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Laboring with the Economics of Mycenaean Architecture: Theories, Methods, and Explorations of Mycenaean Architectural Production

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LABORING WITH THE ECONOMICS OF MYCENAEAN ARCHITECTURE:

THEORIES, METHODS, AND EXPLORATIONS

OF MYCENAEAN ARCHITECTURAL PRODUCTION

By

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

This study examines the connection between architecture and economy in Mycenaean Greece; it is a deep investigation of economic theory and models of the Mycenaean economy, existing methods for the study of prehistoric architecture, and particular Mycenaean structures. Over the course of the study, I present current thinking on the Mycenaean economy and fundamentally rethink the concept of economic embeddedness and human agency. With a novel theoretical grounding, I present a methodology based in human action to study the intersection of architecture and the Mycenaean economy, and in three detailed case studies, I apply the methodology to the Treasury of Atreus at Mycenae, the harbor town of Kalamianos in the Corinthia, and the Northeast Extension of Mycenae's fortification wall.

I argue that to advance the study of Mycenaean economy and theory, the concept of economic embeddedness, which posits that economic actions and decisions are bounded by larger social concerns, must be rethought. In its place, I offer a theory of complex embeddedness that envisions human action as fluid and cross-cutting traditionally circumscribed categories of economy, society, and polity. This foundation in human action with it links to agency theory helps to move the study of architecture away from the static sociopolitical meaning of the final built form and towards the human processes of construction. Under the guidance of this theory, I envision construction as a form of production in which individuals interact with one another and the material world to build a structure. I ultimately use the term *architectural production* to label this novel viewpoint.

To study architectural production at a range where human actions and agency matter, I advance a methodology that draws together architectural energetics, chaîne opératoire, and tools from the construction management industry. I argue that architectural energetics offers a starting

point for studying architectural production, but that existing applications of architectural energetics have placed too much weight on summed labor-costs and macroscale typologies. By reformulating architectural energetics with a focus on the chaîne opératoire, or operational sequence, and by using construction management tools to investigate the dynamic nature of the chaîne opératoire, I propose a method that builds on architectural energetics' basis in labor-costs to explore the temporal and spatial configuration of architectural production. With the method, I reconstruct and detail processes of architectural production, model the ordering of human-centric production tasks and patterns of labor organization, explore timeframes for the completion of structures under different conditions, and isolate how active human agents move through space and time during architectural production.

I apply the method to the Treasury of Atreus at Mycenae, the town of Kalamianos in the Corinthia, and the Northeast Extension of Mycenae's fortification wall. For each, I collate published data and field observations to recreate the structures in 3-D CAD models, profoundly contemplate the entire process of production from the planning stages to the finishing touches, investigate the spatiotemporal configuration of labor during production, and stress the plethora of human choices and actions that occurred in the production of these structures. Finally, I fold my study of each structure into larger topics that engage models of the Mycenaean economy, including decision making and group interactions during architectural production, the creation of architectural monumentality and power, and the administration and compensation of builders. I argue for a networked view of the Mycenaean economy that builds on close range analyses of human acts of production; the acts of architectural production that I stress in this study were a complex and integral part of this networked Mycenaean economy.

Four supplementary PDF files are included with this study. They form part of the application of my methodology to the Treasury of Atreus at Mycenae, the harbor town of Kalamianos in the Corinthia, and the Northeast Extension of Mycenae's fortification wall. The supplementary files (Supplements 1–4) are referenced in Chapter 7.

CHAPTER 1

INTRODUCTION

There is a deep bond between humankind and architecture, so much so that the emergence of large monuments has been heralded as a marker of civilization itself,[1] and Mycenaean scholars have not ignored this connection; upon opening the early foundational works of Mycenaean archaeology, Schliemann's seminal volumes on Mycenae and Tiryns or Tsountas and Manatt's *Mycenaean Age*,[2] a reader will immediately find architecture at the heart of discussion. To this day, architecture holds a commanding sway in the field. As Mycenaean scholarship changes, though, with the rapid increase of fine-grained datasets and renewed engagement with long-standing archaeological theories, the way we interpret architecture and the vocabulary we use to explore its place in the Mycenaean world needs to change, too. While Mycenaean architecture is overwhelmingly discussed as a reflection or tool of elite power, a symbol rife with sociopolitical meaning, or the facilitator of a particular economic, defensive, or mortuary function, in this study, I argue that architecture must likewise be viewed as the result of a network of human actions; architecture is not only a finished product whose completion was inevitable but it is also the result of a complex process of production driven by cognizant human agents who collectively transformed the material world around them.

Through the lens of economic production and with the grounding argument that it is equally valid to speak of the production of architecture as it is the production of pottery, lithics, or other goods, in this study, I investigate the dynamic, human-driven processes of architectural

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[1] See especially Osborne 2014.
[2] Schliemann 1880; Schliemann et al. 1885; Tsountas and Manatt 1897.

production and I confront how studying architectural production informs our understanding of the Mycenaean economy. To tackle Mycenaean architectural production and economy, I take a multipronged approach that engages architectural energetics, chaîne opératoire, and tools from modern construction management. With these, I detail and explain how builders organized the architectural production of three major building projects in Mycenaean Greece: the Treasury of Atreus at Mycenae, the harbor town of Kalamianos in the Corinthia, and the Northeast Extension of Mycenae's fortification wall. My goal, in each case, is to explore architecture in a manner that moves away from vague ideas of elite power and stylistic symbolism, and shifts focus towards situating groups of human agents in time and space during acts of production.

Before engaging the problem of architecture directly, I first work through the theoretical issue of what I mean by "economy" and "the Mycenaean economy." In Chapter 2, I present an overview of previous and current theoretical approaches to the Mycenaean economy by highlighting the scholarly movement away from a dominant palatial model to more nuanced pictures of production, consumption, and exchange. I argue that the concept of social embeddedness, which has surfaced in recent Mycenaean scholarship (and has been tacitly influential in past approaches), is beneficially reframed with the help of Austrian economic theory so that embeddedness is viewed as complex in the sense that individuals act at the confluence of social, economic, and political concerns. Theoretically, this dissolves the strong boundary between economy and society that has undergirded much anthropological theory. In its place, I present a view of "the Mycenaean economy" as inherently diverse and grounded in materially-based human actions and interactions. I then posit that complex embeddedness is effectively a manifestation of agency theory and situate it within the increasing scholarly emphasis on agency. With complex embeddedness and its link to agency as a guide for studying

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architecture, I argue that, to date, Mycenaean studies have placed too much meaning on the final built form of architecture and too little on the human-level processes of construction, which textually-based, historical studies, demonstrate are a consequential arena of study. Due to the limitations of the Linear B data, though, a materially-grounded approach is necessary and I propose that framing construction as a type of production is beneficial in this regard. Finally, I draw together complex embeddedness, agency theory, and producer-oriented theories of craft production to pin down the concept of architectural production, which I define as the spatially- and temporally-coordinated actions of individuals and groups of individuals who each use particular knowledge and tools to alter material resources and who cooperatively work towards the goal of producing a final structure.

With the theoretical basis and definitions set, in Chapter 3, I lay out a method for studying architectural production that builds on the topic of human labor. I begin by discussing the method of architectural energetics, which is popularly used to study economic aspects of architecture through labor metrics. After summarizing the method of architectural energetics, I discuss its theoretical underpinnings, particularly concentrating on its historical connection to social power and evolutionary typologies. Some of its notable studies are highlighted to illustrate the method's previous applications in the Americas and the Aegean. Based on these previous applications, I stress that architectural energetics has been valuable for macroscale analysis, but that the method suffers from viewing metrics of labor statically while placing too little emphasis on the human-level processes of architectural production where "labor-costs" were realized in human practice. Instead, I reason that energetics can be restructured in order to analyze architecture as a productive process. To do so, I advocate a method that emphasizes the close description of material remains and uses inference to unravel the chaîne opératoire, or

operational sequence, of production. Coupling this with architectural energetics' focus on labor and modern construction management tools that explore the dynamics of construction, I present a novel method that allows us to explore how architectural production was dynamically organized by human agents in time and space.

In Chapters 4–6, as case studies, I begin to apply the method to the Treasury of Atreus, structures 4-VI and 7-X from the town of Kalamianos in the Corinthia, and the Northeast Extension of Mycenae's fortification wall. I collate past research on each to detail the state of the architectural remains and the larger archaeological contexts. Using AutoCAD, I then create a 3-D model of each structure that illustrates the materials employed, stresses assumptions made about the structure, and reveals the hidden elements of construction. Based on the models, previous research, sets of comparative and experimental data, and my own observations in the field, I outline the particular tasks of the production process at a very close range, including the techniques, tools, and raw materials used during individual tasks, the ordering of production tasks and stages, and the organization of production in the landscape. In Chapter 7, I finish applying the method by modeling and simulating the production of each structure. I use the tasks and 3-D reconstructions from the preceding chapters to create a set of energetic flowcharts, a type of chart that I have designed to merge energetics and the chaîne opératoire. The energetic flowcharts present the human-level tasks of production and their interconnections alongside the rates of labor builders expended in each task and the types of materials they worked on. These charts visually describe the production of an individual structure and move examination closer to the level of past agents. Next, I use the data in the energetic flowcharts to present a traditional energetics analysis of each structure that shows the person-hours builders expended during construction. This serves to situate this analysis within past energetics research and highlight

how my approach differs. I then model the ordering of the tasks in the energetic flowcharts in

Microsoft Project and estimate the ranges of people who could have worked at each task.

Ultimately, this model is used to simulate various timeframes for construction and isolate

different strategies that builders could have chosen and different ways labor may have been

organized. The simulation results for each structure and their implications are discussed

throughout Chapter 7, but the major point that emerges is that the production of architecture is

highly variable; it not only requires the cooperation of many discrete groups operating under

fluctuating levels of administrative oversight, but the configuration of labor and the spatial

organization of production can shift drastically over the course of producing a structure.

Fundamentally, this distinguishes architectural production from the production of traditional

craft goods.

Finally, in Chapter 8, I fold the models of architectural production, the simulation data,

and the discussion from Chapters 4–6 into higher level issues. I argue that architectural

production and the theory of complex-embeddedness offer a new way to understand

monumentality that deviates from past descriptions of monumentality. I advance a form of

"productive monumentality" that is based in the engagement of laborers and witnesses during

production as well as the creation of memories, especially those linking acts of production to

parts of the landscape. Rather than reading a summed labor-cost as a measure of elite power or as

a mark of a particular form of sociopolitical organization, architectural production also draws out

how power, whether economic, social, or political, may be created through interactions on the

building site and, I argue, that many participants can gain during architectural production so that

we should not envision monumental architecture as inherently exploitive. Next, I move to a more

general level and draw on the Linear B texts and broader archaeological data to discuss how

building projects may have been administered and to set out some reasons why builders of varying skill levels may have participated by looking at forms of compensation. To conclude, I circle back to the seminal issue of the study and discuss the broad connection between architectural production, human action, and the Mycenaean economy. I resolve that we need to weaken typological thinking in order to better understand close-range data and that modeling the Mycenaean economy as a network of human actions and interactions offers an improvement on past models.

CHAPTER 2

THEORIZING ARCHITECTURE AND ECONOMY

Setting Out: Scholarship on the Mycenaean Economy

The Monolithic Palace

Understanding of the Mycenaean economy over the later course of the 20th century and

the early 21st century has evolved considerably and can be broken into three broad theoretical

views or approaches. Although the boundaries between each are necessarily fuzzy, scholarship

shows a general movement away from a monolithic view of the Mycenaean economy, where the

palaces were dominant, to a more nuanced picture, which acknowledges that a variety of

economic processes occurred at an individual and institutional level. The first of these theoretical

views emerged in the 1950s as a direct result of Ventris and Chadwick's work on Linear B and

the publication of *Documents in Mycenaean Greek.*[1] Following decipherment, the content of the

Linear B tablets was read through the lens of Near Eastern texts.[2] This initial interpretation,

which is sometimes called the "monolithic view," understood the Mycenaean palaces as the

dominant force in the economy.[3] The concept of redistribution as expressed in the work of

Polanyi was vital to this interpretation.

In creating a typology of economic systems, Polanyi suggested that pre-capitalist, non-

market economies were built on reciprocity, in which goods moved between symmetrical groups,

and redistribution, where goods moved towards a center and back out.[4] Within the Linear B

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[1] Ventris and Chadwick 1973.
[2] Finley 1957, 134–9; Ventris and Chadwick 1973, 106–7.
[3] Finley 1957; Ventris and Chadwick 1973; see also Killen 1964, 1985, 2008.
[4] Polanyi 1957, 250–6; see also Nakassis et al. 2011.

tablets the latter economic system seemed to be at work, as the texts listed a variety of raw materials and finished products moving to and from the palace centers. At Knossos, for example, Killen noted an extensive cloth industry in which the palace monitored sheep flocks, set targets for the acquisition of wool, and closely oversaw the production of cloth.[5] Around the Palace of Pylos, a variety of raw materials were extracted from individuals and regional centers via contributions and taxation,[6] and bronze was distributed to smiths in a specialized production system.[7] A comparable form of centralization was a hallmark of Bronze Age economies in the Near East, as they were traditionally conceived.[8] Both Near Eastern archives and the Linear B tablets, moreover, revealed a high degree of craft specialization;[9] since the monolithic view under the influence of Polanyi accepted *a priori* that market exchange did not exist, a centralized, redistributive palace was viewed as the only means for these craft workers to make a living.[10]

This position was seminally outlined in the work of Finley, who envisioned in Mycenaean Greece "a far-reaching and elaborately organized palace economy."[11] Since Finley's publication, the monolithic view has persisted in various forms, especially among textual scholars. Most recently, Killen has reasserted that after 50 years no evidence suggests "that we need alter [Finley's] basic conclusions about the nature of the society: that this is a redistributive (or command) economy of the Near Eastern (or 'Asiatic') type".[12] Ultimately, the impact of the

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[5] Killen 1964, 2008, 177.
[6] Shelmerdine 1973; Ventris and Chadwick 1973, 275–301; Killen 2008, 173.
[7] Ventris and Chadwick 1973, 352–9.
[8] For a brief overview on the evolution of Near Eastern political economy see Yoffee 1995.
[9] Ventris and Chadwick 1973, 133–6
[10] Killen 2008, 175; see also the discussion in Parkinson et al. 2013.
[11] Finley 1957, 134.
[12] Killen 2008, 159.

monolithic view on the history of Mycenaean scholarship cannot be overstated; its acceptance or rejection, whether in part or whole, provided the starting point for all ensuing debate.[13]

The Two-Sector Model

      In response to the textually-oriented, monolithic interpretation, a second view emerged which sought to balance archaeological data and the Linear B texts. The resulting picture of the Mycenaean economy that arose from this approach has been termed the "two-sector model" by Nakassis.[14] In contrast to the singular, palatial focus of the monolithic interpretation, the two-sector model offers a more tempered view; it retains an important, economically-motived palace, but argues that a variety of economic behaviors also occurred outside of the palace's interests, thereby, splitting the Mycenaean economy, and indeed Mycenaean society as a whole, into diametric categories. On the one side, is the textually-attested, elite, and centralized palatial economy; and on the other side, is the archaeologically-attested, peripheral, non-palatial economy.

      Typically, Halstead is cited as the formative author of this perspective.[15] In his work on Bronze Age agriculture, he originally noted that the Mycenaean palaces were more focused than the monolithic view allowed. They largely directed their efforts to the production of particular wealth goods which were used to acquire exotic materials and to draw in specific staple resources. Meanwhile, outside of the palaces a broad array of unmonitored activities occurred,

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[13] Halstead (2011, 233) put this well, saying that the work of Finley and his contemporaries "was invaluable in helping steer the undertheorized field of Aegean Bronze Age studies away from uncritical and anachronistic application of models derived from modern mercantile capitalism."
[14] Nakassis 2006, 14.
[15] Halstead 1992; see also de Fidio 1987; Aravantinos 1995; Halstead 1999, 2001.

most notably the production of cereal and pulse crops.[16] These two economic sectors, one

centered on the palace and one dispersed outside of the palace, he argued, were integrated

through mobilization, a particular form of redistribution in which one group extracts resources

from another for its own benefit.[17] According to Halstead's model, the Mycenaean palaces

mobilized assorted agricultural produce and labor from the non-palatial sector and in return,

supplied craft goods and subsistence relief in times of need.[18]

While this dichotomous attitude is the defining characteristic of the two-sector view,[19]

over time, scholars invoking the two-sector model have moved away from a rigidly polarized

model of palatial and non-palatial spheres to a more sensible continuum which includes more

gray-area between the palatial and non-palatial sectors.[20] Studies of the delineation, overlap, and

integration of palatial and non-palatial economies have consequently played a dominant role in

modeling the Mycenaean economy over the past two decades. This is particularly apparent in

attempts to situate various craft products within the palatial/non-palatial continuum, frequently

with a specific concentration on pottery manufacture and exchange.[21] Such studies have revealed

an increasing attention to the specificity of both evidence and arguments. This continuing trend

exemplifies a crucial change in the scale of analysis which has accompanied the rise of the two-

sector model. In contrast to the monolithic view, which tackles the economy at the macro-level

by relying on cross-cultural textual comparisons and broad typologies, the two-sector model and

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[16] Halstead 1992, 2001.
[17] Derived from Earle's (1977, 214–6) typology of redistribution.
[18] Halstead 1992, fig. 1.
[19] The literature is characterized by a number of overlapping dichotomies including palatial/non-palatial; textual/archaeological; elite/commoner; luxury/utilitarian; specialized/non-specialized; and center/periphery.
[20] de Fidio 2001; Galaty and Parkinson 2007a; Shelmerdine 2011.
[21] Knappett 2001; Whitelaw 2001; Parkinson 2007.

its continuum of the palatial/non-palatial has advanced more precise explanations of discrete temporal and regional patterns.[22] From an archaeological perspective, this theoretical change in scale has been intimately linked with an expanding appreciation for the variable functioning of the Mycenaean palaces, including the distinct circumstances that conditioned their emergence, as well as the growth of pedestrian surveys which have offered high resolution data beyond the palace confines.[23] As a result, there is now strong evidence that individual Mycenaean palaces administered industries in distinct ways,[24] and that regional paths towards centralization were dissimilar, while centralization itself was not an inherent trajectory in every region.[25] The increasing attention to specific models and data at the expense of generalizations, as well as the expanding gray-area between the two-sector model's palatial/non-palatial extremities, has led to a new phase of exploratory thought.

Current Trends

Unlike the monolithic view or two-sector model, current exploratory trends in the Mycenaean economy cannot be lumped under the heading of a single, dominant model. Instead, recent scholarship is loosely unified by a proclivity to question the established beliefs which have previously dictated the terms of discussion and by an increasing reliance on bottom-up approaches. Although the origin of these trends is apparent at least as early as Halstead's formative work on agriculture,[26] recent approaches to Mycenaean economy have pushed back

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[22] e.g. Voutsaki 1998, 2010; Dabney et al. 2004; Parkinson 2007; Nakassis 2010; Shelton 2010; Tartaron 2010.

[23] Parkinson et al. 2013, 414. Tartaron (2008, 89–93, 100–4) provides an overview of these trends and their impact.

[24] Galaty and Parkinson 2007a, 3–7.

[25] Voutsaki 2001, 2010; Nelson 2007; Pullen and Tartaron 2007; Tartaron 2010.

[26] Halstead 1992.

against the overdrawn, impersonal two-sector model[27] and have more boldly pursued novel

economic theory, largely under the influence of developments in American anthropology. The

refutation of Polanyi's and Finley's long-standing influence is especially meaningful and may

signal the nascent stages of a paradigm shift in Bronze Age Aegean scholarship.[28]

Many scholars now view redistribution (and its subtypes) as an outmoded and

overgeneralized way of describing economies.[29] Instead, the precluded topic of Mycenaean

markets and market exchange is becoming a permissible area of research so that it is now

possible to envision multiple exchange mechanisms at work without typing the entire Mycenaean

economy based on a single, dominant strategy.[30] Schon has illustrated that even in particular

cases of close palatial control where redistribution might retain typological use, the palace could

employ several acquisition strategies for the same raw materials.[31] Furthermore, Lupack's work

on the Pylos tablets indicates that there were multiple institutional players with economic

interests, including the *damoi* and religious sector,[32] so that the simplistic palatial/non-palatial

dichotomy implied by the two-sector model with its basis in redistribution (i.e. into the center,

out of the center) is not necessarily capable of accurately capturing the nuances of Mycenaean

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[27] Nakassis 2006, 16–7; however, this is not to say that the concepts of palatial and non-palatial have lost their value, only that there is a desire to describe shades of human behavior in a way that cannot be done with a single, overarching dichotomy.

[28] Where this will lead is unclear, but see Feinman (2013, 453) who believes that we are now "at the cusp of new theoretical conceptualizations that should jettison, or at least circumvent, the now rather unproductive misconceptions, dichotomies, and typological frames that have dominated our dialogues for many decades."

[29] Galaty et al. 2011; Nakassis et al. 2011. Halstead (2011) presents a contrary assessment of redistribution. See also Bennet and Halstead (2014) who find the term useful for describing certain types of palatial exchanges which occurred alongside other types including gift-giving and voluntary, market-like exchanges.

[30] Aprile 2013; Feinman 2013; Hruby 2013; Parkinson et al. 2013; Pullen 2013a.

[31] Schon 2011.

[32] Lupack 2011. See also de Fidio 1987; Bendall 2007.

economies. Finally, the extent to which individuals and institutions are more complex than previous models have acknowledged is demonstrated by Nakassis' prosopographical work in which he characterizes the array of social, political, and economic roles that individuals played at Pylos.[33]

The emerging picture of mixed economic strategies, and the ability of groups and actors to negotiate their roles within the economy reflects a fundamental change in thinking. Scholarly emphasis now, more and more, falls on examining the complex and flexible nature of past behaviors and approaching the Mycenaean economy "at close range." [34] The results are more nuanced, temporally- and spatially-focused models which regard the economy as inherently dynamic and populated by many interests. There is greater acceptance that individuals themselves are meaningful and act across traditionally bounded categories. In this regard, Nakassis offered the most significant statement when he recognized that the state is an "active network of exchanges enacted and reproduced by individuals."[35] As a theoretical underpinning, Nakassis employed a form of agency theory which attempts to mediate between purposefully acting, conscious agents and external structures which are constituted by, influential upon, and intertwined with individuals and their actions. The entanglement of acting individuals and supra-individual institutions expressed in Nakassis' networked model of the Pylian state is equally consequential for economic analysis; it suggests that we should speak of the Mycenaean economy or Mycenaean economies[36] not only in broad strokes but, wherever possible, in terms of the situated behaviors and interactions that constituted these economies and the recursive

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[33] Nakassis 2006, 2013.
[34] Tartaron 2008, 107.
[35] Nakassis 2006, 16.
[36] Pullen 2010, 2013a.

interplay between these behaviors and dynamic, supra-individual forces and institutions, including the palaces. Coupled with the growing patchwork of archaeological data and a greater appreciation for the strengths and limits of the Linear B texts, the movement from traditional, macro-scale explanation to novel micro-scale considerations is leading into unexplored theoretical pastures and consequently, opening up room for fresh approaches to economy in Mycenaean Greece.

Laying the Foundations: Rethinking Economics

Embeddedness and its Problems

In light of changing attitudes about the Mycenaean economy, it is worth rethinking the broad but essential problem of how we theorize the ancient economy, economic behaviors, and the relationship between economy and society in general. Granovetter's concept of embeddedness, which has been drawn loosely into Mycenaean scholarship,[37] provides a useful starting point because it specifically addresses the entanglement of individual economic action and supra-individual phenomena and the connection between "economic" acts and "non-economic" acts and institutions.[38] Specifically, Granovetter argues that 20th century theories failed to adequately recognize the way in which individuals function socially and economically. On the one hand, in theories based on classical sociology, pre-capitalist economic behaviors were socially dictated and individuals passively enacted external social scripts; only with the advent of modern market exchange did economic behavior disengage from social concerns, becoming both calculative and atomized.[39] On the other hand, theories grounded in neoclassical

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[37] Feinman 2013; Parkinson et al. 2013.
[38] Granovetter 1985, 2005.
[39] Granovetter 1985, 482–3.

economics contended that, in both capitalist and pre-capitalist societies, economic behaviors

were predominantly individualized and based on an objective rationality which was only

narrowly constrained by external social forces.[40] Granovetter maintained that both the former,

oversocialized and latter, undersocialized positions needed to be tempered in order to reach a

more accurate theory of human behavior.[41] To do so, he reasoned that individuals act with

meaning and purpose, but do so within the structure of social networks, not as isolated,

calculative "Robinson Cursoes." Drawing on a Polanyian term,[42] he concluded that in both pre-

capitalist and capitalist societies, economic action was and is always embedded, a word which he

defined as "the extent to which economic action is linked to or depends on action or institutions

that are non-economic in content, goals or processes."[43]

By theorizing a rational and socialized individual who exists in the middle-ground of the

under- and oversocialized views, Granovetter sought to reconcile the divide of sociological and

economic theory. Fundamentally, his theory of embeddedness posited that economic activity has

both a calculative (i.e. neoclassical economic) and supra-individual (i.e. classical sociological)

component.[44] Granovetter's embeddedness consequently had the important effect of introducing

"a new kind of analysis: where the actor is rational and where social structure counts."[45] In

effect, this was an affirmation that economic analysis was not the sole domain of formal

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[40] Granovetter 1985, 482–3.
[41] The ongoing conflict of the under- and oversocialized theories was at the heart of the substantivist/formalist debate. Wilk (1996) discusses the history and effect of the substantivist/formalist debate at length; see also Sjöberg 1995.
[42] Embeddedness in Granovetter and Polanyi are arguably distinct. Where the original term tended towards macro-level explanations of society and economy, its rebranding by Granovetter moved it towards describing behaviors at the meso- and micro-level (Machado 2011).
[43] Granovetter 2005, 35.
[44] Swedberg 1997, 162–3.
[45] Swedberg 1997, 163.

economists, but was also a justifiable research topic in the social sciences, and in this sense, although it sought to reconcile the economic and sociological divide, embeddedness was simultaneously a pushback against the perceived dominance of neoclassical formalism.[46]

Since Granovetter's original publication, embeddedness has remained important, forming a core tenet of the New Economic Sociology.[47] Although his particular formulation of embeddedness has not been fully engaged by those working in the Bronze Age Aegean, the underlying struggle to explain economic behaviors in socially meaningful ways and to mediate individual action and social institutions is a hallmark of Bronze Age scholarship.[48] This has often been under the tacit influence of Polanyian substantivism, which posited a type of pre-capitalist, social embeddedness that contrasted with neoclassical economic formalism.[49] With the continuing deconstruction of strict Polanyian typologies (e.g. redistribution) and the increasing move to specific close-range explanations, Granovetter's work has recently appeared in Mycenaean scholarship as a viable theoretical foundation which retains a concept of embedded economic action and, by tempering the under- and oversocialized individual, still makes room for a variety of economic behaviors at the individual and institutional level, particularly forms of market exchange.[50]

In a 2013 *American Journal of Archaeology* forum on market exchange, Granovetter's work is twice drawn in to fill the substantivist void. Parkinson et al. note that "all economies are embedded, albeit to varying extents"[51] and Feinman likewise states that "all economic systems

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[46] See Swedberg 2004, 325–6.
[47] Krippner 2001, 775.
[48] Ventris and Chadwick 1973; Voutsaki and Killen 2001.
[49] Polanyi 1957.
[50] Garraty 2010; Garraty and Feinman 2010; Feinman 2013; Parkinson et al. 2013.
[51] Parkinson et al. 2013, 415.

and markets, past or present, are embedded, albeit in different ways and to distinct degrees."[52]

While engagement with economic sociology offers a constructive path for developing economic

theory, it is worth noting that richer theories of embeddedness have emerged since Granovetter's

original publication in 1985, and that reliance on the concept of embeddedness as expressed by

Granovetter and the New Economic Sociology is likely to be more harmful than helpful. This

danger is made apparent when Parkinson et al. argue that "by making some theoretical room for

the existence of market exchange in the Aegean Bronze Age, it will be possible to examine more

accurately the degree of political centralization of different parts of the economy (i.e., their

embeddedness) over space and time."[53] Here, embeddedness is problematically exposed as a

euphemism for political centralization. Along these lines, a continuum of

embedded/disembedded economic activity is fashioned which directly mirrors both the

palatial/non-palatial continuum of the impersonal Mycenaean two-sector model as well as the

redistribution/market (or centralized/atomized) antagonism established in Polanyi's work.[54] In

other words, Granovetter's embeddedness sets out on a path to a richer sociological conception

of economic activity, but ultimately leads back to the same underlying dichotomies that have

characterized past debates and models; it simply couches them in a new terminology.

This problem has been observed by heterodox economists as well as economic

sociologists.[55] Those working in the tradition of Austrian economics have particularly discerned

that the issue lies in the strict theoretical division of economic and social action.[56] Granovetter

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[52] Feinman 2013, 454.
[53] Parkinson et al. 2013, 419.
[54] For example, Parkinson et al. (2013, 420) note that "perhaps as the power of individual palatial centers over local systems of production and distribution waned, markets flourished."
[55] Swedberg 1997, 170–2, 2004, 325–6; Krippner 2001; Boettke and Storr 2002, 165–7; Lewis 2004.
[56] Boettke and Storr 2002; Mikl-Horke 2008; Migone 2011, 372–3.

himself notes that the schism of economy and society, which emerged from the theoretical

separation of passions and interests during the 17th and 18th centuries and was reified by the 19th

and 20th century's esteem for economic formalism, was a crucial motive in formulating his

theory of embeddedness.[57] In theorizing embeddedness, he rightly sought to mediate the

disparate conceptualizations of individual action that historically arose in economics and

sociology, but Krippner bluntly and accurately criticizes that "in attempting to steer an

intermediate course between the twin perils of under- and oversocialized views of action,

Granovetter has run the ship aground on a conception --- common to both --- that insists on the

separate nature of economy and society."[58] The result is that Granovetter's embeddedness retains

the atomistic, rational, and maximizing mentality of neoclassical economics, but slots it within a

sociological framework that emphasizes the guiding influence of networked human

relationships.[59] In this way, embeddedness is mistakenly measured in degree.[60] It advocates a

middle ground in which individuals are both meaningful and socially embedded, but then

requires that one reject this middle ground and qualify the extent to which an action or actor is

more economically calculative and individualistic (i.e. less embedded) or more socio-politically

dictated and centralized (i.e. more embedded). Rather than smoothing over the divisiveness of

neoclassical formalism and sociological substantivism, this approach places the two on opposite

ends of a continuum with the insufficient acknowledgement that social relations always play

some role across the continuum. Boettke and Storr have called this theoretical approach, which

absorbs the traditional division of economy and society, "single embeddedness" in that, when

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[57] Granovetter 1985, 506.
[58] Krippner 2001, 801.
[59] Mikl-Horke 2008, 213.
[60] Granovetter 1993, 16–7; Garraty and Feinman 2010, 171; Feinman 2013, 454; Parkinson et al. 2013, 417–9.

envisioned, it depicts society (and polity) as a large ring which engulfs the smaller, discrete ring of economy.[61] They remark that there is nothing preventing this arrangement from being reversed so that economy inscribes society as in New Institutional Economics;[62] in all cases, though, the division of economy and society remains fixed and problematic. The economic ring encapsulates a maximizing, atomized individual and the social ring holds "irrational" scripts that moderate "rational" economic behaviors.

The Theory of Complex Embeddedness

As a solution to this problem, Boettke and Storr propose a form of embeddedness which reshapes Granovetter's single embeddedness by liberating economy and society from their separate confines. To reformulate embeddedness, Boettke and Storr draw on Austrian economic theory with emphasis on its particular form of methodological individualism and subjectivism.[63] Following in the footsteps of Weber,[64] Austrian methodological individualism emphasizes the importance of purposeful human action found in both the interaction of human and human, and human and object.[65] As in Granovetter's theory of singular embeddedness, action is accomplished by individuals who reside in a middle ground between isolation and over-socialization; in the Austrian conception, the individual "lives as a son of his family, his race, his people, and his age; as a citizen of his country; as a member of a definite social group; as a

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[61] Boettke and Storr 2002.
[62] Boettke and Storr 2002, 168–9.
[63] The methodological individualism of Austrian economic theory is distinct from that found in mainstream neoclassical economics. This is important to note immediately, since the mainstream formulation of methodological individualism has a negative connotation in the social sciences and has often been what social scientists defined themselves against. See Udehn 2001; Boettke and Storr 2002, 162; Zwirn 2007.
[64] Zafirovski (2010) reviews the Weber-Austrian connection.
[65] Horwitz 1994, 17–8. See especially Mises 1996, 1–71; Prychitko 1994; Rothbard 1997.

practitioner of a certain vocation; as a follower of definite religious, metaphysical, philosophical, and political ideas; as a partisan in many feuds and controversies."[66] Additionally, individual actions and supra-individual forces and institutions are viewed as recursive so that larger phenomena, like society or polity, condition peoples' actions without dictating them, and are reproduced by those actions.[67] This emphasis on the recursive nature of action and institutions necessitates that broad concepts like society or economy be understood as the fluctuating effect of ongoing processes of meaningful human action.[68]

In contrast to the orthodox economic view, Austrian methodological individualism does not accept an atomized or maximizing individual.[69] Individuals, instead, are subjectively rational in that they form plans and utilize means to achieve goals; however, the process by which they devise plans or decide means and goals is neither universally grounded nor objectively rational. Individuals make decisions and act based on finite knowledge and subjective assessments of this knowledge, assessments which necessarily include their perceptions of larger social phenomena and the actions of other individuals, as well as their self-styled interests.[70] Coupled with methodological individualism, this principal of subjectivity has the key effect of invalidating the firm bounding of economy and society because, in its formulation, "the distinction between 'rational' action as typical for 'economic' and 'irrational' or 'non-rational' behavior as typical for 'everyday life' becomes irrelevant."[71] Instead, the boundary between economy and society is

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[66] Mises 1996, 46.
[67] Hayek 1955, 38–43; Mises 1996, 41–3; Lewis 2004, 365–73; Zwirn 2007, 58–76; Migone 2011, 361–2; Salter 2013.
[68] This draws us back to the view that the Mycenaean state is an active network of interactions (Nakassis 2006, 16).
[69] See supra n. 63.
[70] Horwitz 1994; Mises 1996, 19–22; Udehn 2001, 114–25; Lewis 2004, 365–73; Garrouste 2008; Mikl-Horke 2008, 206–7.
[71] Mikl-Horke 2008, 206.

fluid and subjectively dictated by the meaning that individuals assign to their or other's actions and the context within which they assign this meaning.[72] The early 20th century Austrian economist Mises summarized this point well when he said, "The hangman, not the state, executes the criminal. It is the meaning of those concerned that discerns in the hangman's action an action of the state."[73] The broad result of this subjectivism is that the goal of economics becomes fundamentally sociological: "to render intelligible economic phenomena in terms of the purposes and plans of the social actors involved and second, trace out the unintended consequences, both desirable and undesirable, of those actions."[74]

Relying on this foundation in Austrian economic theory which dissolves the firm bounding of economy and society, Boettke and Storr argue that Granovetter's theory fails to recognize the multiple levels of embeddedness.[75] Since society and economy are difficult concepts to isolate from one another and are distinguished by subjective assignments of meaning to individual actions, they argue that it is more sensible to elevate such categories to an equal level and visualize embeddedness heterarchically; society does not circumscribe economy as in Granovetter, but rather society and economy, as well as other high level concepts such as polity, are interlocking rings within the comprehensive sphere of human action.[76] This theory, which Migone has termed complex embeddedness, stresses that individuals act at the "convergence of social, political, and economic realms"[77] and the larger result of individual actions is "a complex and fluid system of rules and of organizations that both influences (without determining) and is

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[72] Boettke and Storr 2002, 170–6; Migone 2011.
[73] Mises 1996, 42 (quoted in Boettke and Storr 2002, 175).
[74] Boettke 1990, 37.
[75] Boettke and Storr 2002, 165–7.
[76] Boettke and Storr 2002, 169 fig. 1, 177 fig. 2.
[77] Migone 2011, 375.

affected by individual activity."[78] By permitting a variety of economic, political, and social strategies to be at work at the same moment, complex embeddedness avoids creating a strong typology which tries to objectively and strictly delineate the social, economic, and political. Rather, all remain decisively flexible and no division between them is so rigid that one subjective subcategory of human action (e.g. economy) can be made universally subservient to another (e.g. society).

When applied to the study of Mycenaean economy, the fluid integration of polity, society, and economy found in complex embeddedness stresses that there is no monolithic, bounded Mycenaean economy, or strictly distinct palatial and non-palatial economies. Terms like palace, economy, or society are employed as convenient labels to simplify complex and fluctuating patterns that are both influential upon and generated by a plethora of human actions and interactions. To link this with Nakassis' study of the Pylos tablets,[79] not only is a polity an active network of human interactions, but economy and society are as well. The natural overlap of these categories further means that the networks of human interactions which constitute the political, economic, and social are not distinct, but are inherently and intimately entangled with one another. In this regard, complex embeddedness intersects with a variety of agency-based approaches that are now popular in archaeological analysis.

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[78] Migone 2011, 375.
[79] Nakassis 2006, 16.

Complex Embeddedness as Agency Theory

Although there are various ways to tackle agency,[80] at a general level, agency theory might be defined as any approach that considers the active involvement of humans[81] or to phrase this differently, that humans are meaningful in the creation of the world around them. In this regard, agency theory does not actually imply a single theoretical or methodological approach to the material record, but it represents a broad outlook which affects the questions researchers ask;[82] it is analysis directed towards understanding human agents in the past based on diverse ontological theories of what it means to be an thoughtful, active human who also lives within an external material and social world that is composed of many other acting humans and objects.[83] As an approach which emphasizes purposeful human action, the importance of human and human, and human and object interactions, and the recursive relationship between supra-individual structures and individual actions, complex embeddedness fits comfortably under the label of agency theory. In particular, it shows a degree of overlap with Giddens' structuration theory[84] in its formulation of the dialectic nature of individuals and structure.[85] Both Giddens' theory and complex embeddedness recognize that agents are knowledgeable and capable;[86] however, unlike Giddens' structuration, complex embeddedness has a distinct history, emerging from Austrian economic theory and the principle that humans act, reason subjectively, and assign meaning to theirs and others' actions.

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[80] Dobres and Robb 2000, 2005; Dornan 2002.
[81] Gardner 2009, 95.
[82] Cowgill 2000, 58–9.
[83] Barrett 2000, 65–8; Dobres and Robb 2000, 6–14; Joyce and Lopiparo 2005, 365–8.
[84] The connection between complex embeddedness and Giddens' structuration theory is, in part, due to the mutual influence of Weber.
[85] Giddens 1984, 16–28; Dornan 2002, 307–8; Loyal 2003, 51–92.
[86] Giddens 1984; Dornan 2002, 307–8; Loyal 2003, 139–46.

As a type of agency theory, complex embeddedness engages with and suffers from problems typical of such approaches. Gardner has isolated five themes that are found to varying degrees across agency-based theories: power, action, time, relationships, and humanity.[87] Among these, action and time are the fundamental domain of agency since individuals necessarily act across time;[88] to this, I would add space as a complementary element, so that a well-grounded agency theory will account for the spatial as well as temporal contexts of action and how the spatial configurations of action change in time.[89] The last two themes, relationships and humanity, characterize agency theory's diverse ontological understandings of human and society.[90] Complex embeddedness specifically addresses both through its theory of the recursive relationship between human (inter)actions and society, and the subjective nature of human rationality.[91] Finally, power or rather the power to act is not specifically addressed by complex embeddedness, but can be viewed as historically and situationally contingent.[92]

Intersecting with these five themes, Dornan notes three obstacles that agency theory regularly encounters: the unit of analysis, the question of rationality, and the intended versus unintended consequences of action.[93] The most significant of these, from an archaeological perspective, is the first since the scale of analysis is effectively where a guiding theory of agency must confront the material record via a precise methodology. Dornan raises the dilemma here,

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[87] Gardner 2009.

[88] For the importance of time in Austrian economic theory and consequently complex embeddedness, see Mises 1996, 99–104; Rothbard 1997, 59.

[89] Giddens 1984, 132–8; Barrett 2000, 61–2, 66–7. See also Carter (2007) who grounds agency in time and space through the metaphor of performance.

[90] Dobres and Robb 2000; Dornan 2002.

[91] See supra n. 70.

[92] Explicit ideas of power and the historical/structural limitations placed on one's ability to act do appear in Austrian economic theory (Mises 1996, 647–9; see also Weber 1978, I:212–301).

[93] Dornan 2002.

one which is acutely relevant to Mycenaean archaeology where agents are often imperceptible:[94]

"Methodologically, if we seek to locate change at the level of the individual and yet we can only look at widely shared actions, where do we locate the unit of analysis?"[95] In response to this problem, Barrett suggests that, although agency theory displaces "society" as the main object of study, agency should not be confounded with the status of individual motivations.[96] It is, instead, in the temporal and spatial intersection of individuals and perceived structures where agency presents itself in materially grounded actions.[97] For the study of Mycenaean economy, this means that one way we can locate agency is to investigate the interactions of individuals as reflected in normative (and hence also deviant) practices, the strategies used to integrate these practices across time and space to reach desired goals, and the effect of social, political, and economic structural phenomena on these practices and their integration. While acknowledging the inherent limitations of the material record and the recurrent inaccessibility of the isolated individual in prehistory, situating agency at the juncture of time, space, individuals, and structures propels us towards understanding the past nearer to the level of human experience and moves us closer to unraveling the human-centered processes and negotiations that occurred during the production, exchange, and consumption of material goods.

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[94] The Linear B is a notable exception (Nakassis 2006, 2013). Ethnography provides another means to bring faces to prehistoric agents (Carter 2007).
[95] Dornan 2002, 315.
[96] Barrett 2012.
[97] Barrett 2000, 63; Dornan 2002, 324.

