THE PENNSYLVANIA STATE UNIVERSITY

The Graduate School

Department of Anthropology

THE PALENQUE POOL PROJECT:
AN ENERGETIC ANALYSIS OF MONUMENTAL CONSTRUCTION COSTS
OF AN ANCIENT MAYA STRUCTURE

A Thesis in

Anthropology

By

Elijah J. Hermitt

© 2018 Elijah J. Hermitt

Submitted in Partial Fulfillment
of the Requirements
for the Degree of

Master of Arts

May 2018
The thesis of Elijah J. Hermitt was reviewed and approved* by the following:

Kirk D. French
Associate Teaching Professor of Anthropology
Thesis Advisor

Timothy M. Ryan
Associate Professor of Anthropology
Undergraduate Honors Advisor

Kenneth G. Hirth
Professor of Anthropology
Graduate Program Chair

*Signatures are on file in the Graduate School
ABSTRACT

The Palenque Pool Project began excavations of the largest pool of the Picota Group in the Classic Maya site of Palenque in 2014. This group is located one kilometer from the Palace on the western edge of the site. Although the function of the pool is still unknown, its placement adjacent to one of Palenque's two stelae and its similarity to modern Maya examples, suggests ceremonial use. Prior research shows that a laborer could transport 586 kg of limestone per five-hour person-day from the determined source quarry to the location of the pool. These rates can then be applied to the total volume of stone used to construct the pool to estimate the number of person-days each process would require. The goal of this project is to quantify the energetic rates of quarrying, stone manufacture, and assembly in an effort to build a comprehensive monumental construction cost analysis. While analyses of this type have been done at other Maya sites, this approach has never been applied to any structure at Palenque.
# TABLE OF CONTENTS

LIST OF FIGURES ................................................................................................................. v

LIST OF TABLES ................................................................................................................... vii

ACKNOWLEDGEMENTS ..................................................................................................... viii

Chapter 1  Introduction ............................................................................................................ 1

Overview of Mesoamerica ............................................................................................... 2
Overview of the ancient Maya ......................................................................................... 7
Overview of Palenque ...................................................................................................... 16
Overview of the Picota Group.......................................................................................... 23

Chapter 2  Monumental Construction & Energetics ............................................................... 28

Development of archaeological energetic analysis ......................................................... 29
Labor organization across cultures ............................................................................... 33

Chapter 3  Methods & Theory ................................................................................................. 41

Components of architectural energetic analysis ........................................................... 44
Application to the Picota Group ..................................................................................... 47

Chapter 4  Results & Discussion ............................................................................................. 51

Results .............................................................................................................................. 53
XRD results .................................................................................................................... 54
Energetic results ........................................................................................................... 56
Discussion ....................................................................................................................... 67
Significance to Palenque .............................................................................................. 67
Broader implications .................................................................................................... 71

Chapter 5  Conclusion .............................................................................................................. 77

The origin of the ceremonial pool .................................................................................... 78
Future archaeological investigations ............................................................................ 85

References Cited ...................................................................................................................... 88

Appendix A  Pool measurements ............................................................................................. 107

Appendix B  Labor calculations .............................................................................................. 108
LIST OF FIGURES

Figure 1-1: Map of Mesoamerica (Source: FAMSI.org – Foundation for the Advancement of Mesoamerican Studies).................................................................3

Figure 1-2: Place map of Palenque in relation to other ancient Maya sites (Source: FAMSI.org – Foundation for the Advancement of Mesoamerican Studies). ..........8

Figure 1-3: Temple V at the Classic Maya site of Tikal. For scale, see the author standing at just over 6’1 in the lower center of the image. Photo by Kirk D. French ..........16

Figure 1-4: Main Palace complex at Palenque, taken from atop the Temple of the Cross. Photo by Elijah J. Hermitt.................................................................18

Figure 1-5: Site map of Palenque (Barnhart 2001).................................................................20

Figure 1-6: Map of the Picota Group. Readapted by Claire Ebert (Barnhart 2001).................24

Figure 1-7: Main Picota Pool after reconsolidation in 2015. Photo by Elijah J. Hermitt ..........26

Figure 1-8: Ceramic sequence of Palenque (Rands 2007).....................................................26

Figure 1-9: Picota Aqueduct exit. Photo by Elijah J. Hermitt .............................................27

Figure 2-1: The Avenue of the Dead from atop the Pyramid of the Sun, Teotihuacán. Photo by Elijah J. Hermitt.................................................................39

Figure 3-1: The original map of Palenque by Frans Blom, found in Barnhart (2001).........42

Figure 4-1: The PANalytical X’Pert³ MRD used for XRD testing of the “sand” in the Main Picota Pool. Photo by Elijah J. Hermitt ......................................................52

Figure 4-2: The stage upon which the “sand” was placed in the PANalytical X’Pert³ MRD. Photo by Elijah J. Hermitt .................................................................53

Figure 4-3: Results from X-ray diffraction (XRD) tests.........................................................55

Figure 4-4: Map showing the two possible quarry sites – circled in red – in relation to the Main Picota Pool – noted with a yellow star (Barnhart 2001).................58

Figure 4-5: Thin section samples under microscope.................................................................60

Figure 4-6: Geologist and collaborator Tim White cuts limestone samples using a wet rock saw to make thin sections for petrographic analysis. Photo by Elijah J. Hermitt ...73
Figure 4-7: The author extracts limestone samples using a tool fashioned by Andrés and Eduardo, the Maya workers on the project. Photo by Kirk D. French.................................75

Figure 5-1: Walter “Chip” Morris and Kirk D. French discuss aspects of the Spring of San Juan, a sacred waterhole in the Maya village of Chamula in 2015. Photo by Elijah J. Hermitt.................................................................81
LIST OF TABLES

Table 1-1: Time periods of ancient Maya chronology (Evans and Webster 2010, 426). ........ 10

Table 1-2: Known dynastic chronology of Palenque (Skidmore and Greene Robertson 2010; D. Stuart and Stuart 2008). The two most significant rulers responsible for much of the largest monumental construction (e.g. Temple of the Inscriptions, the Cross Complex) are in bold..........................................................22

Table 2-1: Five models of labor recruitment (Udy 1959).........................................................34

Table 3-1: Breakdown of work rates........................................................................................50

Table 4-1: Breakdown of labor investment results.................................................................64

Table 4-2: Theoretical amount of workdays for varying group sizes.................................66
ACKNOWLEDGEMENTS

Parents. Mandy and Joe. I would like to first recognize the love and encouragement of these incredible people. I can’t imagine there are many parents who would react with unyielding support to your child saying, “I want to be an archaeologist,” but y’all did.

Mentors. Kirk, Tim, Jeffrey, David. Under no circumstances could I have done any of this without the constant support and guidance of Kirk French. Inviting a wide-eyed teenager to the field was surely a gamble, and one that I will appreciate for the rest of my life. Over five years of collaboration, you have been an engaging teacher, a committed colleague, and always a friend. I would be remiss not to mention the academic support of Tim Murtha, Jeffrey Glover, and David Webster. Murtha, thank you for your full commitment to me, both as a student and as a collaborator. Jeffrey the Friendly Gringo, you trusted the word of your colleagues to invite a student from a different university into your Proyecto Costa Escondida family. Along with getting to do some pretty badass archaeology, I was also able to meet some life-long friends. For this and so much more, I thank you. David, you inspired me from the moment I began the Ancient Maya introductory class my freshman year. I was enamored by your storytelling, and I thank you for igniting the scientific fire under me.

Memories. Paula and Al. This all started on a freezing Sunday morning at the Phillips and Conrail sites in Duryea, Pennsylvania when I was just ten years old. After screening dirt for hours and finding a piece of a Native American pipe stem, I was hooked. Though I was only able to return to the site when my family was visiting for Thanksgiving, your newfound passion, Paula, and your outstanding mentorship, Al, are what drove me to actually pursue this dream.

Music. Perhaps my second most important support system were the artists that accompanied me along the way. Thank you to Jack White, Bob Dylan, Alabama Shakes, Kendrick Lamar, the Avett Brothers, Solange, Kamasi Washington, Talking Heads, Jason Isbell, SZA, Run the Jewels, Frank Ocean, Tom Petty, and Childish Gambino. Y’all pushed me through.

Amigos. Alex, Haydn, Serena, Diego, Alex, David. Whether you were next door or across the country, your support never went unnoticed.

Partner. Emma. Uplifting, empathetic, and compassionate. Without you I undoubtedly would have gone off the rails at some point during this process. Thank you for always being here emotionally even when you were far away physically.

Funding. Thank you to the College of the Liberal Arts, the Department of Anthropology, the Schreyer Honors College, the James W. Hatch Memorial Fund, National Geographic, the Waitt Foundation, and the Hamer Center for the financial support throughout my time at Penn State.
“Presuming that there is such a thing as ‘progress’ when it comes to music (and architecture), and that it is ‘better’ now than it used to be, is typical of the high self-regard of those who live in the present.

It is a myth. Creativity doesn’t ‘improve’”

-David Byrne
Chapter 1

Introduction

This thesis focuses on the investment of collective labor necessary to build a ritual structure and the broader social consequences of such organization. Utilizing the labor calculation methodology outlined by Elliot Abrams (1984, 1994) this research seeks to calculate the amount of person-days it would have taken to construct a pool in the western periphery of Palenque, a Classic Maya site in modern-day Chiapas, Mexico. A quantitative energetic cost analysis such as this has yet to be carried out at Palenque. It will elucidate possible tactics for labor organization as well as the physical and social costs of constructing a structure that was not “necessary” for survival in the region, from a modern outsider perspective. The inhabitants who built the Main Picota Pool, the central feature of this study, did not need a reservoir for water collection due to numerous perennial waterways throughout Palenque. Furthermore, the construction of the pool itself involved excavating into the bedrock, made of dolomitic limestone, to expose the water table. Therefore, the level of the water would have been minimally affected in times of both drought and especially wet seasons. The background and significance of this research will be reviewed in this introductory chapter.
Overview of Mesoamerica

The culture area of Mesoamerica is an ethnic conglomerate that spans an enormous spatial and temporal range. After the hunter-gatherer groups, ambiguously labeled Paleo-Indians, of the Archaic Period ancient Mesoamerica continues on to include the Olmec of San Lorenzo and La Venta, the great city-state of Teotihuacán, the Maya of modern day southern Mexico, Guatemala, Belize, Honduras, and El Salvador, and finally the Aztec of Tenochtitlan (Evans 2013; Smith and Masson 2000, see Fig. 1-1 below). However, these archaeologically identified groups represent only the tip of the cultural iceberg, for there were always various hinterland groups that undoubtedly existed throughout the landscape. As one of the most prominent culture areas of the world, this tangled web of culture has been woven and encompasses a wide range of artistic expression, religious beliefs, and architectural style.
The Paleoindian period, or the Lithic Stage, (8000 – 2000 BCE) refers to the band-level hunter-gatherer occupants of Mesoamerica before the formation of more “complex,” state-level society (Evans 2013, 64). Due to the presence of almost exclusively lithic material evidence, it is difficult for archaeologists to reconstruct cultural phenomena. An even more demanding task is to absolutely date any directly anthropogenic artifact because of the lack of carbon-based material.

Figure 1-1: Map of Mesoamerica (Source: FAMSI.org – Foundation for the Advancement of Mesoamerican Studies).
The cultural chronology is contingent upon the presence of Clovis technological culture, characterized by a chipped stone tool technique that results in a bifacial fluted point that could be potentially attached to a spear or other projectile (Haynes 1964). Pre-Clovis culture, however, was not void of useful tools, as there is evidence of bone projectile point fragments in megafauna such as mastodon (Waters et al. 2011). Since the Clovis style points are the principal pieces of material evidence for identifying the Clovis culture complex. One topic in particular that can be examined with such scant evidence is the technological seriation across time and associated demographic shifts, such as the “staging-area model” which predicts a drawn out progression of Clovis settlement (D. G. Anderson 1990; Smallwood 2012). It is likely there was a widespread Clovis knapping technique that was transmitted through contact with outside groups (Sholts et al. 2012).

As time progressed, foraging was gradually replaced as the most common form of subsistence with agriculture. With sedentary lifestyle and formal political hierarchy being two main consequences of agricultural subsistence, the term “civilization” would become a more appropriate descriptor of the settlements. The oldest of which known in Mesoamerica was the Olmec civilization (1200 – 300 BCE) predominately residing in the plain regions of Veracruz and Tabasco (Breiner and Coe 1972). Mostly concentrated in the large provincial centers of La Venta and San Lorenzo, the Olmec dwelled the fertile areas at the base of the Tuxtla mountain range. In reality, this label of “Olmec” more accurately represents an artistic style that is used, as a proxy, to describe a group of people, for virtually nothing is known about the occupants themselves including their actual ethnic identity (Coe and Koontz 2008, 35). This artistic style is best known
through the famous Colossal Heads of the Olmec that depict snarling warrior faces adorned with signature helmets (Joralemon 1971). Motifs from the Olmec style remained in Mesoamerica, as is evident by the inclusion of some in Maya iconography that serve similar ideological functions (Reilly 1986).

In addition to the Olmec, another major influence on Maya iconography and ideology was the great city-state of Teotihuacán (100 BCE – 600 CE). Located roughly 40 kilometers to the northeast of the modern metropolis of Mexico City, this primate center cast an influential shadow that continues to impact the region even today. Based on results from strontium isotope testing of human bone and teeth, it is clear that there were myriad ethnic identities represented throughout the city (Price, Manzanilla, and Middleton 2000). In fact, ethnic enclaves were situated throughout separate barrios such as Tlajinga 33, which was inhabited by artisans involved in specialized craft production (White et al. 2004; Manzanilla 2016). There is ceramic and lithic evidence of interaction between Teotihuacán and the Central Maya Lowland region, specifically the site of Altun Ha, in modern day Belize, as early as the second century of the Common Era (Pendergast 1971) as well as Kaminaljuyu in the modern Guatemalan Highlands (Sanders, Diskin, and Coe 1974). Additionally, green obsidian, a diagnostic artifact of Teotihuacán that originates from the Pachuca source in Central Mexico, is present throughout the Maya region as symbolic representations of deep spiritual ties to the great city (Spence 1996). Regarding the site itself, the enormous Pyramid of the Sun and the expansive Avenue of the Dead illustrate that this site was an impressive demonstration of monumental construction. As is evident from the Feathered Serpent Pyramid and the Moon Pyramid, two other major structures at Teotihuacán,
those in power were focused on the materialization of important aspects of their worldview (e.g. astronomical movements and calendars) throughout monumental construction (Sugiyama, Sugiyama, and Sarabia G. 2013). Even long after the decline of the city around the sixth century CE, the far-reaching influence of Teotihuacán is evident in the *talud-tablero* architectural style, which became ubiquitous throughout Mesoamerica.

