 2000:234). Many of the plants identified as key components to this solution are part of the *Oxiladaceae* family (Petersen...
2010 57.; Habashi 2008:96). Fernandez de Oviedo (1996:253) described his awe at this process when he wrote:

“They know very well how to gild copper pieces that have a low gold content; they do this and it vies and excellent color that looks as if the whole piece is of 22 karats or more gold. This color is done with certain plants that none of the expert Spanish, Italian, or any other metalsmiths have; one could become very rich with this secret method of gilding.”

In addition to widespread copper alloying and gilding, the Intermediate Area also shared the techniques of hammering, soldering and lost wax casting (LaNiece and Meeks 2001:231). One of the most remarkable advancements achieved by goldsmiths in the Intermediate Area is the application of granulation onto lost wax casting molds. Granulation describes the application of small spheres of gold at a single point as a decorative motif. It appears that these granulation motifs were carved into the lost wax molds, and along with serving as a decorative element, also formed a part of the artifact’s structure. (LaNiece and Meeks 2000:230).

Unlike Mesoamerica and the Intermediate Area, the Andean region archaeological record boasts extensive archaeological evidence of metal production. Surveys by Shimada et al. (2007:338 et passim) and Lechtman (1976:1 et passim) have identified a number of production sites along the northern and central coasts of Peru where they encountered small ovoid pit furnaces used for the casting of metals. These measured 25 centimeters wide, 35-40 centimeters long and 25-30 centimeters high. Shimada et al. (2007:341 et passim) collected five charcoal samples and analyzed them through neutron activation analysis. All of the samples yielded about 200 to 400 parts per billion of gold. Natural occurrences of gold are situated around one or two parts per billion, strongly
suggesting that gold production was one of the primary functions of this furnace (Shimada et al. 2007:343).

Along with early furnaces, archaeologists in the Andean region have also recovered the remnants of metallurgical tool kits. Lothrop (1950:160 et passim) has identified a number of hammer and anvil stones of varying shapes and sizes made out of hematite, andesite, and quartz in the central coast of Peru (Figure 3.8) These weighed up to 36 ounces and have uncanny similarities to those stones that have been mentioned in ethnohistoric records. According to Garcilasso de la Vega (1985:161) Andean smiths “…used very hard stones of a color between green and yellow instead of anvils. They flattened and smoothed one against the other and held them in great esteem…Some are large so that the hand can just clasp them, others middling size, other small, and other lengthened out to a hammer on a concave.” Similarly, Fernandez de Oviedo (1996:118) documents that the people of Northern Colombia “…have their forges, anvils, and hammers, which are of hard stone…The hammers are the size of eggs or somewhat smaller, and the anvils are as big as a Mallorca Cheese.”
Furnaces were fueled by a variety of woods, corncobs, highland grasses, and llama dung, which the Inca called *taquía* (Lecthman 1976:38). Most fires can reach temperatures of up to 800° Celsius, and while these temperatures are effective for the firing of pottery or annealing of copper, they are not high enough to melt gold nor copper in their native state (Rehder 1986:87). Early metalsmiths had to use blowpipes in order to reach the appropriate temperatures for metalworking. These blowpipes were crafted out of a variety of materials that ranged from hollowed reeds to ceramic tipped copper tubes.
De La Vega (1985:201) has supplied one of the most complete accounts of Andean metalworking techniques.

“They blasted by means of tubes of copper, the length of a half-a-cubit, more or less...The tubes were closed at one end, leaving one small hole through which the air could rush with more force. As many as...twelve of these were put together according to the requirements of the furnace...they used no tongs for drawing the metal out, but did this with poles of wood or copper, and threw the heated metal on small heaps of damp earth which they had ready, to cool it.

Though some furnaces required a number of individuals blowing into it, Rehder (1994:346) calculates that a 150 pound individual blowing into a blowpipe would have been able to reach a maximum temperature of 1,200 ° Celsius, a temperature high enough to melt both copper and gold.

Throughout the Andes, metalsmiths also developed furnaces that relied on the natural drafts instead of blowpipes in order to increase kiln’s the temperature. Spanish chroniclers referred to these wind furnaces as *huairas* (Figure 3.9). Replicative firing experiments of these furnaces have demonstrated that with only natural draft from the Peruvian Pacific coast, the temperature of the charcoal beds of these furnaces can reach up to 1,100° Celsius in only 20 minutes, while the furnace exterior remained safe to touch at temperatures of 60° Celsius or lower (Shimada et al. 2007:349).

Notwithstanding with the similarities in the basic catalog of crafting techniques, there are also a number of differences between the methods used by Andean goldsmiths and their counterparts from Mesoamerica and the Intermediate Area. It appears that the smiths from the latter two regions had a preference for the casting of gold while those in the Andes favored hammering it. This preference for hammering techniques is seen when comparing the process of making gold beads. While in Mesoamerica beads were
predominantly manufactured by using the lost wax casting method, in Peru goldsmiths soldered two half hemispheres that had been hammered into shape (Le Niece and Meeks 2000:231).

Figure 3.9. Sicán Huaira excavated by Shimada et al. (2007:343)

Along with advanced hammering techniques, an electrochemical replacement gilding process is one of the technological highlights unique to the Andean Region. It was only practiced among the Vicus and Moche smiths of Northern Peru. Through this process, a remarkably thin layer of gold could be deposited on a copper sheet from a solution. The process began by gently heating gold for two to five days in a solution of salt, potassium nitrate, and potash alum until it was dissolved. This solution was then neutralized with sedum bicarbonate and heated to its boiling point. As the copper objects were immersed into this solution a naturally occurring electrical charge would plate the surface of the copper object with a layer of gold, allowing for the plate to be gilded using
a minimal amount of gold (Lechtman 1979:3 et passim; Lechtman et al. 1982:3 et passim).

**Summary**

Despite the vast expanse comprised by Mesoamerica, the Intermediate Area, and the Andean region, the similarities between each region’s metallurgy largely outweigh the differences (Table 3.1). It appears that Mesoamerica and the Intermediate Area shared more similarities with each other than with the Andes. The former two areas had a much larger affinity for the casting of metals. While this method has been the most cited, recent evidence suggests that pre-Columbian goldsmiths had access to a broader repertoire of casting techniques. Though casting methods were not unknown in the Andean region, it appears to have been secondary to the hammering of gold. This distinction could be linked to the availability of necessary raw materials such as beeswax for the lost wax casting method, as well as social differences in the ways gold artifacts were to be manufactured.

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<th>Table 3.1. Comparisons of gold manufacture techniques</th>
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<td><strong>Mesoamerica</strong></td>
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All of the regions surveyed in this chapter widely employed copper/gold alloys to manufacture gold products, and used a variety of depletion gilding techniques in order to
maximize the golden tones of said artifacts. The next chapter will briefly review the methodological underpinnings of experimental archaeology, and present the methods used in the experimental portion of this thesis.
Chapter 4

Research Methods

This chapter will provide a brief background into the historical and theoretical bases of experimental archaeology and the way it has been used to influence archaeological research. Additionally, it will also introduce the materials as well as the methods used in the experimental portion of this thesis in order to assess the efficiency of a number of manufacture techniques that would have been available to the goldsmiths of Tlapa in order to produce the smallest of their tributary sheets.

Experimental Archaeology

Experimental archaeology has been a longstanding methodology used to draw analogies and make inferences about the past. This approach is best defined as “The fabrication of materials, behaviors, or both in order to observe one or more processes involved in the production, use, discard, deterioration, or recovery of material culture” (Skibo 1992:18). While ethnoarchaeology has been rather useful for the examination of material culture within its social context, experimental research can provide a more fine-tuned focus on the effects and relationships of small sets of related variables (Marsh and Ferguson 2010:2). Because of this ability, this type of research is well suited for the study of technological developments, and it is based on the notion that by reproducing the actions of the ancient craftsman, archaeologists can better understand his or her technical abilities as well as his or her reason for choosing one course of action over another (Coles 1979:1 et passim; Mathieu 2002: 3 et passim).
The application of experimental research for understanding archaeological assemblages was popularized during the late 17th century by the Royal Society of London, who used experiments to determine the fabrication and function of some documented artifacts (Trigger 1989:61 et passim). These early experiments lacked rigor, which led Scandinavian scholars to develop a comprehensive methodology that included interdisciplinary investigation and experimental testing (Shimada 2005:605 et passim). By the late 19th century American archaeology began to embrace experimental research as a legitimate exercise by which researchers could bolster their interpretations of the past (Coles 1979:26).

The acceptance of experimental archaeology did not come unchallenged however, and by the mid 20th century it was subject to much criticism. Some, such as Clarke (1953), condemned this methodology for oftentimes leading to equifinal results. Similarly, others (see Tringham 1978:171) bemoaned an overall lack of rigor and theoretical applications to the bulk of experimental research of this time. In order to avoid these pitfalls this thesis readily adopted Ascher’s (1961:809) for experimental research: 1) The subject to be investigated by the experiment must be known to have been available or could have been available in the past, 2) The material used must be or simulate those means available by people in the past, 3) Experiments must be conducted within the potential limitations of the physical characteristics of the object and effective materials.

As experimental research has continued to develop, it has earned an important place in archaeology. Binford (1981:25 et passim) saw experimental archaeology and ethnoarchaeology as the two primary means by which archaeologists could establish
middle range theory, and he was only one of many archaeologists who advocated for the use of experimental archaeology with ethnoarchaeology (see Ascher 1961; Coles 1979; Renfrew and Bahn 2004; Yellen 1977; Outram 2002). The applications of experimental archaeology have steadily grown, and now the amount of actualistic studies numbers in the thousands (Marsh and Ferguson 2010:2; Cunningham et al. 2008:v).

While most of these studies consist of flintknapping experiments, other experimental studies include garbagology, assessments of taphonomic processes, and reconstructions of entire settlements (Renfrew and Bahn 2004:332 et passim; Shimada 2010:613).

Along with a wide variety on research foci, there is also some diversity in the kinds of experiments used in archaeology. Reynolds (1999:161 et passim) has defined five major classes which are: “One to one Constructs, Technological Innovation studies, Simulations, Eventuality Traits, and Processes and Functions Experiments.” The latter are aimed to investigate how things were achieved in the past, and best defines the experimental study in this thesis. When undergoing an experiment archaeologists can decide between controlling variables in a highly controlled lab environment or a natural field setting. However Marsh and Ferguson (2010:5) argue that in order to replicate the realistic use context to the extent possible one should use lesser-controlled experiments that mimic the natural environment while still accounting for variables related to the specific research question.

The bulk of experimental archaeology projects focused on metallurgy have been concerned with the smelting of various ores using simple furnaces that would have been available in the past (See Rehder 1986, 1994; Donnan 1973; Tylecote and Merkel 1985; Coghlán 1940; Shimada et al. 2007). In the late 1800s the discovery of a Hopewell
copper plated disk prompted some of the first experimental projects aimed at understanding the metallurgy of the Americas. In 1892 McGuire demonstrated that that copper nuggets from Lake Superior could be hammered and annealed into six-millimeter thick sheets (Coles 1979:23). Years later Cushing and Willoughby used Sam Heame’s 1771 accounts Journey to the Northern Ocean in order to recreate ancient copper smelting and hammering techniques used by Native Americans (Coles 1979:24). Lastly, in a manner very similar to this thesis Long (1964:190) used Sahagún’s accounts of Aztec goldwork to successfully cast a number of copper bells using the lost wax casting method.