Constructing the Frame: Embeddedness, Agency, and Architecture

From *the* Building to *the Process of* Building

Complex embeddedness, which contends that humans act across the fluid boundaries of economy, society, and polity and that human actions reproduce and are subjectively influenced by these larger phenomena, offers a useful theoretical basis with which to examine architecture in Mycenaean Greece. As a form of agency theory, complex embeddedness advocates an understanding of human-level processes, promotes temporally- and spatially-grounded studies of construction, and forces us to engage with the broader social, political, and economic structures that groups and individuals concurrently encounter and recreate during construction. Whereas traditional approaches to Mycenaean architecture have variously concentrated on the origin and typology of building styles,[98] technical knowledge,[99] relationships between form and function,[100] and interpretations of symbolism or monumentality,[101] this represents a novel approach which views architecture through an agentive-producer lens and marks a movement away from stressing foremost the product of construction by instead accentuating the productive processes of construction.

While previous studies have not directly employed this agentive-producer approach, certain scholarship has expressed an interest in the human-level processes of construction. This is particularly true in discussions of monumentality and function, since it is here that problems of

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[98] Shear 1968; Iakovidis 1983; Kilian 1987a; Loader 1998; Darcque 2005.
[99] Wright 1978; Cavanagh and Laxton 1981; Santillo and Santillo Frizell 1984; Evely 1993; Küpper 1996; Santillo 1997; Santillo Frizell 1998; Cremasco and Laffineur 1999; Downey 2001; Como 2006, 2007, 2008, 2009.
[100] Wright 1984; Palaima and Wright 1985; Shelmerdine 1987; Cavanagh 2001; Bendall 2003, 2004; Maran 2006a; Lupack 2007.
[101] Mee and Cavanagh 1984; Darcque 1987; Kilian 1988; Santillo Frizell 1997; Fitzsimons 2006, 2007, 2011.

agency and the building process are often informative. For example, noting how actors produce space and move through it, Wright has variously stressed the experiential character of architecture and highlighted the regional and temporal differences which reflect active building practices.[102] In a similar vein, Maran has discussed the palaces at Tiryns and Mycenae from the perspective of visitors moving through them. Engaging with Giddens' practice theory, he stresses that social cues are built into the palaces and in turn, actively confronted and reaffirmed by visitors.[103] Additionally, studies which invoke architectural power regularly include basic consideration of economic issues, but these are usually reflected in broad, comparative statements about labor control.[104] Fitzsimons' use of volumetric measurements, which parallels labor requirements, to discuss the evolution of sociopolitical power at Mycenae is illustrative of this approach.[105] It is significant, however, that although they scratch the surface, most of these studies do not readily attack the human-scale processes of construction as a consequential topic in their own right, but privilege either the meaning found in the final building or long-term changes in building practices and their sociopolitical implications.

Cavanagh and Mee,[106] and Loader[107] represent some of the few Mycenaean scholars who do approach the level of human experience during a Mycenaean construction project. Even here, though, the active processes of construction are muted by a greater focus on aggregates of labor demand, which has the effect of flattening the dynamic processes of construction.[108] In contrast to traditional approaches to Mycenaean architecture, complex embeddedness tells us that these

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[102] Wright 1987, 2006a.
[103] Maran 2006a.
[104] Mee and Cavanagh 1984; Fitzsimons 2006; Laffineur 2007.
[105] Fitzsimons 2011; see also Wright 1987.
[106] Cavanagh and Mee 1999.
[107] Loader 1998, 42–73.
[108] Cavanagh and Mee 1999.

dynamic acts of construction (as enacted by individuals and groups of individuals) which produced a structure, including the organization, motivation, and meaning of these acts, are also significant. If we conceptually understand the economy, which is heterarchically embedded with polity and society, as a network of human actions and interactions, then we must move away from searching out meaning only in the final product of construction or in long-term architectural changes since it is in the building process where an abundance of human actions and interactions necessarily occur. As Wright notes, "the first performance of architecture is its construction."[109]

Lessons from Historical Periods

Historical examples underscore the value of studying construction at a closer level by focusing on construction processes and agency rather than privileging the final building alone. Both Burford's study of the Sanctuary of Asclepius at Epidauros and Delaine's investigation of the Baths of Caracalla in Rome reveal that construction projects can draw together individuals of varying skills, backgrounds, and status for a common goal and that during construction, social, political, and economic tensions are continuously negotiated, resolved, or solidified.[110] In *The Greek Temple Builders at Epidauros*, Burford's examination of the Sanctuary of Asclepius' building records, which partially cover the operations between 370–250 B.C.E., reveals that individual building projects relied on temporary associations of men "from every level of society."[111] The records list an assortment of named individuals from different areas of Greece performing piece-meal work. Contracts established with these individuals stress a variable

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[109] Wright 2006a, 50.
[110] Burford 1969; DeLaine 1997; see also Burford 1965; Salmon 2001.
[111] Burford 1969, 9.

process of negotiation that changed over time and with different building tasks.[112] At points,

individuals were not compensated until their work had been entirely completed; at other times,

individuals required partial or full upfront payment either because they could not afford to begin

work without some disposable funds or they required assurance that they would actually be

paid.[113] For some foreigners, compensation even included travel expenses to reach Epidauros.[114]

Burford further illustrates that during the construction process, there was a "tendency

towards definite economic and social grouping."[115] Contractors, administrators, and workers

came from distinct classes due to the broad social implications of certain jobs.[116] For example,

she suggests that aristocrats did not often take up the job of contractor because working on

another's terms implied a loss of freedom and was, therefore, stigmatized;[117] however, for those

who did becomes contractors, the motivations were diverse and could include the desire for

profit or a civic sense of duty.[118] Most importantly, Burford points out the uncertain nature of

construction. Although scheduling and organizing tasks is essential to the completion of any

building, the reality of the unforeseen in day-to-day activities is always problematic; the records

of Epidaurus show that the building commission and architect played vitals roles in managing

unanticipated obstacles. In a number of outstanding cases, contractors at Epidaurus failed to

complete jobs by their assigned deadlines and were heftily fined as a result; as an extreme

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[112] Burford 1969, 102–18.
[113] Burford 1969, 115.
[114] Burford 1969, 108–9.
[115] Burford 1969, 120.
[116] Burford 1969, 119–58, 222–45.
[117] Burford 1969, 148–9.
[118] Burford 1969, 149–53.

example, Megakles was levied a fine totaling two thirds of his original contract price for heavy transport which he failed to complete on time.[119]

Delaine offers a similarly detailed approach, although she focuses on a single albeit massive structure, the Baths of Caracalla. Unlike Burford, Delaine did not have access to detailed building accounts for the Baths of Caracalla, but relied on good archaeological preservation, a thoughtful reconstruction, and supplementary primary sources. Her stated motivation for studying the process of constructing the Baths of Caracalla is significant because it reveals a problem comparable to the past study of Mycenaean architecture. She points out that analyses of Roman buildings are typically "isolated from human involvement except perhaps for the ambitions and ideological programmes of their patrons"[120] and most emphasis has been placed on "the cataloguing of details, [but] rarely on the consecutive process of construction of specific buildings."[121] By envisioning construction as active and meaningful, Delaine tries to remedy these problems. As a result, she is able to offer a qualitative and quantitative analysis of the building process and to situate the activities of construction within a broader understanding of Roman society.[122] To do this, she specifically focuses on what she terms, the "generative processes," which include the daily labor and materials employed and the logistics of organizing construction.

The focus on generative processes makes Delaine's study effectively agency-oriented, which is supported by her straightforward view of construction as the transformation of materials by *human action*.[123] An important component of her focus on process and human action is her

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119 Burford 1969, 106, 149.
120 DeLaine 1997, 9.
121 DeLaine 1997, 9.
122 DeLaine 1997, 207–24.
123 DeLaine 1997, 131.

recognition that numerous materials were not directly visible in the final structure, such as scaffolding or rope, but were nonetheless an integral part of construction.[124] While she goes on to quantify the materials and manpower used in different stages of construction, perhaps the most substantial aspect of her study is that she presents schedules of construction.[125] Using a set of historical dates, she is able to generate a timetable which illustrates how the numbers of men and the types of materials fluctuated over the building project's lifecycle.[126] Considering the human-level processes of construction, Delaine, like Burford, enlivens an otherwise static building by drawing out the dynamic acts of construction and their social, economic, and political importance.

Architecture in the Mycenaean Texts

In the case of historical construction, Burford and Delaine benefited from access to a variety of textual sources which offer firm dates of construction, descriptions of building techniques, and even the names, social positions, and assigned tasks of individuals involved in the building process. Furthermore, their discussions and conclusions relied on the monetized nature of the Greek and Roman economies.[127] While these authors' results are extremely encouraging, particularly in the light that they shed on the complex, sometimes frenetic, nature of the construction process, the Mycenaean period had neither a clear medium of exchange for use in analysis nor has the material record provided written documents of the same detail. The Linear B tablets from Pylos and Thebes, and to a very limited extent those from Knossos and

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[124] DeLaine 1997, 91–4.
[125] DeLaine 1997, 182–94.
[126] DeLaine 1997, 190–2 table 21–3.
[127] Although DeLaine (1997) relied on the later Price Edict of Diocletian, she accounted for variations in the purchasing power of money by converting costs to measures of grain.

Midea, nevertheless, do offer scattered glimpses of architecture, builders, and the construction process during the Mycenaean period.

Much of the textual data pertaining to Mycenaean architecture has been recently summarized by Montecchi;[128] although the information found in the tablets does not include records of particular building projects, Montecchi does isolate types of buildings, possible materials used in construction, professional titles, and examples of how builders were compensated.[129] In the category of building types, she identifies a number of occurrences, but most do not clearly refer to a building proper and may have broader meanings; words such as *na-wo* (ναϝός, "temple"),[130] *i-je-ro* (ἱερόν, "temple"), and *e-ka-ra* (ἐσχάρα, "hearth") seem connected with religious institutions in general rather than specific buildings.[131] Given the limited presence of discrete Mycenaean "temples," it is difficult to regard such words as purely architectural.[132] More general terms for buildings include **e-do* (ἕδος, "dwelling-place"), *wo-(i-)ko* (ϝοίκος, "house"), *do* (δῶ, "house"), and possibly *wo-wo / wo-wi-ja* (ϝόρϝος / ϝόρϝια, "boundary?").[133] A few terms appear to be very specific in their use. The word *a-mo-te-ja* (ἁρμοτειών) may be a workshop for wheel or chariot manufacture,[134] possibly located in the Northeast Building at Pylos,[135] and *ta-to-mo* (σταθμός) refers to an animal pen or stable.[136] The most interesting term and the one which links most clearly with Mycenaean architecture is *me-*

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[128] Montecchi 2013; see also Montecchi 2011; Nakassis 2012, 275–9.
[129] Montecchi 2011, 2013.
[130] *na-wo* appears only as part of the adjective *na-wi-jo* (Aura Jorro and Adrados 1985, 466).
[131] Montecchi 2013, 4–18.
[132] See Wright 1994; Montecchi 2013, 69–110.
[133] Montecchi 2013, 1–3, 18–28, 24–8, 56–63.
[134] Montecchi 2013, 44–9.
[135] See Bendall 2003; Schon 2007.
[136] Montecchi 2013, 50–2.

ga-ro (μέγαρον, "megaron").[137] The term occurs once, on the side of nodule MI Wv 6 where it is coupled with the allative suffice *–de* (-δε), which indicates that it was likely attached to some unknown object being sent to the megaron at Midea.[138]

Of professional titles related to building, four examples are found: *te-ko-to* (τέκτων, "builder")[139] and its variant *pa-te-ko-to* (παντέκτων, "all-builder"),[140] *to-ko-do-mo* (τοιχοδόμος, "wall builder"),[141] and *pi-ri-je-te* (πριετήρ, "sawyer").[142] The most widely attested is *te-ko-to(-ne)* which occurs at Pylos, Knossos, and Thebes while the other three terms are limited to Pylos alone.[143] The Pylos tablets show specific cases of the palatial monitoring of building professionals; texts list distributions to builders or monitor their movement in the larger region. For example, in PY An 35, which records the dispatch of wall-builders specifically meant to do building work (*de-me-o-te,* δεμέοντες), two and four wall-builders are already present at *pu-ro* and *re-u-ko-to-ro*, respectively, while three are sent to both *me-te-to* and *sa-ma-ra*.[144] Since *re-u-ko-to-ro* was capital of the Further Province and *sa-ma-ra* was the center of one of the Further Province's seven districts, the tablet demonstrates that the palace's interest in builders was not limited to its immediate environs; instead, it took some interest in directing skilled workers to important centers throughout the kingdom as they were needed. PY An 18 underscores this

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[137] Montecchi 2013, 29–38.
[138] On the other two sides of the nodule are the words *o-pa* (ὀπά) over a sealing of a lion attacking a bull and the anthroponym *a₃-so-ni-jo* (Ἀισόνιος); see Montecchi 2013, 29–38.
[139] KN Am 826.2, TH Fq 247, Gp 112, 114, 147 and 175; possibly appearing on PN An 5.1-5, 18.2, 852.3, and Es 540; see Aura Jorro and Adrados 1993, 326–7.
[140] PY Fn 7; see Aura Jorro and Adrados 1993, 89–90.
[141] PY An 18, Fn 7, An 35; see Aura Jorro and Adrados 1993, 359–60.
[142] PY An 207, Fn 7; see Aura Jorro and Adrados 1993, 124–5.
[143] "*pi-ri-je-te*" also appears on KN Ra 1547, 1549, and 1550. The context, however, indicates that the sawyers are cutting ivory and not engaged in the building trade (Duhoux 2008, 271). For sawyers in the Pylos tablets, who do appear as part of the building trade, see Nakassis 2012.
[144] Ventris and Chadwick 1973, 174; Duhoux 2008, 296–8; Montecchi 2013, 149–50.

geographic range, noting a wall-builder is missing (*to-ko-do-mo a-pe-o*)[145] at *te-re-ne-we*, which

lies in or near the Further Province.[146]

How building professions may have been partially supported by centralized institutions is

illustrated by two texts from Pylos and five tablets from Pelopidou Street in Thebes. The texts

show mechanisms for compensating builders that include the allocation of regular rations, the

allocation of feasting rations, and the possible assignment of land. On PY Fn 7, grain[147] is

distributed to sawyers, wall-builders, and one all-builder.[148] Five sawyers and twenty wall-

builders each receive a daily ration of Z 3 (1.2 liters), the standard for male workers.[149] The

single all-builder receives a higher amount of V 2 (3.2 liters), likely an indication of his greater

status and function as an overseer.[150] Ultimately, all of these workers are supplied by the palace

with daily rations for a month's time (*o-pi-me-ne*). In addition, two named individuals, *qa-ra₂*

and *pa-ka*, receive a large quantity of olives for the month. This was possibly accompanied by a

distribution of grain, which is typically given with olives, although the tablet is damaged here.[151]

This potentially worked out to *qa-ra₂* and *pa-ka* receiving T 2 (19.2 l.) and T 1 (9.6 l.) of olives

and grain daily.[152] Nakassis has made the attractive suggestion that this large distribution reflects

the role of *qa-ra₂* and *pa-ka* as recruiters of unskilled labor, with the olives and grain received

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[145] PY An 5, 18, and 852 include *te-ko-to-na-pe* as a single word. This is almost certainly a place name rather than the phrase "τέκτων ἄτης" referring to absent builders. See Killen 1998, 2012; Montecchi 2013, 146–8; Nakassis 2013, 187–8 n. 4.
[146] Killen (2012) discusses the possible location of these sites.
[147] The grain is specifically *121/HORD which has been interpreted as wheat (Palmer 1992) or as barley (Halstead 1995).
[148] Nakassis 2012, 275–9; Montecchi 2013, 123–31.
[149] Palmer 1989; Nakassis 2010, 131, 2012, 275; Montecchi 2013, 125.
[150] Nakassis 2012, 275; Montecchi 2013, 126.
[151] Nakassis 2012, 275–6.
[152] Nakassis 2012, 276.

either as their own payment or to be reallocated to those they recruit.[153] He suggests that the

tablet may reveal the composition of skilled workgroups so that there were five groups, made of

one sawyer and four wall-builders each, and aided by whatever unskilled labor *qa-ra₂* and *pa-ka*

supplied.[154]

At Thebes, on the page-shaped tablet TH Fq 247, grain is distributed to individuals listed

by personal name or profession, including a group of builders (*te-ka-ta-si*).[155] The tablet does not

specify what type of grain is distributed, but *121/HORD is typical of the Fq series.[156] To those

listed on the tablet, only small quantities of grain are distributed. The builders receive V 1 (1.6

l.), a bit above the standard daily ration of 1.2 l;[157] however, totals listed on other tablets in the

Fq series show that, despite small individual distributions, the overall quantities were often quite

large. Fq 277 lists the largest total distribution of 256.4 l.[158] Since the building where Fq 247 was

found contained carbonized seeds and cereals, the tablet may have recorded commodities

distributed directly from this storeroom, including to the group of builders.[159]

As a corollary to the Fq text, the Gp series shows builders receiving wine on four

separate tablets.[160] The amount listed on each of the tablets differs dramatically, including V2

(3.2 l.; Gp 114), V 3 Z 1 (5.2 l.; Gp 175), V 6 (9.6 l.; Gp 112), and 4 (115.2 l.; Gp 147).[161] This

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[153] Nakassis 2012, 275–9.
[154] Nakassis 2012, 276.
[155] On the Fq series, see Aravantinos et al. 2001, 180–262, 328–38, 363–5; 2005, 10–64; James 2002.
[156] Montecchi 2011, 174.
[157] Palmer 1989.
[158] Montecchi 2011, 175.
[159] Montecchi 2011, 174.
[160] On the Gp series, see Aravantinos et al. 2001, 276–302
[161] The quantities of wine are summarized by Aravantinos et al. 2001, 338–40, 351–3; Bendall 2007, 161 table 4–7.

last, very large amount is described as *qe-te-jo*, meaning "to be paid."[162] The appearance of

similar names and professions in the Fq and Gp series suggests that we should understand these

distributions of grain and wine as interrelated.[163] Though the exact nature of the distribution is

unclear, one possibility is that the distributions in the Fq and Gp series represent grain and wine

given for religious reasons as a sacred meal or a festival ration.[164] The varied amounts and the

particular commodities listed, namely *121/HORD and wine, are common in other religious

contexts.[165] Another possibility is that the Fq series lists rations distributed for work completed

in which case the variation in amounts reflects the relative importance of the work. The small

amounts distributed would suggest that these were supplemental rations and not the sole source

of an individual's sustenance.[166]

It is notable that, although at both Pylos and Thebes building professionals sometimes

receive allocations, the surviving tablets highlight different systems of distribution. While the

Thebes Fp and Gq series indicate *ad hoc* distributions of supplemental grain and wine for

services rendered or perhaps feasting, Pylos Fn 7 shows a system of rations given on a monthly

basis. In addition to the evidence of rations at Pylos, PY Es 650 may list a builder holding land,

but this requires the dubious reading of *pi-ro-te-ko-to* as two elements, "Φίλον τέκτον," rather

than a single personal name, "Φιλοτέκτον."[167] At Knossos, too, one tablet, which shows a roster

of five builders grouped with forty-five *telestai*, indicates the palace had some interest in

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[162] Aura Jorro and Adrados 1993, 201–2.
[163] Montecchi 2011, 175. James (2002, 413 n. 49) notes that there is no correlation between the amounts distributed in each series.
[164] Aravantinos et al. 2001, 363–9; Bendall 2007, 61–4; Montecchi 2011, 175–9.
[165] Bendall (2007, 153–64, 174–80) discusses wine and barley in religious contexts.
[166] James 2002; Palaima 2008, 386.
[167] Aura Jorro and Adrados 1993, 128; Montecchi 2013, 142–5; Nakassis 2013, 344.

tracking building professionals.[168] In the case of Pylos, at least, the presence of multiple terms

for building professionals stresses that there was an intuitional or social separation of certain

jobs, and the variable rations given to them might relate to their perceived importance or level of

skill.[169] Across all sites, however, there is never mention of a personal name for a builder; they

are always listed by professional title and typically in a group, excepting the single "all-builder"

on PY Fn 7.9. In the case of *qa-ra2* and *pa-ka*, use of their personnel names seems related to their

function as labor "recruiters" or supervisors, rather than as builders themselves.[170]

Although none of this information approaches the level of detail as that found in Delaine

or Burford's studies, these texts do offer occasional glimpses of the sustenance of builders,

recruitment of unskilled laborers, composition of workgroups, and even missing builders. Given

the abundance of Mycenaean architecture, the paucity of texts mentioning builders is striking,

but it is important to remember that tablets covering such daily matters could quickly be

pulped.[171] Many issues that arose during building projects, such as absent workers, and

distributions of food or tools could have been handled directly on site under a decentralized

administration. There is no requirement that we presume writing was used at all (or at any)

building sites, or that we impose a unified administrative approach to construction, but evidence

for writing, nodules, seals and sealings deposited in or originating from outside the Mycenaean

palaces' confines[172] are a reminder that written or sphragistic administration was employed in

diverse situations. Although we lack such daily records for construction, the Linear B tablets do

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[168] Montecchi 2013, 114–23.
[169] Palaima 2008, 386, 2015; Nakassis 2012.
[170] Nakassis 2012, 276–9.
[171] Bennet 2001; Palaima 2003.
[172] The context of the Linear B finds is briefly covered in Driessen 2008.

highlight close range, day-to-day interests in a variety of practices[173] and similar interests could

have extended to parts of the building trade, particularly for those projects with strong palatial

links.[174] Still, since the tablets cannot offer the necessary details to generate a picture of building

projects in the manner of Delaine or Burford, it is necessary to advance primarily from material

remains, for which the textual evidence can offer some high-level context. Studies of craft

production are a natural springboard for working out a holistic theoretical framework of

architectural production that engages complex embeddedness and agency theory, and that can

eventually be operationalized through a materially-based methodology.

Finishing Up Construction: Defining Architectural Production

Construction as Craft Production

To examine, describe, and understand construction projects under the guiding theory of

complex embeddedness and its focus on human agency, it is useful to frame construction as a

form of craft production in which individuals and groups of individuals actively transform raw

materials and interact with one another to produce a structure.[175] This offers a fruitful way to

build an economic approach to construction since it allows us to draw on the informative

approaches that have emerged in studies of prehistoric craft production. Simultaneously, defining

construction as a particular type of craft production can link the building process with a field of

study that has been integral in modeling prehistoric economies and societies. This connection is

especially fitting because, as with the guiding theory of complex embeddedness, craft production

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[173] For example, see Killen 2006; Halstead 2007; Schon 2011.

[174] The Garšana archives offer one detailed ancient example of the written administration of construction (Heimpel 2009).

[175] This channels Delaine's simple definition of construction as "materials transformed by human actions" (1997, 131).

studies fundamentally wrestle with analyzing material remains through an economic lens while grasping that production is "as much a social and political phenomenon."[176] The question then becomes how to utilize craft production in an approach to architecture. Because of the term "craft" and the theoretical baggage that comes with craft production studies, this requires some maneuvering.

Perhaps the largest impediment to the easy coupling of construction and craft production is that architecture is markedly different from crafts as they are traditionally conceived, and as a result, the study of architecture and craft have followed different scholarly trajectories.[177] The distinction is prominently reflected in architecture's dissimilar material qualities, such as its immobility and scale. The label of "craft," in contrast, is traditionally applied to high-value, low-bulk, *moveable* goods.[178] One archaeological advantage of architecture, though, is that unlike moveable crafts, it often resides in its original context of production[179] and provides a wealth of information on the spatial organization of production.[180] On the other hand, from a theoretical perspective, the mobility of craft goods has tightly bound up craft production studies with theories of exchange mechanisms and surplus production, concepts which are not readily applicable to architecture.[181]

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[176] Costin 2001, 274; see also Costin 1998.
[177] For example, in Childe (1950) monumental architecture is a distinct characteristics of the Urban Revolution. In this regard, architecture is viewed as a finished element, abstracted from the processes of construction, and with fixed sociopolitical meaning.
[178] Costin 2005, 1034–5; 2007, 247. Sinopoli (2003) includes architecture in her account of craft production.
[179] Architecture is not always in its original context since building materials can be reused in later construction.
[180] DeLaine 1997, 12.
[181] The exchange of architecture is an intriguing topic. Since it is not moveable, exchange cannot be discussed using spatially-based methods as with other craft products; however, "exchange" can occur via transfers of ownership or grants of access.

A second obstacle is that craft production characteristically focuses on a single type of object which is composed of one or a few specific materials, such as ceramics, cloth, or metals. These craft products are perceived as being produced in discrete areas, often labeled "workshops," by a small numbers of workers who possess atypical skills, often labeled "craftsmen."[182] For architecture, the focus on spatially discrete workshops in which limited materials are processed by few individual craftsmen is highly problematic. Even small domestic structures can employ an array of materials such as wood, stone, and earth;[183] each of these materials originates in a distinct physical context, requires different tools and skills to extract and process, and after initial processing must be competently assembled into a whole. The extraction, working, and joining of these materials can ultimately require multiple groups of workers with differing skillsets along with a healthy dose of unskilled laborers who do not possess any particular construction abilities. For large scale buildings, a potentially distinct organizational or administrative apparatus must also be taken into account. While crafts like pottery or metalworking are often categorized as specialized or non-specialized, these labels (and craft production typologies in general) become difficult to apply to architecture because the production of architecture can employ such a diverse assortment of workers and materials.

Shimada has recognized that craft production's attention to discrete, single-medium goods results from overwhelming historical emphasis on the production of pottery, which "has unintentionally slanted our approaches."[184] While pottery and other traditional craft products are essential elements of study, the segregation of crafts into discrete categories based on material types is not always appropriate and the inattention shown to acts of complex production, which

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[182] Shimada 2007, 3–4.
[183] Darcque 2005, 65–82; Shaw 2009, 54–155.
[184] Shimada 2007, 3.

engage a variety of materials and workers, needs to be remedied.[185] Advancing a bottom-up

approach, Shimada isolates three neglected forms of craft production that confront these

problems: multicrafting, multicraft production, and coproduction.[186] The first, multicrafting,

refers to the same or closely related craftsmen producing two or more separate craft goods. The

second, multicraft production, describes different craftsmen or groups producing separate crafts

in the same or adjacent locations.[187] Finally, coproduction is a particular type of multicraft

production; it describes a creative relationship between different types of craftsmen who actively

collaborate to produce a composite good.[188]

Both Stark and Li have zoomed in on coproduction and highlighted good examples of it

in action.[189] In Shang dynasty China, Li demonstrates that clay workers, who built molds, and

bronze casters, who operated foundries, worked jointly to produce intricate bronze vessels.[190] For

the Maya, Stark highlights examples including the coordination of potters and vase painters, and

the integration of stone masons and woodcarvers who produced lintels.[191] This later example

suggests that acts of construction might be fruitfully viewed as craft coproduction; because of the

complexity of architecture in its materials and the diverse types of workers employed,[192]

construction can effectively be viewed as the integration of many discrete workers and

production tasks through coproduction. This general understanding of construction as

coproduction has the advantage of stripping away broad typologies or imposing an elite-oriented,

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[185] Shimada 2007, 3–4. See also Schortman and Urban 2004, 210; Costin 2005, 1041–2.
[186] Shimada 2007, 3–6.
[187] Brysbaert (2014) touches on ideas of multicrafting and multicraft production in workshops at Tiryns.
[188] Shimada 2007, 6.
[189] Li 2007; Shimada 2007, 6, 13–4; Stark 2007.
[190] Li 2007. For a Mesoamerican example of this, see Meanwell et al. 2013.
[191] Stark 2007, 231.
[192] Recall the examples of Burford (1969) and Delaine (1997).

top-down perspective. Instead, it builds on an understanding of construction from a producer-oriented perspective. Under the rubric of coproduction, architectural production is a system composed of the integrated transformative actions of many individuals and groups of individuals. Because this systemic approach engages notions of agency and the complex-embedded nature of human action, it further addresses Clark's critique that craft production studies must "acknowledge the faces and hands really involved."[193]

Embedded Agents and Architectural Production

Under the theoretical influence of coproduction, complex embeddedness, agency theory, I define architectural production as the spatially- and temporally-coordinated actions of individuals and groups of individuals who each use particular knowledge and tools to alter material resources and who cooperatively work towards the common goal of producing a final structure. In addition to being applicable to any form of architecture, this definition delineates a few major analytical categories within architectural production: individuals, resources and tools, time, and space. Although these categories are inherently entwined, their general separation moves attention towards particular components of production and can help to describe the productive processes underlying certain buildings. When viewed at the macro-level, these categories can encompass useful metrics for an entire building project such as the duration of construction, the spatial relationship between a building and natural resources, or the overall labor requirements for construction. As discussed previously, however, such macro-level approaches have been typical in studying architecture and, by themselves, flatten the dynamic

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[193] Clark 2007, 21. The impersonal nature of craft production studies have been critiqued elsewhere (Tringham 1996, 235–7).

processes of construction and the role of human agency. For example, statically viewing the spatial relationship between a finished building and natural resources ignores the shifting nature of this relationship, which changes as various resources are phased in and out during construction. Instead, it is useful to address these categories as they relate to the individuals and groups of individuals who perform one or a few closely related tasks so that each of these individuals or groups is viewed as acting in time and space to modify a particular material resource with specific tools and knowledge and for an immediate goal. It is by isolating and describing these human-level productive processes that we can approach ideas of choice, practice, and meaning during architectural production at a scale where embedded agents and their actions matter. Moving to a higher level by using the concept of coproduction, it then becomes possible to envision the finished building, not as a flattened inevitability, but as the result of the complex, horizontal integration of these acting individuals and groups. Rather than overlooking the dynamic nature of construction or finding meaning only in a finished building, the general bounding of these categories then addresses both the role of agents in production, including their particular transformative actions and the impact of these actions, and the overall manners in which these agents holistically integrated their actions to produce buildings.

As components within architectural production, the categories of individuals, resources and tools, time, and space intersect heavily with Costin's six dimensions of craft production;[194] however, they possess some noteworthy distinctions which make them more readily applicable to architecture. The category of individuals (or groups of individuals) is similar to Costin's category of "aritisans,"[195] but the implications of the term are quite different. While "artisans"

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[194] Costin 2001, 2005.
[195] Costin 2001, 278–85.

implies those who possess special skills or produce traditionally defined, single-medium craft goods,[196] "individuals" imposes no *a priori* definition of skill or profession; it simply accepts that individuals possess knowledge, whatever that may be, and that they employ this knowledge during construction in an attempt to reach immediate goals. Foremost, this strips away concepts of specialization that have been built into theories of craft production in a variety of ways and with variable success.[197] The category of individuals does not preclude specialization or the presence of specialized artisans, but leaves room for these problems to be addressed as particular scenarios warrant. For architecture, this open approach has the desirable effect of acknowledging that a diversity of workers[198] can participate in an architectural project and this may include a continuum of specialized and non-specialized personnel. Finally, the term "individuals" stresses the idea of human-level agency and opens agentive roles in construction to all categories of people, including women and young children, who are only sometimes included in craft studies.[199] This may also include non-producing workers who instead fulfill managerial or administrative roles.

The category of resources and tools encompasses the tangible components of construction which one might expect to find in the finished structure or elsewhere in the archaeological record. Resources are raw materials, such as stone, mud, or wood, that are modified by the actions of individuals and ultimately form the finished building. In the archaeological record, these are identifiable in contexts intimately associated with the remains of any structure and are vital to reconstructing a structure's original form. Tools are, instead, the

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[196] Costin 2005, 1035–6; 2007, 146–7.

[197] Clark 1995, 2007; Costin 2001, 275–6, 2007; Flad and Hruby 2007.

[198] See Costin 2001, 282–5.

[199] Both *ko-wa* (κόραι, "girls, daughters") and *ko-wo* (κοῦροι, "boys, sons") appear in personnel lists at Pylos and Knossos (Aura Jorro and Adrados 1985, 394–7).

more peripheral materials that facilitate the transformation of primary materials or assist in the building process, but do not themselves form part of the building. Archaeologically, these peripheral materials are best represented by the physical remnants of construction tools, such as chisels or saws, used in the building process, but this category could be expanded to include other supporting materials such as draft animals, grain to feed workers, or even written records used to manage a project. In contrast to resources or raw materials, information on tools or peripheral materials often needs to be inferred from the presence of tool marks, a broader knowledge of ancient practices, and ethnographic comparisons. While both raw materials and tools form part of Costin's "means of production,"[200] I do not include intangibles such as skill, which is a feature of an individual's knowledge and agency. The term "resources and tools" further drops some of the theoretical baggage that comes with the use of a Marxist term.

Although they are part of Costin's "organization of production," I draw out time and space as two distinct analytical categories. The explicit inclusion of time and space underscores that individuals and groups of individuals necessarily act across both and that architectural production is, therefore, not fixed. As time progresses new problems are confronted and consequently, the types of resources and tools, the groups of individuals, and the pace of construction often change. Likewise, over time, the spatial organization of production and the location of resource exploitation can vary. The distinct addition of time and space fundamentally emphasizes that construction is a process and it compels an appreciation for the human agents who drive the construction process.[201]

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[200] Costin 2001, 286–92.
[201] This intersects with the idea of the taskscape where time, space, and action intermesh (Ingold 1993).

Missing from my categories of individuals, resources and tools, time, and space are Costin's "relations of distribution" and "consumers."[202] The first, an important aspect of traditional craft production studies, is less applicable to architecture which is inherently fixed. Nevertheless, the category of "space" loosely engages with the idea of distribution since buildings are situated in the landscape and purposefully arranged in relation to resources and other structures. The second of Costin's categories, consumers, is an essential component of architecture, but this term is not typically employed. Instead, consumers and their demands form a part of the discussion of architectural function. In my four categories, intended function is not explicitly addressed. I envision this as part of individuals and their agency, since their plans, actions, and goals are influenced by the demands of "consumers" and the intended function of a structure.[203]

Moving In: Architectural Production and the Material Record

The above theoretical discussion as a whole and the linking of architecture with Costin's study of craft production represents a fundamental shift in how we think and talk about architecture. Architecture as a finished product and its discussion as such remains a valid and valuable point of study, but when practiced alone it isolates architecture from other categories of material remains. Historically, this has been the case and it has skewed the creation of economic models which emphasize a few moveable products, relegating architecture to discussions of elite power, and social organization and evolutionary stages. Recognizing that architecture is the result of a process, or really an integration of processes driven by individuals interacting with

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[202] Costin 2001, 303–6.
[203] This fits with the producer-oriented approach taken here.

one another and the material world, recalls architecture from its isolation and lets us talk about not just architecture but *architectural production*.

Having traversed the false dichotomy of economy and society that has structured past thinking, reformulated embeddedness as an agentive concept, and called for a new approach to architecture through the lens of production, in the following chapter I move closer to the material record and present one way to operationalize the theoretical views and definitions adopted in this chapter. With a simple but functional definition of architectural production in hand, and its intentionally broad categories of individuals, resources and tools, time, and space, I explore a bottom-up method that uses the material record to scrutinize these categories and think through the productive processes that underlie individual structures. Building on a suite of established methods that includes architectural energetics, practices of modern construction management, and the chaîne opératoire, I advance a method for the close range study of architectural production that allows me to study the production of individual Mycenaean structures in their own right and, to eventually link up with larger topics of Mycenaean economy.

CHAPTER 3

A METHOD FOR STUDYING ARCHITECTURAL PRODUCTION

Architectural Production as Social Power: Architectural Energetics

The Method of Architectural Energetics

The term architectural energetics was coined by Abrams to describe an approach for quantifying human labor investment in architecture.[1] On the premise that every form of architecture physically embodies "articulated materials and behaviors, involving costs, construction decisions, and human labor organization,"[2] architectural energetics uses the standing remains of a building and ethnographic studies or experimental archaeology to reconstruct labor-costs. To calculate labor-costs, the method begins with a hypothesized reconstruction of the building under study. Since even under the best conditions an ancient building's original form may remain speculative, information on often decayed materials such as mudbrick or wood from excavations, as well as broader knowledge of architectural traditions must regularly be used to extrapolate the missing elements of a building. Once a reconstruction has been completed, a list of a building's components and their raw materials is created and measurements, usually in cubic meters or kilograms, of each raw material are estimated.

When used by itself, this first stage of architectural energetics is aptly known as volumetrics. As a straightforward mathematical estimate of building materials, volumetrics has been applied to compare buildings in a more rigorous fashion than fuzzy terms like "monumental" or "elite" can facilitate.[3] For example, at Mycenae, Fitzsimons recently applied

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[1] Abrams 1989, 1994.
[2] Abrams 1998, 123.
[3] Turner et al. 1981; Kirch 1990.

such an approach to the grave circles and tholoi as a way of contrasting the monuments' scales diachronically to draw out information on sociopolitical change.[4] In formulating architectural energetics, however, Abrams specifically sought to enhance volumetric calculations, which he viewed as overly simplistic.[5] Because material volumes reflect only one component of a structure's costs, Abrams argued that volumes do not gauge monumentality as precisely as is possible nor are material volumes alone sufficient to estimate construction costs; structures with similar volumes might draw resources from disparate locations or require the use of dissimilar technology during construction, neither of which can be accounted for by volumes.[6]

As a way to move beyond volumetrics, Abrams presented architectural energetics which contextualizes material volumes by using work-rates to estimate the human energy consumed during the treatment of each raw material.[7] To accomplish this, Abrams broadly divided the process of construction into four phases: procurement, the gathering or extraction of the material; transportation, the movement of the material from extraction location to the building site; manufacture, the modification of the material from its raw state to some more usable form; and assembly, the incorporation of the material into the structure and any necessary finishing.[8] Carelli later added maintenance as a possible fifth stage;[9] and, although this stage is typically not considered in energetic studies because it occurs after the original episode of production, it can be useful for addressing architectural reuse and decay.

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[4] Fitzsimons 2011; but see also Fitzsimons 2014.
[5] Abrams 1994, 37–41.
[6] Abrams 1994, 38.
[7] Abrams 1994, 41–62.
[8] Abrams 1994, 43.
[9] Carelli 2004, 117–8.

For each of the raw materials measured during the volumetrics stage, the required labor-cost is estimated for the four construction stages.[10] In practice, one or more of these stages is often negligible so that not every raw material will progress through each. Certain construction materials like cobbles, for example, may be procured, transported, and assembled without requiring modification during an interceding manufacture stage. Furthermore, the four stages may abridge complex temporal and spatial configurations of materials processing. In a variety of contexts, quarried stones are extracted, roughly shaped to reduce their size, transported to a building site, and then further modified before assembly.[11] Strictly speaking, the manufacturing stage of such stones does not represent a discrete event, but occurs twice: once before transport and once again before assembly. In this case, to reach general estimates organizational breaks could be ignored so that both the roughing out and final modification are unified under the heading of manufacture or they could be apportioned to different stages of construction (i.e. counting the roughing out as part of procurement and the on-site modification as manufacture). The value of this four-part staging is that, while it may gloss over organizational features, it presents an overview of construction with the flexibility to tackle diverse situations.

Work-rates are then drawn from a variety of sources in order to estimate costs for each stage through which a raw-material passes. Possible sources include timed replicative experiments,[12] ancient texts,[13] ethnographic observations of premodern construction techniques,[14] and early construction manuals.[15] The chosen work-rates do not have to be site-

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[10] Abrams 1994, 41–62.
[11] Korres (1995) provides an excellent illustration of this process.
[12] Erasmus 1965; Jorgensen 1985; Love 1990; Protzen 1993; Abrams 1994, 44–52; Hard et al. 1999.
[13] Goetze 1962; Simpson 1963, 1969; Heimpel 2009, 221–88.
[14] Wulff 1966; Fathy 1996; Ayres and Scheller 2002.
[15] Laxton 1878; Hurst 1899; Rea 1902; Gillette 1920.

specific, and they are typically not, but they should be technologically appropriate for the period

and region under study. That is to say, they should reflect the tools and techniques available to a

practitioner of that time and area as much as possible. Because the nature of these technological

practices in the past is not directly visible, choosing work-rates can be a source of contention.

Inferences from tools, remnants of raw material processing, and the remains of buildings supply

the most valuable information on past building techniques and aid the choice of suitable work-

rates. A second difficulty can arise in sourcing the raw materials of a building.[16] This knowledge

is particularly important for transportation work-rates which are principally derivative of the

distance to resource extraction points, such as quarries, clay beds, or forests. In lucky cases, the

location of natural resources will be well-defined but in many, as with technological practices,

this information must be inferred from broader studies of the ancient landscape and building

practices.

Architectural energetics does not dictate that work-rates be measured in a specific way,

but it is common practice to express them as units per person-hour (*x* units / ph) or person-hours

per unit (*x* ph / 1 unit) where a person-hour is the general work that one individual performs in a

single hour. For example, stone may be quarried at a work-rate of one-half cubic meter per

person-hour (0.5 m^3 / ph) which is equally expressible as two person-hours per one cubic meter

(2 ph / m^3). The manner in which the rate is expressed depends both on the units employed in the

volumetric stage and personal choice, with some even choosing kilojoules of energy in place of

person-hours.[17] In all cases, however, the use of person-days to express work-rates should always

be avoided. Because the work day is culturally defined, the initial use of person-days obfuscates

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[16] For example, Devolder (2013, 134–6) encountered this problem when applying energetics to
Minoan architecture.
[17] Lacquement 2009.

actual timed work-rates and limits their comparative value.[18] Because an hour, instead, is an absolute measure of time, it is culturally neutral. One person-hour is one person-hour, but one person-day might be eight person-hours for an Egyptian working on a royal tomb[19] or ten person-hours for a Mesopotamian excavating a canal.[20]

Once suitable work-rates have been reached, the work-rates are applied to the measurements of raw materials in order to calculate the total person-hours expended by builders during each stage through which the raw materials progressed. The results are frequently expressed in a tabular format with each row listing a raw material and each column showing a stage of construction.[21] This table found in traditional energetics often includes additional statistics as well, which indicate the percentage of person-hours devoted to each raw material and each stage of construction. Finally, summing the person-hours of all stages and materials provides an overall person-hour measure for the entire building project which may then be compared to measures of other structures.[22]

Energy and the Power of Architecture

Although architectural energetics as a method is not inherently bound to any theoretical framework, its development and applications are heavily rooted in theories of social power and neoevolutionary typologies. Under this theoretical orientation, labor-costs are regarded as direct

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[18] This is apparent in studies which egregiously mix the number of hours in a person-day. Work derived from Erasmus (1965) notoriously uses both a 5-hour and 8-hour person-day depending on the perceived difficulty of the construction task. The only effect of this is to muddle the initial energetic calculations. The use of person-days is best left to a later interpretative stage after initial person-hours have been calculated and clearly expressed.