The final dominant political center of Pre-Columbian Mesoamerica was Tenochtitlán, the capital of the Aztec Empire. Situated at the center of Lake Texcoco, the inhabitants of the city developed a complex system of intensive cultivation fields called *chinampas* located in the shallow waters of the lake (Frederick 2007; Morehart and Frederick 2013). Though quite influential and powerful throughout the region, the Aztec Empire lasted less than one hundred years due to the Spanish forces lead by Hernan Cortes destroying the capital (Carmack, Gasco, and Gossen 2016, 175). After completely defeating the Aztec, the Spanish re-established this city as the administrative center of New Spain, which has now been transformed into the modern capital of Mexico City (Mundy 1998).

Each of the aforementioned cultures had a tremendous impact on Mesoamerica and the development of complex society in the region. However, none of them could compare to the immense geographic and cultural diversity exhibited by the ancient Maya, a culture comprised of numerous autonomous polities.
Overview of the ancient Maya

One of the most geographically and temporally expansive culture groups of Mesoamerica was the ancient Maya. Sites deemed to be Maya extend from the Lowland region around the Isthmus of Tehuantepec to the Yucatán Peninsula, and into the Petén region of Guatemala, all of Belize, and some areas of Honduras. This group is temporally organized and conceptualized into the general epochs of Formative, Classic, and Postclassic Periods (see Fig. 1-2) ranging from approximately 2500 B.C. until contact with the Spanish conquistadors during the mid-sixteenth century A.D., although many Maya urban centers began to decline around 900 A.D. (Coe 2011; Graham, Pendergast, and Jones 1989). Unlike the Aztec Empire, which had a true capital city, Tenochtitlan, now the site of the modern-day urban center of Mexico City (Mundy 1998), the Maya represented a network of autonomous polities that shared stylistic similarities in architecture, art forms, political organization, and theological practice. There were a number of mathematical (W. Anderson 1971), architectural (Abrams 1994), and epigraphic (Coe 1992; Schele 1991) contributions made by the ancient inhabitants during their political occupation of southern Mesoamerica that spanned nearly two millennia. One widely known example was the infamous long-count calendar (Long 1924), which was egregiously appropriated in 2012 in anticipation of a possible global apocalypse scenario (Sitler 2006). Aside from the superfluous hysteria invigorated by modern tourism and viral internet sharing, the ancient Maya were a prolific culture, and the modern inhabitants continue to thrive on the region.
Despite its importance to archaeological and sociolinguistic study of the region, no individual in Prehispanic times ever used the label of “Maya” to describe her or his ethnic identity. Though they do share a common language group, this even is comprised of a
myriad of related yet mutually exclusive dialects such as Yucatec, Tzeltal, Tzotizil, Ch’ol, and many more spanning across the entire Maya culture area (Coe 2011, 26). The modern-day inhabitants of the Maya region of Mesoamerica do not identify solely as “Maya.” Rather, they identify as their language group such as “Tzeltal” or “Ch’ol” and do not recognize the ancient occupants of the area their decedents, even though they may be genetically related (Marken, Guenter, and Freidel 2017). Ethnicity, in broad anthropological terms, can be described as a cultural entity that is biologically supported, displays cultural unity, interacts through a shared form of communication, and is discernible from other ethnic categories by those both within and outside the group (Barth 1969). This is to say that while outsiders may have assigned the macro-ethnicity of “Maya” to anyone living in the specified region of Mesoamerica, those inside self-identify as members of more specific ethnic groups based on language and place. Archaeologically, it is important to make the distinction between the signaling of class and ethnic group affiliation. Many archaeological investigations and subsequent interpretations of material culture are top-down in nature and tend to focus on the former, rather than examining how it may be communicating and furthering the latter (Jones 1997). In the case of Palenque specifically, it has been argued that elite perpetuation and the participation of local common people in ethnicity identification made Classic period Palenca nos ethnically separate from other Maya groups in the Lowland region (Marken, Guenter, and Freidel 2017, 195).
Table 1-1: Time periods of ancient Maya chronology (Evans and Webster 2010, 426).

<table>
<thead>
<tr>
<th>Period</th>
<th>Time range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Late Postclassic</td>
<td>CE 1250 - 1500</td>
</tr>
<tr>
<td>Early Postclassic</td>
<td>CE 1000 - 1250</td>
</tr>
<tr>
<td>Terminal Classic</td>
<td>CE 800 - 1000</td>
</tr>
<tr>
<td>Late Classic</td>
<td>CE 600 - 800</td>
</tr>
<tr>
<td>Early Classic</td>
<td>CE 250 - 600</td>
</tr>
<tr>
<td>Protoclassic</td>
<td>CE 100 - 250</td>
</tr>
<tr>
<td>Late Formative</td>
<td>400 BCE - CE 100</td>
</tr>
<tr>
<td>Middle Formative</td>
<td>1000 - 400 BCE</td>
</tr>
<tr>
<td>Early Formative</td>
<td>2500 - 1000 BCE</td>
</tr>
<tr>
<td>Archaic</td>
<td>Before 2500 BCE</td>
</tr>
</tbody>
</table>

The Maya culture chronology (see Table 1-1) begins more than 2,000 years ago, as hunter-gatherers in the highlands began to gradually turn to more sedentary, agriculture-based subsistence over the next millennia (Coe 2011, 26). As the Formative period transitioned to the Classic, city construction complete with monumental construction becomes a common characteristic across sites. The label of “city” has been brought into question in regards to Maya centers, especially in comparison to Teotihuacán, which conforms to many modern standards of city-hood. Fox (1977) lays out a typology for pre-industrial cities which includes the labels of regal-ritual, mercantile, and administrative. According to Sanders and Webster’s (1988) analysis of this model, many Maya centers fall into the classification of regal-ritual urban centers. This means they generally adhere to characteristics such as a low population with low social variation between core and periphery inhabitants, kinship-based inheritance of power, and intense ideological institutions. But
Palenque seems to run counter to this claim that applies to most Maya centers due to its dense population settlement, monumental public works and hydraulic engineering, and its expansive public plazas (Barnhart 2007; Barnhart 2001). The limiting factor of environmental circumscription (i.e. large network of streams running through the site) confined Palenque to develop its public and residential architecture within a restricted area (French 2009). This is significant because it further amplifies the significance of its subterranean aqueducts and water management engineering, which will be discussed in detail throughout this thesis.

The “collapse” of the Maya civilization, as it is colloquially termed, has been an extreme point of contention among both the general public and Maya archaeologists alike for decades. In addition to the various opinions and subsequent arguments within the academic community, there is also a great deal of public misunderstanding about collapse in general and the Maya as a whole. Due to a problematic history of archaeologists being particularly focused on ceremonial centers that were inhabited by mostly elite class members, there has been little study of the Maya at the household level until relatively recently (Wilk and Rathje 1982; Robin 2003). Although this plague of top-down archaeological focus extends to many other regions around the world, it has certainly ignited much disagreement regarding the infamous demise of the Maya. This purported concept was not an utter societal breakdown that wiped the entirety of the Maya population from the landscape, as the word “collapse” itself would imply. Instead, the timing and proximate reasons for dramatic change in the sociopolitical landscape varied regionally (Aimers 2007; Andrews IV 1973). As is true with
any multifaceted issue ranging from the origins of agriculture to the rise of complex society, there can almost never be a singular cause identified. Instead one must think about answers to complex questions on a continuum of simultaneously contributing explanations. From the litany of explanations for the decline of the Maya proposed by archaeologists over the years, four widely known hypotheses will now be outlined.

First, the monopolization of access to water by political elites may have led to the decline of many regional centers (Lucero 2002). It has been asserted that control over water, the most important resource in many instances, has the potential to enable total power under a “hydraulic empire” coordinated by powerful elites (Wittfogel 1957). However, the Classic Maya elite’s system of control over access to water was never quite as pervasive as the Wittfogelian model suggested based on the cases of despotism in China and India (Scarborough 1998). It has been suggested due to increased solar activity, there was a period of increased aridity that began around 750 A.D. and lasted through 1000 A.D (Hodell et al. 2001; Lucero 2002). From this, Lucero suggests the sharp decrease in rainfall resulted in the failure of water management and control systems, which then began a domino effect of losing overall ritual and political control of the population.

Although this might have been the case for many Maya sites, it appears as though this would not have held true at Palenque due to the shear abundance of water in and around the urban center. The intricate system of bajo reservoirs for water retention at the sizeable Classic Maya site of Tikal made elite control over access to this scarce resource possible (Scarborough and Gallopin 1991). But at Palenque, the abundance of perennial running
water throughout the urban core would have made state level control nearly impossible. Further, drought would have had little effect on the state of hydrological conditions at Palenque, which will be further discussed in the following section (French and Duffy 2014).

Next, there were several intense and extended periods of drought throughout the Late and Post Classic Periods that could have also been a driving force behind many factors contributing to the demise of the Maya (Kennett et al. 2012). This claim by Kennett and colleagues created a sub-annual climate record for the past 2000 years based on speleothem data from the Yok Balum Cave in the modern day country of Belize. These data are then aligned with the historical record of events associated with dates proven to be accurate. From this, they suggest that uncharacteristically high annual rainfall rates allowed for extraordinary population growth and subsequent florescence of the prolific urban centers previously mentioned above. Then, a period of climatic aridity directly followed and prompted balkanization, warfare, and political strife, which led to the eventual collapse of the Maya polities. The same basic message has been put forth using a seasonally resolved record of titanium, which also suggests multiyear drought events through the Terminal Classic Period around 810, 860, and 910 A.D. (Haug et al. 2003; L. C. Peterson and Haug 2005). Although the scope of the supporting data for these studies is very narrow (i.e. speleothem dates from a single cave in Belize), the trajectory of rapid population expansion during extended time periods of uncharacteristically high annual rainfall is intuitive. An increase in water resources for an area that generally must be equipped to sustain through an intense dry season would result in the increasing of population size and later political
development. Further, a sharp decrease in this resource would undoubtedly have rippling effects across the natural and sociopolitical landscapes. However, Palenque represents an exception to this hypothesis because through hydroarchaeological modeling of the site’s watershed even under the most severe drought conditions there would have still been a sufficient amount of water for both personal consumption and agricultural use for the estimated 6,000 inhabitants (French and Duffy 2014). This counter example only further aids in the rejection of the idea that all of Maya civilization came to an abrupt and collective halt due to a single catastrophic cause.

Third, these warmer drought conditions could have been a byproduct of widespread deforestation (Oglesby et al. 2010; Abrams and Rue 1988). This suggestion of human-induced drying is offered as an addition to, rather than a replacement for, the extended natural drought events described above (See Kennett et al. 2012; Haug et al. 2003). Deforestation was an essential practice for the Maya in relation to elaborate monumental construction projects. In order to create lime powder (CaO) for making plaster stucco, the brilliant white paste used to cover nearly all monumental surfaces including plaza floors, an extremely hot and constantly burning fire is needed. The annual potential of one hectare of rainforest is 444 kilograms of lime per hectare per year (Schreiner 2002, 74–75). With these figures in mind, it would be plausible to state that deforestation could be the culprit for anthropogenic aridity.

Lastly, another ecological suggestion focuses on anthropogenic soil degradation and subsequent erosion leading to poor agricultural conditions (Bennett 1926; Morley and
Brainerd 1968, 71). The issue with this suggestion is the lack of consideration for the regional limestone bedrock. This type of karst environment has the potential to naturally weather, leaving behind a thin layer of residual soils (Beach et al. 2006). However, despite possible natural contribution to soil degradation, the agroengineering strategies of the Maya (e.g. terraces, canalized irrigation systems, etc.) enabled for agricultural success in the steep topography of the region (Beach et al. 2002). Principally, it is important to acknowledge that the human-induced geomorphic impacts were occurring from the time the Maya began to coalesce as a civilization, therefore anthropogenic soil degradation would not have been the cause for its eventual decline millennia later.

As is the case with any hierarchical cultural organization, monumental architecture was vital to the expression of authority by the Maya elite. This was a strategy employed by those in power to further perpetuate the aforementioned unified local identity (Marken, Guenter, and Freidel 2017). Monumental structures were often visually impressive feats that not only undoubtedly captured the attention of the local inhabitants but also guided them toward the ideological or political obedience desired by the elite (e.g. Fig. 1-3).
Overview of Palenque

Palenque is an ancient Maya site (100 BCE – 800 CE) located in the modern day state of Chiapas in southern Mexico that flourished during the Late Classic Period. Its ancient Maya designation of Lakamha’, or “Big Water” was indicative of the setting dominated by perennial running arroyos or streams such as the Picota, Otolum, and
Murciélagos cutting through the urban center (French, Duffy, and Bhatt 2013). The site is situated on a large limestone escarpment running east to west. The westward-flowing Michol River, located to the north of the escarpment, drains into the Grijalva River, while on the south side of the site center the Chacamex River flows east to the Usumacinta River. This would have given Palenque access to two of the largest watershed networks in the Maya region. In addition to the pervasive presence of running water, rainfall is also in abundance with an average annual total of approximately 3000 mm, much of which comes during a distinct rainy season beginning in July and lasting until October (D. Stuart and Stuart 2008; French and Duffy 2014). The copious amount of water in combination with the rich agricultural soil made the Palenque region a likely candidate for large-scale urban settlement and growth (Liendo Stuardo 1999). Nearly 1,500 structures have been identified over Palenque’s 2.2 square kilometer area and are attributed to an estimated population of around 6,000 people (Barnhart 2001).
Palenque had a long history of dynastic rulers that were predominantly, though not exclusively, kings (See table 1-2). In fact, Lady Yohl Ik'nal, the eighth ruler in the Palenque chronology, is the only completely documented queen anywhere in the Maya culture history who ruled in sole power (Tuszyńska 2015). There are three known portraits of this ruler that enable this claim, two of which are on the famous sarcophagus of K’ínich Janab Pakal, the heralded king of Palenque entombed in the Temple of the Inscriptions (Spencer 2007, 48).
The architectural grandeur of the site center, now a tourist attraction, can be initially attributed to the efforts of Pakal to erect monumental architecture. Throughout his remarkably long reign of nearly 69 years, he oversaw the construction of many large monumental structures that still stand today. These structures are manifestations of the intersection between political and ideological supremacy. An important tool in this demonstration may have been the manipulation of sound through specific construction plans, such as those seen in the North Group adjacent to Palenque’s main ceremonial center (Zalaquett 2010). In this complex, buildings covered in stucco such as Templo del Conde (Temple of the Count), named after Count Fredrick Waldeck who resided in the ancient structure for a year in 1832, and Templo X could project sounds from certain parts of the plaza over greater distances. This presumably would have been used in the context of political or ceremonial events in order to communicate a message with a large group of people in the plaza.