Outram (2008:6) argues that “Perhaps the most effective experiments are those that are totally integrated into a larger scheme of academic research with the experimentation being just one of the methods being employed in pursuit of a research goal.” Similarly, Coles (1979:160) contends that the three major sources of evidence available for the formulation of experimental research in archaeology are: the surviving artifacts themselves, evidence from historic records, and experimental archaeology itself. Accordingly, I posit that in lieu of extant materials and ethnoarchaeological research, ethnohistoric sources can be paired with experimental research to formulate a better-informed understanding of Mesoamerican goldworking methods.

The high price of gold has proven to be one of the major obstacles of doing experimental research with this metal. Consequently I will use copper as a proxy for gold in the same way that Stanley Long did in 1964. Copper costs fraction of gold’s average price of $1,550 per ounce, yet both metals share numerous physical characteristics such as their malleability, high ductility, and electrical conductivity (Morteani 1999:51).
Despite these similarities, there are some major differences that this study will have to adapt to, namely the difference between each metal’s melting temperature and density. Gold’s melting temperature is 1062° Celsius, while copper’s is 1085° Celsius, which will slightly delay the production process of the tributary sheets in this experiment. Additionally, gold’s density of 19.3 grams per cubic centimeter is significantly higher than copper’s 8.96 grams per cubic centimeter (Eissler 2009:9).

Given the dimensions of the experimental tributary sheets, it would have taken approximately 253.2 grams of gold to produce one fifth of a tributary sheet. However, given copper’s smaller density it will only take 117.6 grams of copper to produce a sheet of the same size. Notwithstanding with the differences between these metals, I argue that it is possible to draw useful analogues from actualistic studies aimed at understanding the production process of metal artifacts even if the metal being used does not have the exact same qualities as the one it is intended to emulate.

*Individual Technique’s Performance Assessments*

The last three decades have seen a rapid growth in the way that archaeologists perceive the development of various technologies. Namely there has been a widespread acknowledgement that oftentimes artisans not only have a spectrum of techniques from which they can manufacture certain goods, but that efficiency is not the only factor in picking a specific technique. Along with efficiency and the material properties of what is being worked, there is also an interaction between material culture, cultural values, and social relations when making choices regarding the production of artifacts (Sillar and Tite 2000:2 et passim; Appadurai 1986:3 et passim; Lemmonier 1986:147 et passim). This position is best summarized by Lemmonier (1993:3) who argues that “Any technique, in
any society, though, be it a mere gesture or a simple artifact, is always the physical rendering of mental schemas learned through tradition and concerned with how things work, are to be made, and to be used.”

Though the effects of cultural values in the manufacture of artifacts is undeniable, one must also bear in mind that the artifacts being evaluated in this study served one specific purpose: the payment of tribute. Aside from conforming to a degree of standardization in order to comprise a complete tributary payment, these artifacts had to be produced punctually at regular intervals. Failure to comply with these parameters would indubitably lead to retribution from Aztec imperial officers, and in some cases death. Accordingly, the methodologies by which these artifacts are produced must balance cultural values with productivity. Schiffer and Skibo (1997:29) propose that when crafting an artifact, craftsmen have a variety of technical choices to solve a particular problem. I posit that the production of tributary sheets in an efficient and timely manner was one of the problems that helped shape the techniques used by those goldsmiths in the province of Tlapa.

The performance of each of the techniques analyzed in this study was examined by two criteria: Labor investment, and its production step measure. Labor investments can be defined as “…manufacturing costs, measured by the time required to produce some commodity” (Costin and Hagstrum 1995:621). Every step of the production techniques assessed in this study was carefully timed, in order to quantify the total labor investment. Along with labor investments, this study also adapted portions of Feinman et al.’s (1981:872 et passim) production step measure. This ordinal scale uses ethnographic analogies to quantify the steps necessary for the manufacture of ceramic artifacts in order
to assess their labor inputs and social costs. Though originally aimed at evaluating the
tasks involved in the production of ceramics, I adapted a simplified version of this scale
to the experimental portion of this thesis, and tabulated one point for each of the steps in
each technique’s manufacturing process. Those techniques with fewer points will be
considered more efficient than those with more points.

While I recognize that not all steps are equal in value since some may be far more
time consuming than others, there is a correlation between the number of steps involved
in the production process and the absolute labor investment. Results from DeBoer and
Lathrap’s (1979:110) study of Peruvian ceramics indicated that those vessels that
required the most production steps took the longest to build, and vice versa. By
conferring the same value for each of the individual steps I will have a homogenized
score will not only allow me to assess for efficiency, but also prevent my lack of
expertise in the casting of metals from creating a bias for any technique in which one of
the steps may take me longer to complete than someone that is specialized in metallurgy.
Similar to the previous studies that employed a Production step measure, this thesis did
not count those steps that were identical in all methods assessed such as the melting of
metal, pouring into the mold, and removing from the mold. While the step of melting the
copper will not be quantified in the production step measure, the time required for the
metal to melt will be added to the total labor investment.

Materials Used

The kiln used in this study aimed to simulate the small portable kilns that have
been documented ethnohistorically. Though likely larger than those used in the past, this
kiln worked in a very similar manner to those used by Mesoamerican goldsmiths. It
consisted of a galvanized tin garbage can that measures 45 centimeters tall and has a circumference of 40 centimeters. The inside was layered with a seven centimeters of firebrick and refractory cement (Figure 4.1). A false bottom made out of refractory cement was built approximately 14 centimeters from the base of the kiln. Six evenly spaced firebricks were used to support this false bottom.

![Figure 4.1. Side and top-down view of the kiln used.](image1)

There is a circular opening of approximately five centimeters in diameter along the lowermost section of the kiln. A copper pipe was inserted into this opening to serve as a blowpipe. This process is crucial to raise the temperature in the kiln to copper’s melting point. To do this, I used a blow drier in order to simulate the action of a craft specialist or a group of smiths continuously blowing air into the kiln (Figure 4.2).

![Figure 4.2. Simulated blowpipe](image2)
The coals used in this study consisted of 100 percent hardwood, or lump charcoal (Figure 4.3). This type of charcoal differs from the average briquettes used for grilling by being of made purely out of charred hardwoods such as hickory, mesquite, and oaks, among other hardwoods. Briquettes on the other hand, are made out of a compressed mix of charcoal, starch, nitrates, and other additives. Though popular for most grilling purposes, briquettes burn at a much faster rate and cannot reach the same high temperatures as lump charcoal, thus making them far less desirable for metal casting.

![Sample of lump charcoal](image)

Evidence from the site of Mayapan indicates that some Mesoamerican metallurgists were using ceramic vessels as crucibles (Paris 2008:50). The crucible used for this experiment resembled those found at Mayapan. For safety reasons I used a commercial crucible made out of clay and graphite. It measured 10.8 centimeters in height and has a diameter of nine and half centimeters (Figure 4.4). Prior to being used, the inner portion of this crucible was coated with a thin layer of borax and heated with a torch. The sodium borate forms a thin film along the walls and base of the crucible that prevents the molten metal from adhering to it. Unlike its Mesoamerican analogues, this
According to Book 9 of the Florentine Codex, two different kinds of clay were required in the making of a lost wax-casting mold. While Sahagún aptly describes each of the major steps in this technique, he provides very little information regarding the composition of the materials used. Instead he simply states that the inner layers were carved using charcoal-based clay, and the outer layers were crafted with a different clay that is much more coarse. Clay is an effective refractory material, however upon sudden temperature increases it can be subject to drying and cracking. The addition of charcoal to the clay can counteract the shrinkage, and the inner section of the mold can preserve a significantly greater amount of detail (Long 1964:191). On the other hand, the coarse clay that is layered on the outside of the mold serves as a protective shell, and insulates the inner layers so the metal flows freely through the entirety of the mold (McCreight 1986:3).

The clays used for this project were applied from the pre-industrial metalworking techniques of the Ashante peoples of Ghana. These techniques were presented at the
Yuma Art Symposium by Werger et al. (1992:2), and their similarity to those outlined in the Florentine Codex make them a suitable analogue to those clays used in ancient Mesoamerica. The charcoal layer consisted of a combination of charcoal, fine grog, and bentonite. In a plastic bin I mixed three cups of charcoal powder with three cups of fine grog (Figure 4.5). I then added 110 grams of bentonite, and mixed all three powders together. Once evenly mixed, I added two tablespoons of rubbing alcohol, in order to break up the surface tension of the charcoal, and distilled water until the clay reached a creamy consistency. This mix was then placed in a plastic bag and allowed to rest for 72 hours before shaping into a mold.

Figure 4.5. Ingredients and steps of charcoal clay mixing: a) ingredients used, b) fine grog, c) charcoal powder with fine grog, d) mixing the fine grog and charcoal powder, e) adding water to the mix, f) final product
The outer layer of the mold was made up of both fine and coarse grog, bentonite, and half a cup of chopped grass. I began by combining 2,720 grams of coarse grog, 907 grams of fine grog and 272 grams of bentonite (Figure 4.6). Once the powders were evenly mixed, I added the half a cup of chopped grass and added water until the mix had the consistency of cookie dough. This paste was then kneaded for 10 minutes in order to ensure that it was mixed uniformly.

![Figure 4.6 Steps for coarse clay mixing: a) mixing the coarse and fine grogs, b) adding bentonite, c) mixing the powders, chopped grass, and water, d) final product.](image)

Much like ceramics, charcoal also has the appropriate qualities to function as mold for metal casting. Large blocks of it can be carved out and these can serve as both open and two-part molds. Charcoal would have been readily accessible for Aztec metalsmiths, and evidence suggests the use of craft provisioning systems for this type of
raw material. In his description of the lost wax casting method, Sahagún begins by writing “He who presided distributed charcoal among them” (Anderson and Dibble 2012 V.9:73) suggesting that at least in those workshops located within the Basin of Mexico metalsmiths were provisioned with charcoal and likely other materials necessary for the production of metals. Though a major portion of the charcoal used was certainly used as fuel for the furnaces, one cannot discount the possibility that some larger pieces may have been carved into molds. The charcoal blocks used in this thesis were commercially prepared hardwood charcoal rectangular blocks. These measured 17.5 centimeters by 10 centimeters with a thickness of three and a half centimeters. They were carved with a double-ended wax carving tool, which allowed for precise control over the carving of the charcoal blocks, and a paint scraper to expedite the carving (Figure 4.7).

Figure 4.7. Charcoal block, and the tools used to carve it.

Another highly accessible alternative for mold making is using sand. Casting sand, or green sand, largely consists of moist fine silica sand combined with approximately five to eleven percent clay (McCreight 1986:64). Due to its effectiveness and low cost, sand casting is highly popular with foundries. Approximately 70 percent of
all commercial metal casting is done on one of various techniques of sand casting (Rao 2003: 26). For this replicative exercise, I mixed one and a half kilograms of fine silica sand, with 150 grams of bentonite. I then sprinkled this blend with water until the mix would pass the squeeze test that is outlined by Chastain (2003:42). It consists of slowly pouring water into the sand mix and squeezing it. Once the sand retains the shape of a cylinder as it is squeezed it has been watered enough (Figure 4.8).