[19] Bierbrier 1989, 52–3.

[20] Burke 2004, 297–8.

[21] e.g. Abrams 1994, 133–45.

[22] e.g. Abrams 1994, 84 fig. 16.

metrics of power; higher levels of energy invested in monuments or residences are taken to signify greater top-down access to labor and, therefore, directly reflect an individual's ability to channel the behavior of others via coercion or legitimated force. When examined synchronically, labor metrics are taken to reflect the general level of social complexity and to illuminate levels of differentiation within the sociopolitical hierarchy.[23] Diachronic uses are then argued to reveal changes in sociopolitical complexity and hierarchical organization.[24] Applying architectural energetics to Mayan residences at Copan, Abrams, for example, used labor-costs to generate a hierarchical model of power that he thought reflected a lineage model, a typological characteristic of an early state.[25] Within his proposed hierarchy, he went on to identify clusters of labor-costs and attributed each to a sociopolitical class which utilized a particular labor recruitment mechanism.[26] Moving from highest to lowest labor-cost, each residence at Copan was assigned to royal-elites, sub-royal elites, lower-ranking retainers, or commoners.[27] Effectively, the energetics of residential architecture at Copan was read by Abrams as a manifestation of Copan's level of sociopolitical development and, when employed comparatively, each structure's labor-cost was the material expression of a class within the proposed sociopolitical hierarchy, and a specific recruitment and reward system.[28]

While Abram's work illustrates the common theoretical approach which links architectural energetics with power and neoevolutionary thinking, the connection between architecture, power, and social complexity emerged earlier than Abrams. The association has a

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[23] Abrams 1994, 76–95.
[24] Murakami 2010.
[25] Abrams 1994, 76–95.
[26] Abrams 1994, 81–91.
[27] Abrams 1994, 81–91.
[28] Abrams 1994, 81–95.

long history in archaeological thought preceding Abrams' work and seems to have a natural basis

in human psychology; general human experience of the monumental instills feelings of power

and often inspires the belief that to achieve such monumentality, power must have been centrally

wielded by an inherently exploitive individual or group of individuals.[29] Herodotus' (2.124)

treatment of Cheops, whom he characterized as abusing his people in order to complete the Great

Pyramid, is an excellent ancient example of this psychology, as well as an account which we

now know oversimplifies the true nature of construction.[30] Like Herodotus, early modern

anthropologists similarly drew on the perceived connection between architecture and power.[31]

Both Lewis Henry Morgan and V. Gordon Childe associated architecture with degrees of social

complexity and early evolutionary typologies.[32] Later, similar ideas surfaced in the work of

Leslie White, who built on the ideas of Morgan.[33] Through the work of White, however, the

connection between architecture and power was ultimately to become more scientistic via the

mediating influence of energy.[34]

    In his neoevolutionary approach, White argued that development in human societies was

the direct result of increased per capita energy or an improved ability to harness energy through

increased technological efficiency.[35] He expressed this idea as a simple, mathematical formula:

Energy x Efficiency = Cultural Development.[36] Although ideas of cultural evolution have been

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[29] This is the most common archaeological interpretation of monumental architecture (Osborne 2014, 4–8).

[30] Lehner 2002; Murray 2005. On the changing scholarly views of architecture, see also Osborne 2014.

[31] Trigger (1989, 1998) provides excellent overviews of these trends.

[32] Morgan 1877; Childe 1950.

[33] White 1943.

[34] The architecture/energy connection is best expressed in Trigger 1990.

[35] Trigger 1998, 126–9.

[36] White 1943, 337–8.

subjected to heavy scrutiny,[37] White's line of thinking, that complexity is quantifiable and typeable, made its way into processual archaeology and today continues to exert influence on archaeological thinking.[38] The underlying principal that "behavior, whether of man, mule, plant, comet or molecule, may be treated as a manifestation of energy"[39] was the inherent basis for Abrams' formulation of architectural energetics in the 1980s and 1990s[40] while the thinking of White's processualist successors provided the theoretical backing for the interpretation of labor-costs as metrics of power:[41] architecture is a tangible manifestation of energy that is directly attested in labor-cost; in turn, energy expenditure mirrors sociocultural development and complexity; therefore, larger amounts of labor spent on architecture signify higher levels of development and greater complexity. Souvatzi suggests that, coupled with the interest in energy emerging from White, the evolutionary thinking of processualism has strongly shaped interpretations of power, particularly in the disposition to equate complexity with centralized power, and to regard all power as inherently hierarchical, self-interested, and antagonistic.[42] Trigger hits upon and summarizes many of these ideas well in his discussion of monumental architecture through a thermodynamic lens. Following processualist notions of power and energy, he remarks that architecture not only reflects power but, by making it visible, "becomes power rather than merely a symbol of it."[43] Likewise, this power is characterized as naturally hierarchical, centralized, and exploitive so that "by participating in erecting monuments that glorify the power of the upper classes, peasant labourers are made to acknowledge their

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[37] Trigger 1998, 152–85; Yoffee 2004, 4–21; Pauketat 2007.
[38] Trigger 1989, 289–328.
[39] White 1943, 335.
[40] Abrams 1984, 87–92; 1989, 52–3; 1994, 37–41.
[41] Abrams 1994, 76–95, 101–8. See also Osborne 2014, 4–8.
[42] Souvatzi 2007, 37–8, 51–4.
[43] Trigger 1990, 122.

subordinate status."[44] Under this view, monumental architecture becomes a form of conspicuous consumption in which elites wastefully expend the labor of others to advertise and cement their own power.[45]

Two particular studies highlight how this integration of architecture, energy, and power was playing out both in American and European archaeology prior to the work of Abrams. In the Americas, Erasmus' estimation of construction costs for the Maya site of Uxmal was seminal.[46] To calculate labor-costs Erasmus employed an experimental approach in which he gathered time rates for digging, earth moving, and stone extraction in Sonora, Mexico. His results, which produced a total cost of 7.5 million person-days for Uxmal's construction, were couched within an evolutionary model of labor extraction that correlated labor investment and sociopolitical stages much like Abrams' work at Copan.[47] Erasmus' model relied on a continuum of 40-150-500 person-days devoted by each household per year to construction, amounts which he argued offered "a rough measure of the degree of centralized power in any political structure employing corvée labor."[48] By dividing the total cost of Uxmal by its 250 year occupation, Erasmus concluded that each household invested approximately 40 person-days per annum. Within his continuum, this labor demand was on the lower end; therefore, he suggested such investment was consistent with a chiefdom level society.[49] Although this conclusion has been criticized,[50] his use of experimental archaeology to estimate construction costs and his emphasis on the broader

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[44] Trigger 1990, 125.
[45] Trigger 1990, 124–5.
[46] Erasmus 1965.
[47] Erasmus 1965, 281–3, 294–9.
[48] Erasmus 1965, 281.
[49] Erasmus 1965, 296–9.
[50] Abrams (1984, 81–5) was critical of Erasmus' continuum since it accounted only for labor devoted to ceremonial architecture. For this reason, Abrams suggested that his measure should be on the high end of the continuum.

societal implications of these costs, including their interpretative function within sociopolitical

typologies that were then emerging, paved the way for future studies, including Abrams' own

work.

Somewhat later than Erasmus' work in the Americans, Renfrew utilized an early

energetic approach to study prehistoric monuments in England.[51] Countering earlier notions of

Near Eastern influence and seeking a social explanation for regional changes in the Neolithic,

Renfrew scrutinized the construction and location of long barrows and causewayed enclosures in

Wessex.[52] Calculating the labor-cost of these monuments, he created a five-part hierarchy of

increasing person-hours. At its extremes, this ranged from early barrows that cost less than

10,000 person-hours to Stonehenge III, which required perhaps 30 million person-hours.[53] As a

hierarchy moving from less costly to most costly architecture, he correlated changes in labor-cost

with increasing complexity and expanding territorial control. Employing the idea of a chiefdom,

he associated each level of labor investment with social change so that the monuments supported

a hypothetical explanation in which numerous emerging chiefdoms evolved over time into a

single, territorially-unified chiefdom.[54]

Architectural Energetics in the Bronze Age Aegean

Although earlier studies had estimated labor-costs and connected labor metrics with

power,[55] Abrams' logical exposition of architectural energetics and his clearly stated

interpretations caused his work to be readily picked up by other Mesoamerican scholars and

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[51] Renfrew 1973.
[52] Renfrew 1973, 544–7.
[53] Renfrew 1973, 547–8.
[54] Renfrew 1973, 549–54.
[55] Kaplan 1963; Erasmus 1965; Renfrew 1973, 1983; Aaberg and Bonsignore 1975.

eventually to reach a diverse range of world archaeologists.[56] Architectural energetics has now

become a widespread method for the study of premonetary and prehistoric architecture. Its

popularity has been aided considerably by the method's aim of connecting the material remains

of architecture with far-ranging anthropological issues including sociopolitical organization,

labor systems, and long-term changes within both. In addition, outside of textual remains, there

are few other methods suitable for probing the difficult topic of premonetary costs.[57] Because of

its utility, Abrams' architectural energetics has been applied well beyond the original temporal

and geographic confines of Pre-Columbian Mesoamerica. In addition to its continued use

throughout the Americas, studies of the past twenty years have included architecture as diverse

as Chinese fortifications of the Late Neolithic and Early Bronze Age,[58] and 2nd millennium C.E.

stone platforms in northern Cameroon.[59] In the Bronze Age Aegean, too, scholars have dipped

their toes into the swelling waters of energetics.

Two of the earliest applications of architectural energetics in the Aegean (although this

term was only recently drawn into Aegean scholarship)[60] that were roughly contemporary with

Abram's dissertation work[61] are attested in Walsh's study of house construction at Nichoria and

Wright's analysis of mortuary architecture at Mycenae.[62] In both cases, energetics was a segment

of the larger study and, as a methodological component, its connection to power and

evolutionary theory typical of archaeology in the Americas at the time was less forceful. Walsh,

in her dissertation research, used energetics calculations to understand both the physical

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[56] Abrams 1984, 1994.
[57] Smith 2004, 91–2.
[58] Shelach et al. 2011.
[59] Richardson 2004, 57–74.
[60] Devolder 2013.
[61] Abrams 1984.
[62] Walsh 1980; Wright 1987.

construction of houses at Nichoria and the intersection of construction with other activities. Taking a systems approach, she built a computer simulation of construction activity which she then used to test hypotheses by altering parameters such as population statistics, resource availability, and work-rates.[63] This last component functioned in the vein of energetics and measured the person-hours required to perform construction activities for different materials. As a part of the simulation, Walsh used work-rates and population statistics to generate models of construction over time in order to understand the conditions necessary to produce a town layout comparable to Nichoria, including the basic population and the number of person-hours that were needed for the town's construction.[64] Results of the simulation showed that Nichoria's construction would have required an average of 1,100,000 person-hours expended over the course of 650 to 750 years. On a yearly basis, this broke down to approximately 1,000-2,000 ph. With an ethnographically established agricultural off-season of 75 days, this meant that only two to three people were employed in construction per day, although when construction peaked during Nichoria's later days this number may have increased to twelve.[65] In all cases, though, Walsh suggested that, for a village of over 400 people, this labor demand was no great burden. For individual house construction, the low yearly labor requirement implied that it was typically unnecessary to hire workers outside of the extended family, but outside workers may have been employed for social reasons. Finally, the low yearly investment in building hinted that any construction specialists were part-time since there was too little work to engage them throughout the year.[66]

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[63] Walsh 1980, 63–79.
[64] Walsh 1980, 80–5.
[65] Walsh 1980, 99–100.
[66] Walsh 1980, 100.

Next, in 1987, Wright briefly employed energetics, not for house construction, but to comparatively study mortuary practices at Mycenae.[67] Taking Shaft Grave V as his starting point, he estimated that at 98 m³, excavation of the tomb would have required 10 workers 10 days to complete. This measurement did not include removal of the spoil, but when factored in, Wright suggested a total of 2,400 person-hours was appropriate.[68] For contrast, he similarly examined the Aegisthus Tholos. With a dromos and chamber requiring the removal of 2,395 m³ of spoil, the same 10 workers would have required 240 days to complete excavation.[69] The addition of the masonry, he reasoned, boosted the cost to 57,600 person-hours while construction might have required as long as a year.[70] Interestingly, he used these comparative measurements not to bolster the simplistic notion that "the latter burial represents a larger more complex societal group,"[71] but to argue that the preparation of the Aegisthus tholos must have been a much more public phenomenon than that of the shaft graves. Although succinct, Wright's diachronic use of energetics was a pragmatic addition to his qualitative study of changing mortuary symbolism.

Since Wright's initial work, this quantitative approach to mortuary architecture at Mycenae has been advanced in much greater detail by Fitzsimons.[72] Although he has not always employed a full energetic approach,[73] Fitzsimons has examined mortuary facilities at Mycenae using a combined qualitative and quantitative method while further drawing in ideas of power

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[67] Wright 1987, 173–4.
[68] Wright 1987, n. 15.
[69] Wright 1987, 174.
[70] Wright 1987, n. 15.
[71] Wright 1987, 174–5.
[72] Fitzsimons 2011.
[73] Fitzsimons (2014) has recently coupled some new energetics data with his past study of tholoi at Mycenae.

typical of energetics studies. From his volumetric estimates Fitzsimmons roughly calculated

person-hours for cist graves, shaft graves, and tholoi at Mycenae by applying Wright's

excavation task-rate of 1 m^3 / pd.[74] For Middle Helladic cists, he suggested two to three person-

days were required, while shaft graves showed an exponential increase in labor investment

ranging as high as 100 person-days.[75] The increased investment was linked to both a changing

workforce and the tomb's "more elaborate set of logistical requirements that demanded the

organization and control of groups of workers drawn from beyond the confines of the immediate

family,"[76] as well as the concomitant emergence of elites who advertised their status through

their tombs' monumentality.[77] For the tholoi, soil removal again showed an increase in labor

requirements[78] that was linked with "a corresponding rise in the status of the elite in the

Argolid."[79] Recently, Fitzsimons has published more explicit energetic data on Grave Circles A

and B, and some of the tholoi at Mycenae that expands this approach.[80]

In the 1990s, two studies began to address the energetics of Mycenaean architecture more

fully than Wright or Walsh had done and to draw in more of the relevant literature from the

Americas. The earlier of the two studies was completed by Loader as part of her dissertation

research, which later formed the core of her book, *Building in Cyclopean Masonry*.[81] The broad

purpose of her work was to examine the large, cyclopean fortifications of Mycenaean Greece

with briefer consideration devoted to other examples of cyclopean construction. With an

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[74] Wright 1987, 174; Fitzsimons 2011, 80.
[75] Fitzsimons 2011, 80–2.
[76] Fitzsimons 2011, 82.
[77] Fitzsimons 2011, 83.
[78] Fitzsimons 2011, 94 table 5.7.
[79] Fitzsimons 2011, 94.
[80] Fitzsimons 2014.
[81] Loader 1995, 1998.

especially keen technical focus, Loader addressed the typological classification of cyclopean

masonry[82] and detailed the available methods for quarrying, transporting, and erecting cyclopean

walls' massive blocks.[83] Here, she cogently included task-rates for construction activities and

suggested partial labor-costs for a few Mycenaean fortification walls.[84] To transport blocks for a

single face of the walls at Gla, Tiryns, and Midea, she estimated a labor requirement of 195, 55,

and 14 years respectively;[85] however, the presentation of these numbers is somewhat unclear.[86]

She more clearly explained the drainage works at Tiryns and in the Kopais, which she thought

required approximately 144 and 825 person-years respectively.[87] Despite some obfuscation of

her overall calculations, Loader's work was especially productive because of its close attention

to the intricacies of building practices. She provided well-structured sections on the technical

skills and tools used during cyclopean construction, and utilized an abundance of experimental

sources from Europe and the Americas, including Erasmus' famous study, to isolate suitable

task-rates. With this data, she went so far as to suggest the minimum number of individuals per

team needed for dragging a block or lifting it into place, and she strengthened arguments for the

symbolic nature of Mycenaean fortifications, which as her results illustrated, could not have

realistically been built for an immediate defensive need.[88] Although Abrams' work and the term

"architectural energetics" had still not made its way into the vernacular of Bronze Age

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[82] Loader 1998, 5–41.
[83] Loader 1995, 31–61; 1998, 42–73.
[84] Loader 1998, 65–73.
[85] Loader 1998, 68, appendix 3.
[86] She seems to indicate that this number reflects a single team of men working. Using Atkinson's work on megalithic transport, she estimates that 4 men required 11.19 hours to transport a single cyclopean block, assuming the distance was 1 km over flat ground. This emphasizes the point made earlier that person-hours should be clearly stated and only later should they be interpreted in absolute time.
[87] Loader 1998, appendix 4.
[88] Loader 1998, 72–3.

scholarship, the application of labor-costs in the Aegean was beginning to parallel its use in the Americas, especially as ideas of power were more freely integrated. Shortly after Loader, this parallel development matured when Cavanagh and Mee completed the first dedicated energetics study in the Bronze Age Aegean.[89]

Although Cavanagh and Mee still did not include the term architectural energetics, despite a brief citation of Abrams' work, the structure and tone of their study was strongly evocative of energetics scholarship in the Americas. While they engaged the concepts of symbolism in mortuary architecture which had earlier surfaced in Wright's work, they went further in addressing the power of architecture as reflected in labor-costs. Citing the "power of the sovereign *wanax*, manifest in his fine tomb,"[90] they investigated the technical aspects of the Treasury of Atreus' construction and the labor-costs associated with each stage of construction. Like Loader, where possible, they drew on a selection of experimental sources for task-rates, although in places their numbers were rough guesswork.[91] The result was a total labor-cost of 20,280 person-days for the Treasury of Atreus.[92] In order to contextualize this number, they used the general picture of sociopolitical structure derived from the Linear B tablets. As a "royal" project, they suggested that the Treasury of Atreus was constructed by a labor force "directly commanded by the palace and remunerated with rations."[93] Skilled workers, on the other hand, may have been paid through an exemption from imposts or they could have been pressed into

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[89] Cavanagh and Mee 1999.
[90] Wright 1987; Cavanagh and Mee 1999, 93–4.
[91] Cavanagh and Mee 1999, 95–99, 100 table 1.
[92] Note again that the use of person-days obscures the actual energetic cost of the structure as it says nothing about how many hours per day were devoted to each task. Since they have drawn on Erasmus (1965), it is likely their summary implicitly mixes five and eight hour workdays. In any case, their numbers differ from the results of my own detailed research.
[93] Cavanagh and Mee 1999, 100.

service as a form of taxation.[94] Explicitly barred in Cavanagh and Mee's discussion was the

possibility that labor could have been hired, which they considered anachronistic;[95] instead, as

with many energetics studies in the Americas, the process of construction was discussed in the

context of top-down power with its undertones of force and exploitation. Unlike most studies in

the Americas, however, Cavanagh and Mee did not use energetics in a comparative manner, but

they did draw on Burford[96] to offer a small, albeit incongruous measure of comparison with a

Classical temple in Greece.[97]

Most recently, McEnroe and Devolder have applied energetics to Minoan architecture.[98]

Throughout his book, *Architecture of Minoan Crete: Constructing Identity in the Aegean Bronze

Age*, McEnroe included occasional tables of energetic costs. Citing time-rates found in Erasmus'

and Walsh's earlier studies, he applied energetic calculations to four Minoan houses which

spanned nearly two millennia, from the Early Prepalatial to the Postpalatial period: the South

Central House at Myrtos, the South House at Knossos, House AM at Pseira, and House I at

Vronda.[99] His reasons for choosing these particular houses were variable. In the case of the

South Central House at Myrtos, he suggested that energetics offered a way "to understand the

value of the house to its users"[100] and for the South House at Knossos, he linked the house's

monumental and impressive nature with its intensive labor-cost.[101] For those at Pseira and

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[94] Cavanagh and Mee 1999, 100–1.
[95] Although, see Hruby (2013) for the changing perspective on this topic.
[96] Burford 1969.
[97] Cavanagh and Mee 1999, 99–100.
[98] McEnroe 2010; Devolder 2013. Kvapil (2012, 198–203) also includes a brief discussion of the energetic costs for Mycenaean agricultural terracing.
[99] The South House at Knossos and House AM on Pseira were restudied by Devolder (2013, 84–5, 100–4).
[100] McEnroe 2010, 22.
[101] McEnroe 2010, 95–7.

Vronda, he touched upon possible durations of construction and, in comparing the two, he posited that house building was a major industry on Minoan Crete.[102]

Finally, Devolder's recent book, *Construire en Crète minoenne: une approche énergétique de l'architecture néopalatiale*, is the most comprehensive energetic treatment in the Bronze Age Aegean to date.[103] Breaking her study into two parts, Devolder first presented a detailed outline of task-rates for a variety of building practices common to Neopalatial Crete. After discussing the building materials and techniques of the period, for the benefit of future researchers, she summarized her time-rates in two compact tables. Included is a wide-range of task-rates expressed in person-hours for diverse, but important building tasks, such as procuring ashlar blocks of limestone, erecting gypsum walls, and mixing materials for mudbricks.[104]

In the second part of her study, Devolder utilized her task-rates to analyze an array of buildings, ranging in scale from smaller houses on Pseira to large sections of the palace at Gournia.[105] For each, she paid close attention to the materials and techniques used, generated costs for each stage of construction, and then offered a total cost for all stages. Using a work season of 90 eight-hour days, she made an effort to better illustrate the magnitude of each project by calculating how many individuals would have been required if construction occurred during a single work season.[106] These numbers were evaluated against the laborers that each building's own inhabitants could hypothetically have supplied; she conjectured that each building contained one individual for every $10m^2$ of floor space and, of the total inhabitants, 33% were available to

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[102] McEnroe 2010, 107, 148–50.
[103] Devolder 2013; see also Devolder 2008, 2012.
[104] Devolder 2013, 42–7 table 7–8.
[105] Devolder 2013, 116–39.
[106] Devolder 2013, 119, 129–31.

work.[107] Finally, the buildings were compared to one another from several perspectives including the overall cost, the cost of individual stages and particular masonry types, and the presence or absence of sufficient inhabitants to complete construction without additional help.[108]

Based on her energetic analysis, Devolder offered a number of conclusions about Minoan builders and building practices. In an attempt to approach the issue of skilled versus unskilled labor, as well as recruitment mechanisms, she drew in ideas from Costin,[109] particularly the use of an attached/independent continuum to describe the relationship between builders and patrons.[110] Although she acknowledged the great difficulty of this subject, she generally posed, as might be expected,[111] that patrons of more elaborate buildings had privileged access to resources, men, and materials with which they were able to maintain or increase their social position through the construction of more costly buildings.[112] While it was harder to place builders of individual structures precisely on the attached/independent continuum or to describe the exact manner of recruitment, she found that the existence of independent builders was supported by the geographical distribution and distinct configurations of elaborate architectural features.[113] As a result, during the Neopalatial period there may have been broader access to skilled builders so that "l'élite ne contrôlait pas sévèrement l'accès aux formes architecturales du prestige, même si elle disposait d'un accès privilégié à ces dernières."[114] A secondary feature of the more costly architecture that she identified was that it was characterized more by the use of

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[107] Devolder 2013, 119.
[108] Devolder 2013, 116–39.
[109] Costin 1991.
[110] Devolder 2013, 124–31.
[111] See Osborne 2014.
[112] Devolder 2013, 124–6.
[113] Devolder 2013, 142.
[114] Devolder 2013, 142.

quality materials and technical skills than the employment of a large force of unskilled labor. Particularly, she exemplified this with her energetic analysis of the western façade of the palace at Gournia and the gypsum walls in the South House at Knossos where unskilled tasks, like transportation, demanded little cost.[115] In contrast to monumental architecture in the Mycenaean world and especially in the Argolid, where the use of massive stones required large pools of unskilled labor as suggested by Loader,[116] Devolder recognized in Neopalatial Crete a particular form of monumentality typified by "un excès dans le raffinement et l'élaboration."[117] Finally, she broached the connection between labor-costs and the choices of builders, of which she isolated two examples: First, more expensive types of masonry were often limited to highly visible or structurally essential areas and second, foundations were generally built to conform to terrain except in the case of "palatial" houses, where terrain was ignored and foundations consumed large amounts of labor.[118] For both, she suggested that builders were aware of higher labor demands and that such knowledge impacted their choices during construction.[119]

Novel Uses of Architectural Energetics

Architectural energetics, as it stands today both in its evolving application in the Aegean and its ongoing efficacy in the Americas, has demonstrated its resiliency and effectiveness for analyzing the material remains of architecture from an economic perspective. Its flexibility in tackling situational problems has led to diverse extensions of the method which are tailored to suit particular scenarios. While the traditional formulation of energetics, with its strong

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[115] Devolder 2013, 144 table 32.
[116] Loader 1998.
[117] Devolder 2013, 143.
[118] Devolder 2013, 132–3, 143.
[119] Devolder 2013, 138, 143–4.

typological and evolutionary overtones, persists and has been heartily embraced by those studying mound-building in the Americas,[120] elsewhere, the method has been employed in novel ways. A few of these studies are worth briefly singling out in order to exhibit the adaptability of the method.

Rather than attacking architecture directly, Webster and Kirker used a reverse method in which they employed population estimates to calculate how many temples Copan *could* have built over 500 years. In so doing, they illustrated the comparative paucity of temples that Copan actually built. With their results they cautioned scholars that monumental architecture does not always presuppose a large population or inherently overtaxing demand on labor; for Copan, in fact, each household likely provided significant construction labor only two to three times over the course of a generation.[121] Likewise mixing population estimates and structures, Bernardini successfully coupled energetic analyses with labor catchment areas to weigh ideas of community isolation and integration during the Hopewell Period in the Scioto Valley of Ohio. His results showed that catchment areas overlapped multiple mounds so that communities had to regularly interact in a pan-regional system for the purpose of mound construction.[122] Finally, energetics has been used to assess architectural function and compare construction to other productive activities. Through experimental archaeology and labor-costs, Hard et al. showed that a set of prehistoric rock terraces at the site of Cerro Juanaqueña, Mexico functioned as house platforms and not agricultural terraces. For every hectare of land created by the terraces, 24,000 person-hours were needed; if planted with maize, though, each new hectare could only feed four adults

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[120] Blitz and Livingood 2004; Hammerstedt 2005; Abrams and LeRouge 2008; Lacquement 2009; Ortmann and Kidder 2013
[121] Webster and Kirker 1995. Compare the conclusions from Walsh 1980, discussed supra.
[122] Bernardini 2004.

per year, a result which made the interpretation that these were house platforms more probable.[123] Similarly, Arco and Abrams used energetics to compare the economic burden of chinampa construction and cloth production in the Aztec Empire, which they found to be similarly taxing for populations under Aztec control.[124]

Architectural Production as Social Process: Construction Management and the Chaîne Opératoire

Refocusing Architectural Energetics through Complex Embeddedness

In response to ongoing, high-level applications and extensions of architectural energetics, Richards has criticized the method's overwhelming focus on the final built-form as well as the 'barometric' use of architecture as a measure of power.[125] He remarks that, from the perspective of modern scholarship, monuments are viewed as fulfilling their purpose only when they have reached completion so that "there exists the tendency to compress construction into a unitary endeavor, a single event regardless of the temporality of practices embodied in the process of making."[126] Consequently, in traditional architecture energetics, architecture can become lifeless, to be summed up as a labor-cost and read as a fixed display of social structure and power. Architecture, however, is not passive nor is its meaning fixed;[127] it is actively created through the intersection of numerous processes carried out by individuals concurrently interacting with each other and the material world.[128] As Richards stresses, these processes of construction and their

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[123] Hard et al. 1999.
[124] Arco and Abrams 2006.
[125] Richards 2004, 72–4.
[126] Richards 2004, 74.
[127] Moore 1996, 3.
[128] Here I focus only on the initial act of construction, but finished architecture is equally recreated through inhabitation.

intersections are critical because "in the temporality of building lie practices that embody social

transaction and the renegotiation of identities in the presencing and fusing of people together

through their labour and the product of that labour."[129] From this perspective, the high-level use

of architectural energetics becomes one sided, affixing too much meaning to overall labor-costs

and too little to the temporal, spatial, and agentive elements which are integral to all productive

processes.

In large part, the criticism of Richards and others is not leveled against architectural

energetics as a method, per se, but reflects an ongoing reappraisal of the theory which frequently

dictates the scale of analysis in energetic studies and guides the interpretation of labor-costs.

Critiques of high-level social typologies have surfaced over the past decades[130] and for

architecture in particular, the traditional interpretative link between social complexity, power,

and monumentality is being gradually dissected. The nebulous relationship among these

categories has lately materialized in studies of monumentality in egalitarian or tribal societies, as

they are traditionally typed.[131] Recent energetic work at Poverty Point, Louisiana, has

persuasively demonstrated that "simple" societies are capable of rapid, labor-intensive

construction; in this case, an egalitarian hunter-gather society paradoxically drew together

somewhere between 1000 and 3000 laborers to build the massive Mound A (c. 238,000 m^3 of

earth) in only a few months.[132] Given that any signs of permanent social hierarchy are lacking at

Poverty Point and that population densities were low, Ortmann and Kidder have used this rapid

pace of monumental construction to argue that "there are many paths to mobilizing labor and

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[129] Richards 2004, 74.
[130] Chapman 2003, 33–70; Yoffee 2004, 4–21; Pauketat 2007, 7–30.
[131] Randall and Sassaman 2010; Howey 2012, 3–33.
[132] Ortmann and Kidder 2013.

deploying social and material resources"[133] and that this can include not only the exercise of coercive power, but the guiding influence of communal ritual and shared ideology.[134] This suggests, then, that labor-costs should not be read as direct metrics of social complexity or power but instead, energetic analyses require contextualization at a closer range of study than summed labor-costs permit. Because energetics emerged as a way to understand large patterns of sociopolitical organization or to describe change across broad spans of time, many studies, though, have necessarily avoided the fine-grained investigations of construction as a human-level process which are needed to tackle the criticism of Richards. The guiding theory of complex embeddedness and concept of architectural production, however, moves us to this closer range.[135]

Parallel to the general movement towards interpretative and agent-based archaeology, complex embeddedness shifts perspective from high-level social typologies and vague elite power strategies towards the scales of analysis where human action is temporally and spatially situated, and where social, economic, and political negotiations occur. For construction, this is where diverse issues of power manifest themselves as hierarchical and heterarchical relationships play out in practice; it is where not only exploitive but mutually beneficial relationships may form; and it is where manifold interactions and exchanges between typologically dichotomized types such as elites and commoners (or palatial and non-palatial) transpire. Rather than broadly typing buildings, societies, and labor systems through a supposedly objective labor metric, complex embeddedness induces us to interpret energetic data, as much as possible, at a human-

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[133] Ortmann and Kidder 2013, 79
[134] Ortmann and Kidder 2013, 78–81. For an Old World example of monumentality in hunter-gatherer societies, see also Notroff et al. 2014.
[135] Supra, pp. 14–25.

level where contextualized labor-costs can aid in understanding productive practices and experiences, exploring labor relations, and recognizing the ability of many agents to variably engage with one another during the construction process. Methodologically, Smailes has offered a useful step for operationalizing energetics at this scale of analysis.[136]

The Construction Management Approach to Architectural Energetics

For Smailes, the impetus for a closer view of construction was the difficult person-time problem that plagues energetic studies: given an overall person-hour metric for a building, how does one then break this into specific numbers of persons and absolute time thereby grounding construction in human experience? As Webster and Kirker accurately mused, "nothing is more true or tiresome than the 'it could have been built by one person in 1,000 years or 1,000 people in one year' evaluation."[137] Historically, this person-time problem has been addressed by comparing hypothetical time frames for project completion,[138] using population estimates with suggested person-days per year devoted to construction,[139] or contrasting the results of theoretical labor recruitment strategies.[140] The results, however, are expectedly high-level and still leave the construction process flattened and removed from human experience. A measure of 2,000 person-hours, for example, becomes 10 people working 25 eight-hour days. This newfangled measure is then typically fed back into macroscale comparisons and typologies with limited concern for the underlying building processes and interactions that this division of people and hours masks. Smailes, taking note of this overarching problem, argued that progress could be

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[136] Smailes 2011. See also Abrams and Bolland 1999.
[137] Webster and Kirker 1995, 380.
[138] Bernardini 2004.
[139] Abrams 1984.
[140] Webster and Kirker 1995.

made by more meticulously studying how labor was dynamically deployed during construction.[141] Quite simply, the distribution of labor during construction projects is rarely as uncomplicated as 10 people working 25 days. Incorporating tools from modern construction management, Smailes approached this problem using the Critical Path Method (CPM).

At the heart of CPM is the idea that any construction project can be graphically modeled to show its tasks and their interconnections, and that this modeling can then be used to analyze schedules of construction, labor organization, and resource usage.[142] The traditional application of CPM begins by establishing the scope of construction through a Work Breakdown Structure (WBS), a graphical representation of a structure which hierarchically illustrates its major components and the tasks or activities that go into constructing each component.[143] The number of levels in the hierarchy is not fixed so that the detail of information is dictated by personal choice and project necessity. For example, Figure A.1 shows a WBS for a hypothetical mudbrick wall. It has only two major components: a set of stone foundations upon which sits a mudbrick wall. The major tasks required to construct each component are then given. From an archaeological perspective, a WBS is an excellent way to think about the material record since it forces careful consideration of a building's standing remains and requires that assumptions about missing components and their construction be presented explicitly.

In traditional CPM, the creation of the WBS is followed by a 'volumetric' or quantity surveying stage in which the amount of building materials in each component is measured. For each component's tasks, work-rates are then estimated and applied to the previous volumes in

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[141] Smailes 2011, 38–9.
[142] Smailes 2011, 39–40.
[143] Mubarak 2010, 46–7; Baldwin 2014, 84–6.

order to generate labor-costs.[144] In this way, the use of a WBS, quantity surveying, and work-rate

estimation mirrors architectural energetics, which similarly breaks down a structure into its raw

materials, assigns volumes to each, and establishes rates for the procurement, transportation,

manufacture, and assembly of each material.[145] The similarity of the two, however, dissolves

after this when CPM graphically models the construction processes in order to explore schedules

of construction.

To move from task-rates, volumes, and person-hours to schedules of construction, the

next step that CPM takes is to model the interconnection of the tasks that were established in the

WBS by creating a precedence diagram. A precedence diagram is a type of network model which

illustrates how tasks are relatively organized during the construction process.[146] Within a

precedence diagram, a single box or node represents a discrete construction task. What defines a

discrete task is a function of choice.[147] In the hypothetical WBS (Fig. A.1), for example, "make

mudbrick" was represented as a single task; however, this could have been broken down into

further tasks including the procurement of earth, the procurement of water, the mixing of these

materials, and the forming of the brick, if that level of detail were useful. For this reason, CPM

provides a great degree of flexibility and is easily adapted to the level of archaeological detail

available or the scope of the research questions being asked.

In every precedence diagram, construction graphically begins with a "project start" node

and ends with "project finish" node, which act as placeholders that aesthetically structure the

diagram.[148] *Task nodes* occupy the space between these placeholders and their layout, from left

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[144] Smailes 2000, 38–9; Mubarak 2010, 48–9; Pierce 2013, 70–5.
[145] Smailes 2011, 38–9.
[146] Mubarak 2010, 83–101; Pierce 2013, 51–5.
[147] Pierce 2013, 43.
[148] Mubarak 2010, 29–32.

to right, mimics the logical progress of construction through time. From the "project start" node

to "project finish" node, every task node is connected to at least one other node using a line to

indicate that a logical relationship exists between the connected tasks. The "project start" and

"project end" nodes must also connect to at least one task node. The connection of a task to the

start node indicates that this task marks the beginning of construction; those connected to the end

node signify that, after their completion, construction will be over. Overall, a precedence

diagram's resulting web of nodes and their connecting lines gives a graphical, process-oriented

overview of construction.

In establishing the connecting lines or *relationship* between tasks, there are three

fundamental questions that are asked:

1) What task(s) must be completed before this task can begin?

2) What task(s) cannot begin until this task is completed?

3) What task(s) can proceed at the same time as this task, without interfering with this

task's execution?[149]

Typically, the physical nature of tasks will provide the answer to these questions. Since the

laying of a roof, for instance, must always follow completion of the walls, the relationship

between the two tasks is fixed according to *hard logic*.[150] In other cases, though, relationships

between tasks are discretionary.[151] Building materials for a roof physically can be gathered while

the walls are being constructed; because of limited labor, personal preferences, or tradition,

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[149] Del Pico 2013, 67.
[150] Mubarak 2010, 49.
[151] Mubarak 2010, 49.

though, a choice might be made to complete the walls first and only then begin gathering roofing materials. This type of relationship is said to rely on *soft logic*.[152]

Using hard or soft logic, two general temporal relationships between tasks emerge; a task may be subsequent to or concurrent with another task. In practice, these two temporal links are represented by four specific relationships used in precedence diagramming (Fig. A.2): finish-to-start, start-to-start, finish-to-finish, and a combined relationship.[153] The simplest and most common type of these is finish-to-start (FS) which indicates that the first task, or *predecessor*, must be completed before the following task, or *successor*, can start, as in the above roofing example. A start-to-start (SS) relationship indicates that one task cannot start until the other has already started. Finally, a finish-to-finish (FF) relationship is comparable to start-to-start, but shows that one task cannot be completed until another has already been completed. These last two types may be used together in a combined relationship so that both the start time and the finish time of one task is entirely dependent on the start time and finish time of another task. For example, if quarrying and transporting stone are two separate tasks, then these could be linked using a combined relationship; since the transportation of stone cannot start until quarrying begins, a start-to-start relationship would be needed, and since it could not finish before quarrying was completed, a finish-to-finish relationship would be also added. In this way, one avoids a paradoxical model in which stone can be transported before it is quarried.

To make these four logical relationships more realistic, a minimum waiting period between activities, known as lag time, can be added.[154] Using the example above, stones could

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[152] Mubarak 2010, 49.
[153] Mubarak 2010, 87–8. Another relationship, start-to-finish (SF), also exists, but is very rarely used.
[154] Mubarak 2010, 32–3.

not rationally be transported at the exact moment quarrying started since it would take some

startup time to remove the first stones. Here, a lag might be added to the start-to-start relationship

to indicate the minimum time before transportation could begin. Lag can be expressed in

absolute time or as a percentage, which represents the amount of the predecessor task that must

be completed before the successor task can begin. A lag time may also be negative. In this case,

it is typically called a lead time. In precedence diagramming, a lag or lead time is listed next to

the relationship which it affects. Two types of graphical representations for these four

relationships and the placement of lag time are shown in Figure A.2. The first uses distinct line

placement to indicate the relationship while the latter, output by Microsoft Project,[155] uses the

same line placement with an abbreviation of the relationship type.[156] Microsoft Project has no

way to represents a combined relationship between two tasks, so this type of relationship must be

accounted for in scheduling by inserting a zero-duration placeholder task (Fig. A.2 D). This

placeholder serves to link the two tasks through a finish-to-finish relationship. Graphically it is

more complex and it adds to the list of tasks, but it achieves a combined relationship in

scheduling.

A hypothetical precedence diagram derived from the earlier WBS (Fig. A.1) illustrates

how these concepts are put into practice (Fig. A.3). At the left and right of the precedence

diagram are situated the nodes indicating project start and project finish. Between these nodes,

the layout of tasks from left to right approximates the progression of construction over time. Two

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[155] Microsoft Project is an application commonly used for all phases of project management. This study uses its functionality as a task and labor scheduling tool for construction projects. For more details on Microsoft Project, see Biafore 2013.

[156] The former is commonly used, but the latter is output by Microsoft Project, which is used for scheduling within this dissertation. Both are presented here for the sake of completeness. Microsoft Project has no graphical representation of a combined relationship. This relationship must be approximated in scheduling via other methods.

task nodes, "dig trenches" and "gather stones," are connected to the project start. Either one or

both of these tasks will mark the beginning of construction and the two may be performed

concurrently. The right side, or finish, of both tasks is connected to "lay foundations" by a finish-

to-start relationship indicating that foundations can only be laid after both tasks have completed.

The same is true with "make mudbrick" which can only begin after the foundations are done.

The use of a finish-to-start relationship here is a good example of soft logic. Mudbricks could

just as easily be started at the very beginning of construction since they do not interfere with any

of the preceding tasks. In this example, though, a choice has been made to delay this task in

order to concentrate first on the foundations. Once mudbricks start to be made, the start-to-start

relationship with "lay mudbrick" and its lag time specifies that builders can commence laying

these mudbricks only after a minimum wait of two days. The lagged finish-to-finish relationship

similarly requires a minimum of two days after mudbrick making is complete before the laying

of the mudbrick can be finished. Finally, the laying of mudbrick is connected to the project finish

designating that after this task, the mudbrick wall is complete. A second version, using Microsoft

Project's graphical representation, is given in Figure A.4. The Microsoft Project format will be

the standard used throughout the later part of this study.

Once a reasonable precedence diagram has been created, the next step in CPM is to

assign durations to each task.[157] As in architectural energetics, each task's duration is a function

of volume, task-rate, and the number of laborers working on the task[158] so that mathematically

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[157] Pierce 2013, 67–75.

[158] Microsoft Project has three task types: fixed work, fixed units, and fixed duration. The tasks used here is fixed work, meaning each task always required a certain number of person-hours and its duration will vary based on the number of people working on it. This is also known as an effort-driven task, since the amount of effort put in drives the duration of the task.

the duration in hours (D_h) is equal to the units of material (U) divided by the product of the task-rate in units per person-hour (R_{ph}) and the number of laborers (L).

$$D_h = U / (R_{ph} * L)$$

For example, if there are 100 m³ of limestone (U=100) and masons work at a rate of 0.5 m³ / ph (R_{ph}=0.5) to lay a wall, the duration of the task for 10 masons (L=10) would be:

$$D_h = 100 / (0.5 * 10)$$

$$D_h = 20 \text{ hours}$$

Durations can then be converted from hours into days, weeks, months, or years as necessary by dividing the appropriate number of hours based on hypothesized timeframes. In CPM, this data is typically summarized in a tabular format for all tasks. For our mudbrick wall example, fictitious data for each task's volume, task-rate, cost in person-hours, assigned laborers, and duration in days appears in Table B.1.