Though he did not begin his architectural crusade until his thirty-second year in power with the construction of the Templo Olvidado (Grube 2006), K’ich Janaab Pakal managed many more projects such as his own funerary building, the Temple of the Inscriptions (Schele and Freidel 1992). All of this was done in an effort to solidify Pakal’s historical interpretation that hails him both on a large architectural scale as well as on portraits and other inscriptions. Recently, Pakal’s age has become a hotly contested topic of debate among epigraphers who state that inscriptions show Pakal was nearly eighty years of age and osteologists who ascertain that the physical evidence points to somewhere in the
range of forty to fifty years old (Watson 2014). The son and successor of Pakal, K’ínich Kan Bahlam II, continued the trend of extensive monumental construction efforts during his reign. In addition to the completion of his father’s penultimate monument of the Temple of the Inscriptions, Kan Bahlam also headed the great Cross Group architectural complex directly adjacent to the southwest side of main Palace area (Houston 1996). This push for monumental architecture to solidify elite familial legacies continued on with the grandson of Pakal, K’ínich Ahkal Mo’ Nahb III, who oversaw the construction of Temples XIX and XXI (D. Stuart 2007). It is evident that monumental architecture was a significant tool employed by rulers of Palenque for establishing public trust and control.

Figure 1-5: Site map of Palenque (Barnhart 2001).
Many sites in the Maya Lowlands relied heavily on water storage features in order to sustain through the annual dry season such as those present at Tikal (Scarborough and Gallopin 1991). At many other sites across the Maya region water storage in plaster-lined reservoirs, called *aguadas*, were the fundamental innovation in place to ensure access to water throughout the intense dry season. An example of a site that utilized this strategy is Tikal, one of the most prolific Classic Maya sites located in the Petén region of Guatemala (Ferrand et al. 2012; Scarborough and Gallopin 1991; Weaver et al. 2015). However, Palenque was presented with the opposite challenge, as there was an abundance of perennial water flowing through the city (French and Duffy 2010). Palenque’s ancient name of *Lakamha’* or Big Water was indicative of this issue. Its mountainside situation in addition to six perennial arroyos, and more than fifty natural springs that flow throughout the site were all factors that contributed to availability and overabundance of water (Barnhart 2001, 98). In response, there were intricate water management systems constructed in order to divert the water underground through aqueducts. In fact, in the Piedras Bolas Group of Palenque there is evidence of a practical understanding among engineers about creating water pressure in order to create an urban conduit system for water transport (French and Duffy 2010). One of the most complex subterranean aqueducts at the site manages the Picota Stream, the principal waterway of Palenque’s western periphery (French 2009). Due to this vast and constant access, there was a high level of independence among the people of Palenque in regards to acquiring and using water. This was the opposite at most sites that faced the heavy social cost of reliance on elite control over access to water (Lucero et al. 2014).
Demonstrated by the grandiose architecture of the main site center (see Fig. 1-4), monumental undertakings were certainly a strategy used to legitimize power and gain influence. Due to its situation atop a large limestone escarpment, builders had infinite access to the strong dolomite limestone present in the region (Littmann 1958). Because of this, the structural integrity of the architecture in Palenque has been able to, for the most part, withstand the test of time.

Table 1-2: Known dynastic chronology of Palenque (Skidmore and Greene Robertson 2010; D. Stuart and Stuart 2008). The two most significant rulers responsible for much of the largest monumental construction (e.g. Temple of the Inscriptions, the Cross Complex) are in bold.

<table>
<thead>
<tr>
<th>Order</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>K'inich Janaab Pakal II</td>
</tr>
<tr>
<td>14</td>
<td>K'inich Ahkal Mo' Nahb III</td>
</tr>
<tr>
<td>13</td>
<td>K'inich Kan Joy Chitam II</td>
</tr>
<tr>
<td>12</td>
<td>K'inich Kan Bahlam II</td>
</tr>
<tr>
<td>11</td>
<td>K'inich Janaab Pakal I</td>
</tr>
<tr>
<td>10</td>
<td>Muwaan Mat</td>
</tr>
<tr>
<td>9</td>
<td>Ajen Yohl Mat</td>
</tr>
<tr>
<td>8</td>
<td>Lady Yohl Ik'nal</td>
</tr>
<tr>
<td>7</td>
<td>Kan Bahlam I</td>
</tr>
<tr>
<td>6</td>
<td>Ahkal Mo' Nahb II</td>
</tr>
<tr>
<td>5</td>
<td>K'an Joy Chitam I</td>
</tr>
<tr>
<td>4</td>
<td>Ahkal Mo' Nahb</td>
</tr>
<tr>
<td>3</td>
<td>Butz' aj Sak Chik</td>
</tr>
<tr>
<td>2</td>
<td>&quot;Casper&quot;</td>
</tr>
<tr>
<td>1</td>
<td>K'uk' Bahlam I</td>
</tr>
</tbody>
</table>
Overview of the Picota Group

Tucked away in the western periphery of the site of Palenque is the Picota Group, named after the perennial arroyo running beneath the 1,477 m² plaza (French 2007). The water enters the aqueduct under a sizable lintel (3 m X 1.5 m X 40 cm), flows into a smaller-sized pool (~2.5 X 2.5 m), exits and returns to the aqueduct, flows downstream entering and exiting the Main Picota Pool, repeating the process once more in the third and final pool (~6 X 6 m) before exiting the aqueduct and continuing to naturally meander through the site (See Fig. 1-9). This water management system allowed for a 23% increase in the size of the Picota Plaza (French 2007). The Main Picota Pool, the artifact of interest in this thesis, measures approximately 10 X 4 m with an average depth of 1.25 m (See Fig. 1-7). The inhabitants of the area dug about 1.5 m into the bedrock during the construction of the pool. It was constructed in a single construction phase as a part of the subterranean aqueduct system that manages the Picota arroyo.
Though the subterranean aqueduct was necessary to create space and avoid flooding, the Main Picota Pool itself is an example of monumental architecture likely undertaken with the intent of creating a shared ceremonial space. Since the engineers of this project excavated into the bedrock, the water level of the pool is actually the natural water table. That is, the Picota arroyo...
does not act as a water source to fill the pool but rather acts as means to keep the water from becoming stagnant. The gradual entrance and exit of the water acts as a quasi-skimmer system that one would observe with a modern pool filtration system. This process circulates debris left on the surface and leads it to the larger exit drain, diverting the clutter downstream.

Exact dates for this complex water management system remain unclear, as does the actual function of the pool. Due to poor preservation in the region, researchers rely heavily on the extensive ceramic sequence developed by Robert L. Rands (1974) for dating in Palenque. After test pits were dug in the surrounding territory, it was determined that the largest concentration of Picota Phase ceramics (CE 250 – 400) is found in the Picota Group (see Fig. 1-8). This ceramic phase is associated with the transition from Preclassic to Early Classic and demonstrates certain characteristics of the Palencano ceramic tradition that eventually came to fruition during the Classic period (Rands 2007). This makes it plausible to trace one of the initial settlements of Palenque back to this area of the site (French 2009). Although the precise function of the pool itself will likely forever remain a mystery, its placement adjacent to one of Palenque's two stelae and its similarity to modern Maya examples outside the city of San Cristóbal de las Casas just over 200 km to the south in Chiapas, suggest ceremonial use. This possible migratory connection to the highland region of southern Chiapas will be discussed at greater length in the conclusion of this thesis.
Figure 1-7: Main Picota Pool after reconsolidation in 2015. Photo by Elijah J. Hermitt.

Figure 1-8: Ceramic sequence of Palenque (Rands 2007).
Figure 1-9: Picota Aqueduct exit. Photo by Elijah J. Hermitt.
Chapter 2
Monumental Construction & Energetics

Throughout the existence of a hierarchical structure in human societies, monumental architecture has been used as a principal tool for expressing elite political control. This characteristic is true across both time and space, from the Giza pyramid complex in Egypt to Teotihuacán’s great Temple of the Sun to the tallest building in the modern society, the Burj Khalifa tower in Dubai. With each of these examples, elites seek to declare their dominance to constituents through two main strategies: the visible grandeur of the structure itself and the organization of a sufficiently large labor force. There would have been a wide range of tactics used by the elite class to exercise power over the working class such as controlled allocation of resources, ideological control, or “Big Man”-style festivals (Strathern and Stewart 2005). However, monumental architecture remains an obvious and universal manifestation of such authority that is also easily detectable through archaeological analysis. Often large-scale monumental architecture and small-scale household structures are the only surface remnants of a given ancient culture. The origin story of large monuments or elite sponsored buildings is the facet of society that depicts the actual human effort needed to bring together a project of such magnitude.
Development of archaeological energetic analysis

Since ancient monumental architecture represents the physical manifestation of organized labor, archaeologists can extrapolate a broad range information about the culture responsible for the construction from the vestiges of a sociopolitical structure that no longer exists. This could be information about the social development of the culture, its social “complexity,” use of natural resources, and divisions of labor. As a short aside, the hesitation to use “complexity” stems from the erroneous implication that societies without formal economic and political institutions are somehow inferior. The initial labels of “savagery, barbarism, civilization” are no longer directly used, but have long plagued archaeological theory with a unilateral social evolutionary track that complex statehood is some sort of end goal (Childe 1950). However, studies of egalitarian societies like the Martu Aborigines of the Western Desert in Australia show that although there may be a lack of formal political institutions and hierarchies, there is still a complex network of social relations that drive the society (Bird and Bliege Bird 2010). In relation to the monumental architecture of the Maya, it is evident that the magnificence of the structures themselves does not directly translate to a “complex” level of social development (Abrams 1984, 265). In the following section, the several facets of energetic analysis of monumental construction will be outlined.

The currency of monumental construction is energetic expenditure, measured in person-days; a unit that describes the amount of work (e.g. acquisition, transportation, manufacture, assembly) a laborer could muster during a five-hour day. This seemingly short workday length will be explained and justified later in this chapter. This approach of theoretical quantification of work came as a byproduct of more hypothetical analysis of architecture. Lewis Henry Morgan’s
*Houses and House-Life among the American Aborigines* (1881) is credited by Abrams (1989) with being the first work to discuss the relationship between architecture, social relations, and hierarchy. Further, the aforementioned suggestion of a correlation between architectural characteristics and cultural complexity, an idea that became rampant throughout the anthropological community, draws its origin from this work. For example, Morgan suggests a high level of communism throughout Native American populations, especially the Iroquois. This proposal is based on the village layout of multiple kin-based households being attached or open to enable community members to easily pass through different residences. There were also various roles assigned to residents based on gender or age, such as a matron who would oversee the domestic economy. Evidently, the use of architecture as a means of explaining social organization is not a new idea in anthropology. However, after being neglected by several generations of anthropologists, its revitalization came with the quantification of energetics to explain architectural labor investment. Its originality within the discipline makes this work a significant springboard into modern detailed energetic study.

In order to theoretically quantify energetic expenditure and resource consumption, one must perform representative experiments from which theoretical equations can be created. The use of experimental archaeology is vital to revealing any information about the processes involved in ancient construction (Outram 2008). Archaeological experiments can be used in many facets of the field outside of just monumental construction analysis and are divided into five categories (Reynolds 1999). 1.) Construct trials refers to a test replica for an ancient edifice that is no longer standing but is archaeologically identifiable. 2.) Processes and function experiments assess how ancient technologies may have been used and at what rates its users could perform the
given purpose of the tool (Milner, Hammerstedt, and French 2010). 3.) Simulation seeks to mimic and thus reveal information about the post-depositional processes that occur to create the archaeological record. 4.) Eventuality trial is often used to examine long-term responses of complex systems like agriculture to unforeseen climatic events. 5.) Finally, technological innovation experiments seek to validate the functionality of actual archaeological techniques in controlled yet realistic situations. Each of the experiments described in this section fall into the category of processes and function experiments because archaeologists employ modern workers to use ancient technologies and record the rates at which certain tasks are completed.

In what has become a seminal work in monumental architecture study, “Monument building: Some field experiments,” Erasmus (1965) looked at the excavation, transport, and manufacture rates at the Late Classic Maya site of Uxmal. He employed “some peasants” to perform tasks related to these processes to measure the person-day rates associated with various phases of monumental construction. In order to cut down on time and cost, Erasmus performed abbreviated yet comprehensive tests that serve as samples of what would be the total process (Coles 1979, 41). The aforementioned five-hour person-day is established rather than the ethnocentric eight hours that had been used in the previous investigations. He demonstrates that the work pace of the men declined significantly during the sixth hour of work. From here, the intent was to estimate the total amount of labor needed to construct a ceremonial center and, thus, calculate the annual household labor contribution based on population density estimates.

The first experiment took place in Las Bocas, Sonora, Mexico and involved transport of earth by two different carriers. Carrier I had to take each load a distance of 50 meters, while Carrier II traveled 100 meters per trip. The former averaged about 20.15 kg per trip and the latter
Although the total kilograms of weight carried by Carrier II was less than that of Carrier I, he did travel a greater total distance with nearly half of the trips. The next experiment was to measure earth-excavation rate by shovel versus by digging stick. Due to an agreement that payment would be based on number of cans of earth moved, overzealous digging by both the shovel and digging stick participants caused for a halt after thirty minutes. Conservative estimates based on the data obtained are 7.2 cubic meters by shovel and 2.6 cubic meters by digging stick per person-day.