Figure 4.8. Steps for mixing casting stand: a) mixing silica sand and bentonite, b) adding water, c) performing the squeeze test to see if the blend is balanced, d) final product.
The casting sand was then rested for an hour to allow the bentonite to fully absorb the water. This blend was packed in a 20.5 by 25.5 rectangular wooden frame. To serve as an enclosure for the two-part mold, I selected a thin sheet of wood that measured 25 centimeters by 20 centimeters. These were fastened together using a combination of commercial metal and plastic clamps (Figure 4.9). Securing both pieces together is a crucial step for the two-part casting process since it prevents any metal from pouring out of the mold once it is poured. In order to ensure that the mold was efficiently clamped I held up to the light and looked into the sprue to ensure that there was no daylight between the frame and the wooden sheet. Both pieces of this two-part mold were immersed in water for a full 24 hour period to prevent them from igniting once exposed to the extremely high temperatures of the molten metal.

![Figure 4.9. Clamps and wooden frame used for sand casting.](image)

Though there have been few portions of metallurgical tool kits found in Mesoamerica, such as the crucibles in Mayapan, other artifacts such as hammers and anvils have yet to be identified archaeologically. Fortunately, both the ethnohistoric and archaeological records in South America have been more successful at identifying these
types of tools. This thesis utilized De la Vega’s (1985:161), and Fernandez de Oviedo’s (1996:118) descriptions, along with Lothrop’s (1950:160 et passim) excavations from Coastal Peru to ascertain the size and weight of the hammer that are to be used. As it was previously mentioned all of them described a number of rocks that were palmed by goldsmiths. While their colors and sizes varied, these did not appear to have exceeded the weight of 36 ounces. For this exercise I selected a two-pound brass horseshoe mallet with a head of three centimeters. Unlike those hammers used in the past, this one has a handle that measures 31.5 centimeters. I decided to deviate from these descriptions due to safety concerns (Figure 4.10). As for the anvil in which the ingot will be hammered on, I used a ten-pound driveway tile. It measured 30.5 by 30.5 centimeters and had a thickness of four centimeters.

Figure 4.10. Hammer and anvil used.
Kiln Control

The kiln used in this study was placed on a concrete surface away from any potential flammable materials. I then placed three kilograms of lump charcoal into the kiln. While the larger pieces were positioned along the false bottom, the smaller ones were layered on top while making room for the crucible along the middle of the kiln (Figure 4.11). A small amount of lighter fluid was sprinkled on the charcoal and a fire was lit at exactly 9:58 am. I waited 15 minutes for the flames so subside and inserted the empty crucible and turned on the blow drier on the “low” setting, which will expectedly mirror the effects of a group of smiths using a blowpipe. Once the coals began to glow uniformly I inserted the desired amount of scrap copper into the crucible using a small camp shovel and closed the lid at 10:25 am. Approximately every 10 minutes I opened the lid to check on the state of the metal. Though this process likely delayed the melting time of the metal, I found necessary due to the lack of means to control the temperature inside of the kiln.

Figure 4.11. Crucible in the kiln.
Because of the risks of inhaling carbon monoxide as well as any other noxious gases associated with the smelting process this replicative exercise took place outdoors (Figure 4.12). While this setting allowed me to more accurately mimic those in which pre-Columbian goldsmiths were working in, it also limited my control of certain variables, namely the outside temperature which can affect the time required for the kiln to reach the melting point of copper. In order to homogenize my results I calculated the average time elapsed for the copper to melt in each of the successful trials. This time was added to the individual preparation time of each technique assessed, resulting in a standardized copper melting time. Moreover, I divided the rest of the lump charcoal into 10 plastic bags each weighing two kilograms, and five plastic bags each weighing one kilogram. This allowed me to carefully monitor how much fuel was necessary for the completion of the casting techniques assessed here.

![Outdoor work station.](image)

Figure 4.12. Outdoor work station.
Ingot Casting and Hammering

According to Sahagún there was a separate class of goldsmiths who “beat gold and attempted to flatten it with a stone (Anderson and Dibble 2012 V.9:69).” Though some have argued that Mesoamerican smiths had a preference for the casting of metals, Sahagún’s passage makes it clear that artisans were also quite familiar with the process of hammering gold. Since it was expected to be one of the lengthiest techniques to be assessed, the first one to be examined was the casting of an ingot from a two-part sand mold, and the hammering of said ingot into the dimensions of the smallest of tributary sheets. I began by tightly packing the casting sand into the frame and using a wooden template of the ingot to create an imprint onto the sand (Figure 4.13). This ingot measured 92.5 millimeters long, 51.5 millimeters wide and three millimeters thick.

Figure 4.13. Copper model of tributary sheet and wooden model for the ingot

Next, I used the clamps to secure the wooden sheet to the mold, ensuring that there were no openings in which any metal could flow out of. While the experimental copper sheet should have a weight of 117.6 grams, I decided to melt 130 grams of copper
in order to account for the sprue that is formed along the opening of the two-part sand casting mold. Once the copper melted, the crucible was removed from the kiln using the tongs and metal casting gloves, and poured into the two-part sand casting mold (Figure 4.14). After the ingot cooled, it was carried to the cement anvil and hammered into the dimensions of the tributary sheet. Using a counter clicker I accounted for the amount of hammer strokes necessary to shape the ingot into the appropriate dimensions.

![Figure 4.14. Casting of the ingot: a) 130 grams of scrap copper, b) the scrap copper in the crucible, c) molten copper in the crucible, d) pouring the copper in the sand casting mold.](image)

By using copper there was a likely disjunction between the techniques used by a pre-Columbian goldsmith and those used in this replicative exercise. While gold and copper do share very similar properties one must highlight that gold is considerably softer
and more malleable than copper. Because of its superior malleability, gold does not require to be annealed as many times as copper (Figure 4.15).

Figure 4.15. The hammering of the ingot: a) ingot being hammered, b) ingot being annealed

If a metal is not annealed properly during the hammering process it is subject to cracking. The time elapsed during the annealing process was not added to the timed assessment of the hammering technique. The timer was set to stop once the ingot attained the dimensions of the smallest tributary sheets, or could not be worked anymore. Furthermore the sand used to cast the ingot, along with the wooden pieces were collected and bagged individually for analysis of any archaeologically identifiable debris.

Lost Wax Casting

Sahagún in the Florentine Codex covered the lost wax casting process in remarkable detail. Though some of the specific techniques used in this study varied slightly, this actualistic study should bear a very close resemblance to Sahagún’s description of this method. Due to the intricate technical knowledge required to
successfully create a lost wax mold, I decided to create two molds. This allowed me to assess this technique in case that one of the molds malfunctioned.

The mold preparation began with the mixing of the charcoal and coarse clays one week before the casting. Once the clays were ready to use I used a double boiler to melt 10 ounces of beeswax on a stovetop (Figure 4.16). In order to form a sheet, the beeswax was poured onto a baking sheet partially filled with hot water. As the wax touched the water it began to float, and form a thin layer on the surface. I then used a pin roller to flatten these sheets to a thickness of one and a half millimeters. Once they reached the desired thickness I used the wax-carving tool to cut them into the shapes of a tributary sheet. Once the wax models were successfully carved, I rolled three strands of paraffin wax and attached them to the top of the wax model. The three stands were then linked together to form a sprue into which the metal could flow into the indentation left by the wax model. Once finished each wax model weighed exactly 23 grams.
Figure 4.16. Steps for carving wax models: a) melting the beeswax, b) pouring molten wax onto a tray filled with water, c) using a pin roll to flatten the beeswax, d) flattened wax sheet, e) wax sheets with copper preform of tributary sheet, f) wax sheets with the sprues attached to them

Prior to applying the various layers of clay onto the wax models I generously applied rubbing alcohol to the wax model in order to remove any impurities that may affect the casting process. While the model was still wet I palmed the model and dabbed small amounts of the charcoal clay onto the model. Using a soft paintbrush I spread the clay until there was a uniform layer of approximately one millimeter covering the mold (Figure 4.17). Extreme caution must be taken when adding the first layers of clay since air bubbles can lead to metal leaks within the mold. Once the mold was covered in its
entirety it was placed on a windowsill to sundry. I repeated this process three more times, each time applying increasingly thick layers of the charcoal-based clay.

Figure 4.17. Ingredients and steps for adding layers of charcoal clay to lost wax mold 1: a) all the ingredients used, b) first layer of charcoal clay, c) using paintbrush to apply charcoal clay, d) lost wax molds drying, e) final layer of lost wax mold 1, f) final layer of lost wax mold with copper preform next to it.

After all four layers of charcoal-based clay were applied to the lost wax mold I began applying the coarse clay. When applying this clay one had to bear in mind that it is significantly heavier than the previous clay, so extra care must be taken to not break the inner layers of the mold. In a manner similar to charcoal-based clay I palmed the mold and dabbed small clumps of coarse clay onto it (Figure 4.18). Using a paintbrush I coated the mold with a one-millimeter layer. The mold was allowed to sundry in the same
windowsill. Once it was completely dry I repeated this process twice adding a two-millimeter layer each time. I placed extra attention on the area covering the sprue and thicker layers were added here since that is where the tongs were to handle the mold. Additionally, I fashioned a concave opening along the end of the sprue to facilitate the pouring of metal into the mold. The molds became quite heavy after applying all the layers and while Lost Wax Mold I weighed 712 grams, Lost Wax Mold II weighed 634 grams.

**Figure 4.18** Steps for applying the coarse clay to lost wax mold 1: a) adding the second layer of coarse clay, b) adding the third layer of coarse clay, c) reinforcing the neck of the mold, d) concave opening and the sprue, e) finished lost wax mold, f) finished lost wax mold next to copper preform.
Since Lost Wax Mold I was slightly heavier and had a more adequately shaped concave opening along the sprue I decided to use this mold. I placed the mold into the kiln with the sprue facing up next to the crucible. I then added one kilogram of charcoal. As the coals began to burn I placed 130 grams of scrap copper into the crucible. Due to the extensive spruing that had been added to the wax model of the tributary sheet I chose to melt more copper so the metal would completely fill the mold. After 20 minutes of placing the mold into the kiln the high temperatures had melted and evaporated the wax, leaving an imprint of the sheet and the sprues inside of the mold. I used the tongs to remove the mold from the kiln and used four bricks to secure it upright on the workstation (Figure 4.19).

Once the metal melted I used the tongs and metal casting gloves to remove the crucible from the kiln, and poured the metal into the sprue. The metal was then allowed to solidify as the mold cooled. After being cool to the touch, I used the mallet to crack the lost wax mold open and retrieve the metal sheet. The entire process of mixing both clays, preparing the wax figures, sculpting the molds, and melting the metal will be added in order to calculate this technique’s labor investment. As with the sand from the two-part sand casting every piece of the broken mold was collected and analyzed.
Two-part Molds

While there are no direct mentions of the use of two-part molds in the past, this technique would have been within the scope of pre-Columbian goldsmiths. Moreover, Weeks’ (2013:120) recent discovery of pumice molds at the site of Utatlán in Guatemala significantly elevates the possibility that Mesoamerican smiths had access to this type of mold. Two-part molds combine some of the basic principles of an open mold, and a lost
wax mold. The carving of a desired shape onto a mold, and fastening it against a flat surface to manufacture a thin product applies the same principles of pouring metal into a lost wax casting mold. Additionally the fastening of a two-part mold seems much easier than the application of numerous layers of clay. Thus I contend that pre-Columbian goldsmiths would have surely been aware of this technique and readily employed it when it suited them.