Having established task relationships, assigned laborers, and calculated task durations, CPM makes it possible to examine ways that construction could have progressed in real time. To do this, CPM utilizes the relationships and task durations to calculate each task's earliest possible start (ES), latest possible start (LS), earliest possible finish (EF), latest possible finish (LF), and float (F), which is the amount of time a task may be delayed without delaying the project's finish date.[159] When CPM was first employed in the 1950s, these calculations were completed by hand.[160] A *forward pass* was first performed in which ES and EF were calculating by following chains of relationships from the project start to project finish and summing task durations. Next, moving along task chains from project finish to project start, a *backward pass* was performed to

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[159] Pierce 2013, 75–7.
[160] Baldwin 2014, 4–5.

calculate the LS and LF. Finally, F was calculated as the difference between LS and ES.[161] Presently, these calculations are easily performed by many types of planning software. Microsoft Project is used for all such calculation in this study.

In professional construction management, the information derived from the forward and backward passes of CPM can be added back into the original precedence diagram following a standard layout. Figure A.5 shows the layout of this information. In this standard node, two types of measurements are present: start and finish boxes represent the day on which the task can begin or end (i.e. a calendrical time); the duration and float represent the amount of days that the task will last or can be delayed (i.e. a length of time). Using this layout, the data has been added to the precedence diagram for our mudbrick wall (Fig. A.6). There are a few points to take away from this schedule. First, each task lists its ideal range of start (ES to LS) and finish dates (EF to LF). For most of the tasks, there is only a single ideal start (ES equals LS) and finish (EF equals LF). Gathering stones, for example, has a matching ES and LS so that it can only begin at the start of day one and finish at the end of day four. The float, or time it could be delayed without affecting the project's overall finish date, is therefore zero. Tasks with floats of zero are consequently known as critical tasks.[162] Delay of a critical task or an increase in its duration means the overall project duration must also increase. For every project, in fact, there is a chain of critical tasks that runs from the project start to the project finish nodes and drives the project schedule. This is aptly termed the critical path, hence the Critical Path Method.[163] In our example, the critical path (Fig. A.6 in red) includes all tasks except digging trenches. Because digging trenches has a float

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[161] The mathematics of the forward and backward pass are explained in detail by Mubarak 2010, 43–81.
[162] Mubarak 2010, 44–5.
[163] Mubarak 2010, 58–9.

of one day, it could finish one day late without affecting the finish date of the project. A task

with float, which does not drive the schedule, is therefore called non-critical. By moving along

the schedule's critical path and summing its tasks' durations, the Critical Path Method shows that

construction of the mudbrick wall would ideally finish at the end of day 13 based on the task-

rates, volumes, and laborers assigned earlier. It is important to underscore that this is an ideal

schedule, the veracity of which is reliant on the quality of the data and assumptions built in to the

model. If our data or assumptions change, our schedule will change. The great strength of this for

prehistoric architecture, however, is that we can compare the explicit effects of different

interpretations and datasets without being forced to accept one 'correct' model of construction.

Although displaying this data in the precedence diagram can give a very explicit picture

of the model, it is also cumbersome, especially when there are many tasks. As a replacement for

such precedence diagrams, a time-scaled bar chart, termed a Gantt chart is frequently used.[164]

Presenting the information in a Gantt chart makes the schedule of construction more readable by

removing many of the numerical elements that can crowd a precedence diagram. The exact same

information from Figure A.6 is presented in a Gantt chart in Figure A.7. Calendrical time, here

measured in the day number of the project, is represented along the upper horizontal axis. Along

the left vertical axis, the tasks of the project are listed. The blue bar corresponding with each task

represents both when the task may start during the project and what its duration is. Note the

black line and bar that are part of "Dig Trenches." This line and bar is a representation of float. A

further advantage of using a time-scaled Gantt chart is that other time-scaled charts can be

incorporated to illustrate details of the construction model, such as summary events that can be

expanded or collapsed on the Gantt chart (Fig. A.8), the number of workers on site during any

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[164] The name derives from its creator, Henry Gantt; see Mubarak 2010, 13–9.

given day (Fig. A.9), or the cumulative energy expended by workers over time (Fig. A.10). For these reasons, Gantt charts and their time-scaled companion charts are preferred and are used in place of detailed precedence diagrams in this study.

The incorporation of CPM and its attendant modeling concepts advocated by Smailes marks an important move towards exploring the human dynamics of construction. In Smailes' case, the method was used to study a complex of buildings and to establish an overall time for construction and labor needs.[165] The method is equally applicable to the study of isolated structures, though. Since it envisions construction through the lens of human behaviors grouped into tasks that variously overlap, precede, or succeed one another, this method permits us to build on traditional energetics while moving away from its emphasis on summed labor-costs and moving towards dynamic picture of construction that stress timeframes, choices, and changes in human labor.[166] Importantly, the combined use of CPM and energetics does not validate any single schedule or demand a construction model be organized in only one way. When used in modern construction, CPM allows project managers to better confront future uncertainties by explicitly thinking through organizational plans and comparing the potential impact of different actions.[167] In the same vein, for the study of archaeological remains, CPM is an advantageous tool for thinking; it lets us explore ideas about how humans produce architecture by linking the material remains and inferred behaviors in explicit models which can then be compared, questioned, altered, or refuted.

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[165] Smailes (2011) applied the method to the Ciudadela Rivera compound at the site of Chan Chan, Peru.
[166] Smailes 2011, 54–62.
[167] Mubarak 2010, 2–9.

By confronting the integration of tasks, specific assignments of workers, and schedules of construction, the fusion of architectural energetics and the Critical Path Method is a practical step towards exploring architectural production at a closer range. The idea central to this approach, that the building process is a network of many intersecting and overlapping activities through which raw materials are transformed, furthermore, overlaps with the useful chaîne opératoire framework, which has been widely employed in the social sciences.[168] While the construction management approach to energetics helps us ponder the structure of architectural production and various strategies of production, incorporating the chaîne opératoire framework brings additional focus to how the staging of construction intersects with the experiences of agents and the meaning and implications of their actions. Altogether, such a combined methodology of architectural energetics, the Critical Path Method, and chaîne opératoire offers the means to tackle the earlier characterization of architectural production as a process of coproduction carried out by complex-embedded agents. This combined method opens an inroad for exploring the individuals, resources and tools, and spatial and temporal configuration of construction starting from the material remains of buildings so that the juncture of energy, actions, agents, and material remains can be studied.

Incorporating the Chaîne Opératoire

The chaîne opératoire,[169] or "operational sequence," is both a descriptive and analytical framework which, at its root, promotes a thorough consideration of the technical processes

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[168] This overlap has been recognized by Knappett 2011.
[169] The term comes from Leroi-Gourhan 1964.

through which humans transform raw materials into finished goods.[170] The framework offers a means to describe the ordering and logic of activities which constitute a productive process and to highlight the remains of these particular productive activities within the material record. Conceptually, chaîne opératoire views productive activities as links in a chain through which raw materials pass as they are transformed into culturally meaningful objects. This conceptualization of production is metaphorically likened to a film: each technical activity is a scene which is marked by the entrance or exit of a material, tool, or actor, and is composed of rudimentary technical gestures; scenes then entwine across time and space to portray the total transformation of raw material(s) into a final product.[171] Abstractly, each scene or technical activity can be envisioned as a purposeful change of a material from state A to state A + x, in which x represents the technical gestures, tools, actors, and knowledge which alter the material.[172] As these activities enchain through time and space, a technical process arises.

This concentration on technique, technology, and technical process has always been central to the terminology of chaîne opératoire. While the meaning scholars assign to each term has been variable,[173] Dobres has especially enlivened and advanced the chaîne opératoire framework by using "technology" in an active, humanistic sense. For her, technology is not simply mechanical techniques and movements, separated from the individual,[174] but it is "the social practice and the process-*ing* of the material world . . . not reducible to the activities of

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[170] On the different uses of chaîne opératoire, see Balfet 1991a; Schlanger 1994; Dobres 2000, 167–70; Martinón-Torres 2002.

[171] Desrosiers 1991.

[172] Balfet 1991b, 13.

[173] Dobres 2000, 47–95; see also Dobres 2010a, 103–7.

[174] Dobres (2000, 50–60) attributes the division of the things being made and the agents making them to philosophical trends originating in the Enlightenment.

artifact making and use."[175] Technology exists in its practice; it is performed and acted out as the dynamic interplay of categories that are often heuristically separated such as social organization, beliefs, politics, and economy, among many others.[176] It is through technology that individuals --- often termed technicians in chaîne opératoire --- materialize worldviews and values.[177]

Under Dobres' rubric, technology becomes an encompassing term for many types of productive acts, which palpably includes what I refer to as architectural production. So too, architectural production is not simply the mechanical gestures used to create a building or the physical remnants of raw materials modified by humans; it is the suite of processes undertaken by complex-embedded agents who engage with and are engaged by the material world through their transformation of raw materials. Martinón-Torres has cleverly described this concept as the "length" and "width" of the chaîne opératoire.[178] The length of the chaîne opératoire is the literal movement of materials through stages as a productive process marches towards completion. Discrete tasks are performed in a spatial setting using tools to transform raw materials and, as time progresses, these tasks enchain lengthwise with one another to create a final product. Along the length of the chaîne opératoire is where we can isolate expenditures of energy, tangible material changes, and movements in time and space; it is also where we expect to find direct archaeological correlates of production. For example, in the common application of chaîne opératoire to prehistoric lithics,[179] activities along the length are starkly attested by debitage from reductive stages. On the other hand, the width of the chaîne opératoire is less tangible and relates

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[175] Dobres 2000, 96. These ideas emerged, like the chaîne opératoire itself, out of the earlier work of Mauss and Leroi-Gourhan, which is variously summarized in Sellet 1993, 106–8; Schlanger 1994, 144–5; Martinón-Torres 2002, 30–1.
[176] Dobres 2000, 96–126.
[177] Dobres 2010a, 106.
[178] Martinón-Torres 2002, 31 fig. 1.
[179] For example, see Bar-Yosef and Van Peer 2009.

to a central idea of Mauss, one which is firmly reiterated by Dobres, that in creating the material

world, man also creates himself.[180] While the technical and gestural processes of material

transformation form the chaîne opératoire's length, for Martinón-Torres the width describes the

socially, economically, and politically embedded nature of these material actions. Along the

width exist the human agents driving production and the tension of the agency/structure dialectic,

both of which interlock with the material transformations along the chaîne opératoire's length.

In its attentiveness to the series of operations through which raw materials are

transformed (i.e. its length), the chaîne opératoire and its idea of enchained tasks overlaps nicely

with the use of precedence diagramming found in the construction management approach to

energetics; both stress the staging of productive processes, and the material choices and problems

builders confronted during construction. They equally recognize that many tasks may occur at

once so that construction is not viewed as inherently linear or fixed. Tasks progress through time

at various speeds, overlay one another, and cross paths as materials move between the stages of

production or enchain with one another.[181] Stones may be quarried while others are raised and

still others are smooth dressed, all concurrently, so that the building site becomes a web of

material and human action and interaction. What the chaîne opératoire brings to the study of

architectural production which the construction management approach lacks, though, is its

uniquely human consideration of these actions and interactions (i.e. its width). Even as

construction management equally offers a way to model or chart the structuring principles of

production, it takes, as the name implies, a managerial or high-level producer view so that labor

is often spoken of as being allocated and the completion of a project tends to be viewed as an

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[180] See especially Dobres 2000.
[181] Pelegrin et al. 1988, 60.

inevitably.[182] Such an outlook adds undeniable value to the study of architectural production, but the chaîne opératoire encourages us to consider that this labor is not lifelessly assembled like cogs in a machine; it is many conscious human agents, each of whom is complexly-embedded within a social, political, and economic environment, and straddles the intersection of his own individual worldviews and larger structural phenomena while producing the material world around himself.[183] The tasks of the critical path method, in this way, become human-centric interactions, played out in precise settings, using particular tools and materials, and affecting as well as being affected by many external forces.

Although the use of chaîne opératoire in scholarship has not always taken this path, sometimes being used only as a means to chart out the physical stages of production like precedence diagramming, it is more profitably used to create richer pictures of human practices in the past by understanding the interaction of width and length, social and material. Since charts of production alone "fail to provide any sense of the interactive social milieu in which certain sequential technical operations did (or did not) occur,"[184] Dobres has vociferously argued for the fuller material, social, and embodied approach which she refers to as "engendering the chaîne opératoire."[185] To engender the chaîne opératoire is many things, but central is the concept that material production is also social production[186] so that not only is the staging of material transformations important but so are the performances of production "in socially constituted and

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[182] For examples of prehistoric projects which failed, potentially with great impact on the builders' positions in society, see Richards 2004, 78–9; Cummings and Richards 2014 (October 29),

[183] This thesis is widespread in Dobres 2000.

[184] Dobres 2000, 175.

[185] Dobres 2000, 164–211, 2010a, 2010b.

[186] Dobres 2000, 173.

materially grounded contexts."[187] To link Dobres' and Martinón-Torres' terminology, the act of engendering is to recognize the duality of the chaîne opératoire, both studying its materially-correlated length and inferring its embedded-agentive width. As such, the chaîne opératoire framework agreeably complements the construction management approach to energetics by underscoring the social, economic, and political unfolding of material production. While still acknowledging the consequence of larger organizational practices, overall project durations, and top-down choices, chaîne opératoire enhances the method's utility for confronting agentive aspects of production. By forging strong inferential links between production and the arenas in which it transpires,[188] it places weight on situated human practice so that the interactions of humans and materials, *and* humans and humans become entangled objects of study. In practice, this engendering or "widening" of the chaîne opératoire (and thus, the widening of energetics and construction management) can be operationalized by traversing analytical scales.

Paradoxically, to understand small-scale agentive practices and their material expressions through engendering the chaîne opératoire requires that we simultaneously grasp large scale spatial, temporal, and social realities, and that we readily tack back and forth between microscale and macroscale datasets.[189] Because the indivisibility of structure and agency[190] means that humans act in settings which preexist and yet are also reconstituted by human action, understanding small scale acts of construction necessitates a context of larger spatial, temporal, and social patterns. As complex embeddedness posits, agents are historically situated and are influenced by their perception of external realities while they (inter)act at the confluence of the

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187 Dobres 2000, 155.
188 Dobres 2000, 155–7.
189 For example, see Pauketat and Alt 2005.
190 Joyce and Lopiparo 2005, 369; Robb 2010, 497–9.

social, political, and economic.[191] In taking a multiscalar approach, we aim at the bull's-eye of smaller scale human activities but envision the entirety of the target in order that we may hit head-on the tensions of agency and structure, tradition and innovation, individual and group.[192] For studying architectural production, tacking backing and forth between analytical scales occurs in multiple ways. First, in looking at techniques used for a certain building and when inferring those architectural elements that are lost, a larger view of regional architectural practices must be taken. Viewing an individual building against a background of preexisting regional architecture underscores normative and deviant practices, and isolates how builders balanced tradition and innovation to accomplish goals in a specific productive setting. Cross-cultural and ethnographic examples are equally beneficial here to reason how tool marks and material remains might correspond with different building techniques. Second, pictures of regional history and daily life offer clues to the dynamic milieu in which builders worked. The categories of evidence for social class, political offices, administrative practices, exchange mechanisms, access to material goods, and economic differentiation depict, in part, the environment in which builders operated. During material production this environment of structural forces was both influential and influenced so that, for example, individuals and groups could acquiesce to, resist, or create certain worldviews as they built.[193] Third, broader economic datasets can supply additional information on building techniques. Ancient practitioners and producers did not innately categorize and compartmentalize the material world in the way archaeologists do by isolating ceramics, lithics, architectural materials, animal or plant byproducts as separate manifestations of reality.[194]

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[191] Boettke and Storr 2002; Lewis 2004; Migone 2011.
[192] Dobres 2000, 134–41.
[193] Pauketat 2000.
[194] Dobres 2010c.

Techniques employed in daily activities such as making pots, chipping stone, or tilling the land may equally be employed during construction. Particularly if builders are drawn from wide segments of the population and lack knowledge of large-scale construction practices, their experiences in other daily activities can impact the perceived 'right way' to build. Beyond techniques alone, the products of these various productive activities may also intersect with construction through the enchainment of multiple chaînes opératoires.[195] Pots, stone tools, and leather, which each originate from distinct productive sequences, may ultimately be employed in parts of a building's chaîne opératoire, while productive activities themselves, particularly farming, may structure the timing and organization of building activities. Finally, the wider landscape around the building site is meaningful. Not only will the spatial configuration of activities change as different resources are employed, but the preexisting landscape affects the physical location of a new building and the meaning it will have. Likewise, if construction is thought of as performance, then the audience which inhabits the surrounding landscape is witness to the material transformations and social negotiations as they transpire. The performance of architectural production has been implicated as an important topic in other parts of the world. Pauketat and Alt note that "to the extent that any given practice involved collective labor or coordinated performances, it probably created communal sensibilities—or resistance to such sensibilities"[196] and Love has fruitfully framed mudbrick construction as performance at Çatalhöyük, where builders were able to make visible statements to one another with materials that became invisible in the finished structure.[197] Love argues that "construction is an act of

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[195] For examples of enchainment in craft production at Tiryns, see Brysbaert and Vetters 2010; Brysbaert 2013.
[196] Pauketat and Alt 2005, 217.
[197] Love 2013.

performance that constantly repeats, reinforces and contests social roles in a public setting."[198]

To modify this statement somewhat, the theory of complex-embeddedness also tells us that these

performances equally repeat, reinforce and contest economic roles alongside social roles.

Studying architectural production as performance, specifically by using the data from this study

to address how construction activities moved through the landscape, how the scale of activities

changed, and how activities engaged the wider population in their daily lives can reveal

significant information about larger social, political, and economic impacts.

The Method and Its Application to Mycenaean Greece

By uniting aspects of architectural energetics, construction management through the

Critical Path Method, and chaîne opératoire, I present a flexible methodology for exploring

architectural production at a close range. In contrast to traditional architectural energetics, this

approach goes beyond pure tabulations of energetic costs which are used to discuss scale and

power. Instead, the method focuses on the production of architecture by individuals, their labor

and material actions, and the integration of these individuals and their actions across time and

space. Therefore, the method is intimately bound up with the theoretical discussions in Chapter 2

of agency, human-material interactions, and the reconciliation of economy and society through

complex-embeddedness. This method allows us to think about architecture as a process by

building upon the concept of labor (not simply viewing architecture as a finished product whose

scale is passively measured in labor) and to think through the production of individual

Mycenaean structures. My application of the method is broken down into the following steps:

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[198] Love 2013, 264

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1) The material remains and archaeological context of a structure are described in detail.

2) The material remains and inferred missing elements are combined to create a logical reconstruction of the original structure. A 3-D model of the reconstruction is made in AutoCAD.

3) A task-centric analysis of the construction process is presented which considers the builders' decisions, raw materials, tools and techniques, and the spatial and temporal organization of production.

4) Using the 3-D reconstruction and task-centric analysis, raw materials are quantified and task-rates are applied to estimate the person-hours for each discrete task. Task-rates, expressed in units / person-hour (ph), are estimated using available data from experiments, ethnographic studies, and early modern construction manuals. All data on materials and task-rates are published with full discussion in Appendix C.

5) The task-rates are presented in an energetic flowchart. Figure A.11 illustrates the symbols and layout of an energetic flowchart. I have created this format of flowchart specifically to unify traditional energetics studies, which present person-hours in a tabular format, and a work breakdown structure used in the Critical Path Method, which is a hierarchical diagram of a building and its major components broken down into sub-components and tasks. The energetic flowchart is read from left to right and hierarchically breaks each structure into components, sub-components, materials, and tasks. Each task lists the relevant quantity of material the builders used and the estimated person-hours builders expended to complete that task. The energetic flowchart acts as aid in modeling the process of architectural production and also links up with graphical techniques used in many studies of the chaîne opératoire.

6) The tasks established in the energetic flowcharts are entered into Microsoft Project and relationships between the tasks are established using hard and soft logic. A precedence diagram is created to model the logical integration of these tasks during the production of the structure.

7) Ranges for the builders who worked at each task are estimated in order to generate possible task durations. The range consists of three numbers. The upper bound of workers for each task represents a maximum hypothesized number, the lower bound of workers represents a minimum hypothesized number, and a middle number represents a hypothesized reasonable number of workers. To determine these numbers, the physical layout of the building site is significant since only so many can feasibly work at one time. The three numbers representing the range of workers are fed into a statistical distribution that weights the middle number.

8) Using Palisade @Risk, a Monte Carlo simulation tool, and Microsoft Project, a simulation is run for 1,000 iterations during which the statistical labor distribution for each task is sampled and used to generate a possible schedule of construction. The simulation mimics the various ways to organize labor during construction. During simulation, Palisade @Risk records statistical information on how labor changes alter the scheduling of individual tasks, the completion time for the project, the peak number of laborers working at a given time, and the sensitivity of the simulation to specific labor changes.

In the following chapters, the production of four building projects is analyzed, modeled, and simulated with the above method: the Treasury of Atreus at Mycenae, structure 4-VI and 7-X from the Mycenaean harbor town of Kalamianos in the Corinthia, and the Northeast Extension

of Mycenae's fortification wall. I have selected these as case studies, first, because of their individual significance so that the analysis of each is independently meaningful. As a group, the structures have the further advantage of offering unique but complementary viewpoints from which to discuss the larger role of architectural production in Mycenaean Greece. Chronologically, these projects span LH IIIA2 to the end of LH IIIB2 and together, provide some diachronic sense of the economic importance of architecture at the height of the Mycenaean period in the Argolid and Corinthia. Politically and spatially, each is also linked, albeit in different ways, with changes in the Argolid and Corinthia that accompanied the rise of Mycenae so that collectively they offer a perspective on the role of architectural production during this expansionary period. Finally, each exemplifies a distinct function, as a mortuary, domestic/urban, and defensive project, so that a picture emerges which recognizes the disparate uses of architecture.

After closely discussing the production of the above structures in Chapters 4, 5, and 6, I model and simulate schedules of production for each in Chapter 7. There, I discuss the energetic flowcharts and the results of simulation. Despite the different approach taken to architecture in this study and my criticism of traditional evolutionary theory, Chapter 7 includes some discussion of traditional energetics which helps to better situate this study within previous work in the Aegean as well as to illustrate how this approaches differs. Finally, Chapter 8 folds the resulting data into larger concepts. The results of Chapters 4–7 are used to discuss particular aspects of the Mycenaean economy and stress the value of viewing architecture through the lens of production. Ultimately, I utilize my study of the production of the Treasury of Atreus, the houses of Kalamianos, and the Northeast Extension of Mycenae's fortification wall to rethink the traditional interpretations of monumentality and power by emphasizing how human agents move

through the landscape, to discuss how builders interact with one another and make decisions during production, to explore why individuals may have participated in building projects, and to address what architectural production and the focus on human action taken in this study says about models of the Mycenaean economy.

CHAPTER 4

THE TREASURY OF ATREUS, MYCENAE

Background to the Treasury of Atreus

The Mycenaean Tholos Tomb

Mycenaean tholoi are circular, vaulted tombs typically built into a bedrock hollow and covered over with earth. As a general type, they have four main components (Fig. A.12): the dromos, an unroofed corridor which leads from the natural ground level through the bedrock cutting to the burial chamber; the stomion, an entrance to the burial chamber built on a pier-and-lintel system which was sometimes closed with a door or blocking wall; the chamber or tholos proper, the vaulted room in which the remains of the deceased were laid out or buried; and a tumulus, the heap of earth which covered the tomb and acted to counterbalance the outward force of the domed chamber.[1] Despite these common characteristics, there is an amount of variation among tholoi depending, among other factors, on their date of construction, their geographical location, and the presumed status of the deceased. Currently, there are well over 100 known examples of Mycenaean tholos tombs, appearing on the Greek mainland as far north as Thessaly as well as in the Ionian islands.[2] Many of these have unfortunately been plundered of their original grave goods and their domes have collapsed due to erosion of the tumulus so that it is often not possible to know their exact date of construction or their original architectural form.[3]

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[1] For more detailed discussions of the form of tholos tombs, see Pelon 1976; Como 2007, 19–50.

[2] Kontorli-Papadopoulou (1995, 111 n. 2) updated the 108 examples found in Pelon (1976) to 136. Since 1995, however, a number of additional tholoi have been found.

[3] Some were already being looted and destroyed during the Late Helladic period (Papazoglou-Manioudaki 2011).

As a new manner of burial on the mainland, the tholos tomb first appeared in western Messenia during MH III. The earliest example is thought to appear at Koryphasion, but a few others may be equally early.[4] In their original conception, tholos tombs were a geographically limited phenomenon; between MH III–LHI, their construction was prominent only in Messenia and to a lesser extent in Triphylia and southern Elis.[5] At this time, their form was not yet standardized, sometimes lacking elements like a well-defined dromos, and they occurred in a variety of sizes.[6] By LH IIA, tholoi had spread widely across mainland Greece. Beyond their continued use in Messenia, they now appeared at major settlements in Laconia, the Argolid, Attica, and Achaea.[7] The tomb's form, at this time, had reached a standard layout, employing the typical dromos-stomion-chamber configuration. Finally, in LH IIIA–B, tholoi were built at the northern fringes of Mycenaean Greece, but elsewhere construction of tholoi was noticeably curtailed, especially in Messenia and the Argolid which boasted only a few late examples.

Given the far-reaching development of the Mycenaean tholos tomb, there is an ongoing endeavor to explain the basis for the tomb's appearance on the MH III mainland.[8] Typically scholars fall along a continuum which at its extremes regards the tomb as either a Minoan transplant or as a purely Helladic development. Those who fall towards the Minoan side posit a connection between tholos tombs on Crete, which first appeared in the Messara during EM I, and the emergent mainland examples.[9] Those towards the Helladic side hypothesize a link to MH

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[4] Blegen 1954; Pelon 1976, 198; Lolos 1989.
[5] Bennet and Galanakis 2005, 145–6.
[6] Papadimitriou 2011, 476, n. 51.
[7] A tholos tomb found in 2006 at Cheliotomylos, just outside of Ancient Corinth, may be part of this expansion since its construction is comparable to Wace's Group I. Its finds date from LHI–IIIC and its exact date of construction is not clear (Kasime 2013).
[8] Fitzsimons (2006, 92–100) summarizes the major arguments within this debate; see also Pelon 1976, 442–53.
[9] Hood 1960; Branigan 1970, 151–60; Pelon 1976, 442–53; Kanta 1997.

tumuli and cite the sometimes considerable differences in the construction of Minoan tholoi.[10]

Although this debate has no clear resolution, the Minoan tholoi may be more closely linked both

technically and chronologically to early mainland forms than is acknowledged by proponents of

a purely mainland origin.[11] Voutsaki has rightly argued that the more important question is not

the derivation of the tomb's form, but rather "what kind of ideological and social needs [the

tholos] fulfilled,"[12] especially in light of the tholos' regional and chronological evolution.

Whether inspired by Minoan tombs or not, by LH IIA the tholos tomb was a purely Mycenaean

form whose tripartite layout of dromos-stomion-chamber and architectural elaboration had

evolved in an atmosphere of increasingly visible burial rites.[13]

Overview of the Tholoi at Mycenae

In the Argolid, tholoi appeared during LH IIA as an integral part of competitive display.[14]

Unlike in Messenia, where the earliest tholoi show a continuum of sizes and wealth, those first

built in the Argolid had already taken on a large form. This sudden use of the tholos as a

conspicuous marker of status is not surprising given the hierarchical, competitive nature of

burials already apparent in the earlier Shaft Grave Period.[15] Between LH IIA–IIIB, a total of

fourteen tholoi were built in the Argolid, nine of which appeared at Mycenae (Fig. A.13).[16]

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[10] Cavanagh and Laxton 1981; Korres 1984, 1993; Cavanagh and Mee 1998, 44–6; Fitzsimons 2006, 92–98; Wright 2006b; Galanakis 2011, 16–7.
[11] Kanta 1997.
[12] Voutsaki 1998, 43.
[13] Voutsaki 1998; Gallou 2005; see also Papadimitriou (2011) who moves away from an 'elite competition' explanation and argues for a more nuanced reconfiguration of burial practices.
[14] Fitzsimons 2006, 2007, 2011.
[15] Voutsaki 1999.
[16] Pelon 1976, 403–11.

Based on their architectural elaboration and scale, Wace divided these nine tholoi into three

groups which are thought to reflect the relative chronological development of the tombs.[17]

  Wace's first group, to which the Cyclopean Tomb, Epano Phournos, and the Tomb of

Aegisthus belong, is most "primitive." Among these the dromos is not lined with masonry and its

walls are made of the bedrock into which the tomb was cut; the stomion is shallow but tends to

utilize larger stones than the rest of the tomb; the lintels are short, lack relieving triangles, and do

not follow the interior curve of the dome; and the chamber is built of limestone rubble.[18] Only

the Tomb of Aegisthus, which has a partially lined dromos and recently discovered relieving

triangle, offers an exception to this typology and in this regard, it is possibly a transitional type

between group one and group two.[19] To group two belong Kato Phournos, the Panagia Tomb,

and the Lion Tomb.[20] This group shows an increasing use of masonry and an evolving technical

ability: the dromos is now fully lined with rubble or poros ashlar; the stomion is built of dressed

conglomerate and can employ decorative poros ashlar; the lintels are long, have a relieving

triangle, and conform to the dome's curvature; and although the chamber continues primarily to

use rubble masonry, there is an increasing propensity to include dressed stones, particularly as

basal courses.[21] Finally, Wace's group three, which includes the Tomb of the Genii, the Tomb of

Clytemnestra, and the Treasury of Atreus, is most technically advanced and represents the

pinnacle of Mycenaean builders' skills. In group three, the dromos is generally lined with ashlar

masonry; the stomion is built of large, well-dressed conglomerate and, in the case of the Tomb of

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[17] Wace 1921–1923b, 387–93.
[18] Wace 1921–1923b, 287–316; 1949, 16.
[19] The conglomerate and poros ashlar façade of the Tomb of Aegisthus may be a later addition, but Galanakis (2007) presents a counterargument.
[20] Wace 1921–1923b, 316–30.
[21] Wace 1921–1923b, 330–87; 1949, 16–7.

Clytemnestra and the Treasury of Atreus, the façade is lavishly decorated; the lintels are very large and have relieving triangles; and the chamber is fully constructed of ashlar conglomerate.[22]

While Wace's groups present an assumed relative order for tholos construction, it is more difficult to assign specific periods or absolute dates to the tholoi.[23] In the case of group three, following Wace, most place the construction of the Treasury of Atreus after the Tomb of the Genii and before the Tomb of Clytemnestra[24] but the suggested period of construction for Atreus has ranged from LH IIIA1 to LH IIIB2. The basis for this range hinges on the interpretation of three stratified deposits uncovered by Wace (Fig. A.14). The first deposit was excavated in 1920–1921 in a trench dug across the dromos approximately five meters from its eastern end. Here, a gap in the rock under the dromos was filled with mortared limestone, rubble, and earth in order to provide support for the dromos' walls and ensure the dromos floor was level.[25] The pottery recovered from this fill was overwhelmingly LH III, with a few LH II examples, and it included an LH III terracotta figurine.[26] Unfortunately, the finds were never pinned down more exactly within LH III. The second deposit, also excavated in 1920–1921, was found when Wace removed the tholos' threshold. Underneath, a packing of earth and stone yielded gold leaf, bronze nails, scraps of ivory, and a few sherds.[27] A yellow-clay mortar ensured that the finds formed a sealed deposit and that no intrusive materials had seeped in.[28] At the time, the threshold finds were dated to the beginning of LH III, early in the 14th century, based on comparanda

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[22] Wace 1949, 18.
[23] Wace 1921–1923b, 287–387; Pelon 1976, 372–91; Fitzsimons 2006, 100.
[24] Wace 1949, 16–9.
[25] Wace 1921–1923b, 341 fig. 70.
[26] Wace 1921–1923b, 339–42.
[27] Wace 1921–1923b, 347–9, 356–7.
[28] Wace 1921–1923b, 347–9.

found in association with the Lion Gate.[29] Finally, a third deposit was excavated in 1939 to the

north and south of the dromos at a point 10 m from the tomb's facade.[30] This deposit, known as

the Atreus Bothros, consisted of domestic refuse including animal bones, shells, figurines,

painted plaster, and numerous sherds of pottery. The ceramics were again overwhelmingly LH

III with a few earlier examples of LH I and II types. Stylistically, nothing could be dated later

than the Mycenaean ceramics at Amarna.[31] As a sealed deposit of domestic character which was

cut by construction, this established a strong *terminus post quem* of the mid-14th century, a date

which at the time agreed well with the other deposits. In the 1960s French refined this

chronology somewhat. Initially, she dated the bothros material to LH IIIA1 with some early LH

IIIA2 inclusions[32] but later she argued the bothros had a clear-cut date of LH IIIA1 with LH

IIIA2 precursors.[33] Around the same time, a painted deep bowl sherd found in the threshold

deposit was problematically re-dated from early LH III to late LH IIIB.[34] The situation that

resulted and which remains today is that the three stratigraphically sound deposits offer a

conflicting picture: the Atreus Bothros suggests an LH IIIA1 or IIIA2 date for construction; the

threshold deposit suggests an LH IIIB2 date; and the dromos deposit confirms only a date

somewhere in LH III.

    In response to this problem, some have suggested that the finds under the threshold do

not date to the initial construction of the tholos, but represent a later deposit formed when the

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[29] Wace 1921–1923b, 349.
[30] Wace 1940, 239 fig. 1, 242.
[31] Wace 1940, 245–6.
[32] Only the deposit's painted pottery survived World War II; see French 1963, 45–6.
[33] French 1964.
[34] Mylonas 1957, 87–9; French 1963, 46

threshold was removed and reset.[35] Mylonas, though, questioned why the threshold would have

been removed and reset in LH IIIB well after construction had been completed;[36] he contrarily

believed that the deep bowl was contemporary with construction and accordingly, he dated the

tomb to LH IIIB. In support of this date, Mylonas additionally cited the tholos' clear-cut stylistic

similarity to the Lion Gate, a point which Wace himself had previously used to support his own

chronology.[37] At the time of Wace's statement, though, the Lion Gate was thought to date to the

mid-14th century B.C.E., and like the original dating of the deep bowl sherd, this rendered a date

of LH IIIA2.[38] Mylonas' own study of the fortifications, however, altered this chronology and

down-dated the Lion Gate to LH IIIB1, a period closer in time to the deep bowl sherd.[39]

The collective result of the threshold deposit, bothros deposit, and the style of the tomb

has led to an unresolved dispute.[40] Within the range of LH IIIA1 to LH IIIB2, though, I contend

that a reasonable period for construction is between LH IIIA2 and early LH IIIB1 for a few

reasons. First, as a sealed domestic deposit which originated from houses on the Panagia Ridge

antedating the Treasury of Atreus, the Atreus Bothros suggests LH IIIA2 is the earliest possible

starting point for construction. The presence of late LH IIIA1 materials which already presaged

LH IIIA2 forms[41] and Wace's assertion that some of the sherds were indicative of styles found at

Amarna[42] both suggest an early LH IIIA2 *terminus post quem*. Even if the bothros marks the end

of LH IIIA1, such an early construction date is unreasonable: it would imply that the builders of

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[35] French 1963, 46 n. 29; Cavanagh and Mee 1999, 94. Note, however, that Wace (1921-1923b, 349) believed the threshold was part of the original construction and formed a sealed deposit.
[36] Mylonas 1966, 122 n. 47.
[37] Wace 1921–1923b, 352–3; 1921–1923a, 13; 1949, 50–1; Mylonas 1957, 87–9.
[38] Wace 1921–1923b, 12–3; 1949, 132–4.
[39] Mylonas 1966, 19–22, 28–31
[40] These dates are represented by French and Mylonas, respectively.
[41] French 1964.
[42] Wace 1940, 245–7.

Atreus cleared the upper Panagia Ridge of domestic debris; purposefully uncovered a large pocket in the bedrock down slope; threw the debris, including pottery, figurines, and painted plaster into this unearthed pocket; and then excavated the center of the debris deposit as they cut the tomb's dromos. For the *terminus ante quem* of construction, Mason has argued for an early LH IIIB1 date for the Tomb of Clytemnestra's construction.[43] If we are right to follow Wace's typological ordering of the tholoi in the third group, then early LH IIIB1 should mark the end range for Atreus' construction. Additionally, there is good cause to believe that the LH IIIB2 threshold deposit is not from original construction. A variety of destructive events occurred at Mycenae between LH IIIA2 and LH IIIB2, including an earthquake at the end of the LH IIIA2, which destroyed Petsas House and the House of the Wine Merchant, and another in LH IIIB1, which caused extensive damage to the Panagia Houses.[44] It is not unreasonable to imagine that a wooden door and frame, having already been exposed to the elements, and a threshold made of multiple, thin stone slabs would buckle or break under such stresses while the tomb's heavy duty conglomerate masonry, flexibly coursed with chinking, remained undamaged.

Finds under the threshold which accompanied the LH IIIB2 deep bowl sherd back the theory that the threshold was reset well after the primary burials had occurred, possibly in preparation for a new burial. Among the threshold finds, which included gold leaf, ivory, and bronze nails, beads were also uncovered. While Wace had called the first three substances "decorator's waste," he noted that beads were much harder to explain away.[45] In fact, a green snail bead from under the threshold exactly matched one found by Stamatakes when he cleared

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[43] Mason 2013.
[44] Shear 1986; Shelton 2010.
[45] Wace 1921–1923b, 349.

fill from the stomion in the 19th century.[46] Interestingly, Stamatakes' finds also included an array

of gold debris comparable to the quantity under the threshold.[47] The presence of similar items in

fill above and below the sealed threshold (especially the matching bead) is exactly what would

be expected if the tomb were reused. The act of clearing earlier burials would have scattered the

remnants of decayed grave goods, a process attested in chamber tombs, and when a new

threshold and door were set to reclose the tomb after this recent use, fragments of these earlier

grave goods and part of an LH IIIB2 deep bowl were sealed below.

The Treasury of Atreus

Architectural Description of the Treasury of Atreus

East of the Treasury of Atreus a large retaining wall was built in cyclopean style (Fig.

A.15). The wall, where it is preserved, has large limestone boulders on the exterior stacked up to

2 m high in four to five courses. The boulders are backed by a rubble core which is most clearly

seen at the northeast corner.[48] The wall is approximately 27 m long and supports a large platform

in front of the tomb's dromos.[49] Since the bedrock of the Panagia Ridge naturally slopes sharply

to the east, this wall helps to retain the artificial leveling in front of the tomb. Approximately 25

m west of the retaining wall, the dromos begins. It runs east-west and measures 6 m wide x 36 m

long.[50] The dromos was excavated directly into the bedrock of the hill and its floor was

originally covered in packed clay (Fig. A.16).[51] On both sides, the dromos is lined with walls of

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[46] Wace 1921–1923b, 354 find #91 (b).
[47] Wace 1921–1923b, 353–4.
[48] Thiersch 1879, 177–8.
[49] Thiersch 1879, pl. 13; Wace 1949, 28.
[50] Wace 1921–1923b, 338.
[51] Wace 1921–1923b, 339.

hammer-dressed conglomerate blocks. The blocks decrease in size as the walls rise, but many are very large. The largest, which was used to straddle a wide pocket in the bedrock and provide a stable seat for higher courses, appears in the north wall and is c. 6.00 m long x 1.25 m wide.[52] Generally, the courses of the walls are irregular.[53] In a few cases, the blocks have L-shaped profiles where an upper portion of stone was removed in order to fit a block in the succeeding course (Fig. A.17). The horizontal and vertical joints between blocks are only roughly worked and often wide, particularly at the corners of blocks which are prominently rounded. The edges of blocks are slightly obtuse and, overall, they appear loaf-like, which is a mark of hammer-dressing.[54] The dromos' walls increase in height from 0.5 m to over 10.0 m as they run east-west and approach the façade.[55] Its upper courses were worked in order to show an uneven sloping profile. Behind the conglomerate blocks, which act only as a façade, is a thick wall of limestone rubble and yellow clay mortar which is further backed by a claybrick wall (Fig. A.18).[56] Together, these two backing walls retain the surrounding mass of earth and ensure the dromos' walls are water-proof. On their hidden sides, the conglomerate blocks of the dromos are unworked and occasionally bond with the rubble wall.[57] The rubble wall is seated directly on bedrock and the claybrick wall sits on a thin layer of rock-chips 0.1–0.3 m thick which appears to be debris from construction (Fig. A.19).[58] Both backing walls are quite thick and their

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[52] Wace 1921–1923b, 339–40, fig. 70.
[53] This type of masonry is sometimes termed 'broken ashlar'.
[54] Protzen's (1985, 169–76) hammer-dressing experiments support this.
[55] Pelon 1976, 173.
[56] Wace 1939, 211–2; 1940, 238–40.
[57] Wace 1940, pl. 2.
[58] Wace 1940, 240–1, fig. 2.

thickness increases from east to west as the dromos' walls rise higher. The rubble backing wall is 2–3 m thick and the claybrick backing wall is 2.5–4.0 m thick.[59]

The façade of the tomb measures c. 10.5 m high and is divided into three parts: the lower façade, the exterior lintel, and the upper façade (Fig. A.20).[60] The dromos' walls generally abut the lower façade, but in a few cases, a block will project slightly into the lower façade (Fig. A.21).[61] The lower façade is 5.4 m high and consists of nine regularly laid courses of conglomerate.[62] Both the horizontal and vertical joints of the lower facade are much tighter than in the dromos, in response to which some have suggested use of a saw here rather than a hammer.[63] The center of the lower façade is pierced by the stomion which tapers slightly as it rises, gradually shrinking from 2.70 m wide at the bottom to 2.45 m wide at the top.[64] To the north and south of the doorway, two conglomerate plinths remain in situ. They are rectangular and have been cut into a stepped pattern using a band saw.[65] Their tops have dowel holes which once secured carved half-columns, parts of which remained in situ until the early 19th century.[66] The stomion is framed by two fasciae which were made with a hammer and finely edged with a saw.[67] Above the lower façade, the fasciae continue onto the exterior lintel block. The exterior lintel is slightly wider than the façade and is c. 1.1 m high. It is deceptively shallow, measuring

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[59] Wace 1940, 238–9.
[60] Wace 1949, 29; Pelon 1976, 173.
[61] Wace 1921–1923b, 342.
[62] Wace 1949, 29; Fitzsimons 2006, 132.
[63] Wace 1921–1923b, 342; Wright 1978, 231.
[64] Wace 1921–1923b, 346–7; 1949, 29. Entrances with a slight incline are common at Mycenae and also appear in the Lion Gate (Iakovidis 1983, 30), the Tomb of Clytemnestra (Wace 1921–1923b, 360–1), and the Tomb of the Genii (Wace 1921–1923b, 378).
[65] Wace 1921–1923b, 342–4, fig. 72; Küpper 1996, 14–6, abb. 129, 130.
[66] Gell 1810, 29–30. The remains of these half-columns are now housed in the British Museum (registration number 1905, 1105.1-3).
[67] Wace 1921–1923b, 342.

c. 1.6 m deep while most of the stomion is covered by a second, significantly larger interior

lintel.[68] Above the exterior lintel are two more plinths which would have supported a second set

of short half-columns.[69] Finally the upper façade consists of ten preserved courses, of which the

upper course projects slightly like a cornice.[70] A large relieving triangle, measuring c. 2.5 m

wide x 3 m high on the exterior, pierces the upper façade.[71] Its form was achieved through

corbelling and hammer dressing.