The next set of experiments focused on the quarrying and transportation of rock. A worker excavating with an iron crowbar dug approximately five tons in a thirty square meter area in five hours. The worker using a hardwood post for five hours was able to amount one-third of the other man. Therefore the estimate for one primitive tool person-day of labor is roughly 1700 kilograms. Four more workers were then employed to transport the quarried rock. They were each assigned different distances of 250 meters, 500 meters, 750 meters, and one kilometer. In comparison with the results of the earth-carrying experiment, it was determined that 21 kilometers is the “average distance covered in five hours by a man carrying a heavy load half of the time” (Erasmus 1965, 287). In his work at the Classic Maya site of Copán, Elliot Abrams (1984, 1994) drew extensively from these data obtained from these experiments.

Many of the same basic procedures used by Erasmus (1965) are used in any experimental study with the goal of understanding and modeling how the people of the past were able to erect monumental structures. In his book *Experimental Archaeology*, John Coles (1979) laid out the critical guidelines for gathering experiment-based data for the purpose of archaeological research. He stresses the necessity to hire experienced workers in order to replicate the presumable high
level of expertise and skill of ancient workers. No matter the level of skill, however, breaks for rest while working are a natural part of the process and should be timed separately and counted into any measurements of time. Furthermore, the experiment should be replicated numerous times with various workers to ensure the individual prowess of a certain worker does not skew the results of the experiment. Perhaps the most imperative rule established by Coles is the use of locally available resources and ancient technology to best model the conditions present at the time of construction. If experiments are carefully executed and the data are closely monitored, it adds legitimacy to theoretical-based research like estimating the energetic expenditure of ancient monumental construction projects. It is vital to build a strong case to support the results that ultimately come from the energetic equations.

**Labor organization across cultures**

Due to the lack of primary sources from the Maya summarizing the labor organization process, researchers must rely on models to make inferences and interpretations. Stanley Udy (1959) identified five relevant recruitment models that Abrams (1994) utilized in his studies at Copán. These are divided into the two main categories of familial and custodial recruitment. The five models are reciprocal, familial contractual, community contractual, festive custodial, and corvée labor. In the subsequent section these five models, identified by Udy (1959) and analyzed by Abrams (1994), will be outlined in detail. Additionally, cross-cultural examples will be interwoven throughout the presentation of these models.
The familial reciprocal model of recruitment relies on the commitment of a kinship group. As is true in any kin relationship, modern or ancient, reciprocity can come in various forms not simply limited to construction labor. Udy demonstrates an example of this type of labor model in the Philippines with the *bolhon* and *pailhog* systems (1959, 77–79). The *bolhon* system is one where neighborly help, usually in the realm of agriculture, is shared and relatively equal amounts of labor will be reciprocated. The *pailhog* system, on the other hand, is similar but most commonly associated with construction labor that has higher periodicity, as it is only necessary when a project is undertaken. This system as a whole, including both varieties discussed here, is similar to borrowing a cup of sugar or an egg from your neighbor when baking a cake, wherein the arrangement labor help is facilitated by the connection between those living in close proximity to one another.

Table 2-1: Five models of labor recruitment (Udy 1959).

<table>
<thead>
<tr>
<th>Familial</th>
<th>Custodial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reciprocal</td>
<td>Festive Custodial</td>
</tr>
<tr>
<td>Contractual</td>
<td>Corvée</td>
</tr>
<tr>
<td>Community Contractual</td>
<td></td>
</tr>
</tbody>
</table>
The familial contractual model is very similar to the familial reciprocal system with the addition of outside specialists as part of a contractual agreement of labor. However, this distinction is very difficult to identify from an archaeological standpoint. Limited construction tool kits would be one possible way to detect the intervention of a specialist in construction, and even this is mediocre evidence at best (Abrams 1994, 98). An example of this model would be the North Atlantic fishing communities of Newfoundland and their patrilocal recruitment of kin and associated members of society (Stiles 1979). While there is no economic motive for two kin to work together, it would be simply strange for them to not do so within this system (Faris 1972). People with specialization in certain areas of fishing can then be recruited in association with a family. To summarize, this type of labor recruitment model acts as a midpoint between the previous category of familial reciprocal and community contractual recruitment.

The community contractual model is the final member of the generalized familial labor category. This is an expansion on the familial reciprocal system because it goes beyond the limits of kinship and extends into the growth and betterment of the community as a whole. Abrams (1994, 99) cites two very similar ethnographic case studies to support this model: the dokpwe system of the Dahomey in modern day Benin on the Gulf of Guinea and the fagina system of the modern Maya. All workers in these systems are compensated evenly, with the exception of those in managerial positions (e.g. hereditary head, foreman, record-keeper, spokesperson). Within the dokpwe system specifically, there is a colloquially derived pride centered around strength and virility associated with being a young man in the culture (Herskovits 1932). To digress for a moment, it is important to note that while there was this masculine-focused labor system, Dahomey had a unique history of military labor divisions that ran counter to the dogmatic notions.
of gender roles. The *Mino*, which translates to “our mothers” in Fon, was an all-female armed guard that accounted for nearly one-third of the entire military (Alpern 2011). Continuing, under the Maya *fagina* model there is a concrete system of *guardia* to maintain overhead, while the *fagina* is an unwritten drive that provides expansion to *guardia* as a type of moral obligation (Villa Rojas and Redfield 1964, 79). The desire for internal development and interconnectedness in combination with personal pride and public perception are the driving forces behind a labor system of this type.

The festive custodial model represents the first of the custodial category, meaning that there is a disparity in power and wealth between groups of people in the models that fit into this classification. Interestingly, in a festive custodial system a more powerful individual in the society offers a day of feast or party in exchange for a day labor investment (Erasmus 1956). However, the one in charge of the project does not participate, nor does she or he reciprocate later with her or his own labor (Abrams 1994, 99). In order to distinguish this type of system archaeologically from other reciprocal systems, one must look at the architecture itself to identify a higher social status than the hired workers. This model does, however, lead to an unequal exchange of labor, unlike the reciprocal systems. With regionally varying names from *convite* in Colombia and Ecuador to *mingaco* in Chile, the festive custodial model has been common throughout South America but has become less frequent due to the sheer modern cost of food and gifts associated with a feast (Erasmus 1956).

Corvée labor, the final model of labor recruitment, occurs when participation in monumental construction becomes a pseudo tax system. There would be no feasting or formal reward upon completion of the work, for it is simply a devotion or duty of the people to the ruler
or gods to perform the work (Abrams 1994, 100). There is implied institutional disproportion of power and personal investment. This labor, in lieu of a proper tax system, could be anything from cultivating the royal agricultural fields, to maintenance around the temples, or even manual construction work on public architecture. This can be manifested in different forms across cultures with variation in the classes of people employed, or rather obligated, to do the work and the type of work itself expected by the laborer. For example, in the cases of both eighteenth century CE Sweden (Olsson 2006) and seventh century BCE Canaan and Israel (Mendelsohn 1962), only the poorest class was obligated to put forth their labor efforts. However, in the case study of Nahuatl notion of tequitl, outlined in the paragraph below, all non-elites were included in the system of corvée recruitment.

This notion of corvée labor is connected to Mesoamerica via the documented Central Mexican concept of tequitl. Translated as “obligation” or “duty,” any sort of labor investment to contribute to a community would have been considered tequitl (Carballo 2013). No matter social rank, all members of a society would have some form of tequitl. For example, the tequitl of a ruler would be to rule and organize the people and society, while that of a commoner would be service to the ruler and to the gods (Hicks 1982). It was a true quid pro quo system, insofar that the “reward” would be remaining in the good graces of the ruler or gods. This obligation could be fulfilled with corvée labor of any kind, as well as offerings and other services. Alonso de Zurita, a Spanish writer and judge, chronicled this labor obligation in his 1566 work Life and Labor in Ancient Mexico: The Brief and Summary Relation of the Lords of New Spain (Keen and Zurita 1994). The word tax is nowhere to be found in his description of this labor duty, but the concept of a daily labor “service” is communicated. This indicates that even to an outsider this system
was not perceived as a tax imposed on the individuals residing in the area but rather an obvious responsibility. Interestingly, this concept of tequitl is still used among modern Nahuatl-speaking peoples of Sierra in the state of Puebla, Mexico. However, it has become more of a general term for “work” in many contexts from political to supernatural applications (Chamoux 1986). It is likely that in an area as culturally diverse as Mesoamerica, a combination of all of these models was in place. Familial help would be utilized for small, personal projects, while corvée and festive custodial labor would be saved for those in higher social standing to be able to construct monuments to demonstrate their authority and status.

An example of a hybrid model of labor recruitment may be the Avenue of the Dead ritual center of Teotihuacán (see Fig. 2-1). Located at the center of the complex, this area was clearly used by the inhabitants of the primate city for ceremonial purposes. This type of extremely large-scale construction project could be interpreted as a combination of the community contractual and corvée models of labor organization. It is possible that the underlying motivation of this project could have been the creation of a shared identity via participation in both the construction of and rituals centered on a great shared plaza like the Avenue of the Dead complex (Inomata 2006). This inference would support the community contractual model in that a possible incentive of participation is the internal development of the community as a whole. However, this is difficult to prove due to the lack of any specifically named and identified leader in the history of Teotihuacán, therefore researchers must distinguish periods of rulership based on internal growth and external influence (Sanders and Evans 2006). Nevertheless, the corvée model seems to have played a fundamental role in the construction of this massive monumental area. From a practical and realistic standpoint, it would be virtually impossible to have enough people driven by
communal motives alone to build this type of complex. Therefore, a top-down corvée model would be a logical system of labor recruitment for such an expansive architectural endeavor.

Another comparative example of labor organization is the presented by Kolb (1997) on ancient Hawai’i. He too uses the labor arrangements at the levels of family, community, and state to analyze the labor recruitment of the ancient Hawaiian people. In this region there is evidence of familial, festive, and corvée labor models working in combination to construct the ancient monumental architecture of Hawai’i. Communities throughout the islands were divided into

Figure 2-1: The Avenue of the Dead from atop the Pyramid of the Sun, Teotihuacán. Photo by Elijah J. Hermitt.
ahupua’a, the basic yet resourcefully self-sufficient administrative unit that often facilitated
cooperative labor efforts (Earle 1977). This demonstrates that cultures that are perhaps socially
very different from the Maya were also likely implementing similar labor organization tactics.

An instance of a labor energetics study that was based on and benefitted greatly from the
careful selection of comparanda is that of the drystone walled enclosures and hill forts of north
Dalmatia (Chapman, Shiel, and Batović 1996). Due to the lack of scientific or quantitative labor
studies about this type of architectural form, researchers relied upon the knowledge of modern
drystone walling specialists and stonemasons to begin to understand the quantification of labor
costs. This is similar to the route that Abrams (1994, 44–45, 1984) took for estimating the work
rates of quarrying in Copán, as he combined his own replicative study with interviews of the local
quarry supervisor. The study in north Dalmatia was able to turn to specialists with this specific
expertise in drystone walling because the methods have remained relatively constant over a very
long period of time. Building materials such as limestone and tools for drystone walling such as
shovels, sledgehammers, and crowbars have persisted throughout time. The latter is a cultural
constant that differs greatly from the case of the ancient Maya due to the lack of metal tools
in Mesoamerica, turning technological reliance to stone tools such as obsidian blades (Sanders
1962; Saunders 2001).

Each of these examples offers various perspectives and aspects of labor organization and
mobilization across temporal and cultural boundaries. Some may provide actual models for direct
application to the present analysis of architecture in Palenque. Although others may not represent
direct relationships, cross-cultural examples are essential to provide a broader perspective on
something as culturally ubiquitous as monumental architecture.
Chapter 3

Methods & Theory

Monumental architecture has always been at the forefront of the study of the ancient Maya due to its omnipresence and visibility. Large and mysterious structures peeking over the canopy were long the only signs of former occupation centuries after abandonment. The sheer grandiosity of these monuments would pique the interest of modern observers in the same way they surely did during their time of use. In fact, though Palenque was first officially mentioned in a 1773 correspondence (González and Josserand 1986) and first excavated and documented in 1832 by Count Frederick Waldeck (Echánove Trujillo 1968; G. E. Stuart 1989), it was the 1840 publication of monumental architecture sketches by John Caddy that reopened the abandoned political center to the world (Pendergast 1967). After this, the door was opened for the Mexican government to commission Frans Blom, a Danish archaeologist, to study and map the site outside of the main ceremonial center (Matthews 2007; Blom and La Farge 1926). In 1923, Blom was able to bring together the first crude map of the area immediately surrounding the ceremonial center (see Fig. 3-1, compare to Fig. 1-5).
An important step in the quantification of energetic expenditure and resource consumption in the Maya region was Elliot Abrams' dissertation entitled *Systems of Labor Organization in Late Classic Copán, Honduras: The Energetics of Construction* (1984). This work provides some of the most detailed information about the methods and theory associated with a comprehensive archaeological analysis of energetics. Focusing on the Classic Maya site of Copán, Abrams first outlines the history of energetic study and then applies it to a selected group of structures at the site. Additionally, a wide range of labor organization case studies including Zinacantán, the Han Dynasty in China, Ancient Egypt, the Eskimos, the Inca, and several others offer a cross-cultural element unmatched by other works. However, the most valuable piece of
Abrams’ dissertation (1984) is the meticulous reporting of the methodology used to estimate the rate of work and energetic output associated construction. The careful documentation of the field experiments and the comprehensive gathering of outside methods (e.g. Erasmus 1965; Mahoney 1981) played a major role in the estimates of ancient construction.