The two-part mold technique was partially tested with the ingot hammering method since it was used to cast the ingot. However, for this portion of the experiment I decided to also use charcoal blocks instead of casting sand. By having a template of the tributary sheet pressed against a flat surface, two-part molds counteract the viscosity of molten metal and force it throughout the entire mold. This process began by using the wax-carving tool to carve the templates of the smallest tributary sheets. For this I used a preformed copper sheet that had been shaped to the dimensions of the small sheet. Along with the templates I also carved a sprue in which the molten copper could flow into the carved mold (Figure 4.20).

Figure 4.20. Carving of a charcoal block: a) carving the block, b) carved block
To maximize the kinds of techniques analyzed in this study I added a variation to the two-part charcoal molds. While one of these molds was fastened to the flat wooden sheet previously used in the first experiment, the other one was fastened to the flat side of a charcoal block of identical dimensions as the carved one (Figure 4.21). I used a combination of clamps and tape to securely fasten both molds. Beginning with the wood and charcoal mold I placed 130 grams of scrap copper into the crucible. Like in the previous tests, extra copper was apportioned to account for the sprue. After the metal was completely molten I removed the crucible using the tongs and the gloves and poured the metal into the sprue (Figure 4.22).

After being poured the metal was allowed to cool and solidify. I then placed the charcoal block horizontally, loosened the clamps, and removed the wooden sheet. The exact same process was repeated with the double charcoal two-part mold (Figure 4.23). In both cases the entire carving process was timed, and all materials were bagged and labeled separately.
Figure 4.22. Casting with two-part mold made out of charcoal and wood: a) 130 grams of copper, b) molten copper, c) two-part mold, d) pouring metal into the mold

Figure 4.23. Casting with two-part mold made out of two charcoal blocks: a) placing 130 grams of copper into the crucible, b) unfastening two-part mold to remove piece.
Open Casting

Book 11 of the *Florentine Codex* shows a somewhat stylized image of a metalsmith using an open mold, and the molds found by Weeks (2013:120) indicate that open molds were known to pre-Columbian smiths. I began by using the wax-carving tool to carve a template of the smallest tributary sheet onto a charcoal block (Figure 4.24). Along with using a charcoal mold, I also intended to use the prefabricated mold of the tributary sheet to leave an imprint onto the sand casting mold, and 117.6 grams of molten scrap copper were to be poured in each of the open molds. Unfortunately I was not able to complete this portion of the experiment.

**Figure 4.24.** Open molds: a) charcoal open mold, b) sand casting open mold

Due to their simplicity, I reserved the open mold assessments to take place last. Unfortunately a series of factors prevented me from doing so. First the blow drier began to fail, likely due to its continuous use for approximately nine hours. Along with this technical difficulty, the weather conditions proved to be deleterious for the successful melting of the metal. The kiln was placed along the eastern end of a large warehouse in the University of Colorado Campus. The crucible was loaded with 117.6 grams of scrap
copper at 5:24 pm, approximately 48 minutes before sunset. However due to its shaded location, the temperature around the kiln dropped quickly to approximately 12° Celsius, which likely limited the kiln’s ability to reach copper’s melting point. All portions of the kiln except for the metal lid on top were layered with firebrick and refractory cement, which insulated most of the kiln. I believe that as the outdoor temperatures dropped, the heat loss from the lid of the kiln increased, which had an adverse effect in the melting of the copper. Lastly, it is likely that the false bottom in the kiln had filled up with ashes after being lit for such a long time. The high concentration of ashes along the false bottom may have limited the amount of airflow into the kiln and prevented it from reaching the desired temperatures.

While each of these individual factors may have only delayed the casting process, the combination of all three prevented the kiln from functioning appropriately, and halted this replicative exercise. Nevertheless, it is worth noting that in previous trials with contemporary metallurgical tools such as high-powered torches, the open molds had failed to successfully cast a tributary sheet. Due to its high density molten copper does not react like water and take the shape of whatever vessel is holding it. In each of the previous trials, the molten metal simply puddled along the middle of the mold. It appears that while open molds are efficient for the manufacture of thick pieces such as axes, they are unable effectively cast thin pieces such as tributary sheets. Moreover, it was previously mentioned that gold is denser than copper, thus it would have been even more difficult for molten gold to flow through the entirety of the mold.
Summary

This thesis attempted to assess which of these manufacture techniques would have been most likely used by Aztec goldsmiths by replicating them in accordance to ethnohistoric and archaeological evidence throughout the Americas. All of the production methods sampled would have been accessible to Mesoamerican metallurgists in the past, and all of the materials used would have likely been readily available as well. The efficacy of these production techniques was analyzed by combining each technique’s labor investment and calculating their production step measure. Once each of the replicative exercises was completed, careful considerations were taken in the evaluation of any archaeologically identifiable remains. The data collected from these research methods will be analyzed in the following chapter.
Chapter 5

Data Analysis

In this chapter the data from the successful casting experiments outlined in the precious chapter will be discussed individually. Though I was not able to produce a metal piece of the exact dimensions of the tributary sheets from Tlapa, abundant information regarding the performance of each production technique was retrieved. Along with discussing the results of every method tested, I will also note the types of archaeologically identifiable debris produced by each casting technique. Comparisons of the efficacy of each technique, as well as the evaluation of any potential archaeological markers of gold production will be developed in the discussion section.

*Kiln Control*

The kiln used in this actualistic study operated continuously for a total of 10 hours and 32 minutes. Throughout this entire process it consumed 15 kilograms of lump charcoal. Despite the advantages of closely recreating the setting in which pre-Columbian goldsmiths worked in, the outdoor setting prevented me from controlling some of the variables that likely affected the rate in which the kiln reached the melting point of copper. Consequently, I calculated the average time required for the metal to melt in the four successful castings assessed here. This time was of 62.5 minutes (*Table 5.1*), and it is the time that was used to calculate the labor investments of each production technique.

Aside from the four successful castings that were recorded in this study, there were also three instances in which the kiln failed to reach the temperatures necessary to melt the desired amount of copper that had been placed in the crucible. The first of these
erroneous castings took place at 11:32 am with the copper that was to be poured into the lost wax-casting mold. Along with the aforementioned 10-minute intervals in which the kiln was opened to assess if the metal inside the crucible had melted, the lid had also been opened eight times in order to anneal the ingot that was being hammered at the same time. During the annealing process, it is likely that much of the heat within the kiln escaped, which precluded the metal from successfully melting. Rather than fully liquefying, the scrap copper coalesced into a round mass that took the shape of the bottom of the crucible (Figure 5.1). Though somewhat attached to the crucible, it took very little prodding with a metal tool to remove this mass from the crucible. Despite it partially molding to the bottom of the crucible, one could still identify individual pieces of scrap copper, indicating that despite nearing copper’s melting point, the kiln could not successfully melt the metal.

<table>
<thead>
<tr>
<th>Technique</th>
<th>Melting time (min.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ingot Casting and Hammering</td>
<td>50</td>
</tr>
<tr>
<td>Lost Wax Casting</td>
<td>70</td>
</tr>
<tr>
<td>Two-Part Mold Charcoal/Wood</td>
<td>90</td>
</tr>
<tr>
<td>Two-Part Mold Charcoal/Charcoal</td>
<td>40</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>62.5</strong></td>
</tr>
</tbody>
</table>

Figure 5.1. Rounded copper miscast.
The other two instances in which the kiln failed to melt the copper placed within the crucible took place at 5:24 pm and 7:16 pm. These were the failed attempts at casting a sheet out of an open mold that were described in the latter portion of the previous chapter where the combination of dropping temperatures, blow dryer failure, and the likelihood of the false bottom filling with ash precluded me from melting the desired amount of copper. Rather than forming a round mass in the shape of the crucible, the copper in both of these instances simply adhered itself to the walls and the base of crucible (Figure 5.2). After extensive scraping with a metal tool I was able to remove much of the scrap copper that was adhered to the crucible from the 5:24 pm attempt. However, a major portion of the copper from the subsequent attempt was impossible to remove and continues to be attached to the crucible. Despite looking charred, the pieces of scrap copper that were removed kept much of their original shape, suggesting that the temperatures within the kiln did not near the desired 1085°Celsius. The kiln’s inability to function properly below a certain ambient temperature raises some thought-provoking questions about the times and place in which gold production may have taken place that will be addressed in the Discussion section of this chapter.
Despite the relatively simple preparations for the evaluation of this production technique, I believed that the casting of an ingot and subsequent hammering into the desired dimension of the smallest tributary sheets would be the most time consuming method. Though the hammering portion of this method was not as time consuming as expected, and it would have been even faster had I been using gold instead of copper, the addition of this step after the initial casting of the ingot makes this a somewhat undesirable method to craft an tributary sheet. Rather than casting a smaller piece and hammering it into the appropriate dimensions, it seems more effective to cast the initial piece into the apt measurements and forego the entire hammering process. Because of the added step in hammering, this methodology received a production step measure of 3 (Table 5.2). Though I failed to successfully produce a sheet of the precise dimensions of the smallest tributary sheets, the results from this experiment suggest that it is possible manufacture a sheet by casting an ingot and hammering it to the desired size.
Table 5.2. Ingot Casting and Hammering Production Step Measure

<table>
<thead>
<tr>
<th>Step</th>
<th>Production Step Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand Mixing</td>
<td>1</td>
</tr>
<tr>
<td>Preparing the Mold</td>
<td>1</td>
</tr>
<tr>
<td>Hammer Ingot</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>3</strong></td>
</tr>
</tbody>
</table>

The preparation process for the assessment of this technique began with the mixing of the casting sand. Though simple, this process was somewhat time consuming since one had to wait for at least one hour to ensure that enough water had been absorbed by the sand casting blend. In total, the preparations for the casting sand lasted 68.14 minutes (Table 5.3). The rest of the process was more expedient and after 8.12 minutes the sand mold was ready for the casting.

Table 5.3. Labor Investments of Casting and Hammering an Ingot

<table>
<thead>
<tr>
<th>Step</th>
<th>Time (min.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand Mixing</td>
<td>68.14</td>
</tr>
<tr>
<td>Preparing the Mold</td>
<td>08.12</td>
</tr>
<tr>
<td>Melting Metal</td>
<td>62.50</td>
</tr>
<tr>
<td>Hammering the Ingot</td>
<td>12.20</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>150.96</strong></td>
</tr>
</tbody>
</table>

The pour was not as precise as desired due to several factors. First, the sprue I had designed was fairly narrow, which lead to some of the copper spilling as the metal was poured. Additionally, once the casting sand and wooden sheet, both of which had absorbed some water, made contact with the molten metal the mold began to steam moderately. The steam may have not only shifted some of the sand within the mold, but also morphed the wooden sheet, creating some imperfections in the ingot (Figure 5.3). It weighed 127 grams, had a length of 88 millimeters, a width of 53 millimeters, and a thickness of 3.9 millimeters. The ingot cast from the experiment was approximately 4.5 millimeters shorter, 1.5 millimeters wider, and almost 1 millimeter thicker that I had
previously intended. Moreover, despite some of the metal spilling out of the crucible as I poured it into the mold, it appears that I overestimated the amount of copper necessary and casted an ingot that was almost 10 grams heavier than expected.