The façade is marked by a number of drill holes to which a variety of carved stonework

was once fastened.[72] Only fragments of this decoration remain and the original appearance of the

façade has been subject to some debate.[73] On both sides of the stomion, two half-columns were

carved from green-grey marble[74] in a zigzag pattern and topped with capitals of the same stone.[75]

The capitals were level with the top of the lintel and were capped by the two projecting plinths

built into the façade. Two smaller half-columns also carved of the green-grey marble stood on

these upper plinths. At the top of the façade, above the relieving triangle, this arrangement was

concluded with a row of projecting conglomerate stones.[76] Between the smaller half-columns,

the relieving triangle was embellished with a variety of carved stones possibly including

decorations of beam ends, spirals, and bulls.[77]

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[68] Exact measurements of the exterior lintel are not published and are derived from P. de Jong's plan (Wace 1921–1923b, pl. LVI).
[69] Wace 1921–1923b, 342–4.
[70] Wace 1921–1923b, 345–6; 1949, 29–30; Mylonas 1966, 121.
[71] The relieving triangle lacks published measurements (supra n. 68).
[72] Thiersch 1879, tafel XIII.
[73] See Younger 1987.
[74] The green-grey and red stones used on the façade are thought to have been imported from the Kyprianon *rosso antico* quarries (Ellis et al. 1968).
[75] Wace 1949, 29.
[76] Wace 1949, 30.
[77] Wace 1949, 29–31, fig. 51; Mylonas 1966, 120–1, fig. 114; Ellis et al. 1968, 331–3, fig. 1; Younger 1987.

The stomion leading to the interior of the tomb measures 5.40 m high x 2.7–2.45 m wide x 5.40 m deep.[78] It consists of nine regular courses which continue the coursing of the lower façade. The blocks of the stomion tend to be long so that each course contains only two to three blocks while the vertical joints of succeeding courses are staggered. The floor of the stomion is covered with limestone slabs except in the center where there is a slightly raised, 1.2 m long threshold.[79] The threshold is made primarily of two roughly squared conglomerate slabs. A large gap between the slabs was filled with two pieces of poros limestone. The use of poros between the conglomerate slabs was a practical feature which ensured the threshold was flush with the stomion walls. After the conglomerate had been set, one larger poros slab was inserted and then a small, wedge-shaped piece was hammered in, forcing the conglomerate against the stomion walls.[80] The inner edge of the threshold has been worked in order to receive a door. In line with the threshold, two sets of nail holes which would have held in place a wooden doorframe run vertically along the north and south stomion walls.[81] On the interior lintel above, two holes were drilled for the pivots of a double door.[82] This interior lintel covers the majority of the stomion and measures c. 5.0 m long x 8.0 m wide x. 1.2 m tall.[83] As a single block of conglomerate, it has previously been estimated at 100–120 tons.[84] Both the interior edge of the stomion and the lintel block adhere to the curvature of the tomb's chamber.

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[78] Mylonas (1966, 121) provides a depth of 5.2 m, but this is likely to be incorrect since an equal depth and height are also found in the Tomb of the Genii (Pelon 1976, 166–7) and the Tomb of Clytemnestra (Pelon 1976, 167–71). This also contrasts with his earlier measurements of 5.4 m (Mylonas 1957, 86).
[79] Wace 1921–1923b, 347–9; 1949, 31.
[80] Wace 1921–1923b, 347–9, pl. LVII; 1949, 31.
[81] Thiersch 1879, pl. XII; Wace 1949, 31.
[82] Mylonas 1966, 121; Pelon 1976, 174.
[83] Wace 1921–1923b, 346.
[84] Wace (1921–1923b, 346; 1949, 31) estimated it at 100 tons and Mylonas (1966, 121) suggested 120 tons. My estimation differs somewhat and is presented later.

The main chamber is 13.39 m high and has a diameter of 14.60 m.[85] It consists of 33

courses of conglomerate, which become progressively smaller as the height of the chamber

increases.[86] The joints between blocks appear tight and were made with some care; however, the

rising joints are superficial and only remain flush for a depth of a five to ten centimeters (Fig.

A.22).[87] Beyond this, the blocks taper to form a triangular hollow. The hollow space between the

blocks is packed with stones and clay in order to ensure the security of each course.[88] The face of

the blocks have been hammer dressed to form the vertical and horizontal curvature of the

chamber.[89] Of the thirty-three horizontal courses that constitute the dome, nine align with the

stomion/lower facade, two align with the interior lintel, and twenty-two compose the upper half

of the dome.[90] Up to the 11th course the stones measure c. 0.5–0.8 m tall and from the lintel to

the capstone c. 0.2–0.4 m tall.[91] From the third to the fifth course are regular nail holes meant to

fasten some type of decoration, possibly rosettes. In the courses above, further nail holes for

decoration appear irregularly.[92] Above the interior lintel, the relieving triangle of the façade

continues into the chamber, although its height and width are smaller than on the façade,

measuring 2.5 m wide x 2.2 m high.[93]

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[85] Mylonas 1957, 86. Wace (1949, 32) offers a slightly different measurement of 13.2 m high with a diameter of 14.5 m. In any case, the difference is negligible and will vary depending on where the measurement is taken.
[86] Cavanagh and Mee 1999, 99.
[87] Blouet 1833, 152.
[88] Blouet 1833, 150; Wace 1921–1923b, 350; 1949, 32; Pelon 1976, 174–5.
[89] Pelon 1976, 174–5.
[90] Fitzsimons 2006, 134–5.
[91] Cavanagh and Mee 1999, 99. Pelon (1976, 174 n. 6) says the lowest course is 0.9 m high.
[92] Tsountas and Manatt 1897, 120; Wace 1921–1923b, 350; Fitzsimons 2006, 135.
[93] These measurements are derived from P. de Jong's plan (Wace 1921–1923b, pl. LVI).

The north wall of the chamber is pierced by a doorway 1.5 m wide x 2.5 m high. Like the main entrance, it was topped with two lintels and a relieving triangle.[94] The threshold is lost but pivot holes in the outer lintel and bronze nails along the walls indicate that a wooden door and doorframe once existed here.[95] For a depth of 2.4 m this doorway is lined with worked conglomerate that aligns with the coursing of the main chamber. Beyond is a passage which widens to 3 m and is cut directly into the bedrock. The rock-cut passage runs for 2 m until a small, roughly-squared chamber is reached, c. 6 m wide x 6 m long x 6 m high.[96] It is also cut directly into bedrock, but the discovery of two conglomerate column bases within may indicate that it was once lined and roofed in a manner similar to the Treasury of Minyas at Orchomenos.[97] A grave pit, 1.75 m long x 0.80 m wide x 0.45 m deep was dug into the side-chamber's northwest corner, but no human remains were discovered.[98]

The entirety of the tomb and the area behind the dromos' walls were covered by a large tumulus. Over the centuries the tumulus has shifted with erosion, but in its original form the pinnacle would have sat over the main chamber's capstone. A retaining wall helped to support the outward thrust of the tumulus and ran in a partial circle with a radius of 25 m around the chamber before turning east to roughly parallel the dromos' walls c. 10 m to their north and south.[99] At the dromos' entrance, the north and south retaining walls turned in at a right angle and abutted the end of the dromos' walls. The dromos itself was then closed off with a short wall of poros blocks, part of which remains in situ.[100] The retaining wall was built of rubble and faced

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[94] Wace 1921–1923b, 350.
[95] Wace 1921–1923b, 350–1.
[96] Wace 1921–1923b, 351.
[97] Wace 1921–1923b, 351, pl. LVII a.
[98] Wace 1921–1923b, 351–2.
[99] Wace 1939, 212; 1940, fig. 1, 2, pl. 4; 1956, 116–9.
[100] Wace 1949, fig. 40b.

with poros ashlar. The wall's rubble backing consisted of rough limestone tightly packed with clay. It was c. 1 m thick, although it narrowed at the top, and its height is preserved up to 1.5 m.[101] Ashlar blocks of finely worked poros were attached to the rubble wall with dovetail clamps (Fig. A.23). As with the construction of the main chamber, the vertical joints of the poros blocks touch only superficially before tapering inwards.[102] A number of poros blocks with a triangular profile may have surmounted the wall and acted as a coping course.[103]

The CAD Model

The excellent preservation of the Treasury of Atreus and Wace's published excavations significantly ease the creation of the tomb's CAD model. Still, a number of elements are necessarily simplified and some are further excluded in order to reach a model which illustrates the important structural elements as accurately as possible and yet is manageably analyzed. In a number of cases, to improve upon uncertainties, Como's meticulous interpretations of Wace's data are essential as is knowledge from other tholoi.[104] Perhaps the easiest way to go about describing the resultant model and its supporting evidence is literally from the ground up, beginning discussion with the bedrock, moving upward through the major structural elements, and concluding with the crowning tumulus.

The slope of the bedrock in the model is based on Como's proposed two-dimensional bedrock profile (Fig. A.24).[105] Como generated this profile, which slopes from east to west with

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[101] Wace 1956, 116.
[102] Wace 1956, pl. 25 c, d.
[103] Fitzsimons (2006, n. 42) remarks that both the shape of the coping blocks and the fact that they are carved in the round makes them atypical for the Late Bronze Age. Therefore, it seems best to regard them as a later addition.
[104] Como 2007.
[105] Como 2007, fig. III.8.

the natural contours of the Panagia Ridge, from Wace's soundings in 1939 on the north and south sides of the dromos.[106] Plotting the depth of the bedrock in each of Wace's trenches and incorporating the theory, first suggested by Holland,[107] that the tomb's lintel matches the original hill level, she drew an idealized slope line from east to west and extrapolated it through the tomb's chamber. Since Como's slope line is the best estimate that exists and is based on actual measurements of bedrock, I have used it to approximate in three dimensions the bedrock into which the Treasury was dug. Naturally, extending the two-dimensional slope into three dimensions is an oversimplification; while it approximates the general rise from east to west, the slope of the bedrock likely fluctuates considerably and Wace's excavations (and the Atreus Bothros in particular) show that the hill is regularly pockmarked by large clefts and hollows.

Where the model's smooth, simplified bedrock slopes away at the east, there is a section of leveling fill. The exact depth and extent of this fill are unknown but, its existence here is not in question since both Thiersch and Wace noted that the cyclopean wall to the east of the Treasury supported a large terrace here (Fig. A.24).[108] The slope of the bedrock, the large pocket of fill discovered by Wace in the dromos' eastern end,[109] and the cyclopean wall to the east insinuate that this fill began somewhere under the final meters of the dromos and extended perhaps 30 m to the east. The model does not include the full potential extent of the fill nor is the cyclopean terrace wall added. Instead, I have incorporated only the area of fill necessary to provide a level perch for the dromos.[110]

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[106] Wace 1940; Como 2007, 73–4.
[107] Holland 1921, 397.
[108] Wace 1921–1923b, 338.
[109] Wace 1921–1923b, 341 fig. 70.
[110] The terrace is later excluded from energetics calculations because of its uncertain volume.

As is traditional for Mycenaean tholoi, the model's bedrock is deeply excavated to receive the masonry of the dromos and lower half of the chamber, and for the Treasury of Atreus in particular, to form the side chamber. For the dromos, the model's bedrock is cut only to the bottom of the façade which underestimates the actual depth of excavation. Foundation stones are visible in a few cases underneath the lower course of the dromos and a thick layer of clay surfaced the dromos floor.[111] This clay layer is excluded from the model because its depth is known in only one location and its extent is unclear. In its place, I have left the bottom of both the dromos and chamber as raw bedrock. The width of the dromos' excavation is evened to 9 m. This accounts for each wall's 1.5 m thick masonry and the 6 m width of the dromos between the two walls. The dromos masonry itself, which sits in this excavation, runs from 0.5 m high at its eastern extremity to 10.5 m at the west where it matches the height of the stomion (Fig. A.25). The upper courses of the dromos are leveled off in the model, although they have a stepped outline in plan. Excavation for the stomion continues the 9 m width of the dromos since the dromos' walls clearly abut the tomb's facade. The two lintel blocks of the façade and the stomion follow the measurements of Wace. None of the possible decorations for the façade is included in the model nor is the threshold or wooden door added to the stomion.[112]

Beyond the stomion and dromos, the excavation for the chamber has a 19.4 m diameter at the bottom. Here the chamber is 14.6 m in diameter and the lowest course of the dome's masonry is an estimated 2.4 m thick. This measurement derives from the depth of the side chamber's stomion which pierces the chamber's lowest courses.[113] Rather than a simple cylindrical

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[111] Fitzsimons 2006, 135.
[112] The production of these decorative elements is a point for future exploration.
[113] Wace 1921–1923b, 350; see also Como 2007, 75–77.

excavation, the chamber's excavation slopes inward with the curvature of the tomb.[114] This slope

is difficult to estimate, but the upper course of the chamber's masonry was drawn in the 19th

century and measures c. 0.9 m thick (Fig. A.22).[115] To account for the unknown thickness

between the lower course and upper course, the bedrock excavation and the masonry are

assumed to mimic the dome's interior curvature which is taken from Wace's plan. Again, this is

a simplification based on the available evidence and there is likely more space between the

masonry and bedrock which is filled in with rubble, as seen in other tholoi. Finally, the cutting

for the side chamber and its passageway are simplified in the model. Since it was dug directly

into the bedrock, the side chamber is irregular. In the model, though, the passageway and side

chamber have been squared off. The passageway is an even rectangle 2.5 m deep x 3.0 m wide x

4.2 m high and the side chamber itself is a cube of 6 m. The model's side chamber comes off of

the main chamber at exactly 90 degrees, although it is slightly off-kilter in reality. The possibility

that the side chamber was roofed with a cut slab in a manner similar to the Treasury of

Orchomenos is excluded from the model. The size of the side chamber's stomion, relieving

triangle, and two lintel blocks are taken directly from Wace's plan.

Behind the masonry facade of the dromos, stomion, and main chamber are thick rubble

and clay layers. Measurements for these hidden elements are only known for the dromos where

Wace excavated (Fig. A.19), but to make up for this, I have relied on Como's extrapolation of

the measurements for the remainder of the tomb.[116] For the dromos, the rubble wall behind the

façade measures c. 2.0 m thick and c. 0.4 m high at the east end and runs to c. 3.0 m thick and c.

4.5 m high at the west end of the dromos. Immediately behind it, is a claybrick wall which

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[114] This curvature is visible in plan above the side chamber's relieving triangle (Fig. A.16).
[115] Blouet 1833, pl. 66.
[116] Como 2007, pl. III.6.

measures c. 2.6 m thick and 0.3 m high at the east end and runs to c. 4.0 m thick and c. 4.5 m high at the west end. The claybrick wall slopes slightly away from the dromos façade. How the claybrick and rubble elements continue beyond the dromos' west end is difficult to tell. In the model, a rubble wall is included to the north and south side of the stomion. This is suggested by published images from the Tomb of Clytemnestra which show the courses of the tomb's façade become irregular where the dromos abuts and then become rubble construction.[117] Wace's sections may also support this but are somewhat unclear.[118] For the sake of estimation, the thickness of the rubble here continues the thickness of the dromos' rubble backing. No claybrick wall is added behind the stomion, although it is possible that one exists.[119] Behind the chamber's masonry, Como has inferred a thick layer of rubble and claybrick which mimics the configuration of the dromos' backing.[120] I have extended her plan into three dimensions by mirroring the curvature of the chamber so that the rubble and claybrick backing are quite thick at the bottom but decrease as they curve towards the chamber's pinnacle. The presence of claybrick is supported by evidence from other tholoi, but its thickness is suspect and represents the least certain element of the model. Clay layers found around the Tomb of Aegisthus,[121] for example, seem to be thinner layers of applied clay which do not match the thick claybrick walls that are included in the model. On the one hand, this is a weak aspect of the model, but on the other hand, that the dome of Atreus did not collapse over the past three millennia equally suggests that the builders did include an extensive and strong claybrick layer which made it impervious to the effects of moisture and soil erosion.

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[117] Wace 1955, pl. 34.
[118] See in particular Section E-F in Wace 1940, fig. 2
[119] Section E-F (Wace 1940, fig. 2) does point out one area of clay, but its form is unclear.
[120] Como 2007, pl. III.6.
[121] Taylour 1955a, 207–9.

Surrounding the entirety of the tomb is the peribolos wall. Between the rubble backing of the masonry and the peribolos wall the model includes an even, 0.15m thick level of chipped rock. Wace's excavations show this layer behind the dromos' walls[122] and I have extended this to appear behind the chamber. This layer may or may not have been intentional as it seems to be partly composed of debris from working the façade and rubble courses. The peribolos' circular section runs in a c. 25 m radius around the center of the chamber and then roughly follows the dromos' walls, although with a noticeable inward angle. In the model, the peribolos' rubble and mortar backing is seated directly on bedrock. This rubble backing is evenly set at 1.5 m thick at the bottom and 1.5 m high. After it rises 0.5 m, the thickness decreases to form a 0.5 m step in order to form a perch for the poros façade which is 0.5 m thick and 1.0 m high. I have not added any coping course to this poros since it is suspect nor has a blocking wall been included at the eastern end of the dromos. Finally, a tumulus caps the tomb and hides the clay and rubble elements. The tumulus has heavily eroded over the millennia so its form in the model is tentative. Figure A.26 shows a cutaway of the model illustrating all of the major elements of the tomb.

<div align="center">Producing the Treasury of Atreus[123]</div>

Planning to Build

Prior to the start of any construction activities some level of project planning is always required. The degree to which builders and patrons planned in advance before undertaking architectural projects, though, is murky for much of the ancient world. For the Mycenaeans of

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[122] Wace 1940, 240–3.

[123] The energetic flowcharts illustrating the process of constructing the Treasury of Atreus are found in Figures A.98–105. Each individual energetic flowchart is referenced when the relevant part of the construction process is discussed.

the LH III Argolid, the evidence is poor at best; however, the remains of the Treasury of Atreus, the other tholoi at Mycenae, and written and artistic sources from the Bronze Age Near East illuminate the process of architectural planning. Regarding the Treasury of Atreus, the first point to make is that, by necessity, the builders knew in advance that they would construct a tholos. Although this risks stating the very obvious, the fact that builders and patrons consciously selected the type of building they would construct is a salient aspect of project planning with implications that are ease to ignore. As in later Greece, where the general form that a new temple could take was strongly constrained by conventions of time and place,[124] the simple choice to build a tholos tomb had an immediate and limiting effect on the project's layout and organization.

In broad survey tholoi vary across regions and time, yet the developed form of the tomb is conservative in its articulation of the dromos, stomion, and chamber.[125] At Mycenae, tholoi contrast in such elements as the type of masonry, the curvature of the lintel, and the decoration of the façade, but despite their visual or technical differences, over the course of centuries there is virtually no innovation in the formal layout of the tomb; the only true novelty is the addition of a side chamber to the Treasury of Atreus. Otherwise, the form is fixed: a tholos must have a dromos; it must have a façade pierced by a single stomion; the stomion must be roofed with larger lintel blocks; the chamber must form a dome; and the dome must be capped with an earthen tumulus. In the act of choosing to build a tholos, builders immediately placed themselves within this tradition which set out clear conventions for the tomb's form. Such architectural conservatism and its accompanying framework of proper practices has a pronounced advantage

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[124] Coulton 1977, 58–9.
[125] For examples, see Pelon 1976.

when starting a new building. With little effort and no formal planning, the choice of a traditional building type lays out the boundaries for a project; the builders are then able to concentrate on fleshing out their own individualizing details without planning the whole project *ex nihilo*. Additionally, operating within a conservative architectural tradition means that builders gain access to a preexisting store of knowledge and rules-of-thumb that further ease the task of planning. At the time of Atreus' construction, during the final phase of tholos construction at Mycenae, there are customs upon which the builders of Atreus drew: tradition preferred that the dromos be elongated rather than squat, that the stomion's depth mimic its height, and that the diameter and height of the chamber be approximately equal. By choosing a scale, builders could already form a workable mental template for a new tholos. The more challenging problem is what came next. After tradition set the general form and gave some idea of the appropriate proportions for the Treasury of Atreus, how were the exact details of the tomb fixed and did this require tools such as models and plans?

The use of models and plans in ancient construction is a thorny question and there is no direct evidence for the use of either in Mycenaean Greece. A few Minoan and Archaic house models have been found, but these fulfilled votive functions with no clear use in architectural planning. The evidence for plans or models to lay out construction is slightly better if we look to the Bronze Age Near East and Egypt, although it is still underwhelming. For Egypt, where good evidence for construction practices exists, Arnold provides a mere 16 examples of architectural plans, primarily from the New Kingdom.[126] Three of these are likely demonstration objects meant to impress a patron and not intended to be used by builders.[127] These demonstration

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[126] Arnold 1991, 8 table 1.1; see also, Rossi 2004, 96–138.
[127] Arnold 1991, 9.

objects provide overall dimensions but add fancy details, such as landscape illustrations or additional labeling. Another of the examples is a votive plan of an existing temple, which includes a list of the temple's contents and shows no purpose in construction.[128] The remaining plans occur on paving slabs, ostraca, and once on papyrus, and may have been used by the builders themselves. These include ground plans and rough sketches of buildings, quickly drawn architectural details, such as the curvature of a vault or the plan of a staircase, and one example of an elevation on papyrus.[129] The limited evidence for the use of plans in ancient construction cautions that planning did not often take the route of modern practices which rely heavily on drawings.[130] For the Treasury of Atreus, in addition to proportional rules of thumb and a conservative building form, a standardized system of measurement facilitated the planning process without requiring drawn plans.

In laying out the Treasury of Atreus, Como observed that the tomb was fitted into a "geometric module" which, along with the proportional rules of thumb, fixed the dimensions of some of the tomb's components.[131] In her interpretation, the tomb used a base measurement (M) equal to the thickness of the masonry dome, which she put at 2.43 m, negligibly different than Wace's 2.40 m. She confirmed that the chamber and dromos utilized this base unit so that the sum of the chamber's diameter and masonry was 8M (19.44 m) and the dromos was 15M (36.45 m) long and 2.5M (6.075 m) wide.[132] The presence of a modular layout is a significant piece of

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[128] Arnold 1991, 9.
[129] Arnold 1991, 8 table 1.1.
[130] For historical Greece, particularly in the Hellenistic period, Coulton (1977, 53–6) points out that architects did not rely on scale plans, but used technical specifications (*syngraphai*) and specimens of particular elements (*paradeigma*).
[131] Como 2009, 386–7.
[132] Note that these measurements are somewhat greater than the published 6 m x 36 m for the dromos. Generally, there are discrepancy in the measurement of tholos tombs.

information on how the Mycenaeans planned the tomb. Its use within the Treasury of Atreus also goes beyond what Como published and, under further analysis, offers some evidence for reconstructing a Mycenaean system of linear measurements.

The first point to make in expanding upon Como's modular system is a logical one: from the perspective of a system of measurements, 2.40–2.43 m is quite large and, if the system is to be widely useful, this measure should be composed of subunits. Identifying such subunits is difficult and a well-known problem on Crete where attempts have been made to explain the metrology of the Minoan palaces.[133] The problem is, of course, that the process of reconstructing units involves tinkering with numbers so that it is always possible that a proposed unit will reflect one's biases more than an actual ancient unit of measure. For the Treasury of Atreus, though, the tomb's measurements compellingly point to a system based on a foot which measures 1/8th the thickness of the masonry or c. 30.0–30.4 cm (abbreviated as F in future measurements).[134] If we apply this foot unit to the tomb as a whole, the results are attractive. The modular layout and proportions discussed by Como are refined to a more practical unit with which builders could easily work. Figure A.27 shows how this system of feet applies to the Treasury of Atreus. Moving from Como's measurements, the masonry at the base of the chamber can now be expressed as 8F (2.4m), the diameter of the chamber as c. 48F (14.4), the dromos' length as 120F (36m) and its width as 20F (6m).[135] To these observations, some supplementary components can be added, which also support the use of a foot. These include the height of the façade (35F; 10.5 m); the depth, height, and lower width of the stomion (18F x 18F x 9F; 5.4 m x

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[133] Graham 1962; Preziosi 1983; Soles 1991.

[134] The existing measurements are not necessarily accurate enough to pin down the unit of measure to less than one centimeter. We also should not expect that ancient builders were so industrially exacting that errors were not introduced into measurements.

[135] Como 2007, 81–3; 2009, 386–7.

5.4m x 2.7m); the width and depth of the side chamber's stomion (5F x 8F; 1.5m x 2.4m); the side chamber proper (roughly 20F x 20F x 20F; 6m x 6m x 6m); and potentially the height of the chamber (c. 44F; 13.2m).[136]

Beyond these suggestive numbers, there is other restricted support for a Mycenaean foot of 30.0 to 30.4 cm. First, this Mycenaean foot is very similar to Graham's Minoan foot of 30.36 cm which is in evidence at Phaistos, Malia, Knossos, and Gournia.[137] The chronological difference between the Minoan and Mycenaean example might suggest that the measure was borrowed from the Minoans or that this foot was neither specifically Mycenaean nor Minoan but was a more widely used measurement in the Bronze Age Mediterranean. In regards to the latter, it is worth pointing out that the Egyptian palm (4 palms = c. 30 cm) and the smaller Djeser (c. 30 cm) correspond well. Second, a quick glance at the Treasury of Minyas at Orchomenos, which has been noted for its similarity to the Treasury of Atreus, demonstrates other occurrences of the foot (Table B.2). Its measurements further suggest that the foot should be slightly above 30 cm and perhaps closer to the 30.3 cm mark.

A Mycenaean system of linear measurements for construction is a captivating topic and the Treasury of Atreus, at least, offers hints of its existence. For the future, this requires a full study of multiple buildings to determine the accuracy of the Mycenaean foot, fill in other units to understand the larger system of measurements, and see what patterns emerge in the use (and non-use) of this system, especially as it relates to palatial involvement in construction. For now, the central point to make is that the builders of the Treasury of Atreus did used a fixed system of measurements to set the tomb's dimensions, and this was likely based on a foot. Coupled with

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[136] Wace's measurement of 13.2 m would make it exactly 44 F; Mylonas' measure of 13.39 m makes it just under 45 F.
[137] Graham 1960, 1962, 224–9.

rules of thumb on proper proportions this system of measurements streamlined the layout

process. A builder with some experience could configure the tomb in his head and assign real

dimensions to its major components once he knew the scale he wanted. Such measurements are

easy to convey in specifications (i.e. written descriptions) rather than in a drawn plan. With a

general layout in mind, the builders and any administrators involved next had to utilize the

specifications to consider the timeline, materials, and resources for the project.

The Linear B texts related to architecture[138] include a few references to the movement or

absence of construction personnel, but none directly demonstrates this aspect of architectural

planning. The closest evidence for this process exists in Egypt and Mesopotamia where texts

cover how builders accounted for labor, time, and materials. Papyrus Reisner I and III, from the

early twelfth dynasty, describe the management of construction as it was in progress. In the

papyri, the volumes of materials for construction tasks are estimated, the daily output of men is

fixed, work targets are expressed in man-days, and the differences between work completed and

work targets are calculated to plan for future work.[139] While this process was documented by

administrators in day-to-day accounts which could later be summarized for higher level

administration, Ezzamel points out that this basic input-out approach was beneficial to illiterate

workers who could understand how their performance matched quantified work targets and then

grasp the number of days left to work;[140] to function, the method depends only on a numerate

population rather than a literate one. Even earlier, in 3rd millennium B.C.E. Mesopotamia, the

same approach is found. Old Babylonian and Ur III texts calculate labor and volumes for brick-

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[138] Discussed supra, pp. 31–38.
[139] Simpson 1963, 1969; Ezzamel 2004. This is effectively the same process as architectural energetics and illustrates the long history of estimating in construction.
[140] Ezzamel 2004, 513.

making, carrying materials, digging canals, and building specific types of walls.[141] Like the

Papyrus Reisner, these texts relied on general rules to estimate volumes and time. For example,

to predict the amount of materials needed, a wall was assumed to be 5/6th mudbrick and 1/6th

mortar.[142] By discounting variability and local conditions, these estimations were a quick way to

plan for construction without becoming bogged down in messy details.

In modern construction, the planning process seen in Egypt and Mesopotamia is termed

quantity surveying. For quantity surveying to be most effective, G.R.H. Wright argues that there

should be recognized standards of measure for five categories: dimensions (linear, area, and

volume); weight; materials; output of labor; and prices for materials and labor.[143] Though

architectural quantity surveying is not represented in the Linear B tablets, the Linear B record

does reflect some of the standards that would facilitate quantity surveying, such as measurements

for weight and volume (to which we can add the archaeological evidence for linear

measurements) and fixed ration systems for laborers.[144] More crucially, the tablets reveal that the

estimating, input/output mentality at the root of quantity surveying was a fundamental tool of

Mycenaean palatial administration.[145] The *ta-ra-si-ja* system is a clear instance of this.

As a method of organizing production, the *ta-ra-si-ja* system was employed by the

palaces for portions of the cloth weaving, bronze-working, and chariot wheel manufacture.[146] In

these industries, the system relied on quantifying inputs or expected outputs for workgroups and

individuals. The broadest case comes from the Knossos cloth tablets. Here, parts of the Lc, Le,

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[141] Robson 1996, 181–2.
[142] Robson 1996, 189–90.
[143] Wright 2009, 11.
[144] Ventris and Chadwick 1973, 53–60, 213–21.
[145] In general, see Palaima's (2004a) overview of Mycenaean accounting practices.
[146] Killen 2001.

and Od series set cloth targets, allocated appropriate amounts of wool, and recorded deliveries of the finished cloth for groups of women.[147] The process included standardized units of measure (although we are not always certain how these convert into modern units) and rules of thumb for calculating how much wool was needed; to make one unit of *tepa* cloth, for example, required seven units of wool.[148] For smaller architectural projects, quantity surveying could be a purely mental process in which builders roughed out their plans, but for the Treasury of Atreus, the most organizationally complex architectural project surviving from Mycenaean Greece, quantity surveying may have required more permanent administrative mechanisms.[149]

Choosing and Preparing the Building Site

A final aspect of preplanning was selecting the appropriate site upon which to build. The area chosen and the space it allowed for building would have played an important role in setting dimensions for the tomb and planning for access to the resources needed during construction. As it sits, the Treasury of Atreus is situated on the modern road which runs north from the present town to the ancient citadel of Mycenae. Approximately 500 m southwest of the citadel, the tholos is dug into the eastern slope of the Panagia Ridge which looks out over the Khavos Ravine. Although all nine tholoi at Mycenae lie west of the acropolis where the bedrock is softest,[150] Atreus is uniquely isolated from the others, which typically form small clusters (Fig. A.13); the Tomb of Clytemnestra, the Lion Tomb, and the Tomb of Aegisthus are grouped to the north, near the Lion Gate; and to the west, on the other side of the Panagia Ridge, the Tomb of

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[147] Killen 2001.
[148] Killen 2001, 162.
[149] This administration of building projects is returned to in Chapter 7 and 8.
[150] Mason 2007, 39.

the Genii, the Cyclopean Tomb, the Panagia Tomb, and the Epano Phournos Tholos are situated

in two groups while the Kato Phournos Tholos is slightly further north.[151] The placement of

Atreus away from these groups is exceptional due to the spot's visibility. In its position on the

eastern slope of Panagia, any traveler approaching Mycenae from the east, south-east, or south-

west would encounter the tholos' prominent tumulus, retaining wall, and facade on his way to

the acropolis.[152] Since the tholoi to the east of Mycenae at Berbati, Dendra, Prosymna, and Kokla

had all been abandoned by the end of LH IIIA2,[153] the builders of Atreus may have designed the

tomb to face these areas and the road network connecting them in order to advertise Mycenae's

dominance over the central Argolid.[154]

A secondary feature of Atreus' location, which was noted by Mason, may justify its exact

position in the eastern slope of the Panagia Ridge. When looking northeast from above the tomb,

the acropolis of Mycenae is framed by Mt. Profitis Ilias and the mountain's peak looks like a

magnified image of the acropolis itself (Figs. A.28, A.29).[155] Conversely, from the acropolis'

perspective, the Treasury of Atreus may have appeared prominently from the courtyard south of

the propylon which led to palace's megaron;[156] however, this latter proposal is more tenuous

because the acropolis' early layout is imprecisely understood.[157] Still, the position of Atreus in

the eastern Panagia Ridge does seem to be calculated for its eye-catching effect and its

intervisibility with the citadel.

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[151] Iakovidis et al. 2003, maps 6, 7.
[152] Mason 2007, 49; see also Jansen 2002; Iakovidis et al. 2003, 31.
[153] Mee and Cavanagh 1984, 51–3; Cavanagh and Mee 1998, 61–88; Fitzsimons 2006, 144–64.
[154] Mason 2007.
[155] Mason 2007, 48.
[156] Mason 2007, 45–7.
[157] French and Shelton (2005) and Fitzsimons (2006, 260–74) summarize the data pertaining to
earlier palace phases at Mycenae.

A final aspect to consider is that the builders chose this site along road networks both for propagandistic reasons and for the practical reason of gaining access to building materials. The major materials used in the construction of the tomb, particularly the poros, conglomerate, and clay, originate some distance away from the building site. Many segments of the surviving road network approach major areas of resource exploitation, connecting them with the area of the citadel (Figs. A.30, A.31).[158] Near Atreus, there is evidence for roads along the upper Panagia Ridge and on the eastern bank of the Khavos Ravine. A few spots may indicate another road on the western bank of the Khavos Ravine[159] and two bridges, one north of Atreus and one south, join the western and eastern banks of the ravine.[160] The date for many of these roads is likely later than Atreus, but the bulky conglomerate and the massive lintel acquired from the Kharvati Quarry required that a road or well-prepared path run quite close to the Treasury of Atreus, perhaps overlapping with parts of the modern road.[161]

After initial planning and design, work could finally start at the building site. Because of the modular arrangement of Atreus and the evidence for fixed units in its layout, construction needed to begin with a setting-out phase in which points to guide construction were fixed. The preliminary setting-out only needed to be rough since its purpose was to steer the depth and length of excavation into the hillside, and to anticipate the construction of the terrace east of Atreus. When the builders began erecting the masonry, more accurate points would be necessary, particularly to arrange the strictly measured elevation of the stomion and chamber. To set a straight line from which to measure distances for excavation, a stretched rope is a practical

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[158] Iakovidis et al. 2003; see also the least-cost-path analysis performed in Chapter 7 for the Treasury of Atreus.
[159] Mycenae Atlas E4: 27, 28, 21.
[160] Mycenae Atlas E4:20 (Khavos Bridge); F4:12 (Ayios Ioannis Bridge).
[161] Santillo Frizell 1998, 181.

method. Only a single line was necessary for the builders of Atreus. Following the gradient of

the ridge, the surveyor could run the rope up the hillside to fix the angle at which the builders

would dig and to establish a baseline for measuring the horizontal boundaries of excavation. To

take measurements parallel and perpendicular to this baseline, builders could equally use gauged

ropes or rods, each of which has its shortcomings. For ropes, the elasticity which makes them

suitable for setting straight lines will distort measurements when pulled taut. Measuring rods do

not suffer this weakness, but the distance they can measure at one time is much smaller, a few

meters at most; so, to reach large distances means summing up smaller steps with the possibility

of introducing error along the way.

Since the marks of setting-out are not meant to be permanent or visible after construction,

there is no evidence for them in most ancient buildings, including the Treasury of Atreus. Once

again, Egypt offers the best contemporary examples. These include depictions of the "stretching

of the cord," a ceremonial event marking the foundation of a temple which ritualized the practice

of forming survey lines using a taut rope,[162] archaeological discoveries of surveyors' marks

scratched into paving stones, and masons' lines painted in red ocher on walls.[163] So-called

"mason's marks" have been found in the Aegean, particularly on Crete,[164] along with a handful

of examples from Mycenaean Greece. Those on Crete are mostly found in Minoan palatial

architecture, where their function is contentious. There is no solid evidence that these signs

assisted builders as a traditional mason's mark should, but given their long history of use (MM I

–LM III) we cannot expect to assign a single function to all of them.[165] Shaw points out three

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[162] Wright 2009, 28–9.
[163] Arnold 1991, 16–9.
[164] Begg 2004.
[165] Shaw 2009, 76–9.

examples of mason's marks in the quarries at Skaria, Plakes, and Malia which could have aided workers during stone removal.[166]

In Mycenaean Greece, similar marks are rare. Three of five known examples come from Messenia. At Peristeria, Tholos 1 has a double-ax and branch engraved on its ashlar façade while a single block from the earlier palace of Pylos likewise has a double-ax sign.[167] In both cases, the presence of mason's marks is coupled with other evidence for Minoan influence, such as the choice of poros limestone for the tholos' façade, and the use of orthostates and a Minoan-style layout for the early palace.[168] Interestingly, the last two examples of these marks come from the Treasury of Atreus. Two branch signs are incised on the poros retaining wall that blocked the dromos' eastern end.[169] In this case, they are clearly not actual mason's marks; the poros blocking wall was the last part of the tomb erected so these marks would have no use during construction. For the mainland, the lack of setting-out marks suggests that, however they were fixed, the material was fugitive. Perhaps it was accomplished using temporary wooden stakes or painted marks which would not survive exposed to the Greek climate.

Once a few surveyors had set out baselines for construction, large groups of unskilled workers would have begun. The first task was preparing the building site.[170] Loose rock, vegetation, and if the Atreus Bothros and the Panagia Houses are any indication, house remains all needed to be cleared so that builders could access the site. The area cleared needed to be at least as large as the boundaries of the tomb's peribolos wall, possibly larger, and needed to include the area in front of the tomb where the terrace was to be erected. Shoring up

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[166] Shaw 2009, 32 n. 155.
[167] Wright 1978, 147.
[168] Nelson 2007, 151–9.
[169] Wright 1978, 147.
[170] The corresponding energetic flowchart is found in Figure A.99.

infrastructure may have added additional work to this stage. Whatever the configuration of the roads at the time, a clear, well-built path to and from the building site was needed for material, workers, and animals. This may have necessitated repairing existing roads or extending them.

When space had been made and the appropriate infrastructure was in place, gangs of excavators commenced digging into the hillside. The operation would have relied on the established baseline for angle and depth, but a high degree of accuracy was not needed; the hollow dug into the slope of the hill merely had to be large enough to receive the masonry. The technique of ashlar construction requires that facing blocks be backed with rubble and clay packing so gaps between facades and excavated bedrock do not pose a problem since they will inevitably be filled by rubble masonry. In the horizontal plane, irregularities in the bedrock could be filled in with rubble and clay as is seen in a section of the eastern dromos (Fig. A.32).[171] If this was meant to be load-bearing, as in Figure A.32, some care in filling the hollow was crucial to make certain that the superincumbent weight was safely transferred to bedrock.

During excavation, the area for the chamber, stomion, and dromos was taken down at the same time.[172] In this way, the expanding dromos provided a continuous route into and path out of the deepening chamber, which eventually reached c. 8 m below the hill's surface. The tholoi of Wace's Group 1, none of which had a lined dromos, offer a glimpse of what this now hidden excavation looked like. This is clearest in the dromos of the Tomb of Aegisthus (Fig. A.33), which is better preserved than the Cyclopean Tomb and Epano Phournos Tholos. Like the Treasury of Atreus (and all tholoi at Mycenae), the Tomb of Aegisthus was dug into the soft marls west of the harder limestone upon which the citadel was built.[173] A variety of tools were

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[171] Wace 1921–1923b, 339–40.
[172] Como 2007, 25.
[173] Higgins and Higgins 1996, 46–7.

available to the excavators. These included adzes, picks, and hoes, all of which have left surviving examples from the LBA Aegean.[174] To remove the spoil, woven baskets could be used. These would be placed on the ground beside the excavator and the spoil would be pushed into them. For Atreus, the excavated material was not moved far, but was used to build up the terrace to the east of the dromos. This cut-and-fill technique for terrace building is part of the Mycenaean builder's repertoire.[175] Unlike other examples of this technique, there was not a concern for making the terrace level. Even given erosion over the millennia, the terrace still slopes heavily to the east and the height of cyclopean retaining wall suggests this downward slope was original to the tomb. Rather than creating level ground, the intention of the eastern terrace seems to have been crafting a gentle gradient for transporting materials up slope to the building site.