The architectural analyses of Abrams (1984, 1989, 1994), mainly focused on the Classic Maya site of Copán in modern day Honduras, is especially applicable to the current analysis of construction form at Palenque. First and foremost, both are well known across the Maya culture area for having exceptionally constructed and preserved and, thus, widely studied monumental architecture. Though the ceremonial center of Palenque is geographically restricted at just over two square kilometers (Barnhart 2001), the hinterland settlement region has been suggested to have been as much as 37 km² more territory (Liendo Stuardo 1999). Copán has a very similar situation in that the concentrated site core is dwarfed by an extensive settlement area of over 24 km² (Freter 2004; Webster and Freter 1990), they have much in common architecturally. From the standpoint of architectural scale, Copán represents one of the most expansively studied Maya centers (Abrams 1994, 9). Palenque represents a unique architectural style with specific Palencano stylistic markers such as the mansard roof with receding upper façade (Marken 2007; Andrews 1975). The final and most obvious point to be made to justify the employment of Abrams’ Copán methodology to an analysis of Palenque is the simple fact that these two study areas are both Classic Maya sites. Due to these temporal and cultural similarities, there is greater validity in using research regarding energetic expenditure, construction tactics, and labor organization and mobilization in Copán than another non-Maya example or one completely outside of Mesoamerica.
Components of architectural energetic analysis

Once a labor force has been identified and assembled, there are several stages of construction that must occur. It is the goal of an energetic study to break down the process into subdivisions to determine the amount of person-time units necessary for each step. The five main components of an architectural energetics study are resource procurement, manufacture, transport, assembly, and finishing. (1.) Resource procurement encompasses all quarrying and resource extraction. (2.) Transport refers to the movement of the resources from the place of origin to the construction site on foot due to the lack of any beasts of burden among the ancient Maya (Lucero 2006; Lundell 1933). (3.) Manufacture represents the shaping of the raw material into cut stones optimal for subsequent assembly, which in order to reduce the energetic cost of transport would had presumably been done at the quarry site. (4.) Assembly encompasses both the placement of construction fill as well as the stacking of cut stones to form the walls of a structure. (5.) Finally, the finishing component of monumental construction includes both the manufacture and application of plaster made from quicklime (CaO) in the case of the ancient Maya.

Abrams (1984, 1989) determines through energetic quantification and analysis that the architecture as it relates to Maya social complexity and development has been greatly exaggerated. This overstatement is intuitively based on the impressive visual aspect and shear frequency of Maya architecture. Further, the number of specialists (e.g. sculptors, architects, etc.) needed to construct sizeable monumental architecture would have been quite low. Abrams estimates that a maximum of 40 specialists may have been involved in the construction of Structure 22, the largest example at Copán. In addition to these specialists, an estimated 371
unskilled workers over a 60-day period would have been needed to finish the project. This 60-day work period that contrasts the 100-day work period proposed by Heizer (1966) is based on the agricultural off-season. Access to labor varied based on the social rankings of central elite, lineage elite, and commoner. The first clearly utilized a rotational corvée labor system. This conclusion is based on the fact that the estimate of 371 laborers needed to construct Structure 22 is only 2.5% of the entire population estimate of Copán. Lineage elites, however, recruited labor through a festive custodial system. This means that laborers of lower socioeconomic status would work in exchange for a large feast or festival organized by the elite member upon completion of the project. Finally, the commoner practiced familial reciprocity in that a neighbor or kin would essentially lend a hand with the expectation the labor would be returned in the future. The main conclusion that Abrams stressed in his dissertation is that the dogmatic assumption of high social and economic complexity based on the sheer magnitude or aesthetic of architecture is problematic and should be reevaluated.

On the issue of the automatic assumption that large-scale heavy transport of architectural material equates to a class-differentiated society, many archaeologists fall into a tempting trap with concerning broader implications. Although this is not a definitive condition for monumental construction, often in societies where labor-intensive movement of large numbers of massive stone monuments, there also likely existed a superior class that was able to exercise authority to organize labor for such projects. Heizer (1966) argues that the Olmec and the Teotihuacanos also likely followed this model of elite control of labor by comparing them to the cases of ancient Assyria, Egypt, and Mycenae. The transport of enormous stones is often tied to religious processes and beliefs, or else there would not be a viable reason to organize the labor force to
perform such a daunting task. Heizer uses the example of the Temple of the Sun at Teotihuacán, which was built in one construction phase, likely for the purpose of demonstrating or legitimizing existing authority. Further, he states, “It is difficult in any case to see Teotihuacán and Tikal as merely religious capitals of chiefdoms” (Heizer 1966, 830).

Conversely, Kaplan (1963) believes that the presence of immense monumental architecture in Mesoamerica did not necessarily equate to state-level control of labor and could be achieved by a chiefdom level society. He suggests that a population at the chiefdom-level of complexity could have accomplished many of the architectural feats in Mesoamerica. Looking beyond the misogynistic title of this work (“Men, Monuments, and Political Systems”), there are several reasons provided to support his challenge of the dogma at hand. The architectural engineering necessary for construction was relatively simple. The purpose of monumental construction was often keeping a weak institution afloat rather than demonstrating the authority of a strong state, as has been suggested in the past. The populations involved could not foster full-time laborers due to agricultural responsibility. Monumental works were usually representative of several construction phases over extended periods of time rather than in a single intensive phase. Finally, ethnographic evidence shows that non-state systems such as the Hohokam of modern day Arizona did have the capacity to mobilize communal labor to construct a complex canal based irrigation system (Woodbury 1961).

Based on the analysis of several different views, it can be proposed that there was variation between different sites and even within a given site. If religious fervor or trust in a new regime needed to be pushed, perhaps a large-scale, one-phase monumental architecture project like the Temple of the Inscriptions at Palenque or the Temple of Sun at Teotihuacán would have
been the case. However, it is reasonable to say that less dire situations would warrant the type of system proposed by Kaplan (1963). With such a high level of variation over a temporally and geographically expansive culture area like Mesoamerica, it seems problematic to pin down a single labor-organization strategy as the definitive answer.

**Application to the Picota Group**

The next step in this energetic analysis is taking the general energetic methods and theory as well as the guidelines for Mesoamerica and applying them to the Picota Pool Complex at the Classic Maya site of Palenque. As previously mentioned, the five principal aspects of monumental construction cost study are resource procurement, transport, manufacture, assembly, and finishing. Each of these will be analyzed and quantified as they relate to the specified study area of the Picota Group. For all of the following investigations, the total volume of limestone making up the Main Picota Pool – 15.6 m³ (42361 kg) – will be applied to determine the energetic person-day rates of each step of construction for the pool itself.

Resource procurement in the case of the Picota Pool Complex would be the quarrying of dolomitic limestone sourced to a quarry approximately 275 meters to the southwest. The identification of this quarry will be further discussed in Chapter 4. The quarrying rate of 750 kg/p-d is an average of observed results from a replicative experiment as well as ethnographic responses (Abrams 1994, 45).

Based on the identified quarry and total amount of limestone used to construct the Main Picota Pool, the rate of transport to the Picota Group (see Fig. 4-3) has been determined to be
.257 cubic meters or 586 kilograms per five-hour person-day. This was calculated using the equation:

\[
\text{Output} = Q \times \left[ \frac{1}{(L/V + L/V')} \right] \times H.
\]

In this equation Q is the quantity of earth, 1 is one hour, L is transport distance, V is loaded velocity, V’ is unloaded velocity, H is hours per day, and the output is expressed in cubic meters (Aaberg and Bonsignore 1975, 46). In order to ensure that all parts of the pool are indeed from the same quarry as the two samples already tested, it would be beneficial to comparatively analyze more cut stones at the pool with quarry samples. For transport from the identified quarry to the Main Picota Pool construction site, the output is approximately .257 m³ or 586 kg per five-hour person-day.

Manufacture is composed three separate considerations. 1.) The cost of manufacturing basic masonry blocks, which make up the majority of the Picota Pool system, is the first piece to the manufacture puzzle. 2.) The cost of sculpture was also factored into Abrams’ work (1994), however this will not be necessary for an energetic analysis of the Picota Pool system because it is void of any ornate inscriptions or carvings. 3.) The manufacture of plaster is vital to a complete understanding of the energy expenditure because the entire Picota Group was likely covered in a layer of lime-based plaster. This process involves numerous actions such as cutting, transporting, and stacking timber in addition to excavating, transporting, and breaking down the stone before burning it to make quicklime (Ca(OH)₂) (Abrams 1994, 49). In the present analysis, this consideration will instead be part of the “finishing” step rather than manufacture. This component will be outlined later in the final part of this section. The manufacturing rate of 1 m³/11.6 p-d will
be reduced down to .086 m³ / p-d and applied to the cut stones at the Main Picota Pool (Abrams 1984, 48).

Assembly likewise consists of two distinct parts. 1.) The cost related to the placement of basic fill is estimated to be 4.8 cubic meters per person-day (Abrams 1994, 50). 2.) For masonry wall construction, Abrams (1994, 51) observed that 3.2 square meters of surface area or .8 cubic meters of a standard .25 meter-thick wall could be constructed per person-day.

Finally, finishing consists of the manufacture and application of quicklime plaster. First, it is necessary to acknowledge the intensive nature of quicklime manufacture. This required fuel (i.e. trees) to create a long-lasting fires at temperatures between 650 and 1000 degrees Celsius (Rice 2015; Ashurst and Ashurst 1988). The southern Maya lowlands, where there is an abundance of rainfall and jungle vegetation, has a wealth of trees with straight trunks and ideal diameters of 10 to 25 cm (Schreiner 2002, 69). This simplifies the process of stacking inside the kiln because the builder does not have to arrange the pile based on varying size. Including all of the aforementioned steps in quicklime production, a general production rate of 14 kg/p-d has been determined. In order to create one cubic meter of plaster, 325 kg of quicklime is necessary (Schreiner 2002, 106). Based on an estimated standard plaster thickness of 2.5 centimeters, an application rate of 50 square meters per five-hour person-day will be utilized in the current study (Mahoney 1981, 44).
Table 3-1: Breakdown of work rates.

<table>
<thead>
<tr>
<th>Component</th>
<th>Labor rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quarrying</td>
<td>750 kg / p-d</td>
</tr>
<tr>
<td>Transport</td>
<td>586 kg / p-d</td>
</tr>
<tr>
<td>Manufacture</td>
<td>.086 m³ / p-d</td>
</tr>
<tr>
<td>Assembly (Fill)</td>
<td>4.8 m³ / p-d</td>
</tr>
<tr>
<td>Assembly (Walls)</td>
<td>.8 m³ / p-d</td>
</tr>
<tr>
<td>Finishing (Production)</td>
<td>14 kg / p-d</td>
</tr>
<tr>
<td>Finishing (Application)</td>
<td>50 m² / p-d</td>
</tr>
</tbody>
</table>
Chapter 4

Results & Discussion

During the 2014 field season, excavations inside the Main Picota Pool itself revealed a thin 2-5 cm layer of a white, sandy substance beneath a dense layer of mud and debris. Due to uncertainty about the purpose or makeup of the substance (at the time referred to as “sand”), excavations in the pool came to a halt for the season. It then became a priority upon returning to the university to determine the chemical composition of the substance in order to definitively say whether it had naturally occurred or was introduced by the Maya. X-ray Diffraction (XRD) testing is a characterization technique in which X-rays are diffracted from the various crystallographic planes in a material. Unlike other chemical analysis techniques, X-ray diffraction shows that a substance is present in the sample rather than just the elements (Cullity and Stock 2001). These data can then be translated into the different minerals present in the material, making it possible to infer the origin of the material itself. This was the methodology chosen to elucidate the necessary details surrounding the “sand” in the Main Picota Pool.

Through the Materials Research Institute in Millennium Science Complex at the Pennsylvania State University, the author was trained to operate the PANalytical X’Pert³ MRD (Materials Research Diffractometer) with the aid of personnel in the Materials Characterization Laboratory (see Fig. 4-1). The moderately fine material was first ground using a mortar and pestle and then mounted on a silicon holder. The holder is then fixed to a stage at the center of the MRD machine (see Fig. 4-2). One of the two arms take about twenty minutes to fire X-rays at the
substance from every angle on the 180° plane. The other arm catches the diffracted X-rays, recording the angle at which they reflected off the substance. These angles, distinct across various geologic compounds, are then analyzed through a massive database of diffraction angles in order to pinpoint those present in the substance.

Figure 4-1: The PANalytical X’Pert³ MRD used for XRD testing of the “sand” in the Main Picota Pool. Photo by Elijah J. Hermitt.
Results

The results of the various facets of the monumental construction energetic analysis of the Main Picota Pool will be outlined. These range from the process of sourcing the limestone to a nearby quarry to the person-days of work necessary to perform each of the components of monumental construction. These are theoretical figures based on equations derived from...
experimental archaeology results. Short of primary sources (e.g. inscriptions, documentation, etc.), there is no infallible method for completely understanding the labor organization and implementation processes of past societies. Therefore, it is necessary to state that under no circumstances do these results definitively elucidate the amount of work necessary to construct the Main Picota Pool. However, they represent an effective tool for discussing the larger implications of social development and the significance of the structure to the site and beyond, as will be addressed in the discussion section later in this chapter.

**XRD results**

The overwhelmingly high levels of dolomite (CaMg(CO₃)₂) in the sample suggest the “sand” was native to Palenque (see Fig. 4-3). Due to the situation of the site on a limestone escarpment, there is an abundance of dolomite naturally present in the bedrock. The minute presence of quartz (SiO₂) is a recurrent theme in essentially any mineral deposit on Earth. The sodium aluminum silicate (NaAlSi₂O₆) is likely to be the result of a contaminant in the sample, possibly a substance in the debris that lies above the “sand” layer.
These results enable one to check the overall validity of using the identification of “sand.” Through the process of CO₂ outgassing, this limestone has been gradually broken down over millennia, leaving behind a thin layer of powdered dolomite at the bottom of the pool. CO₂ outgassing is the natural release of carbon dioxide from Earth when ground water is exposed to the atmosphere (Pearson, Fisher, and Plummer 1978). The levels of CO₂ resulting from this outgassing process become increasingly variable at the water table (Macpherson 2009). Since the Main Picota Pool is dug into the bedrock, the ground water has been exposed to the atmosphere at the surface, thus releasing built-up carbon dioxide. The concentrations of carbon dioxide are products of both the upper mantle and dissolved carbonate rocks (Yoshimura et al. 2004). This
release slowly disintegrated the dolomite already present in the Earth below Palenque; therefore the original label of “sand” was erroneous. It is essentially pulverized dolomite limestone deposited as a result of CO₂ outgassing.