![Figure 5.3. Copper ingot.](image)

Though somewhat flawed, the ingot cast did have the general shape and measurements that allowed it to be hammered into a tributary sheet. The entire hammering process lasted 12.2 minutes. While far less time consuming as expected, this portion did come with some difficulties. Several minutes into this process the anvil began to shatter from the impact of the hammer (Figure 5.4).
As it continued to shatter I decided to use the pavement as a surface on which to hammer the ingot. Once placed on the pavement it was difficult to control the ingot as it was being hammered. It continually bounced with every hammer stroke despite my best attempts to control it with my left hand, thus it was problematic to hammer the ingot precisely. Despite these complications I was able to hammer the ingot into a sheet that measured 97.8 millimeters, by 93.3 millimeters with a thickness of 1.8 millimeters (Figure 5.5). 1051 hammer strokes were needed to flatten the ingot to these dimensions. During this whole process the ingot was annealed four times. However, it appears that the ingot was not annealed correctly because the ingot began to crack around the 400th hammer stroke. Notwithstanding with my efforts to avoid this fracture, a corner section of the sheet broke off, which prompted me to conclude the hammering. The complete labor investment of this process was of 150.96 minutes. One could expect that this time would have been slightly reduced if the anvil had not shattered. Furthermore, it is also
possible that having a more suitable anvil would have allowed me to be more precise with the hammering and produce a sheet that more closely resembled a tributary sheet.

Figure 5.5. Hammered ingot and copper preform of tributary sheet.

Along with the tiny droplets of solidified copper that were found around the mold, there was also some debris from the sand casting mold that is of particular interest for this study. Due to the clay content in the casting sand, those portions that made direct contact with the molten metal were hardened instantly when exposed to the metal’s high temperatures (Figure 5.6). Also, much of the sand placed in the mold appears to have been charred into a dark brown color. Lastly diminutive bits of copper seem to have permeated into the some portions of the casting sand. Though these changes in the casting sand can be identified effortlessly shortly after the casting process, it is highly unlikely that any deposits of used casting sand can be identified in archaeological contexts. While portions of the casting sand did harden, it is improbable that this process can aide the preservation of that material in a fashion similar to cooking ceramics.
Perhaps the only exception would be in a large-scale workshop in which sizeable amounts of used casting sand were deposited within a small isolated area. However, identifying this feature in situ would prove to be a major challenge.

![Burnt casting sand](image)

**Figure 5.6.** Burnt casting sand.

*Lost Wax Casting*

The assessment of the lost wax casting method can best be described as a partial success. This methodology allowed me to cast a sheet of copper that most closely resembled the dimensions of the smallest of the tributary sheets. However, its production step measure of 10 more than doubled that of the other methods (*Table 5.4*). Furthermore, this technique had a total labor investment of 1,253.23 minutes, which towered above any labor investment assessed in this study (*Table 5.5*).
The preparation process began with the mixing of both charcoal and coarse clays, which took 19.09 and 19.23 minutes respectively. Mixing and preparing the clays was a relatively simple endeavor, however the same cannot be said about creating the wax mold. This process lasted for 73.06 minutes and was lined with obstacles. I had chosen to use pure beeswax for this portion of my assessment. Nonetheless, once beeswax is molten and cooled it loses its plasticity, and breaks rather easily. According to Sahagún, Aztec goldsmiths used a blend of copal sap and beeswax when creating lost wax casting molds (Anderson and Dibble 2012:74). Though he writes that the copal was added to harden the mix, I expect that this mixture would have been more malleable than pure beeswax, and allowed goldsmiths to manufacture remarkably detailed pieces. Since I had no copal sap available to test this notion, I heated the wax model so as to extend its malleability. I did this by wrapping them in wax paper and placing them in a microwave for 50-second intervals once they began cracking under the rolling pin. Throughout the wax carving process I was forced to reheat the wax models a total of seven times, all of
which were added to the complete preparation time. Notwithstanding with these obstacles I was able to carve and roll a wax analogue of the tributary sheets.

Table 5.5. Labor Investment of Lost Wax Casting

<table>
<thead>
<tr>
<th>Step</th>
<th>Time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixing the Charcoal Clay</td>
<td>19.09</td>
</tr>
<tr>
<td>Mixing the Coarse Clay</td>
<td>19.23</td>
</tr>
<tr>
<td>Carving the Wax Model</td>
<td>73.06</td>
</tr>
<tr>
<td>Applying Charcoal Layer 1</td>
<td>91.69</td>
</tr>
<tr>
<td>Applying Charcoal Layer 2</td>
<td>113.28</td>
</tr>
<tr>
<td>Applying Charcoal Layer 3</td>
<td>118.31</td>
</tr>
<tr>
<td>Applying Charcoal Layer 4</td>
<td>149.54</td>
</tr>
<tr>
<td>Applying Coarse Layer 1</td>
<td>189.68</td>
</tr>
<tr>
<td>Applying Coarse Layer 2</td>
<td>207.37</td>
</tr>
<tr>
<td>Applying Coarse Layer 3</td>
<td>209.48</td>
</tr>
<tr>
<td>Melting Metal</td>
<td>62.50</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1253.23</strong></td>
</tr>
</tbody>
</table>

What followed the sculpting of the wax molds was the lengthiest of any of the processes recorded in this study. As it was mentioned in the previous chapter, many precautions had to be taken when applying each of the seven clay layers that shelled the wax mold. Among these precautions was to ensure that the previous layer of clay was completely dry prior to adding the succeeding one. The application of each of the clay layers was not particularly lengthy and it took 126.7 minutes to apply all seven coatings (Table 5.6). However, the rest periods for each layer to try were remarkably extensive and they added up to a total of 952.38 minutes. While many variables such as the temperature, humidity, cloud cover, and wind may have undoubtedly affected the amount of time required for one of these clay layers to dry, one can recognize that even under the climactic conditions of pre-Columbian Central Mexico this process would have been a lengthy one, and Sahagún notes that once artisans applied the layers of charcoal and
coarse clay, the mold would be left outside to dry for two or more days (Anderson and Dibble 2012:73).

Table 5.6. Breakdown of labor investment of applying the layers of charcoal to a lost wax mold.

<table>
<thead>
<tr>
<th>Layer</th>
<th>Application Time (min.)</th>
<th>Rest Time (min.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charcoal 1</td>
<td>09.39</td>
<td>82.03</td>
</tr>
<tr>
<td>Charcoal 2</td>
<td>09.00</td>
<td>104.28</td>
</tr>
<tr>
<td>Charcoal 3</td>
<td>10.16</td>
<td>108.15</td>
</tr>
<tr>
<td>Charcoal 4</td>
<td>08.03</td>
<td>141.51</td>
</tr>
<tr>
<td>Coarse 1</td>
<td>24.44</td>
<td>165.24</td>
</tr>
<tr>
<td>Coarse 2</td>
<td>33.48</td>
<td>173.89</td>
</tr>
<tr>
<td>Coarse 3</td>
<td>32.20</td>
<td>177.28</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>126.70</strong></td>
<td><strong>952.38</strong></td>
</tr>
</tbody>
</table>

Once the lost wax-casting mold was finished the rest of the process was rather expedient. After being placed in the kiln it only took approximately 10 minutes for the wax in the mold to melt and evaporate, leaving the imprint of the sprue and tributary sheet inside the mold. After the average of 62.5 minutes required for the scrap copper to melt, the liquefied copper was poured into the mold. Aside from a few droplets, most of it was successfully poured into the mold. Once the mold was cool to the touch I broke the mold with the mallet that had been used in the hammering assessment, and revealed a sheet that closely resembled the smallest of the tributary sheets (Figure 5.7). It measured 106.3 millimeters by 69.8 millimeters, and had thickness of 2.4 millimeters. On one of the corners one can see a round protrusion that indicates that there had been a small leak within the lost wax casting mold. Including this bulge of metal, the sheet weighed 127 grams. As in the previous experiment, I overestimated the amount of copper necessary for the sprue, which led to a final product that was almost one millimeter thicker than
necessary. Despite the discrepancy with the final product’s thickness, the width of the sheet was very near the dimensions calculated by Gutiérrez et al. (2009:80).

Figure 5.7. Sheet cast using the lost wax casting method and preform of the smallest tributary sheet.

While the lost wax casting method did manage to produce a sheet that closely mirrors the dimension of the smallest of Tlapa’s tributary sheets one must bear in mind that those sheets only comprise one fifth of a complete sheet that was used as part of a tributary payment. These compulsory payments took place every three months and could add up to 38 complete tributary sheets, or 190 of the smallest sheets per year (Gutiérrez et al. 2009:101). Seeing as the manufacture of one of these small sheets lasted for a combined 20.85 hours, it is extremely unlikely that Aztec goldsmiths were using such a time consuming and ineffective method to produce the sheets used in tributary payments.
Time constraints aside, one must also note that lost wax casting molds cannot be reused. Therefore, not only is there no way to streamline this production process, but there also is no way to ensure that every sheet that is cast conforms to the measurements that are necessary for a complete payment of tribute. Keeping in mind that these sheets were used as tributary payments, much like axe-monies, one can expect that there is a level of standardization between individual sheets (Hosler et al. 1990:39 et passim).

Perhaps the greatest attribute of the lost wax casting method is its ability to produce extraordinarily intricate and detailed pieces. However, this technique leaves very little room for standardization, which makes it an unlikely candidate for being the method of choice for the crafting of tributary sheets.

Though an unlikely method for the manufacture of tributary sheets, evidence from this study suggests that the lost wax casting method could be an archaeologically identifiable production method. By requiring each mold to be broken and discarded, this method has the highest potential for leaving an archaeological footprint. Each of the use molds has a distinct composition in which the outer portion has a dark gray color and a brittle texture while the inner part is black, has a smooth texture, and retained some of the shape of the wax model that had been encased within the mold (Figure 5.8).
The identification of diagnostic debris such as lost wax casting molds however must be scrutinized, and one must consider if these broken molds would preserve in the archaeological record. The strength of these clay molds is somewhat dependent on the amount of time they are cooked in the kiln. Along with the strength of the mold fragments, there are other factors that would affect their ability to be preserved that include, but are not limited to, freeze-thaw cycles, erosion, soil chemistry, and the actions of plants, animals and bacteria (Skibo et al. 1989:389 et passim; Bronitsky and Hamer 1986:90 et passim; Neupert 1994:117). The use of lost wax casting molds to identify potential goldworking workshops has significant potential. Yet, additional research regarding these individual variables is necessary prior to making any definitive statements about using lost wax casting molds as archaeological markers of metal casting activities.
Two-Part Molds

The last of the production techniques to be successfully assessed in this research project were conceivably the best suited ones for the manufacture of the smallest of Tlapa’s tributary sheets in antiquity. Not only did the crafting of two-part molds out of charcoal blocks have the lowest labor investments, but also the lowest production step measure (Table 5.7). The two-part charcoal and wood mold had the lowest labor investment assessed, which totaled 83.56 minutes. The two-part charcoal and charcoal mold followed closely with a labor investment of 84.91 minutes. Both of these techniques had shared the lowest production step measure of 2. Another advantage of these methods was that the charcoal molds withstood the blistering temperatures of the molten metal, and could have likely been reused.