Although surviving examples of excavation tools exist in metal, Blackwell notes there is a general dearth of metal digging implements in the Aegean and, in the agricultural sector at least, metal tools were complementary to wooden.[176] The pattern of the agricultural sector is valuable to consider when discussing monumental architecture; it is likely that many Mycenaeans who participated in monumental construction were primarily farmers whose familiarity with tools and techniques came from their own daily experiences. For as large an amount of excavation as the Treasury of Atreus needed (c. 2,885 m^3), the use of only metal tools is unlikely. Although the Argolid is a hotbed of Late Bronze Age metal implements,[177] limited access to metals for many individuals would mean tools of more commonly available materials

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[174] Evely 1993; Shaw 2009, 52–76; Blackwell 2011.
[175] For example, see Wright 1980.
[176] Blackwell 2011, 73–82.
[177] Blackwell 2011.

such as wood were frequent; among these, we should not exclude the value of stone and bone implements for removing soil and softer rock.[178] The quality of tools one used may have been a visible mark of status, technical knowledge, and sociopolitical connections.[179]

Building the Stomion and Chamber

After excavating into the hillside and building up the eastern terrace, the excavators dug out the side chamber. The method was comparable to the excavation of the dromos and main chamber; however, it occurred from the roof down in the manner of chamber tomb construction. The rough nature of the side chamber is a good indication of the general process of excavating the soft marls and bedrock of the Panagia Ridge and there must have always been concern for maintaining the thickness of the roof to prevent collapse. After the side chamber was excavated, skilled masons and helpers could erect the masonry of the chamber and stomion. The bonding of the chamber and the stomion shows that the two were erected at the same time, course by course, but the larger process did break down into stages: the lower chamber and stomion first (during which the entrance to the side chamber and its relieving triangle were incorporated into the masonry),[180] the large lintels[181] and two corresponding courses in the chamber second, the upper chamber third,[182] and lastly the dressing of the masonry and interior relieving triangle.[183]

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[178] Blackwell 2011, 58–63. In Neolithic England, for example, scapulae and antler picks were used to excavate earth and chalk (Jewell 1963; Atkinson 1974, 51–4).
[179] Blackwell 2011, 51–7.
[180] The corresponding energetic flowchart is found in Figure 7.4.
[181] The corresponding energetic flowchart is found in Figure 7.5.
[182] The corresponding energetic flowchart is found in Figure 7.6.
[183] The act of dressing or finishing the masonry is spread across the energetic-flow charts illustrated in Figures A.100–102.

Of all building phases, this staged process was most architecturally advanced and it is arguably the most technical form of construction in Mycenaean Greece, although alongside this we should consider the hydrological works of the Mycenaeans. The horizontal coursing of the stomion and entirety of the chamber were executed with a high degree of regularity and the height of each course was carefully measured. The vertical joints in the chamber and stomion are all appropriately staggered but the length of the blocks is irregular. As the chamber rises, the height of the courses decreases from 0.8 m for the first course to 0.2 m for the thirty-third course.[184] The lowest nine of these bond with the nine courses of the stomion and lower façade so that it is clear these parts of the chamber, stomion, and façade were set down simultaneously. The succeeding tenth and eleventh courses snuggly abut the interior lintel. The upper courses of the chamber are different in that they are not well bonded with the upper façade and these last 22 courses of the chamber were evidently built separately from the upper façade; the difference in size of the interior and exterior relieving triangles, the different coursing, and the change in building technique which is apparent within the passage of the relieving triangle (Fig. A.16, Section A-B) show that the upper façade was added only after the chamber had been fully built, likely at the same time the dromos' walls were going up.

The size of blocks used in the chamber ranges widely depending on the course. The blocks of the lowest courses and those from the entirety of the stomion are very large. In the stomion, some of them reach to 3 m in length. At approximately 2.5 tons / m^3, even the smallest blocks, which come from the chamber's final course, weigh hundreds of kilograms.[185] For the largest blocks, of which the side chamber's lintel is a good example, the weight was on the order

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[184] Cavanagh and Mee 1999, 99.
[185] Loader 1998, 66 n. 19.

of seven tons.[186] While their size made the transportation and installation of these blocks a major

concern for the builders, good communication between quarriers and masons was a prerequisite.

To achieve the height established for each course and ensure the steady pace of construction,

correctly sized blocks needed to be quarried systematically so that they could be transported and

installed in the appropriate order. Haphazardly removing blocks of various size would choke the

building site with materials and leave the masons waiting uncertainly until they received a block

that would fit their current need. To avoid the creation of such bottlenecks during construction,

those quarrying needed to know what block dimensions were expected and those erecting the

masonry needed to know when blocks of certain sizes would arrive. Failure to harmonize these

activities could increase the duration of construction as well as the required labor; continued

problems of this sort could even sink the project with potentially serious social, political, and

economic consequences for patrons and builders. Compared to earlier tholos construction, the

successful coordination of these activities reveals a much greater level of organizational

complexity and a higher degree of administration. Furthermore, it firms up support for the use of

a linear system of measurements in the Treasury of Atreus since to communicate dimensions

effectively, standards were imperative.

Two possible sources for Mycenaean conglomerate are recorded: the area of the modern

town and the southwestern foot of Profitis Ilias.[187] The exact sources for the Treasury of Atreus'

stones cannot be pinned down certainly, but Schliemann believed the Kharvati Quarry, near the

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[186] The exterior lintel to the side chamber is roughly 3 m x 1.6 m x 0.6 m as measured from
Wace's sections.

[187] Schliemann 1880, 116–7; Steffen 1884, 24; Wace 1949, 27, 135–6. Santillo Frizzel (1997,
629; 1998, fig. 15) has suggested the source is a number of kilometers to the north of Mycenae,
but her reasoning is not given. The path from this northern quarry would also be significantly
more difficult than the other options.

modern town, was the source[188] and Wace thought that this area of exploitation was certainly

prehistoric.[189] The Kharvati quarry is also slightly closer to Atreus in absolute terms (c. 0.8 km)

than those identified at the foot of Profitis Ilias such as the Paleogalaro Quarry which was

possibly used for conglomerate.[190] From the perspective of the road network, both areas were

accessible, but if blocks came from Profitis Ilias, they would have to be transported in a

circuitous manner because of the area's steep slope. For this reason, the Kharvati Quarry is the

likelier of the two sources for the Treasury of Atreus' stone.[191]

The technique for quarrying conglomerate relied on exploiting already exposed beds of

stone and the Mycenaeans do not seem to have quarried conglomerate below the surface.[192]

Although conglomerate is harder than limestone, its extraction is eased by the fact that it is

interbedded with softer stones.[193] Quarries and quarrying techniques for the Bronze Age Aegean

are understudied, but a fair amount of direct evidence for ancient practices comes from Minoan

Crete. On eastern Crete, sandstone quarries have been published in detail and elsewhere, a few

examples of limestone quarries are mentioned.[194] There is some additional evidence for the

extraction of gypsum in the vicinity of Phaistos and Knossos.[195] None of these types of stones is

directly comparable to conglomerate but the sandstone and limestone quarries show that

channeling was used to extract regularly sized blocks. The technique of channeling consists of

cutting out small trenches around a block and then prying or undercutting to detach it. This

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[188] Schliemann 1880, 116–7.
[189] Wace 1949, 27.
[190] Iakovidis et al. 2003, C5:05.
[191] In their analysis of the Treasury of Atreus, Cavanagh and Mee (1984, 96) similarly accepted the Kharvati Quarry as the source.
[192] Schliemann 1880, 117–8.
[193] Dworakowska 1975, 129.
[194] Soles 1983; Shaw 2009, 28–36.
[195] Shaw 2009, 36–7.

method of quarrying is not a Minoan invention and was employed throughout the Bronze Age Mediterranean and, likewise, in the historical period of Greece.[196] Tool marks from the Minoan quarries show that picks or points were used to make the channels.[197] For conglomerate, these types of tools are not appropriate because of the stone's properties. Instead, conglomerate must be abraded, sawn, or hammered.[198] If channeling were used to remove blocks from exposed bedrock at Mycenae, which appears likely due to the technique's occurrence in the Mediterranean and its effectiveness in achieving regularly sized blocks, the quarriers would have pounded out channels around the block with stone hammers.[199] This technique is effective for stones which resist metal tools, but it can be very labor intensive.[200]

Direct evidence for channeling in Mycenaean Greece is sparse,[201] but marks at the Asprokhoma Quarry photographed by the Mycenae Survey[202] show an example of channeling for removing limestone blocks.[203] Recently, a conglomerate quarry which includes unfinished column bases has been identified near the Vapheio Tomb in Laconia and it may support the use of channeling.[204] The researchers observed that "where the edge of the column base has begun to be worked on the west, a 0.1m wide groove widens to 0.3m on the north as the base was

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[196] Waelkens 1990; Arnold 1991, 27–40; Papageorgakis and Kolaiti 1992; Wright 1992, 1:361; Loader 1998, 50–3; Shaw 2009, 30.
[197] Shaw 2009, 28–36.
[198] Loader 1998, 44; Shaw 2009, 25.
[199] For Egyptian and Hittite examples of this technique using hammers, see Waelkens 1990; Arnold 1991, 36–40; Summers and Özen 2012.
[200] The unfinished granite obelisk at Aswan has painted marks which show the slow progress of work as individuals pounded out channels around the stone (Arnold 1991, 39 fig. 2.15). In experimenting, Engelbach (1923, 48) increased the depth of a two-foot area by 5 mm after an hour of pounding.
[201] Loader 1998, 42–54.
[202] Iakovidis et al. 2003, fig. 20.
[203] Assigning dates to quarries is very difficult. It is possible this represents activity post-dating the Bronze Age.
[204] Morgan et al. 2011; Chapin et al. 2014.

shaped,"[205] a description which may refer to channeling. A published image of two voids where bases have been removed and a single base in the process of being extracted also hints at the use of channeling to rough out the bases before prying them from their beds,[206] but firmer conclusions must await fuller publication of this quarry.

Unlike the straight, square channeling found in Cretan examples, which could produce regular orthostates, the extraction of conglomerate at Mycenae was rougher, likely due to the unpredictable nature of the stone. The raw form after extraction is exemplified by the unworked, hidden backs of conglomerate ashlar walls. The hidden side of stones from the dromos of the Treasury of Atreus and the undressed stones in the tomb's relieving triangle display a coarse form with bulging ends (Fig. A.18). An even better view of the form of raw quarry stones is seen in the Tomb of Clytemnestra's relieving triangle (Fig. A.34). For the regularly coursed stones of the chamber and stomion, an amount of rough dressing may have occurred at the quarry in order to facilitate easier transportation, but since the hidden side of the stones were not worked, the masons on site evidently performed most of the dressing as they arranged the blocks.

To transport stones from the quarry to the building site, it is possible that wagons were used for the lighter courses of the upper chamber, but a wagon's wooden axles could not support many of the heavy conglomerate stones.[207] Instead, most blocks from the chamber and stomion were dragged to the building site, either on a wooden sledge or directly over a path or slipway. The use of sledges on rollers has often been proposed in archaeology, but prior to the Classical period there is little to no evidence for rollers[208] and more importantly, they are largely

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[205] Morgan et al. 2011.
[206] Chapin et al. 2014, pl. XLVIb.
[207] The axles could not support more than, at most, several tons (G.R.H. Wright 2005, 41).
[208] Heizer 1966, 826.

impractical. To function, rollers must be perfectly rounded, placed parallel to one another underneath the load, and employed on a well-built, hard surface.[209] The serious problem of rollers was seen in Mohen's experiment when they were used to move a monolith. The workers in the experiment *were* able to move the monolith on the rollers, *but* the direction of movement was uncontrollable and the process was theatrical.[210] The use of sledges directly on the ground or over sleepers (wooden elements placed parallel to the direction of motion), in contrast, is attested in the Mediterranean.

In Egypt, the Middle Kingdom Tomb of Djehutihotep II at el-Bersha depicts a monolithic statue being dragged on a sledge (Fig. A.35).[211] Four registers of workers pull ropes connected to the front edge of the sledge upon which the large monolith sits. In the register above them, soldiers accompany the work. Individuals to the left of those dragging aid the process. Below the statue, men carry a wooden apparatus and jars of liquid. On the statue itself, a man claps as he watches over the work while another man to his right apparently keeps a beat with two objects. A third stands on the front edge of the sledge and pours a liquid, perhaps water or oil, which is thought to have lubricated the sledge and reduced friction.[212] Some scholars have estimated the weight of this statue at 60-tons, approximately half of the weight of Atreus' lintel, but well beyond the weight of the tomb's average stone. The complexity of transporting such a large weight is clear from the image, but the process of dragging a sledge in this manner is equally applicable to smaller stones. Actual examples of such sledges survive[213] for more manageable loads and a New Kingdom depiction in the quarries at el-Maasara shows the transportation by

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[209] Davison 1961, 12; Heizer 1966, 825–6.
[210] Mohen 1980.
[211] Davison 1961, 14; Heizer 1966, 826; Arnold 1991, 277–8.
[212] Davison 1961, 14–5; Partridge 2010, 387
[213] Arnold 1991, 276–80; Partridge 2010, 387.

sledge of a smaller block.[214] A historical depiction of transportation by sledge in Assyria provides helpful information on the process.

Uncovered by Layard at the palace of Nineveh, a set of 7th century B.C.E. reliefs depict the movement of a large winged bull (Figs. A.36, A.37).[215] In Figure A.36, four rows of workers or captives drag the bull by ropes attached to the front and rear of the sledge. The workers do not grasp the rope directly but use a strap which loops over their shoulder. This is useful for transferring power to the rope and is necessary if ropes are too thick to hold. As in the Egyptian example, soldiers accompany the work in the lower portion of the scene where they watch over men carrying wood and dragging a cart of ropes. The relief shows the wood being put to use as sleepers in front of the sledge.[216] As the sledge passes over them, the pieces of wood are collected at the rear. The sleepers are an alternative way of easing transport in a vein similar to the use of a liquid in the Djehutihotep scene. In both the Egyptian and Assyrian depiction, there is likewise a man on the sledge coordinating the workers by keeping time.

The Assyrian sledge has a curved front and notched rear like the example from Djehutihotep's tomb. The importance of the curved front is plainly to overcome obstacles in the sledge's path that would jam against an otherwise blunt edge and, in the Assyrian case, to allow the sledge to pass smoothly over the sleepers, but the Assyrian depiction reveals a use for the notched rear edge not apparent in the Egyptian example. Behind the bull, a group of men use a large wooden lever to propel the sledge forward.[217] A second relief from Nineveh provides an alternative view of the lever's use (Fig. A.37). The lever and a fulcrum are set against the

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[214] Arnold 1991, fig. 6.39.
[215] Russell 1987.
[216] Davison 1961, 12–3; Heizer 1966, 826.
[217] Layard 1853a, 106–7; Engelbach 1923, 56–7; Cole 1954, 710; Russell 1987, 522–3.

notched rear of the sledge. Ropes hang from the lever and are pulled down while one man maintains the position of the fulcrum. On top of the statue, four oversees coordinate activity. One of them focuses on the lever and three look forward. To work, those pulling and those levering needed to coordinate their actions: The lever helps to break the force of friction and provides an initial push which aids those pulling in overcoming inertia. The combination of levering and dragging in sync is so effective that when Layard removed a group of colossal lions from the palace of Nimrud, he employed exactly the same method, even including a few men riding on the statues to coordinate (Fig. A.38); in his case, though, a wheeled vehicle was used rather than a sledge.[218]

The vital connection between the notched end of ancient sledges, the Nineveh reliefs depicting their function, and the Treasury of Atreus was made by Santillo and Santillo Frizzel.[219] In the northern wall of the Treasury of Atreus' dromos, there is a large block of peculiar shape that has often been noted for its size (Fig. A.39). From Wace's drawings, the block measures approximately 6 m long x 1.25 m high x 2 m wide, making it largest block in the dromos at around 37.5 tons.[220] The block's shape is not the slightly rounded, rectangular form the other blocks take. A low, bulbous projection extrudes from its western side and, on the eastern end, there is a deep rounded groove above an angled indentation. Taking account of reliefs of ancient sledges, Santillo recognized that this odd shape matches the sledge seen in the Nineveh reliefs and the Tomb of Djehutihotep.[221] The bulbous front allowed the rock to slide over obstacles, the rear notch was used with a lever to break friction, and the deep groove marks where ropes

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[218] Layard 1853a, 203.
[219] Santillo 1997; Santillo Frizell 1997.
[220] Wace 1921–1923b, 339–40.
[221] Santillo 1997.

wrapped around the block (Fig. A.40). Why this block was not dressed after transport is unknown, but its shape argues both that the Mycenaeans knew how to use sledges which relied on dragging and levering, and that the stones themselves could function like a sledge without the addition of a wooden one. The similar shape of the Panagia Tomb's lintel suggests this was not peculiar.[222] One advantage to this practice was that it avoided the need to lift heavy stones onto and lower them down from a sledge. Wace notes that the underside of the large block in Atreus has a "beautifully smooth sawn surface,"[223] but it is possible that this polished surface resulted from the action of dragging the stone directly over the ground.[224] Slipways of smaller stones or crushed rock, sleepers like in the Nineveh reliefs, or the pouring of a liquid lubricant as depicted in the Tomb of Djehutihotep would work as well for transportation directly on the ground as they would for transportation on a wooden sledge. The c. 10 cm thick layer of rock chips surrounding the Treasury of Atreus (Fig. A.19) and the crumbled rock in the dromos may have acted as slipways (Fig. A.32).

When blocks for the stomion and chamber reached the building site, they were dressed down from their rough form and maneuvered into position where their exposed surface would eventually be finished in situ. Some division of labor was necessary to accomplish the task. An experienced master mason who was able to size up a raw block and envision where and how it would fit into the coursing acted as lead. Assistant masons would help to shape the block according to the master mason's directions. As it was taking form, unskilled workers provided the raw force to turn over the blocks and finally, maneuver them into position.

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[222] Wace 1921–1923b, 318, 340.
[223] Wace 1921–1923b, 340.
[224] Compare the Inca site of Ollantaytambo in Peru where dragging stones from the quarry directly over a roadway created a polished underside with striations parallel to the direction of movement (Protzen 1993, 176–7).

According to Wace, the method of dressing and finishing varied depending on a block's position in the masonry. He suggested that the rectangular blocks of the façade and stomion were sawn[225] while blocks in the chamber were hammer dressed.[226] The rounded edges of the stomion and façade's stones and their slightly jagged jointing, though, imply that hammer dressing was used rather than sawing. The only clear places where the builders employed a saw was in edging the fasciae of the façade and cutting the stepped column bases that flank the stomion.[227] The sharp angles produced by sawing in these locations can be contrasted with the rounded edges of the stomion's and façade's masonry, which is more characteristic of hammer dressing.[228] Another point against the use of the saw for the façade and stomion is a practical one. In order to achieve an even surface, the final dressing or sawing of masonry had to occur only after the stones were set in place. In the case of the stomion, at 5.4 m deep and 5.4 m high, the sheer size of the surface area would make the task of sawing in situ impossible.

Still, Wace's distinction between stomion/façade and chamber is fitting because the two areas do show a different quality of dressing and finishing. The masons put more care into the working of the stomion and façade where the joints are deep and even in both the horizontal and vertical. Good jointing was necessary here to transfer the weight of the interior lintel to underlying foundations and bedrock, and to enhance the stability of the tomb since the weakest point in masonry is commonly where it is pierced by an opening. The finishing of the façade and stomion is likewise smoother than the chamber, and the masons possibly used an abrasive to

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[225] Wace 1921–1923b, 342, 346.
[226] Wace 1921–1923b, 350.
[227] Küpper 1996, figs. 129, 130, 143–54.
[228] According to G.R.H. Wright, "blocks can be dressed quite finely by hammers (stone or otherwise) but the surfaces tend to be slightly convex and the arrises are not properly sharp or rectangular, they are slightly rounded and obtuse" (2005a, 52).

polish the surface after hammer dressing it. The care given to the stomion and facade, including

the use of finer dressing, deeper jointing, and larger stones is seen in other tholoi at Mycenae as

well, of which Kato Phournos is an excellent example since erosion has exposed hidden portions

of its stomion's masonry. In contrast, the jointing of the Treasury of Atreus' chamber was less

careful; bedding joints were deep and regular in order to ensure contact between succeeding

courses, but the rising joints of the chamber's masonry were only superficial (Fig. A.22).[229] As a

tool for hammer dressing, stones, metal hammers, or even hard wooden mallets could be used.[230]

The size of stone, hammer, or mallet would vary depending on the quality of dressing; larger

tools are useful for taking off sizable portions of stone while smaller tools are used to draft edges

or finish surfaces.[231] By moving from large to small, very fine surfaces like those of the stomion

and façade can be achieved without the use of the saw.[232] For the chamber's blocks, the masons

would use larger hammers to rough out the hidden rear portion and smaller hammers to form the

deep horizontal joints and shallow vertical ones.

How unskilled workers lifted and maneuver dressed blocks into place is difficult to say.

Lifting devices such as cranes are not confirmed until the historical period and we cannot easily

retroject these devices into earlier periods.[233] The closest possible evidence for their existence in

the Bronze Age are some pulleys from Egypt, but these are better suited to changing the

direction of force when pulling or lowering with ropes rather than as components of a lifting

device.[234] Two often theorized solutions to the problem of ancient lifting are the use of levers (or

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[229] Wright 1978, 134–50.
[230] Evely 1993, 1:97–105; Shaw 2009, 42–4; Blackwell 2011, 172–6.
[231] Good evidence for this process is found in Egypt, Peru, and England. See Atkinson 1956,
117–24; Protzen 1985, 1993, 185–90; Arnold 1991, 47–52.
[232] For example, see Protzen 1993, 193–5.
[233] Coulton 1974.
[234] Arnold 1991, 70–9.

rockers) and cribbing to raise a block vertically and the construction of ramps to raise a block along an inclined plain. The more natural of these two is the use of a ramp[235] and it is clear that the Mycenaeans already took advantage of a hill's inherent slope to move lintel blocks into place.[236] While constructing the chamber of Atreus, the lifting and setting of blocks into place effectively fell into two phases: lifting and setting below the surface level within the excavated chamber, and lifting and setting above the hill level after the first 11 courses or so. The dromos was the logical entry point for dragging blocks into the chamber when building the lower courses. The first course, composed of the largest stones, would not cause difficulty because blocks could be dragged to their position along the ground line. Already, after the first course, though workers needed to raise blocks to waste level, around 0.8 m high; after the second course, the blocks were at head level, around 1.5 m high, and from there the height quickly progressed. Although there is a decrease in the dimensions and weight of blocks as the courses rise, the task of reaching these increasing heights within the chamber is still difficult to grasp.

Santillo and Santillo Frizzel posited that access to the chamber was actually gained from above, by dragging blocks up the hill slope to the level of the lintel and then following a built ramp down into the chamber.[237] Meanwhile, the coursing of the stomion was shored up with struts as the coursing rose. The theory of bringing stones down from above is hard to accept, though. The main problem is that any built ramp which descends from above will prohibit construction of a full course; masons could only build a portion of each course until they encountered the ramp at which point the whole ramp would need to come down. A better solution is to envision that the dromos was always the main access point for the chamber's lower

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[235] Wright 2009, 106.
[236] Holland 1921, 397.
[237] Santillo Frizell 1998, 172.

half and that material excavated in the first phase of construction was used here to build up the ground level and create a ramp as the courses rose. The increasing level of fill would further act to buttress the stomion as the masonry rose without the need for wooden struts.

Commonly, two points of concern are raised in response to theories of ancient ramps. First, to reach great heights and maintain a gentle gradient ramps could become unreasonably long and second, the volume of material needed to build ramps grows rapidly as height rises.[238] For the Treasury of Atreus, the maximum height the builders needed to reach was around 5.4 m, which is the lower height of the lintel course. The ideal gradient for a ramp is around 1:10[239] so at this measure the ramp would need to reach 54 m. This measure is sizeable and would be impossible because of the sharper slope of the eastern terrace (Figs. A.15, A.24). At a slope steeper than 1:10, though, the ramp's length would easily fit in the dromos (i.e. less than 36 m). Increasing the slope is not an unreasonable problem; it merely increases the manpower needed to drag blocks. With a gradient of 1:5, to reach 5.4 m high, the ramp would span 27 m, well within the space allotted by the dromos. As the masons approached these higher courses, larger groups of unskilled workers were needed to pull the blocks up the ramp, but the task was still manageable and it required only the addition of brute force, not skilled laborers. Additionally, the linear distance up the ramp always remained short; in the case of a 1:5 gradient, the hypotenuse of the ramp was only c. 27.5 m. Over the course of time, the volume of the ramp and fill would accumulate; the volume of the final ramp would be around 400 m³ and the fill in the chamber, at its highest, around 900 m³.

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[238] For example, see Loader 1998, 61–5.
[239] Wright 2009, 1:58–9.

As blocks were dragged into the chamber, the masons needed to dress them to fit their assigned position. This required a mason who was well-versed in transforming a raw block into a finished state and who knew how to correctly position a block. Because the circumference of each course was progressively diminished and the blocks were corbelled outward, this later skill was crucial to the stability of the chamber. Without directly observing the hidden sides of the lower courses, it is challenging to know how a mason thought through this process, but in Blouet's drawing of the final course (Fig. A.22), the depth of each stone is even. If the depth of other courses was also kept even, then a master mason may have fixed a single depth for each course based on experience. Other masons could then use this measure as they dressed the blocks.[240] The calculation of overlap between succeeding courses may have been based in strict geometric knowledge or simple rules of thumb. Since the question of whether the dome derives its stability from corbelling or horizontal compression rings is debated,[241] the engineering aspects of laying the courses remains ambiguous.

Before setting, the lower side of each block was first worked flat to make a flush bedding joint. At least one of the two rising joints was then shallowly dressed in order to match its neighboring block. Behind this shallow point of contact, any projections of stone would be removed to create a wedge-shaped stone. There are no apparent bosses to assist maneuvering so, after dressing, the process of setting blocks likely relied on groups of workers levering and pulling the stone with metal or wooden crowbars and ropes. Mud or wet mortar may have been used along the bedding joint to ease the positioning of blocks, which can significantly reduce

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[240] We might imagine something similar to the situation at Didyma or in Egypt where masons measured from an object or inscribed model during construction.
[241] Cavanagh and Laxton 1981, 1988; Santillo and Santillo Frizell 1984; Como 2005

friction.[242] Once a course of blocks had been dressed and set, the masons inserted rubble fill and hammered in small stones between the gaps in order to compress the course and prevent blocks from slipping inwards. Only at this point was the upper surface of the course dressed. In this way, an equal height was maintained across the entire course and an even seat was provided for the subsequent blocks. The exposed face of the course, though, was apparently left unfinished until later in the building process as a way to create the appearance of a smooth curve.

After the masons completed this process for the first nine courses of the chamber, the interior lintel was brought into position. The ramp and fill would have reached their highest point and the slope of the hill alongside the dromos could now be used as a ramp to move blocks. The fill which matched the height of the lintel course would support the lintel as it was dragged across the stomion; without this support the edge of the lintel would teeter over the 2.4 m wide gap. At c. 8 m wide x 7.45 m long x 1.2 m high, the lintel in its finished state is around 56 m^3 or c. 140 tons.[243] Since it was dressed in situ to mimic the interior curvature of the chamber, when dragged into placed it would have been slightly larger. The idea of transporting and dragging this block into position is staggering and it ranks among the largest blocks moved in European prehistory. Like the large block in the northern wall of the dromos, the lintel was conceivably dragged directly on the ground. Its nicked edges may indicate the use of the lever here as well.[244] The smaller exterior lintel, which measured 6 m wide x 1.6 m long x 1 m high, a little under 10m^3, and weighs a mere 24 tons in comparison, was also set at this time. The contact between

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[242] Thiersch (1879, 178) found a mortar covering the joints of the chamber's courses. There is no evidence of this today.
[243] Following the volume from the CAD model. The volumes are tabulated and discussed in Chapter 7.
[244] Santillo 1997; Santillo Frizell 1997, 1998.

the two lintels is close. They were very finely dressed at their point of contact, perhaps even being edged with a saw.

It is conceivable that most of the dressing of the lintels occurred at the quarry, excluding the interior curvature and exterior fasciae, both to reduce weight and to size them accordingly. In contrast to many other blocks of the chamber which needed to be dressed as they were set and whose widths were not as important as their heights, the exact size of the interior lintel was fixed beforehand. It was measured in such a way that one third of it covers the stomion and the remaining two thirds rests on masonry. The ninth course of the stomion's blocks were also evenly sized so that each end of the lintel sits directly on a single block. The division of the lintel into thirds parallels the builders' predilection for proportionality and it is comparable to the vertical division of the chamber into thirds so that the lower 11 courses run up to the top of the lintel and the upper 22 courses complete the chamber.[245]

Above the area excavated for the chamber, beginning approximately with the 12th course, the blocks reduce noticeably in size and as the radius of the chamber shrinks, fewer blocks are needed per course. Since the courses are now above the excavated area, the builders were able to work from the outside to construct the upper courses; rather than needing to work from within the chamber using fill and ramps, as with the lintels, the blocks were dragged up the slope of the hill and installed from outside. The decreasing size of the blocks made them significantly easier for the builders to maneuver into position. Behind the blocks, an uncoursed mortared rubble wall was constructed which reinforced the façade courses. The large volume of limestone rubble could have come in part from the original excavations or from the many limestone outcroppings in the area. The source of the clay mortar is likely the Plesia beds to the south (Figs. A.30, A.31).

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[245] The dromos is also approximately twice as long as the stomion and chamber.

Backing this mortared rubble wall is an inferred claybrick wall which was erected in tandem with the rubble wall and matches the construction of the dromos' backing walls. The thickness of both backing walls decreases with the increasing height of the chamber. In his description of the dromos' clay wall, Wace describes the bricks as made of a yellow clay from the Plesia beds.[246] The size of the bricks and details of construction are never given, but the process of producing clay or mudbricks has changed little over the past millennia. As the source of clay, the Plesia beds are approximately 2 km south of the Treasury of Atreus, and fall into an area accessible by Mycenaean roadways. The process of extracting the clay would have proceeded very much like the excavation of the Panagia Ridge. Those digging the clay beds could rely on a variety of tools including picks and hoes of metal or wood to extract the clay. A 7th century BCE Corinthian tile gives a succinct picture of clay extraction; in it, a male worker picks into the wall of the clay pit, while two other males load the spoil into baskets and hand them out to a female waiting above them.[247]

The volume of clay in the Treasury of Atreus is staggeringly high, so a number of such pits would have been needed and we should imagine the simple process of picking, gathering into baskets, and handing out the baskets multiplied many times. To form the extracted clay into bricks, workers mixed the spoil with tempering materials and a fair quantity of water. The amount and type of temper varies regionally and temporally, but straw and sand are common. Two techniques are available for mixing the materials. Workers can mix the materials and water using their feet in large pits dug into the ground or workers can pile clay on the surface and pool

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[246] Wace 1940, 238.
[247] Antikensammulung (Berlin) F 871. A second possible depiction of clay extraction may be found on Musée du Louvre (Paris) MNB 2858.

water in this pile.[248] Both techniques are used in modern adobe construction and surface mixing is depicted in the New Kingdom Tomb of Rekhmire.[249] In either case, the mixture may be then left alone for a few days in order for any plant materials to ferment.[250] Finally, the mixture will be poured or thrown into wooden molds, excess material will be wiped off the top by hand or with a string, and the brick will be left to dry in the sun. Often, workers will have to turn the bricks over the course of a few days in order to ensure they dry thoroughly. The exact time to dry will vary depending on the moisture content of the brick, its proportions of clay and temper, and the weather. Because the process of manufacturing sun-dried bricks requires access to fresh water, sunny weather, and often dried straw, brick manufacture is traditionally a seasonal occurrence, typically occurring in summer months. It is rare to find ancient brickyards, but evidence suggests the process logically occurred in the immediate vicinity of either the building site or the clay and water source, since either choice could minimize transportation costs. Because a generally flat, open area is required, the bricks for the Treasury of Atreus were likely manufacture by the clay beds where they could be laid out to dry and where fresh water was accessible. Dried bricks could then be carted along the roadways to the building site as needed along with some wet clay mixture which acted as mortar.

Because the upper courses of the chamber, the rubble backing wall, and the claybrick backing were built together in courses, the materials needed to reach the building site at an even pace rather than all at once. This is advantageous, especially for allowing bricks to dry sufficiently, but also demands strong oversight of the different building processes. Since brick manufacture, quarrying, rubble extraction, transport, and wall building in ashlar, rubble, and

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[248] McHenry 1989, 60.
[249] de Garis Davies 1943, pl. LVII
[250] Philokyprou 1998, 155.

claybrick all occurred in parallel, to make progress, every worker depended on the success of others; to proceed on schedule the right volumes of materials and the appropriate numbers of workers with the right skills had to be carefully monitored during this complex process.

When the masons completed the 33rd course of ashlar and the backing walls were finished, a small hole, c. 75 cm in diameter, remained in the top of the chamber. To cover this, a single stone was put into place to cap the chamber. The last step to completion was the dressing of the chamber's interior in order to create its domed appearance, a process which the masons could have tackled at any time after the chamber's masonry was finished. Like the courses themselves, finishing the blocks' exposed surfaces relied on hammer dressing and careful measurements. Based on different angles of the chamber's curvature, the masons evidently approached the task in two stages, dressing the courses above the lintel and below the lintel separately. Some type of light scaffolding was necessary during the dressing process to work up or down the chamber's courses. The Theban Tomb of Rekhmire, vizier under Thutmose III and Amenhotep II, illustrates such light scaffolding used to hammer-dress a large statue.[251]

Building the Dromos

In erecting the dromos, which abuts the lower façade and bonds loosely with the upper façade, the general techniques used in the chamber's construction continued, though there is a stark change in the quality of workmanship and care given to the ashlar masonry.[252] The masons no longer showed a strong interest in the exact layout of courses. Instead, blocks were roughly sized and the result is a series of uneven, wavering courses of conglomerate. Care was given to

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[251] de Garis Davies 1943, 58–9.
[252] The corresponding energetic flowchart is found in Figure 7.7. This energetic flowchart includes the upper façade, which was built at the same time as the dromos.

placing very large blocks in the lowest course in order to support the upper courses' weight, but the height of the blocks is rough and jumps suddenly in places (Fig. A.41). Certainly, this technique is time saving and requires less coordination between quarry and building site, but why attention was given to the hidden chamber and less was given to the exposed dromos is open to question. Possibly, the sole motivation was the time-saving factor; after constructing the chamber with its exacting and time-consuming measurements, the builders and masons could have sped along construction and reduced labor-costs to make up for misjudging the difficulty of the chamber. Likewise, their experience in the chamber's construction may have led them to realize that exact courses were not needed to make the walls stable, so they did not expend the additional effort in the dromos. An alternative is that the masons responsible for the dromos were different from those who built the chamber. In this case, the dromos' uneven courses were the result of less skilled masons or perhaps groups of different, skilled masons who operated independently, without the centralized coordination of dimensions seen in the chamber. The conglomerate blocks themselves offer good information on the building process and lend credence to a decrease in both skill and central coordination.

First, the shape of blocks in the lowest course of the north wall shows that they were only moderately worked into a roughly rectangular form. Due to erosion of the dromos' clay floor the rounded underside of some blocks can been seen. It is possible that much of the dressing of stones took place at the quarry site since exact measures were less relevant, and that any protrusions were then trimmed off at the building site when necessary to fit blocks together. An extreme example of this is the large block in the north wall. As mentioned earlier, the masons did not dress the block at all after transport; it was dragged into place as is.

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Evidence for independent working teams is found in the breaks in course height and the appearance of "hookstones," L-shaped blocks where courses of different heights meet (Fig. A.17, A.41). Approximately 10 m from the tomb's façade, the lower courses in the north wall show good examples of this. From the dromos' entrance and from the façade to this point, in the lowest course there are two different heights of blocks. The western group of blocks is slightly taller and the eastern shorter, excluding the very large block near the dromos' east end. The builders attempted to remedy this discrepancy in height by inserting a leveling course above the eastern blocks; however, the problem arose again in the succeeding course when the blocks installed on the western end were slightly taller than those on the eastern end. When the next course was installed, the block at the junction of the two sections was partially dressed down on its eastern end to fit a succeeding block, thereby creating a hookstone. Comparable hookstones are visible a few other times in the north dromos wall (Fig. A.41) and also occur in the south dromos wall. In terms of technique, the presence of hookstones tells us conclusively that, as was suggested for the chamber's courses, the upper surface of each block was dressed only after the entire course was completed, in this case, as the next course was being set. Organizationally, it suggests that two teams worked towards a center point on the dromos' walls. Each followed its own standards of measurement and attempted to keep courses even. The discrepancy which naturally arose was mediated by hookstones where the teams met. The narrowness of the dromos and large size of many of the lower blocks could have further meant that only one wall was constructed at a time so at any given moment, two teams worked collectively in the dromos to finish a single side. With the use of ramps, though, working on both sides of the dromos may have made greater sense.

Like the construction of the chamber, the lower courses of the dromos were erected from within the excavated area and the upper courses were likely built by sliding blocks up the hillslope and working from the outside. Many of the lower courses' blocks needed to be dragged to the site because of their weight, but the smaller blocks of the higher courses could have easily been transported by wagon. Above the excavation, backing walls of mortared rubble and claybrick were added to the support the upper courses in the same manner as the chamber (Figs. A.18, A.19). These higher courses bond sporadically with the upper facade and workers evidently built the two at the same time (Fig. A.42). For the final course of the dromos' wall, the masons installed irregular stones which they crudely dressed into a stepped profile. Often, the irregular bedding joints of these stones were packed with chinking to level them and give the wall face an even appearance (Fig. A.43).

Building the Peribolos and Tumulus

The materials and techniques used to build the peribolos[253] which supported the tumulus' mass are distinct from those of the chamber and dromos. Eschewing bulky ashlar conglomerate, the builders elected to use poros limestone, a soft sandstone-like stone,[254] to create an ashlar facade backed by a mortared rubble wall. The poros blocks are small and trapezoidal in shape (Fig.4.12). Their rising joints meet only superficially, as is typical of Mycenaean ashlar, and their bedding joints are flush. Some have dovetail mortises cut on their rear side by which the builders attached them to the backing wall via wooden clamps. Exact dimensions of the poros blocks are not published. Wace says only that the peribolos "is built of stones of no great size."[255] Based on

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[253] The corresponding energetic flowchart is found in Figure 7.8.
[254] Wace 1949, 137.
[255] Wace 1956, 116.

the published images,[256] the blocks' volumes are perhaps on the order of 0.1 m^3. It is somewhat difficult to fully reconstruct the number of courses and exact form of the wall in its original state, but the so-called Great Poros Wall which surround the Tomb of Clytemnestra has at least four courses of well-dressed ashlar.[257] As during the construction of the chamber, the regularity of the ashlar courses necessitated that quarrymen carefully plan out the extraction of stone to supply the building site with appropriately sized blocks.

Wace attributed the source of poros to the area of Magoula near modern Monastiraki, about 2.5 km south of the Treasury of Atreus (Fig. A.31).[258] The evidence for quarrying here is solely based on Wace's observations and the presence of a Mycenaean settlement with chamber tombs; however, the evidence from Crete and in the larger Mediterranean confidently points to the use of channeling to extract limestone and sandstone. Channeling had the advantage of providing the regularly sized blocks needed for fine ashlar construction.[259] Because poros is softer than conglomerate, which required stone hammers to extract, metal tools could be used. These might include chisels, picks, axe-adzes, and hammers.[260] The small size of the blocks meant that transportation by wagon along the roadways south of Mycenae was feasible. A few men could load and unload blocks from the wagon while draft animals provided the source of traction between quarry and building site.[261]

At the building site, construction of the ashlar peribolos began with the foundation or socle upon which the ashlar blocks rested. This is composed of a mortared rubble roughly four

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[256] Wace 1956, pl. 25.
[257] Taylour 1955a, 211, pl. 40.
[258] Wace 1940, 248; 1949, 137; Cavanagh and Mee 1999, 97.
[259] See the examples of channeling in Minoan limestone and sandstone quarries (Evely 1993, 207–8; Shaw 2009, 28–36).
[260] Evely 1993, 1:2–19, 62–76, 97–105; Blackwell 2011, 129–93.
[261] Shaw 2009, 37–8.

courses high, much the same as in the peribolos around Clytemnestra.[262] Above this c. 1 m thick

foundation or socle, the ashlar façade and rubble backing went up together. The rubble backing

is comparable to that behind the dromos and chamber, and likely employed materials from the

same sources. The builders seem to have worked in tandem on the rubble backing and ashlar

façade since the two were bonded by wooden clamps. There are no details of how this bonding

took place, whether the clamps directly engaged with the rubble or attached to wooden beams.

The occurrence of clamps in ashlar masonry is rare in Aegean architecture.[263] At

Mycenae, the north wall of the Great Court before the megaron has a few such blocks which are

thought to have bonded to wooden tie beams.[264] Pylos has only three known examples[265] and on

Crete, the technique is equally uncommon, restricted primarily to the Palace of Knossos.[266] For

the Treasury of Atreus, the structural necessity of these clamps is questionable; the poros wall

around the Tomb of Clytemnestra does not use any, despite its similarity in construction. Images

of the tumbled poros blocks[267] show tool marks from their dressing. Chisel marks fan out across

the surface of the blocks while other surfaces show deeper grooves. This possibly reflects the use

of different tools depending on the importance of the surface since an exposed face might receive

finer treatment than one that was hidden. Such distinct surface treatment of ashlar blocks is

recognized on Crete by Evely, who notes that the finer surfaces are the result of a point or punch

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[262] Wace 1949, 240; Taylour 1955a, 211.
[263] Hult 1983, 79.
[264] Wace 1949, 72–3; Küpper 1996, fig. 168, 169.
[265] Nelson 2001, 80–4.
[266] Shaw 2009, 109–11.
[267] Wace 1940, pl. IV.

while rougher surfaces are more in line with chisels or small adzes.[268] The roughest surfaces may

even reflect the state of the block when it left the quarry.[269]

Either after the peribolos was fully completed or during its construction, builders could

begin to heap up the tumulus[270] which covered the dome and hidden elements of the masonry. It

did not require any special materials and presumably utilized rubble, earth, or construction debris

which was readily available. Although there is no picture of the tumulus' exact composition, a

section from the Tomb of Clytemnestra shows a distinct layering of strata which slope

downwards as they meet the peribolos retaining wall.[271] The strata include various colored soils,

mixed levels, and a clay and stone capping layer. The changing nature of the layers possibly

reflects the use of different material sources which were exploited as the tumulus rose. One layer

which is described as "whitish earth with pink patches" is intriguing. Similar patching is

occasionally found in North American mounds, where stratigraphic analysis of earthen

architecture is more prevalent than in the Aegean; analysis strongly indicates that, in American

mounds, such patching is the result of basket loads dumped during construction.[272] From the

limited information available, the process of tumulus construction seems to have relied on the

arbitrary deposition of available materials, possibly by basket load, and perhaps the occasional

laying of a clay or stone cap to stabilize the mound against the influence of water and erosion.[273]

Whatever its exact composition, the builders of Atreus successfully achieved a high degree of

stability in the tumulus which has eroded very little over the past millennia.[274]

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[268] Evely 1993, 213, pl. 56.
[269] Evely 1993, 213; Shaw 2009, 66.
[270] The corresponding energetic flowchart is found in Figure 7.9.
[271] Taylour 1955a, fig. 5.
[272] Sherwood and Kidder 2011.
[273] As in the Tomb of Aegisthus (Wace 1921–1923b, fig. 15).
[274] See the early section in Gell 1810, pl. 4.