**Energetic results**

In order to apply the aforementioned energetic equations, it is necessary to calculate the total volume of the construction materials used to build the pool. This is done by separately calculating the volume (Length x Width x Height) for each section of the pool. The sections of the pool include nine stairs on the east side (1-6 at .33 x 4 x .33 m, 7 at .33 x 1.5 x .33 m, 8 at .33 x 1 x .33 m, 9 at .33 x .5 x .33 m), the north side wall (10 x .25 x 1 m), the west side wall (4 x .25 x 1 m), and the south side terraced wall (lower section at 10 x .25 x 1 m, terrace section at 10 x .25 x 1 m, upper terrace at 10 x .25 x 1.5 m). See Appendix A for more detailed measurements of the pool sections. Through these volumetric calculations, it has been determined that a total of approximately 15.6 m³ (42361.8 kg) of limestone was used to construct the entire Main Picota Pool (see Appendix B for calculations). This figure will now be applied to each of the following components (i.e. quarry, transport, manufacture, assembly, finishing) of architectural energetic analysis.
**Quarrying**

The total amount quarried was 28.4 m³ (77021.5 kg), determined by dividing the total used limestone by 0.55 to account for waste. The quarrying rate of 750 kg/p-d is an average of observed results from a replicative experiment as well as ethnographic responses (Abrams 1994, 45). This yields a rate of 103 p-d necessary to quarry the limestone for the construction of the Main Picota Pool. This raw and uncut building material is then transported to the site of construction so that the debris from manufacture can perhaps be used either for construction fill or to create quicklime plaster.

However, since the structure of interest is a pool that was excavated into bedrock to be constructed, this “quarrying” must also be taken into account. The negative space (10 x 4 x 1.25 m) where the pool’s water is located equates to 50 m³ (135550 kg). Employing the same quarrying rate of 750 kg/p-d, it can be proposed that 181 p-d of work would have been required to create the cavity itself. These two figures will be combined to henceforth represent the work rate of 284 p-d of quarrying.

**Transport**

Unlike the other aspects of the energetic calculation process, transport requires one to first source the raw material used in the construction of the architectural feature. In the case of the Main Picota Pool, there are two quarries in close proximity. Two samples were taken from each of these two areas identified as limestone quarries during the Palenque Mapping Project (Barnhart 2001). The first possible source is situated roughly 275 meters southwest of the Main Picota Pool...
in an area that can be reached by following the Picota arroyo (see Fig. 4-4, quarry to the west).
The second location, which can be found about 350 meters to the southeast, lies directly uphill
from the Templo Olvidado in the Piedras Bolas Group (see Fig. 4-4, quarry to the east).
Additionally, samples were taken from two different cut stones found during excavation of the
Main Picota Pool. The former will henceforth be referred to as “Quarry 1” and the latter “Quarry
2.” Slide-mounted thin sections of these samples were then comparatively examined using a
petrographic microscope analysis to identify any similarities present.

Figure 4-4: Map showing the two possible quarry sites – circled in red – in relation to the Main
Picota Pool – noted with a yellow star (Barnhart 2001).
Referring to Figure 4-5, it is clear that both the samples from the Main Picota Pool and those from Quarry 1 are micrite (T. White, pers. comm. 2016). This classification, microcrystalline calcite in long form, is composed of tightly packed, small sized grains and is a product of the cementation of carbonate muds with calcitic matter (Folk 1959, 1965, 1974; Munnecke and Samtleben 1996). The samples from Quarry 2, on the other hand, have more euhedral characteristics (T. White, pers. comm. 2016). These show signs of well-formed, larger-grained crystals with easily observed faces that are often associated with a high quartz content (Maliva and Siever 1988). From these observations, it has been determined that Quarry 1 was likely the source of the raw material used in the construction of the Main Picota Pool due to the similarity of grain sizes as well as the general proximity of the quarry to the construction site.
Main Picota Pool

Figure 4-5: Thin section samples under microscope.
For transport from Quarry 1 to the Main Picota Pool, the output is .257 m³ or 586 kg per five-hour person-day. This is then applied to the total amount of limestone manufactured after quarrying in order to determine the amount of person-days necessary to move the materials used to construct the pool. From this, it has been determined that transport of the limestone for the Main Picota Pool would have taken approximately 131 p-d.

Manufacture

As previously mentioned, after being quarried from the source and transported to the construction site, the limestone is then manufactured in order to make use of the debris in construction fill or the creation of quicklime plaster. Using the manufacturing rate of .086 m³/p-d, it would have taken approximately 181 p-d to cut the stones used at the Main Picota Pool (Abrams 1994, 48).

Assembly

Though wall thickness varied slightly among cut stones around the pool, the constant of .25 m was used for the purpose of this analysis. In a single day a person could theoretically construct .8 m³ (1896.8 kg)/p-d of cut construction stones (Abrams 1994, 51). At the Main Picota Pool, 20 p-d would have been necessary to build the structure itself. However, this does not
conclude calculation of the energetics of assembly because also included in this section is the placement of construction fill to support the structural integrity of the pool.

In order for the cut stones to be securely assembled, a foundation of fill comprised of a combination of earth, limestone cobbles, and other byproducts is needed. Since the surrounding plaza area of the Picota Group consists entirely of fill, a practical boundary of 2 m out from the edge of the structure was considered for this analysis. In the region between this limit and the walls of the pool, there is space for 148.1 m³ of fill. However, there are two sources of fill already procured during the construction process that could have been recycled. These are the 12.8 m³ of waste during the quarry process and the 50 m³ of bedrock limestone excavated to form the actual pool cavity. This leaves a remainder of approximately 85.3 m³ of fill still needed. Through excavation around the perimeter of the pool, it was evident that discarded ceramic sherds were often used in this area of the site. It is impossible to define the exact divisions of substances (i.e. earth, limestone, ceramic sherds) within the fill of the pool structure and the plaza. Using the fill placement rate of 4.8 m³/p-d, it can be determined that it would have taken approximately 30 person-days of work to complete. This brings the total assembly rate to 50 person-days.

**Finishing**

As was previously stated, the finishing process of the production and application of quicklime (Ca(OH)₂) plaster is an exhaustive practice that requires many considerations. The process calls for limestone to be exposed to fire for an extended period of time, therefore a great deal of wood-fuel is necessary. This means much of the labor focus of this portion of the
construction process would turn away from the structure itself and toward the procurement of trees.

Schreiner (2002) proposed an all-encompassing rate (tree procurement, transport, and slaking – adding water to the quicklime) of 100 kg of quicklime per twelve hour person-day utilizing steel tools in the southern Maya lowlands where there is wide availability of 10-25 cm straight-trunk trees. In an area with an abundance of small-diameter wood like the Yucatan, it would take more than double (32 person-hours) to produce the same 100 kg of quicklime. Adjusting to the five hour person-day (Coles 1979, 41) used throughout this analysis, this rate would instead be about 42 kg/p-d. However, this rate is still based on the use of steel tools, while the engineers building the Main Picota Pool would have been restricted to the use of stone tools. In order to account for this, it is vital to acknowledge that Maya stone tools are roughly one third as efficient as steel tools (Saraydar and Shimada 1971; Erasmus 1965). Therefore, after dividing the rates by three, a quicklime production rate of 14 kg/p-d can be applied. Of the 2000 kg of total mass in one cubic meter of plaster, 325 kg of it is comprised of quicklime (Schreiner 2002, 86). One cubic meter of plaster can cover approximately 12 m² of surface. This figure was derived from the fact that it took 2200 m³ of plaster to cover the exterior wall surface area of El Tigre, the enormous pyramid at the Late Preclassic site of El Mirador in modern day Guatemala, which totaled approximately 26848 m² (Schreiner 2002, 87).

It has been determined that the total surface area of the Main Picota Pool that warranted application of plaster is 75.84 m² (60 m² for the three walls and the south side terrace and 15.84 m² for the monumental staircase on the east side). Therefore, this surface area would require 6.32 m³ (12640 kg) of plaster, which would take about 146 p-d to produce the 2054 kg of quicklime
necessary to create that amount of plaster. The labor involved in the slaking process of adding water to the quicklime to create the plaster would have been negligible due to the perennial flowing stream, the Picota Arroyo, which connects to the Main Picota Pool. This would have provided all of the necessary water directly on site without any transport costs.

Using the plaster application rate of 50 m² per five hour person-day (Mahoney 1981), it can be surmised that only 1.5 person-days would have been required to apply the plaster to the pool structure. This means the total labor-rate for the entire finishing process would be approximately 148 person-days. Evidently, the plaster production process of procuring trees, transporting the timber, and finally slaking was far more labor intensive than its actual application.

Table 4-1: Breakdown of labor investment results.

<table>
<thead>
<tr>
<th>Component</th>
<th>Person-days (p-d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quarrying</td>
<td>284</td>
</tr>
<tr>
<td>Transport</td>
<td>131</td>
</tr>
<tr>
<td>Manufacture</td>
<td>181</td>
</tr>
<tr>
<td>Assembly</td>
<td>50</td>
</tr>
<tr>
<td>Finishing</td>
<td>148</td>
</tr>
</tbody>
</table>

Combining all of the individual components of energetic study (i.e. quarrying, transport, manufacture, assembly, finishing) it has been proposed that a total of about 794 person-days of
labor were necessary to construct the Main Picota Pool. This figure can now be applied to various hypothetical labor forces to hypothesize the duration of construction. For example, this means that presumably it would have taken a group of 100 laborers just over one week (7.94 days) to construct the pool. However, without a rather large labor pool like that of Teotihuacán, for instance, it is unlikely that even a labor force of one hundred people or more could have been assembled. To provide some more realistic possibilities (see Table 4-2), it would have taken 50 laborers just over two weeks (15.88 days), 40 people slightly less than three weeks (19.85 days), 30 people just shy of one month (26.47 days), 20 people more than one month (39.7 days), and 10 people approximately two and a half months (79.4 days). A more in-depth description and proposal of the most likely labor force size will occur later in the discussion section of this chapter.

From these various levels of labor, it is clear that as the number of laborers decreases, the amount of time necessary to carry out the given construction project increases at an even greater rate. This notion rather obviously can be attributed to the fact that as the labor force reduces in size, there are fewer people to delegate out responsibilities that would have occurred simultaneously under a larger group. While one subgroup of the labor force was quarrying the limestone from Quarry 1, as it has come to be called in the current analysis, another group could have been transporting it to the construction site at the same time. This type of concurrent labor allocation would be less likely to occur under a labor force of only ten people.
However, this does not imply that laborers would have been working uninterrupted for this duration of time. As is demonstrated by several ethnographic studies of agrarian societies, construction undertakings are planned around the annual agricultural schedule (Vogt 1969; Villa Rojas and Redfield 1964; Bierbrier 1982; Abrams 1987). This means that mobilization of labor would have taken place during the dry season, which lasts between roughly two and six months in the Palenque region (Wolf and Flamenco 2003). Based on the previously described labor and energetic totals, it can be proposed that even with a workforce as small as just ten people, the Main Picota Pool could have been constructed in a single season. However, it is evident that the Picota Aqueduct and the Main Picota Pool were built in the same construction phase (K. French, pers. comm. 2015 during excavations). Therefore, it would have taken considerably more person-days of labor to bring the entire project together, perhaps warranting the extension of the project over the course of two construction (i.e. dry) seasons. Regardless of this, it is possible that the

<table>
<thead>
<tr>
<th>Laborers</th>
<th>Workdays</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>7.94</td>
</tr>
<tr>
<td>50</td>
<td>15.88</td>
</tr>
<tr>
<td>40</td>
<td>19.85</td>
</tr>
<tr>
<td>30</td>
<td>26.47</td>
</tr>
<tr>
<td>20</td>
<td>39.7</td>
</tr>
<tr>
<td>10</td>
<td>79.4</td>
</tr>
</tbody>
</table>

Table 4-2: Theoretical amount of workdays for varying group sizes.
labor was done incrementally in several stages, perhaps one to two weeks each, over multiple
seasons of organized work.

**Discussion**

In the final section of this thesis, the results of the energetic study of the Main Picota Pool
will be applied and analyzed. The goal of this is to show not only the meaning and implications
within the site of Palenque, but also on a broader scale across the Maya region and Mesoamerica.
Further, the utility of energetic quantification of monumental construction will be demonstrated
through a more general discussion regarding the development of sociopolitical complexity. In
order to bring an energetic analysis like this to fruition, or any archaeological undertaking for that
matter, it is necessary to bring together a cross-disciplinary breadth of knowledge. A much
broader, introspective analysis of archaeological work concludes this section, with an emphasis
on the necessity of open door research that employs varying perspectives outside of the specific
field of archaeology.

**Significance to Palenque**

Other than the constructed pools throughout Palenque, the only other New World
example of a similar ceremonial pool structure is at the Classic Maya port city of Cancuén in the
Petén region of modern-day Guatemala (Demarest 2013). However, this pool was the only one
thought to be of ceremonial use, while the several others throughout Cancuén were used for water
collection. Because of the uniqueness of a ceremonial pool of the magnitude of the Main Picota Pool and its connection to a subterranean aqueduct, any analysis of these systems is of great significance to contributing to the overall understanding of Palenque. Further, an energetic labor study is especially valuable to bring some perspective to just how much effort was contributed to construct a ceremonial structure like the pool of interest. The proposed 794 person-days create a quantitative base upon which broader discussion about the ideology and social development can be built.