Table 5.7. Production Step Value for both two-part molds

<table>
<thead>
<tr>
<th>Step</th>
<th>Production Step Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charcoal Mold Carving</td>
<td>1</td>
</tr>
<tr>
<td>Mold Fastening</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2</strong></td>
</tr>
</tbody>
</table>

The carving of the charcoal blocks was quite simple. While the metal wax-carving tool allowed me to sculpt an outline of the small tributary sheet, it was not too effective at etching the flat surface of the sheet onto the charcoal block. At this moment I used a flat paint scraper to carve a rectangle that had the same dimension of the tributary sheet into the block of charcoal. This process was rapid and carving each of the molds took 21.06 minutes (Table 5.8) and 22.41 minutes respectively (Table 5.9).
Table 5.8. Total labor investment of the two-part charcoal and wood mold.

<table>
<thead>
<tr>
<th>Step</th>
<th>Time (min.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charcoal Mold Carving</td>
<td>21.06</td>
</tr>
<tr>
<td>Melting Metal</td>
<td>62.50</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>83.56</strong></td>
</tr>
</tbody>
</table>

Table 5.9. Total labor investment of the two-part charcoal and charcoal mold.

<table>
<thead>
<tr>
<th>Step</th>
<th>Time (min.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charcoal Mold Carving</td>
<td>22.41</td>
</tr>
<tr>
<td>Melting Metal</td>
<td>62.50</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>84.91</strong></td>
</tr>
</tbody>
</table>

Once the molds were carved all that was necessary was to fasten them to a flat surface. Using the clamps that had been used in the first experiment I fastened the first charcoal mold to the reverse of the wooden sheet that had been previously used. I used the reverse since there had been some burning and warping from the initial casting. Fortunately the sheet had retained enough of its shape to provide an adequate seal for the metal casting.

After the scrap copper melted, I began pouring the copper into the first two-part mold. However, there were some issues with this pour. Once the metal made contact with the mold there was a somewhat violent reaction in which a blast of steam caused a small eruption of copper out of the sprue, and displaced some of the copper that had been poured into the mold (Figure 5.9). The small eruption startled me, and for a second interrupted the pouring. Once I began pouring again some of the copper along the sprue had begun to solidify and blocked the sprue, preventing any metal from going into the mold.
Despite these setbacks, a two-part mold using charcoal and wood proved to be an effective method and a metal piece that moderately resembles a tributary sheet was successfully cast. The piece in question shows extensive evidence of disarticulation from the steam that accumulated within the mold (Figure 5.10). This piece had a length of 142.1 millimeters, a width of 74.4 millimeters, and a thickness of 3.8 millimeters. Due to its irregular shape it is worth noting that the lengths was calculated by measuring the longest two points of the piece, including the sprue, while the width was measured from the widest points along its base.
The two-part mold using both charcoal blocks was also somewhat problematic, yet enough evidence supports this method as one of the likeliest to have been used in the past. Though there were no issues with steam eruptions, it appears that I may have erred in carving a sprue that was not wide enough to accommodate for the density of molten copper. The narrow sprue precluded me from pouring the copper in a single fluid motion, and instead I was forced to pause several times in order to allow the metal to flow into the mold (Figure 5.11).

Figure 5.10. Piece cast using the two-part charcoal and wood mold.
Had it not been for this mishap with the sprue, I am certain that the casting would have been a complete success. The bottom portion of the finished product largely took the shape of the mold, yet as the sprue became obstructed, only two strands of metal connected this portion with the metal around the sprue. The complete piece measured 155.4 millimeters by 72.3 millimeters. Its thickness was of 3.2 millimeters, and it weighed 101 grams (Figure 5.12).
Archaeologists have generally considered charcoal as a relatively inert material that has a high potential for preservation. Braadbaart and Poole (2008:2434) propose that “Charcoalified material is able to overcome both the physical and chemical decomposition associated with the burial in the soil, and is, thus the most common mode of survival of archaeological plant debris, whilst retaining the physical structure of the original material.” Thus it would be quite conceivable to identify the evidence of charcoal molds in the archaeological record. However, recently archaeologists have begun to recognize that the environment in which the material was deposited may play a larger role than was previously expected on the preservation of charcoal. Experiments by Braadbaart et al. (2009:1675) have identified that those plant materials that were exposed to temperatures of 310°Celsius and deposited in alkaline soils rapidly fragment into small fragments that may not be identified archeologically. Consequently, careful considerations about regarding soil chemistry must be taken when attempting to use the presence of charcoal molds as a marker of gold production on a site.
Discussion

After comparing the results of each manufacture technique, it is evident that despite the technical issues encountered in this actualistic study, the use of two-part molds allowed for the most efficient production of Tlapa’s small tributary sheets. This technique had a labor investment that was nearly half of the ingot casting and hammering method’s, and approximately 15 times smaller than the lost wax casting method (Table 5.10). This pattern also translated into the production step measure where the two-part mold method also had the lowest figure. The second most efficient technique was the combination of ingot casting and hammering of said ingot into the appropriate dimensions. While this technique had a total labor investment of 148.46 minutes, 68.14 of those minutes were aimed at allowing the casting sand mixing. It is possible that this figure may be reduced if Aztec smiths used a different recipe for casting sand.

Additionally, this methodology’s Production Step Measure only exceeded that of the two-part mold by one. When one combines these factors with gold’s superior malleability, one cannot rule out this technique from being used in the past.

Table 5.10. Production Step Measures and Labor Investments of all Techniques Assessed

<table>
<thead>
<tr>
<th>Production Technique</th>
<th>Production Step Measure</th>
<th>Labor Investment (min.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ingot Casting and Hammering</td>
<td>3</td>
<td>150.96</td>
</tr>
<tr>
<td>Lost Wax Casting</td>
<td>10</td>
<td>1253.23</td>
</tr>
<tr>
<td>Two-Part Mold/Wood</td>
<td>2</td>
<td>83.56</td>
</tr>
<tr>
<td>Two-Part Mold/Charcoal</td>
<td>2</td>
<td>84.91</td>
</tr>
</tbody>
</table>

The lost wax casting method proved to be remarkably inefficient for the production of relatively simple implements such as metal sheets. Because of the necessity of allowing each individual layer of clay to completely dry before applying the subsequent one, this methodology required several days of preparation, and had a labor
input of 1253.23 minutes. Along with an extraordinarily high labor input, the lost wax casting method’s production step measure more than doubled the other techniques’ evaluated. Out of the complete labor investment for this technique 952.56 minutes were spent waiting for each layer to dry, which is a process that could be affected by a myriad of environmental and climactic factors. Furthermore, one can feasibly argue that if an artisan alternated casting with preparing lost wax molds on a daily basis, he/she may be able to produce tributary sheets in a more efficient manner than was recorded in this study. However, in the face of these variables, I contend that the lost wax casting method is not a logistically sound technique for the purpose of manufacturing tributary sheets. This lack of efficiency largely disqualifies this methodology from being used in the past.

Though I was unable to test the viability of open molds in the same formal setting as the other techniques, previous examinations with modern equipment indicated that this methodology was incapable of casting a metal sheet that was as thin as specified by Gutiérrez et al. (2009:80). Rather than a rectangular sheet, the final product from these preliminary experiments consisted of an amorphous piece of metal that had a thickness of 6.6 millimeters (Figure 5.13). Due to its high density, molten metal does not take the shape of the vessel holding it much like water does. Metal’s viscosity does not impede it from being cast in an open mold. Rather this technique is limited to pieces of thicknesses that exceed that of tributary sheets.
Aside from the efficacy of using a two-part mold, this technique had another advantage that was not matched by the other ones assessed in this study: the ease by which one can produce a standardized product. The detailed description of tributary sheets dimensions found in the Codex Mendoza serves as evidence that much like contemporary currency, these sheets had homogenous values, and accordingly had to conform to a set of measurements. The ease by which an individual can carve a large piece of charcoal and it’s ability to be reused lends itself to the standardization of a product. Goldsmiths who manufactured these tributary sheets certainly had knowledge of the dimensions required to manufacture an adequate sheet, and could have even had a prefabricated models from which they could have carved the charcoal molds.

The combination of efficacy and ability to manufacture a standardized product qualifies the two-part charcoal mold as the most likely to have been used by goldsmiths in antiquity. The use of two charcoal pieces is particularly appealing due to their ability to carve a wider sprue out of both pieces, and prevent the clogging experienced in this
study. Moreover, if pieces of wood had been used as a flat surface to complement the mold, they would have required to be changed more often than another charcoal block. With charcoal’s molding capacity in mind, one can even raise the likelihood that the open mold that is depicted in the stylized illustration of metal casting from Book 11 in the *Florentine Codex* was likely crafted out of a large charcoal block, much like the one that was used in this study.

With a specific production technique in mind, one can see a more complete picture of the *chaîne opératoire* of tributary sheets in Aztec Mesoamerica. For the purposes of this thesis I will employ Boëda’s (1995:43) definition *chaîne opératoire* as “the totality of technical stages from the acquisition of raw materials through to its discard, and includes the various process of transformation and utilization.” Maldonado et al.’s (2009:226) model for the production of Tarascan copper artifacts is quite attractive since it creates another dimension between attached and independent specialists. Additionally there is evidence that metallurgy was a widespread activity in Mesoamerica prior to and after the Spanish conquest. Shortly after the conquest of Tenochtitlan Spanish officials attempted to ban any metal casting activities outside of the boundaries of Mexico City. However, given the popularity of metallurgy they quickly realized that it was impossible to enforce this measure (Gutiérrez 2013: Miranda 1952:46). Consequently, archaeologists must consider that access to metallurgical knowledge may have been more accessible and widespread than previously expected.

Given the relative ease by which gold appears to have been mined in Mesoamerica, and the widespread practice of exacting tribute through communal works, it is likely that the panning of gold from alluvial placers was part of the tributary
obligations of the people in Tlapa. Once collected, gold nuggets were distributed throughout a number of specialists who separated the raw materials into the compulsory amount of gourds. With the rest of the raw material, these specialists likely used two-part molds to manufacture the tributary sheets. As it was noted on this study, the weather could have proven to be a limiting factor in a kiln’s ability to reach a metal’s melting point. For the most part, climatic conditions in the province of Tlapa do not appear to have limited the production of gold artifacts. However, depending on the availability of raw materials, it is also possible that the production of tributary sheets may have taken place in the warmer parts of this province. If those settlements at higher elevations, where the temperature can drop to three degrees Celsius, participated in the production of tributary sheets, then it is likely that these activities were confined to the warmer portions of the day.