Concluding Remarks

In the above discussion, I have gathered together a large body of published data, comparative sources, and personal observations in the field to build a 3-D model of the Treasury of Atreus and detail the tomb's numerous construction elements. With the model and data, I have presented a thorough argument about the process of producing the Treasury of Atreus, including discussing its staging, the variety of techniques that builders used, and choices the were made during planning and construction. This chapter provides the first 3-D model of the tomb and the most thorough analysis of its construction to date; it forms a staging point for all future discussion of the Treasury of Atreus. In Chapter 7, the reconstruction and discussion of the Treasury of Atreus' production are revisited in order to model how builders organized production in time and space. There, the detailed energetic flowcharts of the production process, which were cross-referenced in this chapter, are created and the temporality of production is addressed through simulation.

Before moving on, I should make three points for future research that have emerged from the preceding discussion. First, the hidden elements of the Treasury of Atreus and nature of conglomerate quarrying at Mycenae require detailed future work to better understand Mycenaean building practices. Second, the proportionality of the tomb and use of a linear system of measurements is greater than previously recognized; this is a significant milestone in the history of Greek architecture that warrants deeper study. Finally, there are numerous suggestive connections to Minoan practices in the Treasury of Atreus, including its peak alignment with Profitis Ilias, the use of a foot also found in Cretan palaces, the poros ashlar with clamps that is also found at Knossos, the presence of mason's marks that are uncommon on the mainland, and

the decoration of the façade with bull imagery. This requires greater attention in the future to

flesh out the nature of these possible Minoan connections.

CHAPTER 5

THE HARBOR TOWN OF KALAMIANOS

Background to Kalamianos

The Site and Region

The site of Kalamianos is situated in the eastern Corinthia near the modern town of

Korphos (Figs. A.44, A.45). As a small, gently sloping cape which juts out into the Saronic Gulf,

it acted as an important anchorage during the Mycenaean Period and offered an uncommon point

of passage between the interior and the waters of the Saronic.[1] From a bird's eye view,

Kalamianos bulges out from the land at a southeasterly angle with a small, knob-like projection

clinging to its southernmost tip. To the east of this knob, the highpoint of a rocky islet, now used

occasionally to moor boats, breaks the surface while the majority of its bulk rests shallowly

below the present waterline. A much larger, steep-sided island, known as Ayios Petros, lies c. 1.5

km further east of Kalamianos, though exploration has provided no signs that it was occupied

during the Mycenaean period.

Along most of its shoreline, Kalamianos is rocky and urchin infested, but a sediment trap

between the rocky islet and southern end of Kalamianos forms a small, sandy beach. Bathymetric

survey and geological evidence indicate that the shape of Kalamianos' coast has changed

drastically since the Late Bronze Age due to a number of subsidence events.[2] During the Late

Helladic period, the shoreline reached out further, particularly to the east and, while not quite

connected with Kalamianos, the rocky islet was more exposed. At points, it is estimated that the

Mycenaean shoreline extended an additional 100 m from its current location, providing a wider

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[1] Pullen and Tartaron 2007; Tartaron et al. 2011; Pullen 2013b.
[2] Dao 2011; Tartaron et al. 2011, 574–5; Pullen 2013b, 248–52.

area for potential habitation and offering two possible anchorages on the eastern side.[3]

Underwater exploration of this now submerged land has located beach rock with Mycenaean

ceramic inclusions and tidal notching along the ancient shoreline,[4] but it has not found evidence

of any underwater architectural remains. That habitation along the coast was once more

widespread, though, is supported by the walls and corners of buildings that touch the current

waterline.

The landscape of Kalamianos is karstic in nature; it consists of a gray Mesozoic

limestone, the surface of which is often heavily weathered and shows rillenkarren, fluting which

forms with the flow of precipitation.[5] Parallel sets of joints in the limestone bedrock have created

naturally block-shaped stones that are the core building material of the region. Some of these

joints have developed over time into large, deep fissures which hold ground and rain water.

Since the site and the region lack regularly flowing water, these were likely a main source of

freshwater in the Bronze Age.[6] In at least one case, the area around a fissure shows modification

in order to ease access to its water. Soil coverage across the site is minimal. The deepest pockets

occur behind walls or terraces which run perpendicular to the slope of the terrain and so,

naturally trap eroding sediments. The soil level during the Mycenaean Period may have been

greater than today, perhaps up to 50 cm deeper,[7] but large quantities of bedrock were always

exposed across the site. This has been archaeologically advantageous since the architectural

remains are exposed without the need for excavation.

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[3] Dao 2011, 54–6; Pullen 2013b, 248–52.
[4] Tartaron et al. 2011, 571–4; Pullen 2013b, 249.
[5] Tartaron et al. 2006b.
[6] Tartaron et al. 2011, 566–8.
[7] Tartaron et al. 2011, 568–9.

After passing over the highpoint of Kalamianos (c. 18 masl), the land opens out into a c. 0.5 km[2] polje. Composed of a distinct red, clayey soil, the polje may have provided arable land and a convenient source for building materials during the Mycenaean period.[8] To its north, two hills slope up from the gentler terrain below and divide the lower lying area of Kalamianos from the interior. Between them, a limited area of ancient habitation, informally known as the Saddle Site, is situated. Further inland, the terrain becomes progressively more difficult. Within a few kilometers of the shoreline, the land ascends into large, steep sided mountains punctuated by flat, open poljes. In this upland region, a second major area of Mycenaean occupation is located at the site of Stiri.[9] Like Kalamianos, Stiri sits near a wide polje, but unlike Kalamianos it was built high on a ridge with a precarious drop-off to its south and southeast. From this position, it is possible to see out a great distance across the Saronic Gulf and to survey much of Kalamianos below. The exact connection between the two sites is still under investigation, but the visibility and position suggests that Stiri may have functioned as a protective lookout for the harbor below and a convenient point of access for exploiting resources in the upland areas.[10]

History of Research

The initial discovery of the site of Kalamianos came as part of the Eastern Korinthia Archaeological Survey (EKAS). From 1997 to 2003, EKAS systematically investigated portions of the 350 km[2] area to the east of ancient Corinth.[11] As one component of this extensive survey, a probabilistic model was designed to isolate potential harbor locations along the Saronic Gulf.

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[8] Tartaron et al. 2011, 614.
[9] Tartaron et al. 2011, 615–20
[10] Tartaron et al. 2011, 622; Pullen 2013b, 256.
[11] Tartaron et al. 2006a.

Incorporating archaeological data and geomorphological analysis, the model suggested viable

locations for ancient harbors based on factors such as slope, water accessibility, and wind.[12] In

2001, groundtruthing of these results revealed two major sites on the Saronic: an EBA site at

Vayia[13] and the remains of Mycenaean, cyclopean style architecture at Kalamianos. At the time,

only limited study of these Mycenaean remains was undertaken, but the discovery later

blossomed into its own field project, the Saronic Harbors Archaeological Research Project

(SHARP).[14]

From 2007–2011, SHARP studied in detail the site of Kalamianos and its environs,

including the ancillary site at Stiri.[15] The project methodology combined intensive and extensive

pedestrian survey with detailed architectural analysis and mapping. Because the extent of

architectural remains at Kalamianos and the difficulty that the site would pose for walkers and

mappers was not apparent at the start of the 2007 season, many details of the field methods were

established over the following seasons and tailored to the peculiar nature of the site. After three

seasons of fieldwork and an additional two study seasons, the result was an expansive and

detailed collection of regional archaeological data, which was stored in a combined database and

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[12] Rothaus et al. 2003; Pullen 2013b, 248–9.

[13] Tartaron et al. 2006b.

[14] The Saronic Harbors Archaeological Research Project, directed by Daniel J. Pullen and Thomas F. Tartaron, operates under the auspices of the American School of Classical Studies at Athens with a permit granted by the Hellenic Ministry of Culture. SHARP works in cooperation with the 37th Ephoreia of Prehistoric and Classical Antiquities; the 25th Ephoreia of Byzantine Antiquities; the Ephoreia of Underwater Antiquities (Enalion); and the Institute for Geology and Mineral Exploration (ΙΓΜΕ). Funding for SHARP has come from the Institute for Aegean Prehistory; U.S. National Science Foundation (BCS-08100960); Stavros S. Niarchos Foundation; Loeb Classical Library Foundation; Arete Foundation; Florida State University; and the University of Pennsylvania.

[15] For preliminary results, see Tartaron et al. 2011; Pullen 2013b.

GIS for ease of analysis, and systematic records of the major architectural remains, including digitized stone-by-stone drawings of many structures.

To facilitate labeling of features and to systematize field survey, SHARP artificially divide the site of Kalamianos into 11 numbered sectors, extending from the southern edge of Kalamianos to the polje at the north (Fig. A.46). A further four sectors, 12–15, were used to label large areas beyond Kalamianos (Fig. A.47), including the area north and east of Kalamianos (12), the settlement at Stiri and its surroundings (13), the uplands to the north of Stiri (14), and the strip of coastal land composing the modern area of Korphos (15). Pedestrian survey in these sectors was accomplished using three major analytical units of differing purpose.[16] Extensive Discovery Units (EDUs) relied on a 50-m walker spacing and were reserved for larger tracts of land where coarser data resolution was desired. Discovery Units (DUs) provided higher resolution by using a 10-m walker spacing and were the most common survey unit. In both cases, walkers maintained counts of finds by type while limiting surface collection to diagnostic examples. The size of each unit was adapted to the locale with smaller units walked in sectors 1–9 and larger units in sectors 11–15. Lastly, Architectural Discovery Units (ADUs) were designed for intensive survey around structures and within the rooms and walls of recognizable structures in order to gather diagnostic artifacts that might help establish chronology.

Beginning with the 2007 field season, a process of feature identification was designed to accompany the traditional pedestrian survey.[17] Over time the array of features recorded included structure walls, corner blocks, terraces, doorways, and fissures. Wherever possible, discrete structures were isolated and labeled. The numbering of features and structures was based on the

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[16] Tartaron et al. 2011, 604–15; see also Tartaron et al. 2006a.
[17] Tartaron et al. 2011, 579–83.

sector number followed by an arbitrary designator, a four-digit number for features (e.g. 0241) and a sector and Roman numeral for structures (e.g. 5-II). Many features were mapped using handheld GPS units to within several meters. Those features and structures of note, though, were mapped in detail using total station and differential GPS, and many were meticulously drawn. Mapping was often augmented by a further layer of architectural documentation in which a structure's walls were cleared of overgrowth, then measured, described, and photographed in 1-m intervals.

Mycenaean Habitation at Kalamianos

Pedestrian survey in sectors 1–11 resulted in finds dating to the Final Neolithic/Early Helladic, Late Helladic, Late Roman, and Early Modern periods, with the majority falling into Late Helladic III (62.4%).[18] Many of the ceramics of this period can be dated no more closely than LH III, but dateable finewares do show an LH IIIA presence expanding into a larger LH IIIB occupation and there may be some evidence for activity extending into early LH IIIC.[19] Architectural discoveries include large building complexes with rooms, circuit walls, paths and avenues, terraces, and various unidentifiable remnants of walls (Fig. A.48). Buildings assignable to the Mycenaean period[20] cover approximately 3.5 ha of the site, while terrace walls, which are mixture of Mycenaean and Early Modern, occupy a larger area.[21] Most of the structures concentrate in sectors 4, 5, 7, and 9, but terracing and a modern building in other sectors may

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[18] Tartaron et al. 2011, 607–8.
[19] Amy Dill, personal communication. Some of the material has a range of LH IIIB into LH IIIC, but it cannot be established that it is specifically LH IIIC.
[20] For a comparison of Kalamianos' buildings and Mycenaean structures at other sites, see Tartaron et al. 2011, 587–91.
[21] Kvapil 2012; Pullen 2013b, 252.

skew this picture. Sector 9 is also likely heavily disturbed due to a nearby Early Modern lime kiln.

Of the dozens of structures isolated during survey (Fig. A.49),[22] I have selected two for close study: structures 4-VI and 7-X. Both have distinct plans, whose exterior walls are easily separable from surrounding remains and whose interior room divisions are largely identifiable. The two lie at opposite ends of the site, about 225 m apart, and occupy different architectural environments; structure 7-X is in a densely packed, well-developed area, and 4-VI remains comparatively isolated.[23] The builders of Kalamianos, to an extent, employed different masonry techniques in 4-VI and 7-X, and the former offers no picture of interior or exterior access, while the latter has clear interior doorways and an entrance. By examining the production of these two buildings in their distinct contexts, the different behaviors and choices of builders at Kalamianos can subsequently be explored and isolated. Later, this close range analysis of two structures feeds into larger points about architectural production at Kalamianos and in Mycenaean Greece.

Structures 4-VI and 7-X

Architectural Description of Structure 4-VI

Structure 4-VI is located in an area that marks the western edge of the dense architectural remains found across sectors 4, 5, and 7 (Fig. A.50). The terrain to both its south and west is difficult, consisting of rough patches of fractured bedrock and sloping, now heavily overgrown topography. The generally featureless southern portions of sectors 3 and 4 are a testament to the

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[22] There are about 50 structures with 120 identifiable rooms (Tartaron et al. 2011, 575–6; Pullen 2013b, 252).

[23] There are potential chronological differences with pottery between these two structures as well, but this is difficult to determine.

difficulty this terrain posed for building. Following the lower contours of these sectors, to the south of 4-VI, however, are the sparse remains of a circuit wall that may have acted as a defensive barrier against entry from the vicinity of sector 2 which was near sea-level.[24] Hard by 4-VI, to its east, is an axially arranged group of rooms and contiguous traces of walls which appear to have constituted a discrete structure, labeled 4-IX. Hints of stones to the south were initially labeled with a unique structure number (4-XI) out of caution, but the presence of a structure here now seems uncertain.

As is the case for most structures at Kalamianos, all that remains of structure 4-VI are the limestone foundations upon which the superstructure would have rested (Fig. A.51).[25] The preservation of these walls, however, is outstanding to the extent that the building's exterior is well-defined and most of its interior divisions are equally apparent. This high degree of preservation may be the result of limited post-Mycenaean activity in the western half of sector 4 as well as the structure's thick masonry. Structure 4-VI was constructed perpendicularly to the slope of the terrain and its long axis shows a clear north-south orientation. The change in elevation between the building's northern and southern walls is perceptible, decreasing from c. 7.5 to 6 masl while the height of the surviving walls increases. As a result of the slope and a particularly sudden elevation change at the southern end of 4-VI, most of the southern wall (401) has tumbled out, remaining only partially preserved at the southwestern corner. Two especially large blocks here likely helped this preservation. Where the walls of 4-VI join or abut one another, their exterior and interior corners maintain strong 90° angles so that all walls follow roughly north-south or east-west orientations. In its exterior plan, the structure has a long eastern

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[24] Tartaron et al. 2011, 598–602; Pullen 2013b, 252–3.
[25] For additional discussion of 4-VI, see Tartaron et al. 2011, 592–4; Pullen 2013b, 253–5.

side, composed of a northern wall (400) which flows into a shorter southern abutting wall (5153). The western side of the building, in contrast, is offset forming a northern, central, and southern segment. At its longest and widest points, 4-VI measures approximately 20 meters north-south by 12 meters east-west. Its overall footprint is on the order of 195 m^2.[26]

Interior walls suggest at least six discrete rooms with the possibly of a seventh.[27] The question of the additional room hinges on the separation of the spaces labeled 2 and 3. A dividing wall between the two is possible, but an olive tree has caused such heavy disturbance that only a pile of rubble suggestive of a wall is left. The other divisions are evident from the standing remains of interior walls: a small northern room (space 1: c. 9.25 m^2); an elongated area, possibly two rooms, where the building expands to the west (space 2/3: c. 31 m^2); a central block of two rooms, the longest dimension of which runs east-west (space 4: c 10.5 m^2; space 5: c. 27m^2); and a southern block of two rooms, the longest dimension of which runs north-south (space 6: c. 21.75 m^2; space 7: c. 17.5 m^2). There is no evidence of purposeful gaps in walls that would suggest exterior entrances or doorways between interior spaces. Darcque discusses a few buildings and rooms which show a similar lack of passages, but this situation is rare among the structures he examines.[28] The best comparanda are Houses Delta and Gamma at Mycenae. Despite walls preserved to a height of nearly 3 m and numerous rooms, Houses Delta and Gamma lack an entrance and internal doors.[29] Their rooms could only have been entered from levels above and therefore, may have functioned as "basements" or storage areas. Since the lack of gaps in the walls of 4-VI is not a factor of preservation, the surviving rooms may have

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[26] See Tartaron et al. (2011, 588–91) for a comparison of building footprints at Kalamianos with structures found in Darcque (2005).
[27] Tartaron et al. 2011, 593–4.
[28] Darcque 2005, 162–4.
[29] Darcque 2005, plan 51.

likewise been basement levels, accessed from the floor above. Those rooms in the northern half

of 4-VI naturally offer less vertical room because of the higher ground level; the underlying

bedrock may have been excavated to compensate for this difference between northern and

southern rooms.[30] Currently, all rooms are crammed with stone, which is especially deep in the

southern rooms. The ubiquitous wall tumble makes it impossible to study how the floors of these

basement rooms were treated, but a quick check with a tape measure indicated that the floor of

room 6 was at least 1.5 m below the level of tumble.

      Where it is possible to observe, the walls of structure 4-VI are founded directly on

bedrock and in many cases the bedrock has clearly been worked down for this purpose (Fig.

A.52). Small stones are sometimes inserted between the bedrock and lowest wall course to

provide a level perch for the succeeding blocks. The technique of wall construction is consistent

throughout the building; walls tend to be two stones thick with significant overlap between the

stones forming the interior and exterior wall faces (Fig. A.53).[31] Sporadically, a larger block is

incorporated which spans the width of the wall to form both the interior and exterior face. The

stones used are irregular but generally have at least one naturally flat side, which the builders

turned outwards to form the wall face. Small stones are employed as chinking to even out

courses and ensure wall stability (Fig. A.54). Excluding chinking stones, wall blocks are medium

to large, roughly weighing c. 25 – 150 kg by my estimates. Larger blocks are more frequently

employed in exterior walls and the biggest were used as corner blocks. For example, at the

southwestern corner of wall 403 and 5152/408, the upper corner block measures 0.72 x 0.53 x

0.35 m and weighs c. 320 kg (Fig. A.55). An even more extreme example of this practice is the

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[30] Tartaron et al. 2011, 594.
[31] Tartaron et al. 2011, 593.

building's southwestern corner, where walls 401 and 402 meet at a block measuring 0.98 x 0.57

x 0.7 and weighing c. 600 kg.[32] Where both interior and exterior wall faces are preserved and

dimensions are available, the width of the walls averages c. 0.73 m with a range of 0.52–0.89 m.

Occasionally, walls are preserved to three courses with surviving heights ranging from 0.2 m in

the northern portion of the building to 1.18 m at the southern end.

Architectural Description of Structure 7-X

Structure 7-X stands in the northeastern area of Mycenaean habitation (Fig. A.56).

Although its squared form and clear walls suggest a discretely built structure, unlike the

ostensible isolation of structure 4-VI, structure 7-X is snuggly fitted into the area of dense

architectural remains that spans sectors 7 and 9. To the northwest of 7-X, a very large structure,

labeled 7-I, covers the site's high ground. The rooms found in 7-I seem to extend to the west into

structure 7-IV and to spill downslope into structure 7-III; consequently, these three structures

may have formed an integrated complex, either through original design or the accretion of rooms

over time.[33] The importance of this complex is affirmed by its position overlooking the buildings

and harbor below and by the architectural features found in 7-I, which include several orthostates

and a built stone pier likely meant to support a large span of flooring.[34]

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[32] If the block were perfectly rectangular, it would weight c. 930 kg. I estimate it is about 2/3rd of this weight based on its wedge shaped underside.

[33] The ceramics from the interior and walls of 7-X indicate heavy post-Mycenaean disturbance. Preliminary identification of the sherds shows a Mycenaean cooking pot, an Early Modern Buff Amphora, a Late Roman Palestinian Amphora, and a Medieval or Early Modern amphora (Amy Dill, personal communication).

[34] See Tartaron et al. (2011, 595–8) and Pullen (2013b, 255) for discussion of this complex and its significance.

The remains of a c. 2.6 m wide ramp, labeled 7-XII, lead southeast from the 7-I/III/IV complex towards 7-X. Built of two parallel walls and packing stones, the ramp terminates abruptly after c. 10 m. Here, a 1.5 m wide doorway in the ramp's wall opens into a bounded but possibly open-air space which provides the only point of access to structure 7-X. The bounding walls of this possible courtyard are formed by the ramp and partially by the remnants of structure 7-I to the north. After a small gap in preservation, the courtyard's northern bounding wall continues eastward to form a thick circuit wall, which follows the contours of the bedrock. Approximately 45 m further to the east, the circuit wall is abutted on its southern face by a second circuit wall that loops south and then heads back westwards, aligning with the southern wall of 7-X. Together, these two circuit walls create another, possibly open-air space on the eastern side of 7-X which mirrors the courtyard on the west, though it is considerably larger than its western counterpart (Fig. A.57, labeled 9-V). To the southeast are two additional detached structures, 9-XI and 9-IV, but most of the area directly south and southeast of 7-X is heavily disturbed and does not offer clear architectural plans, conceivably due to a nearby Early Modern lime kiln that gorged on Mycenaean walls.

Despite exposure over the millennia, the remains of 7-X are in superb condition, surpassing that of structure 4-VI in clarity of wall faces and vertical preservation (Fig. A.58).[35] The terrain surrounding 7-X is flatter and higher in elevation than the area of 4-VI, which may have furthered this level of preservation. A steep drop-off at the southern edge of the building, where a fissure splits the terrain, though, has resulted in the partial loss of 7-X's southern wall (wall 271). All other walls remain intact. Structure 7-X is square in plan, measuring c. 9.5 m north-south by 11 m east-west with a footprint of 105 m^2, a little over half the size of 4-VI. On

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[35] For additional discussion of 7-X, see Tartaron et al. 2011, 583–7.

all sides, its exterior walls are rectilinear with no use of offsets. Interior and exterior corners

maintain 90° angles and walls follow a roughly east-west, north-south orientation, much like 4-

VI. Interior walls divide the structure into three definite rooms, one in the western half with its

long axis running north-south (space 1: c. 21 m^2), and two in the eastern half with their long axes

running east-west (space 2: c. 26 m^2; space 3: c. 17 m^2).

Whereas structure 4-VI shows no evidence for entrances or interior doorways, there is a

clear entrance, convincing indications of two doorways connecting interior spaces, and hints of a

stairwell to an upper floor in structure 7-X. A later circular feature (6078) was built in the area of

the stairwell and therefore, the structure may be disturbed here.[36] The main entrance to structure

7-X, measuring c. 1.32 m wide x 0.75 m deep (Fig. A.59), passes through 7-X's western wall and

gives entry to space 1 from the courtyard north of the ramp. The entrance's northern limit is

marked by a large, squared anta block and a second anta has tumbled out to the west (Fig. A.60).

The southern limit is bounded by a long, irregular block. Between these blocks, a group of

flattened stones act as a threshold. In the southern half of space 1, in an area measuring 2.5 wide

x 3.75 long, a row of small stones and some fallen blocks are interpreted as the remains of a

staircase. Well-preserved staircases are rare on the mainland and are predominantly found in

palatial buildings where they were constructed of stone.[37] Comparatively, the stairwells proposed

for the House of the Sphinxes (room 8)[38] and the Granary (rooms 17-18)[39] have similar

dimensions and an analogous layout to the proposed stairwell in 7-X. The parallel row of stones,

the dimensions of the space, and the placement near the main entrance imply that the stairwell

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[36] This is also affirmed by the ceramic finds, which include Late Roman and Early Modern
sherds (Amy Dill, personal communication).
[37] Darcque 2005, 121–3.
[38] Darcque 2005, plan 30.
[39] Darcque 2005, plan 37.

may have been Π-shape, a configuration which is common at Akrotiri.[40] Immediately next to the stairwell, the first interior doorway pierces wall 9310 and leads from space 1 into space 2, following the axis of the main entrance. On at its northern and southern ends, it is framed by anta blocks (Fig. A.61). A second, probable interior doorway passes through wall 273 in the southeastern corner of space 2 and gives access to space 3. This doorway, however, is not especially well defined and lacks evidence of anta blocks. Rubble in the area of the two interior doorways hints that these may have been blocked at some point. Finally, a gap in the masonry of the north wall may be a possible window (4606).

The walls of 7-X, at a few points, appear to be founded directly on bedrock. This is clearest along the structure's southern edge where wall 271 follows a pronounced ridge of bedrock and has partially tumbled out (Fig. A.62). Elsewhere, there is a larger amount of soil in and around 7-X that often prevents direct observation of the foundations. While some of this soil may be recent accumulation or may have resulted from building decay, it is likely the area also retained soil in the Mycenaean period due to its gentle slope and bedrock ridges. This would mean that during construction, some walls required shallow foundation trenches to reach bedrock.

The walls of 7-X have clear interior and exterior faces throughout the building. The blocks utilized in the walls are irregular but tend to have at least one flat side which forms the wall face. Whereas structure 4-VI showed significant overlap between blocks making up the two faces, the walls of 7-X often have a small rubble core between the facing blocks (Fig. A.63). Chinking is visible in a number of walls (Fig. A.64), but the chinking stones are larger than in 4-VI and appear less frequently, perhaps simply due to preservation. Large to very large blocks are

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[40] Palyvou 2005, 133–6. This configuration is sometimes referred to as U-shaped.

common in both interior and exterior walls, not just as corner block, although they are still preferred here. One large example is found in the western face of wall 274, which measures 1.08 m wide x 0.68 m deep x 0.64 m tall with a weight on the order of c. 750 kg.[41] The more typical blocks can range from tens to hundreds of kilograms. The larger blocks are matched by the very thick walls of 7-X. Where wall faces are in situ and the wall is measureable, the average thickness is 0.88 m with a range of 0.72–1.06 m. The average preserved wall height is 0.67 m with a maximum preservation of 1.48 m at the corner of walls 271 and 272 (Fig. A.65).

The CAD Models

Because only the limestone remnants of the foundations and lower walls of structures 4-VI and 7-X remain, their overall appearance and the nature of their superstructure must be deduced from comparative architectural examples and common building practices.[42] In describing how I reconstruct 4-VI and 7-X, I progresses from the foundations upwards. The two reconstructions are discussed side-by-side to highlight possible similarities in construction and noticeable points of difference. The approach I take in reconstructing each structure marginally differs in order to explore a better range of choices and behaviors during acts of architectural production at Kalamianos. For structure 4-VI (Fig. A.66), I reconstruct only the building's core structural elements. With structure 7-X (Fig. A.67), in contrast, I have allowed leeway to fill out the reconstruction with more complex architectural details that are common in Aegean

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[41] The block would weigh c. 1120 kg if it were perfectly rectangular. I estimate it is about 2/3rd of this weight based on the shape of the block.
[42] See especially Shear 1968; Wright 1978; Aschenbrenner et al. 1992; Küpper 1996; Iakovidis 2001; Nelson 2001; Darcque 2005; Palyvou 2005; Shaw 2009.

architecture and may have been present at Kalamianos, such as lime plastering, a second story, and a built staircase.

In both CAD models, the terrain surrounding the structures is reconstructed from total station and differential GPS points taken as part of SHARP's documentation process. Points taken along the ground line, outside of and around the structure, are built into a 3-D surface model. Since fill and collapse in both 4-VI and 7-X prevent direct observation of the interior ground level, this portion of the surface is interpolated from the known exterior points. These known points, of course, are affected by building collapse, erosion, and other post-depositional processes and measure the ground level as it stands now, not necessarily the level found in the Mycenaean period; however, in the area of structure 4-VI, I do not believe that the ground level has changed much while around structure 7-X, soil and rubble accumulation have potentially altered the ground level slightly.

Direct observation in structure 4-VI made it clear that the building was consistently founded on large pieces of exposed bedrock. The remains of 7-X also suggest it was founded on exposed bedrock, particularly on its southern side, but this is not definite along the northern edge. The preserved threshold in the main entrance to 7-X gives an approximation of the 1st floor's level (c. 8.5 masl), which is lower than the interpolated northern ground level. Therefore, in the model the ground on the northern side of the building has been excavated and worked down slightly to provide a level bedrock foundation for the walls and an even interior floor. The interpolated ground level in 4-VI has not been altered. From lack of doors, it is assumed that the remains of 4-VI reflect basement levels and the interior bedrock may or may not have been worked within them. A basement room of Structure 7-I, where a large chunk of bedrock slopes

into the room on its eastern side (Fig. A.68) is a good example of how builders sometimes left bedrock unworked in lower level rooms.

The outlines of foundations and walls are reconstructed from drawn plans and field measurements. For both structures, I have attempted to trace the in-situ faces of the walls as they are drawn while following the approximate path of the standing remains. As a result, the walls of 4-VI's reconstruction show a rather even thickness and smooth appearance which is typical of the structure, while the walls of 7-X have more pronounced variations in wall thickness and some noticeable kinks. The high points of the standing remains, 1.18 m in 4-VI and 1.48 m in 7-X, indicate the stone foundations and walls were quite tall. The additional amount of tumble, up to at least 1.5 m deep in the southern rooms of 4-VI, suggests the first story of buildings at Kalamianos may have been entirely of limestone. This situation is rare on the mainland where stone socles topped with mudbrick are the normal building technique,[43] but it is not without parallel. At Mycenae, the House of the Warrior Vase, Building Gamma, and Building Delta have walls of rubble occasionally surpassing 3 m in height.[44] Likewise, the first story of Unit III-2 at Nichoria was built in stone, up to 2 m high, based on the volume of stone rubble recovered during excavation.[45]

Beyond the volume of stone in 4-VI and the easy availability of limestone as a building material at Kalamianos, examination at the town of Korphos supports reconstructing the first stories of Kalamianos' Mycenaean buildings in stone; the surviving premodern buildings from the region demonstrate that local rubble was the preferred building material (Fig. A.69). The wall building technique in the premodern period used small to medium sized rubble, generally

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[43] Shear 1968; Darcque 2005.
[44] Wright 1978, 131; Darcque 2005, 95–7.
[45] Aschenbrenner et al. 1992, 380–6.

without any attempt at coursing. Surviving premodern examples are always heavily mortared with the local red, clay-rich soil. In some cases, wooden elements are incorporated into the walls, perhaps as ties and supports like those attested in Aegean architecture.[46] The possible use of wooden elements at Kalamianos is rarely attested[47] and there are no examples of half-timbering, but wood very well may have been selectively incorporated into rubble walls. The use of mortar with rubble finds support in the presence of soil and staining in walls above the ground level and the discovery of seashells within walls that could have been part of the mortar's temper. For these reasons, I contend that the first stories of structures 4-VI and 7-X were entirely built in limestone rubble, mortared with readily available clay and soil.

The height of the rubble first stories is estimated at 2.5 m. There are few preserved heights of first stories in mainland Bronze Age architecture, but published measurements range from 2.0 – 3.5 m.[48] Theran houses, where data on story height is more prevalent, show first stories were also typically greater than 2 m.[49] For the Early Helladic House of the Tiles at Lerna, Wiencke suggests a height of 2.5 m.[50] As a reasonable middle ground of the sparse measurements which exist, I have followed Wiencke's interpretation in my reconstructions and have taken the first stories of 4-VI and 7-X to a height of 2.5 m. In the case of 4-VI, there is the additional question of where the first story begins and the basement levels end. Using as a baseline the walls along the northern end of the building, which rise to c. 8 masl, I approximate

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[46] Shear 1968, 441; Küpper 1996, 67–70; Nelson 2001, 70–95; Shaw 2009, 91–107.
[47] A bedrock cutting in 7-I might have received a piece of timber meant to support a floor (Pullen 2013b, 255).
[48] Shear 1968, 450–3; Darcque 2005, 123–4.
[49] Palyvou 2005, 128 table 1.
[50] Wiencke 2000, 292.

that the first story began at this same level across the entire building.[51] The result for 4-VI's

reconstruction is that the basement rooms are more confined at north, but taller and more

spacious under the southern rooms. In 7-X, the first story begins at the level of the main

threshold. The floor along the southern portion of the building is consequently leveled with a

small amount of fill to account for the sloping terrain.

No doors or passages are reconstructed for 4-VI. They certainly existed, but there is no

reasonable way to guess their placement. Leaving out doorways further maintains the simple,

structural emphasis of 4-VI's reconstruction. For the more complex model of 7-X, the three

doorways indicated by the standing remains are included in the model. Their reconstructed

height is based on examples from Thera. The main entrance to room 1 rises to a height of 2 m,

which is the average of exterior doorways at Thera.[52] The two interior doorways are

reconstructed as 1.5 m high, the average of interior doorways at Thera.[53] Their widths are taken

directly from the drawn plans and field measurements. Windows have been excluded from both

models. Again with 4-VI, there is no suggestion of their placement and though two possible

window locations were identified in the north wall of 7-X, my own observations in the field left

me uncertain of these, for which reason I have left them out.

The thickness of walls in both structures would support additional stories. Structure 4-

VI, though, has been reconstructed as a single story. Structure 7-X has been reconstructed with

two stories, foremost because of the indication of a stairwell and the structure's greater wall

thickness. I theorize that the second story of 7-X is made of mudbrick, which is a more

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[51] This is the most straightforward way to approximate the building's form, although there is no
requirement that all rooms originally had the same floor level.
[52] Palyvou 2005, 136–40.
[53] Palyvou 2005, 140–3.

manageable material for second stories compared to bulky limestone rubble.[54] The decision to

include mudbrick in the model is also a practical one; it allows for the exploration of two

different wall building techniques at Kalamianos: the locally-preferred mortared rubble

construction and the more traditional mainland mudbrick technique. While I think mortared

rubble was the likelier building material for first stories at Kalamianos, this does not preclude

variability in practice. Some of the soil accumulation in buildings, such as in room 2 of structure

7-X, may be the result of mudbrick decay and a geological core taken in the nearby structure 7-I

contained a possible fragment of an unfired mudbrick.[55] In reconstructing the second story of 7-

X in mudbrick, I have followed the wall thickness of the first story, again accepting a height of

2.5 m (excluding the height of the floor between stories). The modeled width of the second story

walls is a potential overestimate. Walls were possibly thinned out as they rose in order to lighten

the load placed on lower walls and foundations.[56] The configuration of the second story's rooms

follows the first story's, including the placement of interior doorways.[57]

      The floor between basement and first story in structure 4-VI, and first and second story in

structure 7-X, is reconstructed following the traditional form.[58] It first consists of large, load-

bearing wooden beams built into the walls to span open spaces. To reduce the stress placed on

each beam, these are set parallel to each room's shortest dimension. In the case of very large

spaces, columns or piers may have been needed to support the beams,[59] but none are added here

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[54] On the construction materials of second stories, see Darcque 2005, 95–100.
[55] Tartaron et al. 2011, 578.
[56] At Thera, the thickness of upper stories typically diminishes, forming c. 20 cm wide ledges (Palyvou 2005, 114–5).
[57] Lower walls and foundations will reflect the placement of the upper story's walls whose weight they had to support. For example, see the plans of multistory houses at Akrotiri, particularly Xeste 3 (Palyvou 2005, 62) and the West House (Palyvou 2005, fig. 46).
[58] Darcque 2005, 124–6.
[59] One example at Kalamianos is found in structure 7-I (Pullen 2013b, 255).

since the spans of all rooms fall under c. 4 m.[60] On top of the main beams are smaller branches

and vegetation, such as reeds or grasses, running crosswise. Finally, there is a layer of tamped

earth or clay, which can sometimes include pebbles or lime. Measurements for the

reconstructions' floors are derived from published Bronze Age examples. The main beams in the

reconstructions are debarked timbers,[61] which are 0.15 m in diameter and are set every 0.50 m.[62]

The layer of branches and vegetation is 0.06 m thick and topped by 0.07 m of tamped earth and

clay.[63] Each of these measurements is conservative and can be considerably thicker in surviving

examples. The construction of roofs for 4-VI and 7-X is the same as the floor. Although gabled

roofs are a possibility, flat roofs seem to be the more typical mainland technique.[64] There is also

no evidence for roof tiles at the site of Kalamianos that would suggest gabled roofs. As flat roofs,

it is possible these were active spaces with verandas or parapets,[65] but for the sake of simplicity I

have not built this into the reconstructions.

In structure 7-X, a staircase to the south of the main entrance leads up to the second floor.

From the shape of the space, the stairway is reconstructed as a Π-shape with a large landing

where the stairs change direction. Examples of staircases survive, in part, at various Mycenaean

sites,[66] but as would be expected, the most complete examples are from Akrotiri.[67] The general

technique of construction is also well-reflected in an example from Malia.[68] These examples

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[60] Shear 1968, 451.
[61] Goldman 1931, 62–3; Schmid 1996, 81–2.
[62] Darcque 2005, 66–7; Palyvou 2005, 128.
[63] Based on a conservative example from Eutresis (Goldman 1931, 62–3).
[64] On flat and gabbled roofs in Mycenaean architecture, see Shear 1986, 8–11; Iakovidis 1990, 2001, 135–7; Küpper 1996, 104–5; Darcque 2005, 124–8.
[65] Shaw 2009, 153–5.
[66] Darcque 2005, 121–3.
[67] Palyvou 2005, 133–6.
[68] Schmid 1996, 84–5.

demonstrate the construction method for stairs is the same as with floors and roofs; it is simply done at an angle. In simple Π-shaped stairwells, wooden support beams are embedded in the main walls of the staircase and a thinner partition wall. The beams are topped with cross branches, earth and clay, and then stair treads. The dimensions of these elements in the reconstruction follows the conservative measurements used for the floor and roof. The angle of the stair case and sizing of the treads is based on ergonomics. Following Palyvou's analysis at Akrotiri, the staircase rises at a comfortable angle of 27°.[69] Each section of the staircases has eight steps which are 0.28 m deep by 0.17 m tall.[70] At a height of 1.35 m, a landing joins the two sections of the staircase. On the second story of 7-X, a thin mudbrick partition wall, 0.20 m thick,[71] has been added to block off the lower section of the stairwell.

Plaster finishing is included in the reconstruction of both buildings. The exterior of 4-VI and 7-X each needed a coating to protect against the corrosive effects of water on mortar and mudbrick. The premodern buildings of the region are coated with a thick, stucco material that serves this purpose, but for the Mycenaean builders the simplest choice was to use a layer of mud or clay plaster. The thickness and use of such coatings are variable across Mycenaean buildings and, so long as they are impervious to water, their thickness matters only in how often they must be renewed.[72] Measurements form Gla suggest 0.04 m is an effective but very conservative thickness for such an exterior coating.[73] For interior coatings, all of 4-VI's first story and basement rooms are plastered with mud or clay to a thickness of 0.03 m, which evened out the

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[69] Palyvou 2005, 158.
[70] Again this approximates Palyvou's analysis (2005, 132–6, 158).
[71] Palyvou 2005, 121.
[72] Küpper 1996, 96–8; Darcque 2005, 101–6.
[73] Iakovidis 2001, 131.

surface of the walls and provided further protection for the mortared rubble.[74] In 7-X's

reconstruction, again, all first and second story rooms are covered in 0.03 m of mud or clay

plaster. Because of the more complex nature of 7-X's reconstruction, though, I model a

hypothetical layer of lime plaster in the eastern and southern upstairs rooms in order to explore

choices of material that faced the builders at Kalamianos.[75] The use of a base coating to even out

the walls in mud or clay plaster topped with lime plaster is found elsewhere, such as in the palace

at Mycenae.[76] The final coating of lime plaster over the base layer of mud or clay is often applied

in multiple stages, moving from a thicker coat to a final wash. In the reconstruction, the overall

thickness of the lime plaster is hypothesized to be 0.005 m, a conservative measurement based

on thinner examples found at Malia and Phaistos.[77] This lime plaster has been reconstructed for

both the walls and floors of the two upper rooms in structure 7-X.

Producing Mycenaean Kalamianos[78]

Planning to Build

Planning a new building at Kalamianos was a multifaceted process which can be

scrutinized archaeologically from a number of angles. The placement of a structure at the site

and the form of that structure required that builders balance larger cultural ideas on the proper

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[74] This measurement is based on a preserved example of mud plaster from Nichoria, Unit III-2 (Aschenbrenner et al. 1992, 380).

[75] Compare the West House at Aktrotiri, where rooms on the ground floor are plastered only with mud (Palyvou 2005, 49). Evidence for the use of lime at Kalamianos is found in a structure revealed by the road cut at Stiri (Fig. A.83).

[76] Shear 1968, 433, 444; Darcque 2005, 101; Shaw 2009, 142–7.

[77] Shaw 2009, 146.