Based on the previously presented final labor rates, it is necessary to discuss the possible labor recruitment models (see Table 2-1). The Main Picota Pool could conceivably have been a result of corvée labor assigned to people through a top-down elite decree of construction. However, another piece of information to recognize is the possible date range of the Picota Group. It is thought the area represents early occupation of the site (Rands 2007), indicating that a clear social ranking may not have yet developed. From the evidence presented in this analysis, it can be proposed that the community contractual model was the labor mobilization tactic employed to construct the Main Picota Pool. This model, while still centered on the familial entity, expands beyond this structure to ensure the betterment of the community at large, rather than just the insular family group (Udy 1959). In addition to the core group of laborers, there are also specialists involved in the construction. A method like this would be potentially suitable within a social system that is in the early stages of hierarchical development. This was the situation that likely existed in the Picota Group area at this time in the early stages of development of Palenque, as this region likely had a rather loose organization at the village level (Bishop 1994, 30).
Earlier in this chapter, there were several possible group sizes of laborers presented ranging from as high as one hundred people down to just ten individuals (see Table 4-2). The proposal of a community contractual model of labor mobilization enables one to focus in on a more specific range of labor group size. As has been stated several times throughout this thesis, the situation of the Main Picota Pool in the Picota Group and its association with the Picota Phase of the Palenque ceramic sequence (Rands 1974) lends one to believe that some of the earlier settlements and development may have taken place around this area. The Picota Phase generally represents the transitional phase between Preclassic and Early Classic ceramic styles (Rands 2007). It is possible that, from all of the aforementioned information, the labor force employed to construct the Main Picota Pool was in the range of twenty to thirty individuals. This means it would have taken approximately between 25 and 40 workdays to bring the monumental project to fruition. Drawing from a labor pool that extended outside the familial unit and into the broader community, a workforce between twenty and thirty people appears to be plausible for the level of organization suspected at this point in the development of the site.

A common misconception that is necessary to address is the thought that, due to the inability to use metal tools and beasts of burden, it took droves of laborers to create ancient Maya structures. Under this presumption, it is assumed that human-based labor is incapable of creating such grandiose monuments. The danger of views like this is the creation and propagation of conspiracy theory logic with explanations such as extraterrestrial assistance. The reality of the situation is that a group of human laborers working simultaneously toward a common goal or project has the potential to move a large quantity of resources and rather quickly erect a structure or monument. Among the first to recognize this misconception was Gerard Powke in his research
of the mound builders of Ohio (Fowke 1902). This connection was made based on process he had witnessed of forty deck hands loading 10,000 bushels of corn onto a vessel in a single day. The same crew loading the equivalent weight of dry earth would be able to construct a mound forty feet across with a height of ten feet (Fowke 1902, 85). He goes on to criticize researchers, “The real significance of important facts has been so obscured by this delusion ... have been led to a faulty interpretation of their discoveries” (Fowke 1902, 86).

In addition to the fact that the necessary labor force is often far less people than one might speculate, it is also important to examine how it was organized and implemented. Clearly, this is a far more important aspect of monumental construction than the tools themselves. This is demonstrated in the ethnographic example of the Udi and Nsukka Divisions of eastern Nigeria where a group of workers moved approximately 650 cubic meters of dirt to create an earthen embankment nearly four meters high in just two days of work (Shaw 1970).

Evidently, labor organization strategies are difficult to identify and support with archaeological evidence, which leads to a certain level of speculation by the researcher to formulate a stronger understanding of the system. This is a main motive behind the study of energetics and monumental construction costs, for there is more of an emphasis on theoretical empiricism rather than simple conjecture. This general discussion of the reasons to utilize energetic analyses will be further elaborated upon in the next section discussing the broader implications of this research.
**Broader implications**

A monumental construction project such as the Main Picota Pool signals a significant level of hierarchical development, at least on the village level. However, as previously stated, the presence of monumental architecture is not the ultimate proxy for determining the level of social “complexity” in a region (Abrams 1984). While it can be a contributing factor in the sociopolitical analysis of a group, it is by no means a direct indicator. Placing this in the broader context of the Picota Group narrative, the Main Picota Pool can be proposed as a partial signal for the development of the social stratification necessary to mobilize top-down public works. This context at this time was likely village-level organization with a vague social hierarchy based on seniority within the house or lineage (Gillespie 2000; Bishop 1994). The aforementioned community contractual labor organization hypothesis is also based on this notion of early development of a social structure in the Picota Group. Since the presence of monumental architecture cannot be the sole gauge for any of these determinations, energetic analyses enable one to rely on quantitative results to construct and justify the suggestion of a hierarchical social stratification.

Energetic studies of monumental construction costs offer a unique opportunity to the field of archaeology to theoretically examine a process that was never officially recorded. To be able to effectively employ experimental archaeology results to first visualize the processes that occurred to create the monument of interest and then to generate equations to use generally in studies of other structures are both particularly valuable applications. For example, the experiments of Erasmus (1965), Kaplan (1963), and Abrams (1984), which were all applied to the current analysis of the Main Picota Pool in Palenque, are still valid and pertinent to present day energetic
studies. Though these studies took place in various regions across Mesoamerica, their utility remains relevant for Palenque. Being within the same cultural region indicates that similar construction tactics were at play, with a definitive lack of beasts of burden, wheels, or metal technology (Lucero 2006; Lundell 1933). These cultural similarities justify the application of these studies to this analysis, while utilizing the methodology of an energetic study of Bronze Age Dalmatia (Chapman, Shiel, and Batović 1996), for example, would be an unfit choice to use as the basis for a labor study in Mesoamerica. This is not only for a lack of comparable technology, but also for the stark geographic and regional differences at play. In summary, energetic studies are advantageous for providing a quantitative-based narrative in an archaeological study.

Archaeologists are often faced with a unique suite of problems from a wide range of backgrounds and must conjure up an even more peculiar set of questions to address them. In addition to archaeological factors, there are often aspects of geology, geography, environmental science, chemistry, or more depending on the situation. It is vital for one to be not only a jack-of-all-trades but also to be willing to collaborate with experts across departmental and field boundaries. In order to bring the current analysis together, there were several perspectives included to address the various facets of the Main Picota Pool construction. During the initial stages of investigation of this topic after the first season of the Palenque Pool Project in 2014, the primary research goal was to source the “sand” found on the floor of the pool. This required the first step to be the characterization of the material to elucidate its specific chemical composition. Nichole M. Wonderling of the Materials Characterization Laboratory in the Materials Research Institute in Millennium Science Complex at the Pennsylvania State University was instrumental
in acquiring these data. She not only trained the author to operate the PANalytical X’Pert³ MRD (Materials Research Diffractometer), but she also aided in the analysis of the results. Together the author and Ms. Wonderling were able to determine the “sand” was actually just powdered dolomite limestone (CaMg(CO₃)₂), a substance infinitely abundant in the bedrock of the Palenque region.

Figure 4-6: Geologist and collaborator Tim White cuts limestone samples using a wet rock saw to make thin sections for petrographic analysis. Photo by Elijah J. Hermitt.
In the following year of analysis after the second field season of the Palenque Pool Project, the next research focus became the sourcing of the limestone used to construct the Main Picota Pool to one of two nearby quarries identified by Barnhart (2001). Samples of the inside of the rocks were taken to avoid weathering interference, admittedly using rather rudimentary tools (see Fig. 4-6, notice the tree branch attached to the sledge). These samples were extracted from the cut stones used to construct the pool, stones found at the site of Quarry 1 to the south of the pool, and stones from Quarry 2 southeast of it. Upon returning, it was necessary to consult a geologist about the necessary process for analysis of these limestone samples. It was then that Tim White, a geologist in the Earth and Environmental Systems Institute at Pennsylvania State University, became a vital collaborator on the project. Under his guidance, thin sections of each sample were made and analyzed under a petrographic microscope (see Fig. 4-5). Collaborating with a researcher like Tim White, an expert in his field, presented the opportunity to explore geologic literature, even beyond his basic recommendations.
Additionally, two more collaborators from outside the field of archaeology were instrumental to the success of the Palenque Pool Project: hydrologist Christopher Duffy and cultural anthropologist Walter “Chip” Morris. The former has been involved in the hydraulic study of Palenque since being on the dissertation committee of Kirk D. French. Dr. Duffy simulates watersheds using his model, PIHM (Penn State Integrated Hydrologic Model), to detail processes such as surface flow, groundwater flow, and vegetation water (Qu and Duffy 2007) and was applied to Palenque using paleoclimate data (French 2009).

The contribution of MacArthur Fellow and cultural anthropologist Chip Morris was invaluable. After living in Chiapas as an ex-pat and anthropologist for more than forty years,

Figure 4-7: The author extracts limestone samples using a tool fashioned by Andrés and Eduardo, the Maya workers on the project. Photo by Kirk D. French.
Chip became fluent in three different Maya dialects (Tzeltal, Tzotzil, and Ch’ol). He was instrumental in communicating in Tzotzil with leaders in the Maya village of Chamula, just outside of San Cristóbal de las Casas. These leaders are in charge of the maintenance of a series of sacred pools used in ceremonies in the town. Located just south of Palenque, these pools built around natural springs served as a modern ethnographic comparative piece to the Main Picota Pool. The results of these interviews will be outlined in Chapter 5, but without the contribution of Chip Morris to gain the trust of the Tzotzil speakers it is likely this information would have been unattainable.

All of these examples of contributors are simply to reinforce the collaborative, communal, and interdisciplinary nature of archaeology as a discipline. It is not only a respectable practice to collaborate with people outside the field; it is imperative to conducting archaeological research. Further, it is critical for the archaeologist herself to have a certain level of familiarity and experience in various facets of science. The archaeologist possesses the versatility to grow and adapt in order to create innovative questions and methods to strengthen the understanding of ancient processes in an ever-changing modern world.
Chapter 5

Conclusion

The overarching goal of this monumental construction energetic analysis of the Main Picota Pool was multifaceted. The primary intention of it was to elucidate the human labor input employed to bring a monumental project like this to fruition. Being able to point to a specific number with comprehensible units like person-days enables one to better communicate to the social and significance of the structure. One can imagine doing five hours of labor to perform each of the necessary tasks in constructing the pool. Additionally, the current analysis sought to break down these individual steps in order to humanize the monumental construction process. More broadly, these two aspects were done with the intention of demonstrating that even though the ancient Maya who inhabited Palenque were constructing monuments almost two millennia in the past, their resourcefulness and attention to cost would be likely similar to that of the modern developer. To say that contemporary creative works of art, architecture, cuisine, or music are an improvement to those of the past is a gross overstatement of the aptitude of the modern human and an extreme underestimation of the ingenuity of people of the past. It is true that this energetic analysis does indeed illuminate some previously unknown archaeological information about the Main Picota Pool. However, its main purpose was to prove the ability to create and imagine is ubiquitous and comes not from metal tools and computer software but rather from the innate human form.
This idea was a platform upon which a discussion about broader social implications, both in Palenque and extending into Mesoamerica, could be realized. Since this type of ceremonial pool structure is not commonly observed throughout Mesoamerica and even the New World entirely, the Main Picota Pool provides an opportunity to discuss a unique architectural form as well as the larger ideological practices centered on it. Furthermore, an exploration into the utility of an energetic analysis to the Picota Group of Palenque and to the field of archaeology as a whole was also built atop this platform of ever-present human creativity.

In the final part of this thesis, supplementary proposals will be offered with recommendations for future investigations. The hypotheses put forth are based on preliminary ethnographic and archaeological evidence. While testing such claims is beyond the scope of the current analysis, it is still necessary to mention them in order to provide direction for forthcoming research endeavors.

**The origin of the ceremonial pool**

Briefly mentioned in the previous chapter, there was an ethnographic component of the Palenque Pool Project that took place in Chamula, Chiapas, just 200 kilometers to the south of the site, during the 2015 field season. This portion of the project was conceived out of the original hypothesis that after the political abandonment of Palenque, Maya commoners moved south to the San Cristóbal de las Casas region that is today surrounded by several Maya villages. There they were thought to have constructed ceremonial pools to emulate the ones they had utilized in their previous residence. Presumably, various ceremonies and ideological notions would have
been centered on this pool in Palenque; therefore it would have been irreplaceable in the religious practices occurring in the new highland settlement. The goal was to test this hypothesis by conducting ethnographic interviews of Tzotzil Maya living in the Chamula community to collect primary source information about their own modern practices around the pools in addition to their thoughts on ancient Maya pools, such as the Main Picota Pool. Walter “Chip” Morris, the aforementioned collaborator, utilized his deep personal connections and fluency in Tzotzil to inquire around the modern Maya village about their traditions surrounding the pools and hypotheses about the ancient examples.

The maintenance and organization of these modern Maya pools, locally referred to as “waterholes,” in highland indigenous villages such as Chamula and Zinacantán is a case of collective action that can be examined through the lens of Elinor Ostrom’s renowned work, _Governing the Commons_ (1990). The term itself, “common-pool resource,” is a large resource system in which prohibiting any prospective consumer from reaping the full benefits would be too costly to be efficiently monitored or enforced. For example, it would be unproductive in the situation of the waterholes present in the highlands of Chiapas for there to be a policing system in place to supervise the use of water. Essential to the organization and management of common-pool resources is the relationship between the transfer of distinct resource units within the broader resource system. These units are the products acquired and exploited by individuals utilizing the system. A resource system is the set of variables that yield the maximum quantity of flow or stock of that specific resource unit. In the event of the rate of flow surpassing the rate of stock, a renewable resource may become unsustainable. However, this would not be applicable to the waterholes of Chamula because the water originates from a reliable natural spring around which
the pool structure was built. In this case, the resource flow could not outweigh the rate of stock replenishment.

The heads of the patrilineal groups make decisions regarding the direction of the patrilocaly extended domestic group’s resource consumption (Vogt 1969). Evon Vogt, an ethnographer from Harvard University who was the principal researcher studying the analogous neighboring village of Zinacantán, coined “sna” due to a lack of a generic Tzotzil Maya term for these groups. Sna literally means “the house of,” referring to a grouping of patrilineages (Vogt 1969). However, these groups also must participate in domestic unit rituals such as the Holy Cross ceremony by performing waterhole maintenance in order to guarantee consistent water supply and a profitable crop yield from the earth gods (Gossen 1974). These units are in charge of both the provision and preservation of the waterholes; they are simultaneously a political, economic, and social unit.