One must note that a complete tributary sheet, which measured 62.5 centimeters long, seven centimeters wide, and had the approximate thickness of one and a half millimeters, would have been too large to manufacture using the techniques used in this study and the small kilns that have been described ethnohistorically. Thus, it is probable that goldsmiths cast sheets that were half the size of a complete sheet, or sheets that were one fifth of their size such as the ones produced in this thesis. These fractions of a complete sheet could have served as equivalencies of a complete tributary sheet and/or could have been soldered into a single sheet. Yet another technique that would have served to attach these sheets is that of cold hammering. Due to gold’s remarkable malleability, one can actually fuse two pieces together through the process of hammering their edges together (Puddephatt 1999:238).
Once the tributary payments were completed they would have been distributed throughout the various levels of provincial government before *calpixque* collected the amount required by the Aztec state (Gutiérrez et al. 2009:53). Since there are no known gold deposits within the Basin of Mexico, imperial officials would have been forced to carry these sheets for long distances. I believe that by being flat and easily stackable, much like certain kinds of axe-monies, it would have been easier to transport the sheets than gold in its raw form. When analyzing the 36 years of tributary payments documented in the codex *Tribute Record of Tlapa*, Gutiérrez et al. (2009:92) (see also Gutiérrez 2013) noted that the amount of tributary sheets paid yearly were always higher than the amount of gourds filled with gold dust, which would simplify the transportation of these commodities. Within the Basin of Mexico, most of the tributary sheets were likely taken to those workshops attached to the Empire and other elite families, melted, and used for the production of fine gold crafts that were lauded in ethnohistoric sources and displayed in museums throughout the world. Along with those sheets that were molten by attached specialists, it is also likely that some of these sheets served as wealth goods, which were paid to state officials, and then exchanged in market settings for staple commodities.

Due to the potentially scattered distribution of metalworking shops, the small size of the kilns that were used, and the organic nature of the rest of metalworking tools the archaeological identification of goldworking activities will be difficult to ascertain. Additionally, gold in Mesoamerica is found in its native state, which eliminates the possibility of finding any slag or other similar residues that may preserve in the archaeological record (Eissler 2000:8; Patterson 286:et passim). In spite of the few
diagnostic features of goldworking, one can combine a number of features in an archaeological site that may be strongly indicative of a gold producing workshop. Given that Mesoamerica seemed to have a preference for casting metal artifacts one can expect to see high concentrations of ash, oxidized soil, and charcoal in a production area.

While most ethnohistoric sources describing the casting of gold in Mesoamerica mention that the blowpipes being used were made out of copper, archaeologists should also consider the possibility of finding ceramic tips placed at the end of them, much like in South America. Ideally, one would be able to identify larger pieces of charcoal as parts of molds, though as it was previously mentioned, one cannot automatically presume the archaeological preservation of charcoal. Similarly, high concentrations of silica sand mixed with clay could be indicative of sand casting. Nonetheless, these concentrations would have to be very substantial to be readily identified. Though it is rather unlikely that they were used for the production of tributary sheets, the remains of lost wax casting molds are best suited to identify metallurgical workshops. While their ability to preserve in the archaeological record remains debatable, their binary color and texture would make them readily identifiable as lost wax casting molds. Furthermore these molds have to be broken and discarded after every use, thus they are the likeliest to leave a substantial archaeological footprint.

As for the evidence of hammering any assemblages that are similar to those identified by Lothrop (1950:160 et passim.) could be indicative of gold hammering activities near that area. Additionally, stones that show a resemblance to those hard egg-sized stones described by Fernandez de Oviedo (1985:161) could also comprise metallurgical took kits. With the collection of these artifacts as well as analyses on their
use-wear, archaeologists can begin to identify those stones that could have been used in the production of metal artifacts. Overall the archaeological identification of metallurgical workshops is subject to innumerable variables. With findings such as the crucibles excavated by Paris (2008:50) Mayapan aside, it is probable that the identification of metallurgical workshops will rest on the identification of some of the artifacts and features that have been outlined in this study.
Chapter 6

Summary and Conclusions

Despite the historic significance of gold in the shaping of the conquest of the Americas, and the recent florescence of archaeometallurgy in Mesoamerica the study of pre-Columbian gold metallurgy continues to be poorly understood. The general lack of extant materials, and the widespread looting throughout Latin America have limited research to archaeometric analyses of pieces with questionable proveniences, and assertions about the symbolic value that auriferous materials held in antiquity. This thesis employed a three-pronged approach that combined ethnohistory, archaeology and experimental archaeology in order to investigate the production of gold artifacts in Late Postclassic Mesoamerica.

In this work, I attempted to recreate and evaluate the efficiency of four metal casting techniques that were available to pre-Columbian goldsmiths to manufacture a number of thin metal sheets that the province of Tlapa used as part of their tributary payments to the Aztec Empire. These techniques were chosen from their presence in either ethnohistoric or archaeological contexts, and their ability to have been easily accessed by Aztec goldsmiths. Along with the assessment of these techniques, careful considerations were taken regarding the archaeological footprint that each of these techniques could have left in order to identify the presence of goldworking activities in the past.

My research shows that the use of two-part molds was a remarkably efficient manufacture technique for the metal sheets in question. Though, it is feasible that pre-
Columbian smiths could have used sand casting molds, I contend that two-part molds crafted out of charcoal were more effective. Due to the charcoal block’s ability to be reused, this technique also allowed those goldsmiths in the past to account for standardization in a more effective manner as well. The combination of these two factors makes the use of two-part molds the likeliest technique to have been used for the manufacture of the tributary gold sheets. While no diagnostic archaeological markers of gold production were identified in this thesis, I highlighted a combination of features and artifacts that may be strongly indicative of goldworking activities. This chapter will recap what was presented in this study, and discuss future research, along with the significant contributions of this study.

Summary

In this thesis four production techniques were recreated and assessed in their efficiency to manufacture metal sheets that measured one fifth of the complete tributary sheets that the province of Tlapa paid the Aztec Empire four times per year. The sheets that I attempted to reproduce measured 12.5 centimeters long, seven centimeters wide, and one and half millimeters thick. Efficiency was accounted using the complete labor input of each of the steps necessary to manufacture a sheet, as well as the individual technique’s production step measure. Chapter 1 introduced some of the difficulties of researching gold metallurgy in Mesoamerica, as well as the introduction of metalworking technology into the region. It also discussed the geographical and historical setting of the province of Tlapa, some of the major ethnohistoric sources used in this study.

Chapter 2 introduced some of the major features of the Aztec tributary system. This system was flexible and the kinds and amounts of commodities that were included in
tributary payments rested on the combination of variables, which included time of the conquest, distance from the imperial capital, materials available, and local resistance. Additionally this chapter also itemized the eight Aztec provinces whose tributary obligations included items of gold, as well as the types of items found in their tributary obligations.

Due to the paucity of archaeological information regarding gold metallurgy in Mesoamerica, I was forced to draw analogies from the Intermediate Region and the Andes. Chapter 3 consists of a comparisons of the major techniques used by pre-Columbian goldsmiths to manufacture gold artifacts. The information here stemmed from a combination of ethnohistoric, archaeological, and archaeometric evidence and much like a mosaic, painted a picture of how pre-Columbian artisans worked gold. This evidence presented suggests that in Mesoamerica and the Intermediate Region artisans had greater affinity for the casting of gold artifacts, while those smiths in South America preferred to hammer gold. These differences aside, the equipment used by goldsmiths in each of these regions was almost identical.

With the necessary background conferred, Chapter 4 describes the methods I used to simulate the manufacture of the smallest of Tlapa’s tributary sheets. This chapter began with a brief discussion of the historical and methodological underpinnings of experimental archaeology, and was followed with a description of the ways by which I analyzed the efficiency of the techniques assessed in this study. The first was their total investments, which refers to the time necessary to produce a commodity, and a simplified version of Feinman et al.’s (1981:872 et passim) production step measure, which tabulates points for each of the steps in each technique’s manufacturing process. Using
materials that attempted to mimic those used by pre-Columbian goldsmiths, I assessed four production techniques: Ingot casting and hammering (Figure 6.1), lost wax casting (Figure 6.2), using a two-part mold with charcoal (Figure 6.3) and wood, and another two-part mold made out of two charcoal blocks (Figure 6.4).

Figure 6.1. Remainder of the sand casting mold, wooden preform, and hammered piece
Figure 6.2. Remainder of the lost wax mold and the sheet that was cast from it.

Figure 6.3. Remainder of the two-part charcoal and wood mold and piece cast in it.
Due to the high cost of gold, I was forced to use copper for each of these trials. However, both of these metals share many physical qualities, which makes copper and adequate analogue. Technical difficulties precluded me from assessing a fifth technique, an open mold, though one must note that previous assessments had shown that one could not cast a piece as thin as the smallest of Tlapa’s tributary sheets on an open mold due to the density of molten metal.

The results from each of the metal castings and their potential archaeological markers were reviewed in Chapter 5. The use of two-part molds proved to be the most efficient of all methods tested. Aside from having the lowest labor investment, it also had the smallest Production Step Measure. Due to its ability to allow for the carving of a wider sprue, it was noted that the two-part mold made exclusively out of charcoal blocks was the most effective out of all methods. However, one cannot discount the potential for
similar molds being manufactured out of other materials such as pumice. The ingot casting and hammering followed the two-part molds in efficiency. It was noted that this technique would have been more successful if one were using gold, which is much more malleable than copper. Accordingly, it should also be considered as a potential methodology used by the goldsmiths of Tlapa. The least efficient of the techniques assessed was the lost wax casting method. Aside from having a labor investment that towered above the rest of the techniques, it also had a much higher production step measure.

Because of the distribution of workshops, small size of kilns, and organic nature of many of the metalworking tools used by early metalsmiths, the archaeological identification of goldworking can be elusive. Rather than a single diagnostic feature archaeologists can use the combination of: high concentrations of ash, oxidized soil, and large charcoal pieces to identify metallurgical workshops. Additionally, the presence of the distinct remains of lost wax casting molds, and concentrations of hammerstones and anvils similar to those identified by Lothrop (1950:160 et passim), or Fernandez de Oviedo (1985:161) can direct archaeologists to the production of gold artifacts in that site.

Conclusions

The development of technologies has been recognized as being subject to an infinite amount of variables, many of which include cultural values, and social relations. However, given the extent of the tributary payments, the regular intervals in which they had to be completed, and the drastic penalties that were involved if one failed to make a complete payment, I contend that efficiency was a highly influential variable. Thusly,
those goldsmiths from the province of Tlapa likely selected the most efficient production technique in order to manufacture the gold sheets that comprised a portion of their tributary payments.

This thesis surveyed a number of techniques that were within the technological scope of pre-Columbian goldsmiths in Late Postclassic Mesoamerica. Two of these techniques were specifically mentioned in Book 9 the Florentine Codex, one was represented pictographically in Book 11 of the same work, and the last one was discerned through the combination of two identified techniques. Though not specifically mentioned, the use of two-part molds employs the same physical processes of an open mold and a lost wax casting mold in a simple manner that was surely identified by early goldsmiths.