These waterholes are constructed around the natural springs that exist throughout this highland region of Chiapas. In fact, there are five separate waterholes in the village of Chamula alone. The construction is integrated into the natural landscape to ensure the survival of these fundamentally useful and sometimes even sacred water sources (see Fig. 5-1). During the summer of 2015, with the help of Chip Morris, Kirk D. French conducted a telling interview with the head of the Waterhole Committee in Chamula that demonstrated the local outlook surrounding the waterholes. As the current holder of this office, it is his responsibility to oversee the heads of the individual waterholes dispersed throughout the municipality. This is to ensure the springs are maintained and any associated religious rituals are carried out in the proper manner.
During the interview, photos of the Main Picota Pool built by the Classic Maya were shown to gather the thoughts of the modern Maya leader about the similarity of construction and perhaps function in comparison to their own structures. This preconceived notion that guided many of the initial questions was the existence of a long temporal connection between the Main Picota Pool at the ancient Maya site of Palenque and the waterholes at the modern Maya villages of the highlands of Chiapas. In other words, it was plausible that the ancestors of ancient
Palenque, with whom the modern Maya have no recognized ancestral connection, were the ones to eventually settle in the highlands, the only other region that has a similar pool structures.

However, these thoughts were immediately turned around when the head of the Waterhole Committee suggested that these pools, including the Main Picota Pool in the photograph, are simply a natural phenomenon. In a very matter of fact manner, this man was saying that these springs exist naturally, and the construction is simply a matter of preservation and ensuring a dependable water source (W. Morris, pers. comm. 2015). Although this was not technically the case in ancient Palenque (the pool was excavated into bedrock and not built around a natural spring), his response presented a new possibility.

The situation could instead be the opposite of what was initially hypothesized; the Maya in the highlands, who long utilized naturally occurring springs as ceremonial centers, could have been the ones who settled in Palenque, where there is no utilitarian necessity for constructed waterholes due to the abundance of perennial flowing water. But due to the deep ritual connection to these structures, the inhabitants excavated into bedrock adjacent to the Picota stream in order to preserve these rituals. It must be noted that in order for this to be a more concrete claim, evidence such as strontium isotopic analysis would need to be presented. Though it is beyond the scope of this thesis, the data gathered from such tests has the potential to track migration by distinguishing the origin of individuals based on regional isotope signatures.

The waterholes often act as the core gathering area for the rituals related to municipal festivals of varying significance throughout the year. Festivals are important celebrations that focus on the worship of a particular saint or deity. Many of these events throughout the highland Maya community follow a similar structure that hinges on the pertinence of the deity to the
individual community. The celebrations are directed by members of the cargo system of voluntary or appointed positions in place to ensure the proper veneration of the saints. The basic pattern involves one or two days of preparation, a day of gathering in front of the church, and a final day of feasting and celebration (Early 2006, 23–41). The night prior to the first day marks the start of the festivities. At this time, the altars of both the church and the home are donned with a fresh flower display. Additionally, the Catholic saint statues are dressed in a new set of traditional Maya garb.

The first full day of the festival involves a series of activities still serving as preparation for the communal celebration. The church is cleaned and decorated, while the standing officials begin to visit the homes of those preparing to leave office. During the next day, festival leaders will entertain the saints by singing, dancing, and drinking sugar cane liquor. This highly potent cane liquor called pox has become widely used by the Maya as a religious ceremonial offering (Nash 2007, 627). At sunset, they then count the value of necklaces composed of silver coins attached to cloth that will then adorn the saint statues during the last and most important day. The main difference between the final day and the other preceding ones is that people residing in the area around the Maya village will visit the church to pay homage to the particular saint. Also, a Catholic priest from the closest large diocese, San Cristóbal de Las Casas in the case of Highland Chiapas, will visit to lead Mass. Although formal, organized service is not normally a part of Maya-Catholic worship, it is considered to be significant during festival times. Among all of the feasting and jubilance of the festival’s main event, there are also auxiliary administrative activities occurring such as a gathering of the elders in the church and the induction of new
officials for the upcoming year (Early 2006) Overall, festivals for the saints are some of the most fundamental and ubiquitous events throughout the indigenous Maya world.

The Festival of San Juan in Chamula is a specific example of one of these religious community events. The origin for this celebration comes from the Second Creation Myth of Chamula tradition wherein San Juan had to leave his home of Sitalá due to his sheep not wanting to eat there any longer (Gossen 1974, 320). After much exploration around the region, he found a lake at the “earth’s navel,” where his sheep enjoyed grazing. Then, a large amount of dirt and rock fell down a hill and filled lake, where the ceremonial center and Church of San Juan is now located in Chamula. Once he was able to gather enough stone to construct a house, he had a grand fiesta on June 24, the same day that the Festival of San Juan is celebrated still today.

In addition to this ethnographic comparison, there is also an historical linguistic approach to propose a parallel between the two regions of Chiapas (French, Straight, and Hermitt, *in prep*). The Tzotzil, the ethnolinguistic group of those living in Chamula, are historically linked to the Greater Tzeltalan branch of proto-Mayan language family (Kaufman 1976). “These Tzotzil-Tzeltal peoples are almost certainly descended from a proto-Tzeltalan population which has become differentiated into various contemporary groups within the past 1,000 years” (Vogt 1969, 1973). This historical linguistic connection can serve as another form of evidence to strengthen the hypothesis of tracing the origins of those residing in ancient Palenque, a region that is now comprised of Tzeltal speakers, to the Tzotzil speakers of the highlands of Chiapas.

The incorporation of ethnographic and linguistic analogies to archaeological analysis is valuable and should not be overlooked. This has been done in various regions across the world, often to examine the methods of craft production that have gone unchanged for generations.
(Costin 2015; Brown 2004; Donnan 1971; N. Peterson 1968). In the copiously cited work of Elliot Abrams (1994, 1984), the quarry labor rate of 750 kilograms per person-day was based on an average between replicative experiments and ethnographic interviews with the local quarry manager in Copán, Honduras. Given the proposed ceremonial nature of the Main Picota Pool, it is plausible that festival events analogous to the Festival of San Juan were held around at the Picota Group Plaza during the Classic Period. Therefore, an understanding of the modern celebrations may provide some insight into the ancient ceremonies that occurred around the Main Picota Pool.

**Future archaeological investigations**

Other than speculation about the cultural processes that could have taken place during the past habitation of the region, there are also larger archaeological questions that can be tested and quantified through further excavation and analysis. During the two years of the Palenque Pool Project, the INAH (Instituto Nacional de Antropología e Historia) permit only allowed for excavation inside the pool boundaries. Therefore, still the only test pits to be dug in the Picota Group, which demonstrated the highest concentration of Picota Phase ceramics dating between 200 and 350 CE, were done more than a half century ago by Rands (1974). Obtaining a permit to excavate in Palenque is next to impossible, but not for archaeologists’ lack of effort. However, if a permit to excavate the entire Picota Plaza were possible, including the consolidation of the damaged aqueduct managing the Picota Arroyo, a myriad of new information could be revealed about this time period and region of Palenque.
The exact dates of construction and the function of the Main Picota Pool both remain a mystery. With further excavation, one may find an even higher density of Picota Phase ceramics, which would confirm the notion of this group being one of the earlier settlements of Palenque. Conversely, a concentration of ceramics from a different phase in the Palenque sequence, building evidence against the current narrative of the Picota Group being an early settlement of Palenque. Perhaps there is a production site, a burial, or some other feature that would completely change the way this group is perceived by archaeologists. In addition to the archaeological value of opening up the Picota Group Plaza, there are also potential conservation benefits. The aqueduct that manages the Picota Arroyo, a perennial stream that still actively flows, is collapsing in several areas. As debris builds up during periods of intense rain it causes the entire plaza to flood, a phenomenon observed during the 2015 first field season. The Palenque Pool Project hired a local stonemason to consolidate the structure of the Main Picota Pool after excavations had come to a close. It would be entirely possible to apply the same conservation methodology after excavating the Picota Plaza around the aqueduct. This would not only enable the Picota Arroyo to flow without interference, but it would also protect the surrounding area from intense erosion and soil degradation that comes along with periodic flooding. Further, there are four other pool structures scattered across the site. Investigations into these pools and the hydraulic engineering around them would also contribute this understanding of hydrology at Palenque.

The continuation and extension of the Palenque Pool Project would yield further energetic analysis of the aqueduct and the entire Picota Group, expand the understanding of the time period and use of the Main Picota Pool complex, and contribute to the overall knowledge about the Classic Maya center of Palenque. The research presented in this thesis provides a point
from which other scientists could continue to develop novel questions to address the new problems that arise from further investigation. The archaeological basis for the continuation of the scientific process in the Picota Group is strong and has the potential to be greatly expanded in future investigations.
References Cited


Beach, Timothy, Sheryl Luzzadder-Beach, Nicholas Dunning, Jon Hageman, and Jon Lohse.


French, Kirk D., and Christopher J. Duffy. 2010. “Prehispanic Water Pressure: A New World


Maliva, Robert G, and Raymond Siever. 1988. “Mechanism and Controls of Silicification of


Morgan, Lewis Henry. 1881. Houses and House-Life of the American Aborigines. Chicago:


Examination of Possible Sources.” *Sixth Palenque Round Table*, 151–66.


Spencer, Kaylee R. 2007. “Framing the Portrait: Towards an Understanding of Elite Late Classic Maya Representation at Palenque, Mexico.” University of Texas at Austin. 


Stuart, George E. 1989. “The Beginning of Maya Hieroglyphic Study: Contributions of


Weaver, Eric, Christopher Carr, Nicholas P. Dunning, Lee Florea, and Vernon L. Scarborough. 2015. “Examining Landscape Modifications for Water Management at Tikal Using Three-
Dimensional Modeling with ArcGIS.” In Tikal: Paleoeconomy of an Ancient Maya City, 87–94. Cambridge: Cambridge University Press.


doi:10.1121/1.3508237.
Appendix A

Pool measurements

### a. Monumental staircase measurements

<table>
<thead>
<tr>
<th>Step</th>
<th>Length(m)</th>
<th>Width(m)</th>
<th>Height(m)</th>
<th>Volume(m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>0.33</td>
<td>4</td>
<td>0.33</td>
<td>0.4356</td>
</tr>
<tr>
<td>Step 2</td>
<td>0.33</td>
<td>4</td>
<td>0.33</td>
<td>0.4356</td>
</tr>
<tr>
<td>Step 3</td>
<td>0.33</td>
<td>4</td>
<td>0.33</td>
<td>0.4356</td>
</tr>
<tr>
<td>Step 4</td>
<td>0.33</td>
<td>4</td>
<td>0.33</td>
<td>0.4356</td>
</tr>
<tr>
<td>Step 5</td>
<td>0.33</td>
<td>4</td>
<td>0.33</td>
<td>0.4356</td>
</tr>
<tr>
<td>Step 6</td>
<td>0.66</td>
<td>4</td>
<td>0.33</td>
<td>0.8712</td>
</tr>
<tr>
<td>Step 7</td>
<td>0.33</td>
<td>1.5</td>
<td>0.33</td>
<td>0.16335</td>
</tr>
<tr>
<td>Step 8</td>
<td>0.33</td>
<td>1</td>
<td>0.33</td>
<td>0.1089</td>
</tr>
<tr>
<td>Step 9</td>
<td>0.33</td>
<td>0.5</td>
<td>0.33</td>
<td>0.05445</td>
</tr>
<tr>
<td><strong>Step Total</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>3.3759</strong></td>
</tr>
</tbody>
</table>

### b. Wall measurements and pool volume total

<table>
<thead>
<tr>
<th>Wall</th>
<th>Length(m)</th>
<th>Width(m)</th>
<th>Height(m)</th>
<th>Volume(m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wall N</td>
<td>10</td>
<td>0.25</td>
<td>1</td>
<td>2.5</td>
</tr>
<tr>
<td>Wall W</td>
<td>4</td>
<td>0.25</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Wall E</td>
<td>STEPS</td>
<td>STEPS</td>
<td>STEPS</td>
<td>3.3759</td>
</tr>
<tr>
<td>Wall S</td>
<td>10</td>
<td>0.25</td>
<td>1</td>
<td>2.5</td>
</tr>
<tr>
<td>Wall S Terr</td>
<td>10</td>
<td>0.25</td>
<td>1</td>
<td>2.5</td>
</tr>
<tr>
<td>Wall S Upper</td>
<td>10</td>
<td>0.25</td>
<td>1.5</td>
<td>3.75</td>
</tr>
<tr>
<td><strong>Pool Total</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>15.6259</strong></td>
</tr>
</tbody>
</table>
Appendix B

Labor calculations

a. Quarrying (750 kg/p-d)
   i. Source limestone
      
      $42361.8 \text{ kg (total used)} / .55 \text{ (waste)} = 77021.5 \text{ kg (total quarried)}$
      
      $77021.5 \text{ kg} / 750 \text{ kg/p-d} = \textbf{102.695 p-d}$
   
   ii. Pool cavity
      
      $135550 \text{ kg} / 750 \text{ kg/p-d} = \textbf{180.73 p-d}$

b. Transport (586 kg/p-d)
   i. Output $= Q \times \left[1 / (L/V + L/V')\right] \times H$ (Aaberg and Bonsignore 1975)
      
      $\text{Output} = 28.6 \text{ m}^3 \times \left[1 / (275 \text{ m} / 3 \text{ km/hr} + 275 \text{ m} / 5 \text{ km/hr})\right] \times 5 \text{ hours}$
      
      $\text{Output} = \textbf{.257 m}^3 \text{ / p-d (586 kg)}$
   
   ii. $77021.5 \text{ kg} / 586 \text{ kg/p-d} = \textbf{131.44 p-d}$

c. Manufacture (.086 m³/p-d)

   $15.6 \text{ m}^3 / .086 = \textbf{181.39 p-d}$

d. Assembly
   i. Cut stones placement (.8 m³/p-d)
      
      $15.6 \text{ m}^3 / .8 \text{ m}^3 / \text{p-d} = \textbf{19.5 p-d}$
   
   ii. Fill placement (4.8 m³/p-d)
      
      $148.11 \text{ m}^3 / 4.8 \text{ m}^3 / \text{p-d} = \textbf{30.86 p-d}$
e. **Finishing**

   i. Plaster production (14 kg/p-d)

      \[
      \frac{2054 \text{ kg of quicklime}}{14 \text{ kg/p-d}} = \text{146.7 p-d}
      \]

   ii. Plaster application (50 m²/p-d)

      \[
      \frac{75.84 \text{ m}^2}{50 \text{ m}^2/p-d} = \text{1.52 p-d}
      \]