Thomas (1999:181) argues that “replicative experiments do not ‘demonstrate the reality’ of anything; experiments demonstrate only that a given technique could have been used in the past- that it was not impossible.” Accordingly, I argue that the due to the advantages noted in this thesis, the use of two-part molds crafted out of charcoal has a large probability of being used in the past by Aztec goldsmiths. Firstly, this method had the lowest labor investment, as well as the lowest production step measure. Moreover, the carved charcoal molds could be reused, which eases the process of manufacturing a standardized product. Once the molds were carved, all the goldsmith would have had to do was simply melt the gold and pour it into the mold. Once these small sheets were cast, they were likely soldered or hammered together to form a complete tributary sheet with the dimensions that are outlined in the Codex Mendoza. One must also bear in mind that according to the Tribute Record of Tlapa (see Gutiérrez 2013) fractions of sheets were also being collected, so it is possible that not all sheets were welded together. Rather a
complete tributary payment would have included complete tributary sheets, and sheets that are one half and one fifth of their size.

Unfortunately, some of the most readily identifiable evidence associated with the production of gold artifacts belongs to the technique that was considered the least likely to have been used for the manufacture of tributary sheets. Due to their distinct composition, the popularity of this technique for the production of jewelry and bells, and the expectedly large rate in which they are deposited, the remains of lost wax casting molds can serve as the strongest single indicator of goldsmithing activities in Postclassic Mesoamerica. Together with the remains of these molds a combination of large deposits of ash and charcoal, oxidized soil, and lithic assemblages of artifacts that may have served as metal hammering tools can aide in the archaeological identification of metalworking shops in the past.

From a methodological standpoint, this thesis has shown that despite a general lack of extant materials, it is not impossible to make assertions about the production of gold artifacts in Mesoamerica. Through the comparison of metallurgical techniques throughout the Americas, and analysis of ethnohistoric sources, and actualistic studies, archaeologists can begin to understand the variety of ways by which pre-Columbian craftsmen manufactured metal artifacts. The next section will outline some of the possible research avenues that can be explored.

*Future Research*

This thesis marks the first step in developing a more thorough understanding of Postclassic Period metallurgy in Mesoamerica. There are a myriad ways that the topics discussed in this thesis can be expanded. Firstly, the repetition of each individual
efficiency assessment completed in this thesis, would not only evaluate my interpretations regarding their each technique’s viability, but also would allow for statistical analyses on each methodology examined and the way it performed. Given the opportunity, I would repeat the majority of the methods used in this thesis, though I would also introduce more modern metallurgical technology to allow me to account for some variables in a more controlled manner. Moreover, it would be fruitful endeavor to repeat these castings using gold rather than copper, or an alloy of these two metals. While I don’t think the results would be markedly different, I believe using gold or tumnaga will paint a clearer picture on the performance of hammering techniques, due to gold’s extensive malleability.

The hammering of gold appears to be the most obscure technique, both in ethnohistoric references and in the results of this study since the ingot that I cast broke during the hammering process. Due to gold’s ability to be fused together through the hammering, it would be interesting to see if one could create a tributary sheet simply by hammering gold nuggets. Also, more experimental research aimed at the hammering of ingots with hard stones such as quartzite and andesite could begin to unlock some of the specifics of metal hammering in Mesoamerica. Along with assessing gold hammering techniques, archaeologists could also profit from analyzing those hammerstones for use-wear, and residues.

Archaeological identification of goldworking shops and gold mining sites has proven to be rather evasive. Archaeologists should embrace ethnohistoric sources to narrow down some potential locations in which these activities could have taken place. Outram (2008:191), for example argues that “the most effective experiments are those
that are totally integrated into a larger scheme of academic research with the experimentation being just one of the methods being employed in pursuit of a research goal.” Thus multidisciplinary projects such as this one should be more readily employed.

Along with ethnohistoric and experimental research archaeological projects are necessary and the site of Texmelincan in Guerrero is an ideal place to begin searching for goldworking activities. Shortly after being discovered in the 1930’s this site was subject to heavy looting, which revealed a cache of dozens of pieces of gold, jade, and amber in a style that is reminiscent of the artifacts from Tomb 7 at Monte Albán. This site is located within the boundaries of the province of Tlapa, and research by García Payón (1939:361), and Gutiérrez (2010:167) has strongly suggested the possibility of gold mining and production activities at this site. Both were able to identify a number of terraces near a river where dozens of mortars were deposited. It appears that these mortars were used to crush quartz in order to extract an unknown mineral from it. Given Texmelincan’s location within a gold producing region, it is most probably that miners at this site were extracting this precious metal from gold bearing quartz in a local vein deposit. Research at this site aimed at the identification of the debris described in this thesis could finally unlock allow archaeologists to identify the location of a goldsmith’s workshop in Mesoamerica.
Bibliography

Aldenderfer, Mark, Nathan M. Craig, Robert J Speakman, and Rachel Popelka-Filcoff

Anderson, Arthur J.O., Charles E. Dibble (editors)

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Coghlan, H.H.


Coles, John


Cooke, Richard, Ilean Isaza, John Griggs, Benoit Desjardins, and Luis Alberto Sánchez

Costin, Cathy Lynne

Costin, Cathy Lynne and Melissa B. Hagstrum

Cunningham, Penny, Julia Heeb, and Roeland Paardekooper.

D’Altroy Terrence N., and Timothy K. Earle

Daumas Maurice

DeBoer, Warren, and Donald Lathrap

De Fuentes, Patricia
1963 The conquistadors: first-person accounts of the conquest of Mexico. Orion, Phoenix.

De la Vega, Garcilaso

Dewan, Leslie, and Dorothy Hosler

Donnan, Christopher B.

Easby, Dudley T.

Edmonson, Munro S.  

Eissler, Manuel  

Elliot, John Huxtable  

Emmerich, André  

Falchetti, Ana María  

Feinman, Gary M., Steadman Upham, and Kent G. Lightfoot  

Fernandez de Oviedo, Gonzalo  

Ferrero, Luis  

Gasco, Janine  
Gutiérrez, Gerardo

2010 Arqueología de la Antigua Provincia de Tlapa: Desde el Período Arcaico hasta la Independencia de México. Letra Antigua, Mexico City.


Gutiérrez, Gerardo, and Mary E. Pye

Gutiérrez, Gerardo, Alfredo Vera, Mary E. Pye, and Juana Mitzi Serrano
2011 Contalco and La Coquera: Arqueología de Dos Sitios Tempranos del Municipio de Tlapa, Guerrero. Letra Antigua, Mexico City.

Gutiérrez, Gerardo, Viola König, and Baltazar Brito
2009 Códice Humboldt Fragmento 1 y Códice Azoyú 2: Nómina de tributos de Tlapa y su provincia al Imperio Mexicano. Centro de Investigaciones y Estudios en Antropología Social, Mexico City

Habashi, Fathi

Harkin, Michael E.

Hassig, Ross

Hossler, Dorothy

Hosler Dorothy, Heather Lechtman, and Olaf Holm

Ibarra, Eugenia

La Niece, Susan and Nigel Meeks

Lange, Frederick W.

Lechtman, Heather

Lechtman, Heather, Antonieta Erlij, and Edward J. Barry, Jr.

Lemmonier, Pierre

Lockhart, James

Long, Stanley

Lothrop, S.K.  

Maldonado, Blanca  

Maldonado, Blanca, Curt-Engelhorn-Zentrum, Archaometrie Mannheim, and El Colegio de Michoacán  

Maldonado, Blanca and Thilo Rehren  

Marsh, Erik J., and Jeffrey R. Ferguson  

Mathieu, James R.  

Matos Moctezuma, Eduardo, and Felipe Solis Olguin  

McCreight, Tim  

Meighan, Clement  

Miranda, José  
1952  *El Tributo Indígena en Nueva España Durante el Siglo XVI*. Colegio de México, Mexico City.

Morteani, Giulio

Neupert, Mark A.

O’Day, Karen

Outram, Alan K.

Paris, Elizabeth H.

Patterson, Clair C.

Pendergast, David M.

Petersen, George G.

Puddephatt, R.J.

Quilter Jeffrey
Rao, T.V. Ramana

Rehder, John E.

Renfrew, Colin, and Paul Bahn

Reynolds, Peter J.

Roskamp, Hans, and Mario Rétiz

Ruvalcaba, Jose Luis, Gabriela Peñuelos Guerruero, Jannen Contreras Vargas, Edith Ortiz Díaz and Eumelia Hernández Vázquez.
2000’s  *Technological and Material Features of the Gold Work of Mesoamerica*. Manuscript on file Instituto de Investigaciones Antropológicas, Universidad Nacional Autónoma de México, Mexico City.

Saville, Marshall H.

Schiffer, Michael Brian, and James M. Skibo

Shimada, Izumi

131

Shimada, Izumi, David J. Goldstein, Ursel wagner, Anikó Bezur

Sillar, Bill, and Michael S. Tite

Simmons, Scott E., and Aaron N. Shugar

Skibo, James M.

Skibo, James M., Michael B. Schiffer, and Nancy Kowalski

Smith, Michael E., and Frances F. Berdan


Thomas, David H.

Townsend, Richard F.
Trigger, Bruce G.

Tringham, Ruth

Tylecote, R.F., and J.F. Merkel

Urban Patricia, Aaron N. Shugar, Laura Richardson, and Edward Schortman

Weeks, John M.

Werger, Paulette J., Betsy Douglas, Nancy Lee, and Karen Pierce

West, Robert C.

Yellen, John
Appendix A

Axe Monies

Around A.D 1200, there appears to be a shift in the metallurgical tradition of the West Mexican Metalworking Zone. This shift is marked by a fluorescence of new alloys, crafting techniques, and artifact types (Hosler 1994). From this point up to the Spanish conquest, various kinds of axe-monies can widely be found throughout the states of Michoacán, Guerrero, and Oaxaca. The large majority of all Mesoamerican are made out of a copper alloy that on average contains 0.5% to 6.35% arsenic by weight (Hosler et al. 1990).

Despite making a relatively late appearance in Mesoamerica, axe-monies have much earlier roots in South America. The first of these South American axe-monies date to approximately A.D 800, and can be found throughout coastal Ecuador, and the region of Batán Grande, Peru (Hosler et al. 1990). Shimada (1985) has interpreted the presence of axe-monies in Peru as evidence of the pre-Hispanic Exchange between coastal Ecuador and Peru. Throughout both of these regions they are most commonly found in burials in varying amounts ranging from a single axe-money to stacked bundles of 500. Their ubiquity in mortuary contexts has led archaeologist to argue that South American axe-monies a grave goods that serve as a proxy to indicate the individual’s status.

Unlike their South American counterparts, Mesoamerican axe-monies have been widely documented in a number of ethnohistoric sources. Throughout all of these sources, these artifacts have been documented in the context of tribute, and exchange. For example, the Codex Mendoza depicts axe-money shaped artifacts as part of the tribute that the Aztec provinces of Quiaitéopan, and Tepequacuilco had to pay to the Triple
Alliance (Berdan and Anawalt 1992). Similarly, the Relaciones Geograficas from Oaxaca state that copper axe-monies were part of the tribute payments from the towns of Tetiquipa and Cocautepec to Tututepec (Easby et al. 1967). Lastly, in a letter to the president of the council of the Indies in Spain, Francisco López Tenorio, a colonial government official from Oaxaca, drew what appears to be a type 2B axe-money and writes “This is the kind of copper coins that were used in New Spain…When new, four of these were worth five reales, while later, when somewhat worn they would not accept them at any price…” (Hosler et al. 1990:39). I contend that the tributary sheets discussed in this thesis served in a manner very similar to axe-monies.