[78] The energetic flowcharts for all structures are illustrated and discussed in Chapter 7. The energetic flowcharts illustrating the process of constructing structure 4-VI and 7-X are found in Figures A.106–112 and A.113–120. Each individual energetic flowchart is referenced when the relevant part of the construction process is discussed.

formation of a town and the peculiar needs of each structure. Broadly, this type of consideration falls under the rubric of urban planning. Smith has pointed out that the concept of urban planning can sometimes be abused in archaeology, where the term "planned" (and hence urban planning) is frequently reserved for a rigid, orthogonal layout and all other towns or cities are labeled "unplanned."[79] The process of urban planning according to Smith, though, takes on many forms and is a collection of practices measurable in their intensity rather than the presence or absence of a single feature. These practices range from building along a predetermined grid, such as at Middle Kingdom Lahun in Egypt,[80] to following cultural patterns during construction, such as the placement of temples around plazas at Mesoamerican centers.[81] For the construction of Kalamianos, some of the characteristics that Smith draws upon to better understand urban planning are valuable. These include the orientation of buildings (not just gridded orientations) and choices of accessibility and visibility.[82] Particularly some of Smith's concepts can be applied to Kalamianos by looking at how each building's outline and room divisions were fixed within the urban layout; what weight the builders placed on resource access, such as to water or building materials, when selecting a building site; the degree to which the function and importance of the building may have affected its location and visibility; and how builders configured a structure's entry points.[83]

During fieldwork and mapping of the structures at Kalamianos, it was noted that many structures follow a common north-south, east-west orientation.[84] In part, this tendency to

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[79] Smith 2007.
[80] Smith 2007, 12–21.
[81] Smith 2007, 26–8.
[82] Smith 2007, 7.
[83] Tartaron et al. 2011, 602–4; Pullen 2013b, 252–6.
[84] Tartaron et al. 2011; Pullen 2013b, 602.

organize buildings along the same lines has been attributed to the geological characteristics of the local bedrock, which runs in east-west, north-south lines. Since the bedrock formed an integral part of the construction process, acting as foundations for many walls, this certainly contributed to the grid-like development of Kalamianos. Not all structures, though, follow this arrangement. Rather, the orientations of structures across sectors 4, 5, 7, and 9 seem to fall into three major groupings (Figs. A.70, A.71), each of which may have a different explanation.[85]

Group 1 structures follow the previously noted bedrock orientation, typically with an east-west bearing around 85°. The majority of surviving structures fall into this group, which spans all sectors and was the builders' preferred orientation for the layout of buildings. The extensive spread of this group across the site supports the geological explanation since there does not seem to be any other unifying factor that would encourage comparable orientations over the hundreds of meters between sectors 7 and 9, and sectors 4 and 5. The orientation of group 2 structures skews to the southwest. The east-west bearing of walls approximates 105° and north-south walls run perpendicular to this bearing. In contrast to group 1, this orientation is a localized phenomenon, appearing only in sector 5 between structure 5-XV at the north and 5-V at the south. The dominant orienting factor of this grouping is the major north-south avenue, labeled 5-XII, that splits sector 5.[86] It is hard to say whether the buildings to the east developed around the avenue or the avenue developed around the buildings, but the area has been compared to an insula.[87] Whereas the orientation of group 1 seems geologically-based, by observing a localized,

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[85] These groupings are based on structures with identifiable rooms. Structures without rooms are listed as "insufficient data." Though it is apparent that many of these tend towards the main groups, the assignment of a building's orientation is most strongly supported when interior and exterior walls are preserved.

[86] If the avenue extended further to the north, along the eastern side of structure 5-XV, then structures 5-XXVIII and 5-XVI may also be considered part of group 2.

[87] Tartaron et al. 2011, 595.

man-made feature, the orientation of group 2 is more in line with traditional notions of urban

planning. Finally, group 3 structures lack a common orientation and the groups is typically

represented by structures or features which conform to the local terrain. There are only a few

examples of this group in sectors 4 and 5 where groups 1 and 2 dominate. Each is a small,

isolated structure that parallels the contours of its location. The western group of rooms in

structure 4-XIX, which does not follow the main orientation of the building and conforms to

ground contours instead, may be a further example.[88] In sectors 7 and 9, group 3 is attested by

the remains of the circuit walls and structure 7-XII, the so-called ramp. Each of these inevitably

has an orientation in line with geology, localized terrain, and its own intended function. I believe

that many group 3 structures in sectors 7 and 9 may have been constructed after the group 1

structures. This is supported by the fact that sections of the circuit wall labeled 7-XX and 7-XXV

take account of the northern edge of 7-I while purposefully skirting 7-II, and by the fact that the

wall abutments and overall forms of 9-V and 7-XII imply they were constructed after 7-I and 7-

X. Group 3 structures, then, might be viewed as organic, need-based developments which post-

dated the site's core structures; as a result, they were constrained more by existing buildings and

current needs than by any single orientation scheme.

Structures 4-VI and 7-X both have orientations that place them in the dominant group 1.

The importance of laying out these structures along geological lines is clear from their remains

since bedrock was integral throughout 4-VI and was equally important in the southern wall of 7-

X. Among the group 1 structures surrounding 4-VI and 7-X, there are suggestions of a

metrological pattern which contributed to the structures' exact boundaries and room layouts. The

strongest evidence of this is seen when structure 4-VI is compared to structures 4-IX and 5-VIII.

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[88] The use of two orientations in 4-XIX could be related to phases of construction.

Laying a grid based on the internal divisions of 4-VI over these structures accentuates their similarities (Fig. A.72). In all three, the north-south dimension is c. 21 m and the bounding north-south walls were constructed along the same east-west line. With structure 4-IX, the walls suggest the east-west dimensions also mirrored 4-VI's width, while 5-VII is double this width, if measuring where its rooms are clearly defined. This parallel metrology further appears in room divisions; from north to south, cross walls within all three structures align well. The northern rooms of 4-XVI may fit this pattern too.

Structure 7-X was, likewise, set out in a manner similar to surrounding structures (Fig. A.73). The position of its north and south exterior walls are analogous to 7-III's walls as is its main north-south dividing wall. That this fits into a larger trend is substantiated by structure 7-III's link with structures 7-I and 7-II to the north, which parallel each other in their east-west room divisions. Some of these similarities in layout and dimensions are likely due to the flow of the bedrock, just as the overall orientations are, but the correspondence between cross walls and room divisions appears more substantive; it required an intentional plan surpassing the practical necessity of building along the exposed bedrock. The connection between structures in sector 7, and structures in sectors 4 and 5 signals, in my opinion, that the construction of group 1 structures in each occurred in punctuated, closely timed events. If they were spaced out in time, it is harder to explain how and why the interior walls were so well coordinated.

The choice of where to build on the site in particular has been linked with access to fresh water.[89] Since there are no immediate sources of free-flowing fresh water in the vicinity of Kalamianos, excluding a perennial stream near the modern town of Korphos, the purest sources available to the Mycenaeans were the fissures that dot the site. Structure 7-X was built

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[89] Tartaron et al. 2011, 576; Pullen 2013b, 253.

immediately next to one such fissure which lies at a lower elevation to its southeast; the bedrock underlying 7-X's south wall is actually the northern face of this fissure. Study showed that the fissure here was enlarged to ease access to it and that an artificial cutting at its edge was made where someone could stand to draw out water.[90] Beyond simple drinking water access, the proximity of water to a building might also relate to construction needs. For construction, mud or clay mortar and brick are water intensive materials that require fresh water, since the salts in sea water will crystalize upon drying and damage the material.[91] Buildings that heavily employed these materials might have been placed nearer to fresh water, which is difficult to transport over distances in volume.[92] Buildings especially close to fresh water, like structure 7-X, may have also had industrial functions that relied on this immediate access. Finally, the choice to build 7-X next to a fissure could relate to water control as much as to water access. In an environment where fresh water is limited, the ability to moderate its use would be important and possibly an indication of status and authority.[93] Structure 4-VI deviates from the pattern of structure 7-X; it is removed from immediate water access. A number of fissures do lie south of 4-VI, but the nearest is at least 20 m away. In choosing this site for 4-VI, the builders were evidently less concerned with direct water availability than the builders of 7-X.[94]

Lastly, structures 7-X and 4-VI were each planned and built with different viewsheds, visibility from sea, and patterns of access. Looking out from the areas of structures 7-X and 4-VI reveals that each have a distinct view of the site. The location of 7-X possessed a commanding

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[90] Richard Dunn and Giuliana Bianco, personal communication.

[91] McHenry 1989, 61.

[92] This is not so much due to weight as it is to finding suitable carrying vessels.

[93] Nagle suggests that 7-X may have had official, non-residential functions (2015, 435–9).

[94] A distance of 20 m is historically not a particularly long way to carry water, but it is in contrast to building a structure directly on top of a fissure. It is also possible that rain water was collected to supplement the fissures.

view of the majority of the site, including the area of structure 7-I to its northwest, the buildings

along the coast of sector 9, and the insula/avenue area of sector 5 (Fig. A.74). Structure 7-X's

placement at a higher elevation seems designed to survey the major area of habitation and its

coastline; during the Mycenaean period, this viewshed from 7-X would have extended even

further to the east, covering the now submerged areas along the ancient coastline. Concurrently,

from below, 7-X was visible to many of the low lying structures. The viewshed of structure 4-VI

is oriented, in contrast, more towards the central and southern areas of the site, where less

evidence for Mycenaean habitation exists (Fig. A.75). Structure 4-VI does not have a view of

much of the eastern coastline or the insula in sector 5, but it does overlook the lower elevations

in sectors 1, 2, 3 and 4, which cannot be seen from the high ground in sector 7. The viewshed

shows, though, that under good conditions, there would have been intervisibility between

structures 4-VI and the area of 7-X.

The dissimilar placement of these structures, in addition, affected their visibility to

anyone approaching the site by sea (Fig. A.76). The builders constructed 7-X in a spot that both

surveyed the major urban areas of the site and was prominently visible to the east. If it were

multiple stories tall, it would have stood out even more to anyone sailing into the eastern

anchorage. Structure 4-VI was constructed in an area hidden from the sea approach. Set at a

lower elevation and masked by other structures in sectors 4 and 5, the building would only be

visible to someone once they had landed and made their way into the town. The prominence of

7-X and inconspicuousness of 4-VI are complemented by the accessibility of the former and

inaccessibility of the latter. The builders designed 7-X with a wide entrance which was

immediately bordered on its south by a stairwell granting access to the second story.[95] Although the doorways are not preserved in 4-VI, the great height of the walls suggests that doors were elevated from ground level and perhaps only accessible by stairs.[96]

While the preceding issues are only a few of the many concerns that the Mycenaean builders faced when building at Kalamianos, they illustrate that before construction, important choices had to be made to balance larger urban tendencies and individual building needs. As part of the ongoing urban planning process, the archaeological remains of Kalamianos offer fortuitous data on the builders' habits of following particular orientations, assessing the visibility of a structure, correlating possible building functions and access to resources, and creating distinct patterns of access. The builders of structures 4-VI and 7-X, in each case, chose to work in the dominant orientation of the site and to apply similar metrical designs across surrounding structures. This contrasts with their diverging choices to build 7-X in a visible, well-watered, and accessible area, while relegating the larger 4-VI to the edge of habitation, hidden from the sea, and ostensibly with less accessibility.

Preparing the Building Site and the Foundations

After the two sites for structures 4-VI and 7-X had been chosen, the builders would have undertaken site clearance and began preparing the foundations. The area to the north of 7-X and south of 4-VI are suggestive of how the raw terrain looked before construction (Fig. A.77).

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[95] Access to 7-X was later curtailed with the construction of the ramp (7-XII) and walls of 9-V to the east. There is also the suggestion of later blocking walls for some spaces. The time between the initial construction of 7-X and the addition of 7-XII and 9-V is unknown. In this context, one might consider the changing patterns of access at Pylos over time (Shelmerdine 1987).
[96] See Nagle 2015 for discussion of Mycenaean exclusionary building practices and the examination of public and private organizational principles in Mycenaean architecture.

Knowledge of the paleoenvironment is limited, but after clearing any brush or trees in the way, a difficult task would begin; the ground is littered with exposed bedrock outcrops that rise in square to rectangular groups, all of which needed to be cleared for accessibility and eventually worked into serviceable foundations for the structure. Often, the pieces of bedrock are quite large (Fig. A.78) and arranged in tight clusters that would impede work. In many places, only a few well-placed individuals could work away at the bedrock at once. The confined nature of this work is reminiscent of the small spaces found in deep channel quarrying. Extreme danger is always posed when working in such tight spaces. As the bedrock was removed and worked down, pieces could shift unexpectedly pinning or maiming workers, and stray blows from an errant coworker could easily knock out teeth.[97]

The danger of this operation was eased by the fact that the bedrock generally fractures along predictable lines. In my own experimentation with the local rock, well-placed blows from a modern chisel were able to separate or split moderately-sized rocks along fracture lines (Fig. A.79). The technique used by the Mycenaean builders may have been similar, relying on directing bronze chisel blows where fractures were apparent in the stone.[98] For larger stones or ones lacking fractures, the process would have been more cumbersome. It may have utilized undercutting the stone with chisels, splitting or prying it with wooden or metal instruments, or the use of rudimentary percussive tools such as stone hammers to fragment it.[99] During this process of stone removal, in addition to clearing the site, there was the added advantage that the

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[97] Bengtsson notes that in 19th and 20th century granite quarries in Sweden, the most common injuries resulted from getting stuck in a "squeeze" or having one's teeth knocked out (1998, 138).
[98] On Bronze Age chisels, see Evely 1993, 1:2–19; Blackwell 2011, 157–64.
[99] For various Bronze Age quarrying techniques, see Dworakowska 1975, 75–84; Waelkens 1992; Shaw 2009, 28–37.

resulting spoil would later form part of the building's walls. The calculated stockpiling of this stone close by, where it was out of the way but easily retrieved, could significantly reduce later transportation costs, which are thought to have been a major limiting factor in the scale of ancient construction. The proximity of raw material to the building site is, to a high degree, accountable for the thickness of walls at Kalamianos and the frequent inclusion of very large blocks, on the order of hundreds of kilograms.

As clearing progressed and patches of bedrock were trimmed to near ground level, finer work was needed to prepare the exposed bedrock where it would become foundations for the building. This may have occurred in tandem with general site clearance or it could have been done *ad hoc* as specific walls went up. The planning that went into the placement of 4-VI's and 7-X's walls, though, implies that the areas of bedrock that needed to be worked into foundations were well known by the builders in advance. Founding walls directly on bedrock is a known practice at Mycenaean sites among other foundation techniques including built rubble foundations and trenching.[100] The builders at Kalamianos seem to have preferred using the bedrock as either a wide, level perch upon which to ground walls or as a small socle, leaving the bedrock to rise slightly above the ground level and intermingle with the lowest courses of the walls. The southern walls of 4-VI are a good example of the former practice. Generally, the bedrock was left in place here with its top worked down only slightly to form a very wide platform which spreads out well beyond the width of the walls (Fig. A.52). The latter technique is found in 7-X, where the south wall ran along a worked bedrock protrusion that mirrors the thickness of the wall and drops away steeply to the south (Fig. A.62). As hypothesized in the reconstruction, some trenching may have been needed along the northern portion of 7-X in order

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[100] Wright 1978, 10–42; Darcque 2005, 88–90.

to break through the shallow sediment and reach bedrock suitable for foundations. Removal of bedrock in the northern rooms of 4-VI is also a possibility. There is no evidence on the site to suggest that the builders ever cut wall trenches directly into the bedrock, though.

Building First Stories[101]

After the stock of limestone created during site clearance and foundation preparation was exhausted, additional stone had to be gathered for the walls in the immediate vicinity of the building site.[102] Contrasting the built up areas of the site with those left untouched, as to the north of 7-X (Fig. A.77), illustrates the propensity of builders to exploit the closest bedrock first, expanding outwards from the building site as necessary. The technique for rock removal would have been no different than for preparation of the building site and foundations; from the builders' perspective, it was merely a continuation of this process. Because structure 7-X was set in a denser area of habitation,[103] the builders may have needed to go further afield to gather enough stone for its thick walls, perhaps extending to the east and south where there are fewer structures but the bedrock at the surface has evidently been removed.[104] The picture of bedrock removal around 4-VI is sharper because of its isolation.

Having left the bedrock along the southern part of the structure 4-VI relatively untouched, the builders elected to remove large quantities of stone immediately along the east and west of the structure and further to its north. The terrain to the east, between structures 4-VI

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[101] The corresponding energetic flowcharts are found in Figures A.107, 108 for structure 4-VI and Figure A.114 for structure 7-X.

[102] This is comparable to other sites such as Minoan Pseira, where limestone was exploited in proximity to the buildings (McEnroe et al. 2001, 30; Shaw 2009, 37).

[103] Chronology is an issue here, but the connections between 7-X, 7-I, 7-III, and 7-II, in my opinion, suggest a close chronological relationship between these buildings.

[104] The evidence here, though, is subpar because of the presence of the lime kiln.

and 4-IX drops away, forming a perceptible depression where stone was removed; as a result, this gap may have functioned as a path or for drainage, but it now holds a fair amount of rubble. To the northwest of the building an area of quarrying, including possible quarried blocks, has also been identified (Fig. A.80). This quarry area is circular with in situ bedrock along the north, east, and west sides and a central hollow where stone has been removed. The drop in elevation between the top of the "quarry face" and central hollow nears 1 m and a number of blocks here are suggestive of unused or abandoned quarry spoil. The area is only a few meters from the construction site, again emphasizing the builders' desire to harvest stone as close to the walls as possible. The evidence for a discrete quarry here is unique at Kalamianos, where quarrying is demonstrated by a lack of bedrock outcrops rather than distinct activity areas showing stone removal in process.[105] This fits a larger pattern on the mainland where quarry sites are difficult to isolate.[106]

As stone was quarried away around 7-X and 4-VI, it needed to be brought a short distance to the wall builders. The use of wheeled vehicles was impossible given the terrain of Kalamianos, particularly in the areas of ongoing bedrock removal. Carrying would have been the best option, but this is burdensome. Smaller rubble and chinking material could be carried by hand or in baskets by one or two individuals, as was demonstrated when rocks in structure 7-I were cleared by SHARP during fieldwork in 2009. Many of the stones in the walls of both structures, however, could not be transported so easily. Moving the medium to large stones that

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[105] This may also have chronological significant and represent a change in the preferred method for acquiring stone. Ceramic evidence from 4-VI and its area suggests dates of LH IIIB2 to IIIC early (Amy Dill, personal communication) and the placement of 4-VI on the edge of habitation could support a later phase for construction. A masonry technique distinct from that found in the area of 7-X may offer further support that the area of 4-VI was constructed later than other parts of Kalamianos.

[106] Although see Morgan et al. 2011.

constitute the majority of the walls likely relied on the use of a wooden framework which would

allow the stones to be raised up and permitted those carrying to navigate impediments on the

ground. For the very large corner stones, if they were not quarried close to the building site, a

customized wooden framework, built around the individual stone, may have even been needed.

Experiments from Columbia and Mexico illustrate this process in action. During 1955 in an

experiment at La Venta, Mexico workers transported basalt blocks weighing 1.5–2 tons using

ropes tied to poles that were slung across their shoulders[107] and in Columbia, a second

experiment describes workers carrying a 1-ton andesite statue braced on a framework of long

wooden poles.[108] Both of these involve stones much larger than the majority found at

Kalamianos, but they demonstrate that this traditional technique is practical in rough terrain

when wheeled vehicles or pack animals are not feasible.[109] In both cases, the pole frameworks

were built informally and to suit the carriers' immediate needs. Since it is difficult to make a

one-size-fits-all framework, especially when stones range from tens to hundreds of kilograms,

transportation at Kalamianos may have involved a fair amount of improvisation. The proximity

of stone to the building site would have simplified the overall process, but there appears to be no

technological substitute for brute force when transporting stones at Kalamianos.

Abutments of the walls in 4-VI and 7-X suggest how the wall builders organized the

process of construction as stones arrived.[110] In 4-VI, their approach utilized a modular, four-

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[107] Heizer 1966, 825.
[108] Heizer 1966, fig. 7.
[109] An example of this technique with a smaller stone (c. 422 kg) is found in experiments
conducted in Micronesia (Ayres and Scheller 2002, 115–7).
[110] Chronology is a potential issue with abutments, which could signify different construction
events. My own interpretation of the architectural remains, though, is that both 4-VI and 7-X
were constructed as a whole based on the larger configuration of the site and the uniformity of
construction techniques within each.

room construction that has been noted across the site, [111] but the walls indicate this began first with a single room at the center of the building.[112] My interpretation of abutments suggests that space 5, a rectangular area, was built first (Fig. A.81, red). The large corner block at the northeast end of space 5 (Fig. A.51, labeled 9051) marks the edge of this rectangular area where a northern wall was later abutted. The builders then moved west to add a c-shaped area, space 4, which established the full width of the structure (Fig. A.81, blue). It is harder to distinguish whether the north or south areas were added next, but the area to the north followed the exact dimensions of this two room core while the southern group of rooms was indented to the east, somewhat over a meter (Fig. A.81, green). Finally, an internal blocking wall was built between area 1 and area 2/3 (Fig. A.81, yellow). Concentration by the builders on the central area of the building first was practical. Construction of space 5 established a working area from which they could move outwards to the north, south, and west. This process might have coincided with where removal of bedrock occurred first so that wall building and bedrock removal were staggered to speed along construction. Space 5 also established the long eastern boundary of the building and with the addition of space 4, set a baseline for the widest east-west dimension of the structure. At that point, multiple teams of wall builders and quarriers could have worked on the north and south rooms concurrently to reach 4-VI's final layout.

The builders' approach to 7-X's construction was different. My interpretation of the remains suggests that a meandering wall, roughly the shape of the letter G tilted 90° counterclockwise was built first (Fig. A.82, red).[113] Rather than moving out from a central area,

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[111] Tartaron et al. 2011, 587–8; Pullen 2013b, 253–5.
[112] This may be compared to Wright's (1980) analysis of Mycenaean palatial terracing in which he mentions that they were built as isolated compartments.
[113] Structure 9-VIII may be laid out in a similar manner.

with this wall, the builders immediately fixed all boundaries of the structure. Later the

northeastern L-shaped addition completed space 1 and the interior L-shaped wall divided two

more spaces (Fig. A.82, blue). The smaller size of 7-X and limited building space available

might explain this different approach; however, it could also be meaningful that by constructing

the meandering boundary wall first, no doorways had to be immediately sized. Only after the

boundaries were set did the builders need to account for the width of doorways. This may have

provided a way for any overseers or master builders to start 7-X quickly, allowing wall builders

to work along a general plan, while they still retained control over the important issue of access

to and flow within the building. When the first wall was completed, they could size up where the

two additional walls should be built and fix an appropriate width for the doorways.[114] This

approach could also have been chosen in order to create a strong, well-bonded wall for retaining

leveling fill on the south and south-eastern sides of building. The nature of this fill is seen in

structure 13-II at Stiri, a Mycenaean structure which has been cut by a modern road (Fig. A.83).

The profile shows that such fill was composed of large rocks, likely construction and wall

building debris, thrown between the walls and topped with smaller stones. This was capped by a

pebble and earth layer which could act as a floor on its own or be coated with lime.

As with their ordering of construction, the builders utilized different masonry techniques

in 4-VI and 7-X, which may be linked to chronology. The most substantive walls of 7-X use the

so-called "double rubble" technique, an interior and exterior facing wall with a rubble core

between (Figs. A.60, A.63).[115] Blocks are often placed as stretchers, with their long edge forming

the wall face. These are interspersed with smaller blocks placed as headers, with their short side

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[114] The doors themselves would have been installed in wooden frames after the walls were
completed; see Darcque 2005, 107–13; Palyvou 2005, 136–43.
[115] Tartaron et al. 2011, 584.

facing outwards. Occasionally larger blocks pass through the core, spanning the two facing walls. The antae are large squared blocks as are some of the corners. At the top of the building's southeast corner, though, a wedge-shaped block was incorporated. The builders' tendency in structure 7-X was frequently to include large stones. For the walls of structures 4-VI, the builders preferred somewhat smaller stones. Where construction is most visible, two wall faces were often built without evidence of a rubble core between them. Instead, the stones of each face frequently overlap one another and appear to utilize somewhat more chinking than in 7-X. Corner blocks in 4-VI are large, like in 7-X, but flatter, more rectangular blocks are normal.

Each choice of masonry is advantageous in some way. For 7-X, larger blocks meant fewer trips and potentially stronger walls to support an upper story. For 4-VI, smaller blocks involved more frequent trips of reduced weight, but the smaller stones and chinking could be less stable and prone to shift over time. The inclusion of clay or mud mortar, suggested previously based on soil remains in buildings and the region's premodern construction techniques, was a solution to this problem. Adding mortar into the walls would not so much cement in place the large stones as it would support and hold chinking and small stones in place. For this reason, the use of mortar may have been sparing, reserved for pockets of chinking or perceived areas of weakness in the walls. The builders could have sourced material for their mortar from a variety of places at Kalamianos since the ubiquitous soil is ideal for this. Existing pockets of soil around 7-X and 4-VI would be most desirable, but for large volumes of material the polje to the north was the best location. Preferably, the builders would acquire enough mortar locally and avoid carrying baskets of material across the site, though, but this would be heavily depend on

conditions surrounding each building. Fresh water from fissures, of course, was also needed, another reason to be sparing with the application of mortar.[116]

Installing Floors and Roofs

During the construction of 4-VI and 7-X, floors had to go up in tandem with the rising walls to cover the basement levels of 4-VI and to separate the first and second stories in 7-X.[117] The technique of floor construction relies on a layering approach, discussed in the CAD reconstruction. It required that the builders embed large support timbers directly within the walls, perhaps even allowing them to project beyond the exterior face.[118] Above the timbers, branches and vegetation were set crosswise and capped with a thick layer of tamped clay and earth which would function as the floor above. This construction technique is widespread because of effectiveness and simplicity, and it continues to be employed today in mudbrick and rammed earth structures throughout the world.

The type and source of wood used at Kalamianos is indeterminate.[119] The major requirements of the support timbers were that they could sustain large weights and that they were long enough to span rooms, although columns or pillars could be built if the span were too large. Remnants of roof timbers are found occasionally in destruction contexts,[120] and Shaw suggests that, in Minoan architecture, fir and cypress were the dominant choices for structural elements

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[116] This is a problem for mudbrick manufacture, as well, and the cost data on water-intensive techniques is useful for exploring the consequences of the builders' choices.

[117] The corresponding energetic flowchart is found in Figure 7.12 for structure 4-VI and Figure 7.19 for structure 7-X.

[118] The depiction of such support timbers is found in Aegean art.

[119] Limited palynological data exists in the region to reconstruct the flora of the paleo-environment, but see Jahns 1993.

[120] Shear 1968, 442; Shaw 2009, 93.

while oak, pine, and olive were used in secondary roles.[121] Of these, the structural function of fir is corroborated by Greek textual sources. In Homer, both Odysseus' and Nestor's palaces have beams and columns of fir, and in his treaties on plants, Theophrastus lists fir as a choice construction material.[122] The Greek building accounts from Epidaurus and Delphi confirm that fir was favored for roofing beams in ancient construction, especially because of its length.[123] The difficulty this choice of material would pose for Kalamianos, however, is that the fir species available in the region (*abies cephalonica*) is mountainous, growing above 1,000 meters.[124] Since this was inaccessible in the area surrounding Kalamianos, pine was a likely substitute.[125] Specifically the builders could have exploited the coastal Aleppo pine (*pinus halepensis*) found at low elevations, but of inferior building quality, or the mountain pine (*pinus nigra*), which grows at elevations of a few hundred meters.[126] This high elevation is still some distance from the site of Kalamianos, but upland areas like Stiri could have acted as intermediaries for acquiring these preferred species of trees and funneling them towards the coast.[127] In many structures at Kalamianos, though, the builders may have been limited to the lower-grade coastal pine that was more accessible.[128]

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[121] Shaw 2009, 94.
[122] Meiggs 1982, 111.
[123] Meiggs 1982, 424–5, 431–2.
[124] Meiggs 1982, 43.
[125] Although much earlier in date, Pleistocene cores from the Nemea valley show that oak and pine were the dominant tree species (Urban and Fuchs 2005).
[126] Meiggs 1982, 43–4.
[127] See Tartaron et al. 2011, 615–7.
[128] Half of the wooden materials from Pylos that were sampled were oak genus and half were pine genus (Nelson 2001, 70–3). This might support the use of Pine as roofing timbers for Kalamianos, although this connection is tenuous. Sea trade is another possible avenue through which certain types of timber were acquired.

Limited Egyptian and Near Eastern depictions illustrate the process of tree felling, showing the use of axes and guide ropes to control a tree's fall.[129] By the Roman period, saws were employed to fell trees, but the earliest date of this practice is indeterminate.[130] Certainly, the Late Bronze Age tool assemblage shows a prevalence of axes, particularly the double axe, which was widely adopted on the mainland during later Mycenaean period.[131] As is typical of metal tools, the densest concentration of archaeologically recovered double axes is at Mycenae, where 41 examples were found.[132] If metal were unavailable, builders and loggers at Kalamianos may equally have used stone axes. For trees of small diameter, there is little difference in the effectiveness of stone axe heads and metal ones, but when a tree's diameter exceeds 10 cm, the efficacy of stone decreases considerably.[133] Bronze axes, on the other hand, perform comparably well to modern steel ones.[134] After felling, raw timbers were likely immediately processed by removing bark and branches with an adze or ax. The method of transportation to the building site was contingent upon distance and terrain. Dragging works well for larger timber, especially when draft animals are available and a rudimentary path has been prepared. Otherwise, by spacing workers evenly, large beams can be reasonably carried on the shoulders for long distances.[135] At least around the site of Kalamianos, this latter method was probable due to the rough terrain.[136]

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[129] Moorey 1994, 353; Gale et al. 2000, 353; G.R.H. Wright 2005, fig. 5, 6.
[130] G.R.H. Wright 2005, 18–20.
[131] Blackwell 2011, 138–45.
[132] Blackwell 2011, 201–2 table 4.23.
[133] Mathieu and Meyer 1997, fig. 5.
[134] Mathieu and Meyer 1997, 348–9.
[135] See Hammerstedt's summary of this issue in the Americas (2005, 63–4).
[136] If timbers came from a long distance, sea transport might also be used. This is suggested on Crete for the transportation of building stone and possibly timber; see Shaw 2009, 28–30, 36.

At the building site, the workers embedded these timbers into the walls when they had reached the desired floor height. Maneuvering larger timbers around the wall edge, particularly higher up, required light scaffolding of some sort.[137] Rudimentary lifting devices or suspension devices would be helpful as well, but archaeologically this is difficult to support. Like the uncertainty of the wood chosen for main beams, the choice of branches and vegetation to cover the main supports could vary greatly; nonetheless, whatever the builders' choice, the effect of the material is the same. Ancient examples from Greece and the Near East include unprocessed branches, woven mats, palm leaves, and bundled reeds.[138]

At Kalamianos, the builders may have employed a mixture of branches already available from felled trees and local reeds. The modern name Kalamianos itself means "reedy" and at one time, wetlands were a prominent feature of the region.[139] In Minoan architecture, reeds were commonly used for this purpose[140] and numerous plaster imprints of such reeds are found at Akrotiri.[141] The distance builders went to gather the cross branches, reeds, or sundry plant material is unknown. It is possible that collection of these materials was informal and that builders took advantage of whatever sources were nearest at hand. The choice might also vary depending on the weight the floor needed to support. The final topping of earth and clay to cover over the branches and vegetation was readily available in pockets of soil around the building site or in polje where large volumes could be acquired. Construction of the roof followed the exact same manner as the floors; however, an additional layer of waterproof plastering was needed (as

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[137] The remnants of such scaffolding are occasionally seen in architecture in the form of putlog holes. One wall in Building T at Kommos has sockets which may have served this purpose (Shaw 2009, 58, fig. 84).
[138] Moorey 1994, 355; Kemp 2000, 93–6; G.R.H. Wright 2005, 134–5; Shaw 2009, 152–5.
[139] Tartaron et al. 2011, 562.
[140] Shaw 2009, 152.
[141] Palyvou 2005, 127–8.

it was for exterior walls) to protect it from the elements.[142] A slight angle was also likely

incorporated into the roof to drain off water accumulation. Organizationally, the builders may

have chosen to complete the roof and building exterior before the interior flooring in order to

prevent damage from the elements, as is often the case in modern construction.

Adding Second Stories and Staircases

Since 4-VI is reconstructed as a single story, after the construction of the roof, the

builders would have proceeded to plaster and finish the exterior of the building. For 7-X,

however, an additional story is hypothesized above the first due to wall thickness and evidence

of a staircase.[143] The volume of stone in the area is suggestive of its extensive use in the first

story, but it seems insufficient for the second story which was possibly mudbrick. The volume of

red soil in structure 13-II at Stiri (Fig. A.83) may, in fact, be the remains of decayed mudbrick.[144]

The process of brick manufacture has been outlined above for the Treasury of Atreus.[145]

Although the application was quite different at Kalamianos, the process of manufacture does not

vary greatly; it is always the mixing of mud and clay with water and additives, all of which is

then shaped and allowed to cure.[146]

The soil of the region is ideal for such brick making due to its clay content. My informal

experiments with material from the site showed that, when mixed with some dried grass as a

binder, the soil is easily formed into resilient bricks. The bricks' cores, though, remained damp

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[142] The corresponding energetic flowcharts are found in Figure 7.14 for structure 4-VI and Figure 7.22 for structure 7-X.

[143] The corresponding energetic flowcharts is found in Figure 7.21 for structure 7-X.

[144] Tartaron et al. 2011, 586–7.

[145] supra, p. 147–148.

[146] The process remains the same today, although the mixing process is mechanized; see McHenry 1989.

after a week and the time to fully dry was likely considerable.[147] In addition to dried grass or straw, a probable additive chosen by the builders at Kalamianos was sand acquired along the coast. This is implied by the volume of seashells found within walls at the site. Analysis has shown that these seashells were not gathered as living specimens[148] and, therefore, these may be the remnants of inclusions from decayed mudbrick added with sand during the manufacturing process.[149] The polje north of the site was an ideal location for the builders to mix and dry their bricks. Not only did it provide a ready source of material to mix, but it offered the open space needed to lay them out to cure and eventually stack them to finish drying. The builders would have to transport water to the area of brick making, though, which is the tradeoff of working at the polje. Brick making could be undertaken on site in areas where water was more accessible, but only at a small scale; such local production is likely to have been used when repairs were needed but would not offer the space for full scale brick production. In general, the large volume of fresh water required during manufacture may have restricted the use of mudbrick at Kalamianos and limited it to special situations.

When the mudbricks had sufficiently dried, after an initial curing and then an extended stacking phase, perhaps of a few weeks,[150] workers could carry them the short distance to the building site and begin installing the mudbrick superstructure of 7-X.[151] As for the roofing and flooring, light scaffolding was necessary to work around the walls as they rose higher.[152] Bricks could then be handed or thrown up by an assistant to masons on scaffolding who would set them

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[147] See McHenry 1989, 63–7.
[148] Tartaron et al. 2011, 613.
[149] These inclusions may also result from mud mortar.
[150] McHenry 1989, 63–7.
[151] See the depiction of mudbrick carrying in the Tomb of Rekhmire (Newberry 1900, pl. 21).
[152] For discussion of light scaffolding in Egypt, see Arnold 1991, 231–6.

appropriately while another worker provided mortar.[153] Unlike in certain places, Bronze Age

Greece had no standardized brick sizes to assist the setting process.[154] At Gla, Iakovidis has even

suggested that some bricks were cut rather than molded.[155] The method of setting (and brick

manufacture) was likely highly individualized and would vary depending on brick size, wall

thickness, and personal skills. As the walls rose, mortar, mixed at the building site as necessary,

only needed to be placed in horizontal joints.[156] Wood may or may not have been incorporated

by the builders at Kalamianos for added stability.[157] The premodern rubble houses of the area, at

least, sporadically include wooden materials (Fig. A.69).

Placement of the timbering for the staircase of 7-X and its dividing wall had to be

accounted for by the wall builders. They would need to lay the timbers at a roughly accurate

angle to support the final staircase. The process of maneuvering and setting them was

comparable to roof and floor construction. In fact, stairways are built like angled roofs and

floors, only topped with treads. When the beams were set, workers could later top them with

branches, vegetation, and earth to prepare the surface that would receive treads. Some stones

have been identified as possible stair treads at Kalamianos, but these are difficult to distinguish

among the jumble of limestone that frequently litters buildings. For treads, single stones,

mortared rubble, wood, or any combination of these materials are all viable. The choice was

doubtless tied to a building's function and the availability of materials. Treads of mortared

rubble, hypothesized in 7-X, would be easiest; for these, the builders could employ small stones

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[153] McHenry 1989, 95–6.
[154] Nodarou et al. 2008; Shaw 2009, 133.
[155] Iakovidis 2001, 130–1.
[156] Kemp 2000, 92. At Gla, thin mortar was applied in the vertical joints (Iakovidis 2001, 130).
[157] Küpper 1996, 67–70; Nelson 2001, 70–95; Darcque 2005, 95–100.

left over from quarrying and wall building, with small amounts of the same mortar used in the

rubble walls.[158]

Plastering and Finishing[159]

Mud plaster and lime plaster were available to the builders of Kalamianos. Mud

plastering on the exterior was necessary for all buildings to protect mortared rubble and

mudbrick from the elements. The builders could have then applied thinner layers of hard lime

plaster to further protect the buildings or for decorative purposes on interior walls. Mud

plastering would have involved the same materials used in mudbrick and mortar production.

Various tempering materials could have been added such as straw which helps to prevent

cracking, but these may not have been necessary. The process of applying thick layers, of at least

a few centimeters, differed depending on whether the surface was flat or vertical. For roofs and

floors, batches of mud plaster could be dumped, spread, and smoothed. Experiments show this

process is relatively easy because large volumes of plaster can be dumped at one time and then

spread across a wide surface area.[160] The application of plaster to walls, though, is more difficult

and time consuming. The plasterer must take a small volume of material that is sticky but still

spreadable and throw it against the wall. This is then forced into gaps between stones or bricks

and spread out gradually across the surface. Only very small amounts of plaster can be applied in

this way and according to Murakami's experiments, the process takes about seven times longer

than plastering floors.[161] The required tools are simple, including baskets or vessels to hold the

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[158] Flat stone slabs, mudbrick, and wood are used as Aegean stairs.

[159] The corresponding energetic flowcharts are found in Figures A.111, 112 for structure 4-VI and Figures A.119, 120 for structure 7-X.

[160] Murakami 2010, 211–2.

[161] Murakami 2010, 211–2; see also the task rates in Appendix C.

mortar and a flat object to spread and smooth it. Trowels of metal or bone and stone floats are found in some quantity on Crete,[162] but small, flat pieces of everyday wood could serve this purpose as well.

The application of lime plaster employed the same process as mud plaster, only it was applied in much thinner coats and sometimes in multiple layers.[163] The manufacturing process, of course, was entirely different than the straightforward mixing of earth, temper, and water required for mud plaster. A key question in reconstructing the process of lime production in the Aegean Bronze Age is whether kilns were used or not. As of now, there are no securely identified Bronze Age lime kilns on Crete or the mainland.[164] Those that have been uncovered in excavation are overwhelmingly of the Roman period, but Bronze Age ceramic kilns exist and could be confused with lime kilns because of similarities in construction.[165] Open air firing was another possibility, as was common practice in Mesoamerican plaster production. It is conceivable that, in fact, both techniques were used depending on the desired permanence of lime plaster production. If lime production were necessary only for a short period of time, a built lime kiln would be unwarranted. A simple pit with some stacked stones would suffice and archaeological experimentation has shown that it is highly unlikely such production areas would be archaeological recognizable.[166] Whatever the choice of production facilities, in all cases broken limestone needs to be subjected to very high heat (900 – 1000° C) for an extended period of time.[167] Larger pieces of limestone require longer firing times, so it is advantageous to crush

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[162] Evely 1993, 474–7.
[163] Shaw cites a LM IIIA bowl half filled with plaster which was being scooped out and applied to walls (2009, 145, figs. 248–50).
[164] Jones and Photos-Jones 2005, 216–7.
[165] Hasaki 2002, 121–2; Jones and Photos-Jones 2005, 216–7.
[166] Goren and Goring-Morris 2008.
[167] Evely 1993, 471.

or pulverize the stone as much as possible beforehand. If the stones are not fired sufficiently, pieces of unburned limestone will contaminate the lime and must be removed by hand.[168]

Ethnographic examples suggest that, in a kiln, burning will take up to six days,[169] but in small batches single-day burns are possible.[170] The firewood required to sustain these burns is considerable.[171] In open-air firing, experiments suggest that the volumetric ratio of firewood to quick lime is on the order of 10:1.[172] After firing, an amount of lime weighing approximately 56% of the limestone's original weight will be left over, with the remainder of the weight lost as CO_2, but the volume of lime is approximately equal to the initial volume of limestone.[173] After this lime has cooled, workers can slake it with water at a ratio of c. 2:1 lime to water.[174] The extensive heat from slaking and the caustic nature of lime makes this process hazardous, though. The resulting hydrated lime can be stored for long periods of time until it is needed.[175] When ready for use, the hydrated lime is typically mixed with sand and some additional water before being applied to walls or floors.

For the reconstructions at Kalamianos, the upper two rooms of 7-X have been hypothetically coated in a thin layer of lime plaster. Wherever lime was produced on site, acquiring and transporting limestone to it was minimally difficult, even less so than for walls because smaller pieces of limestone were most desirable. As for wall construction, the limestone was certainly available close to the firing spot. Collection of firewood likely ranged over some

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[168] Searle 1935, 407.
[169] Hasaki 2002, 123.
[170] Russell and Dahlin 2007; Goren and Goring-Morris 2008.
[171] Hasaki's table of ethnographic examples shows fuel use of a few hundred to few thousand armloads of wood (Hasaki 2002, 123).
[172] Russell and Dahlin 2007, 417.
[173] Searle 1935, 404.
[174] Russell and Dahlin 2007, 417–8.
[175] Evely 1993, 473.

distance, but could have involved any sort of wood, brush, or plant materials[176] so choices were less constrained than when finding roofing materials. As the volume of lime produced increased, workers would have to range further afield to gather enough firewood. Even for small loads of lime, the large amount of wood needed could mean many trips foraging for wood in the area behind Kalamianos. In an experiment with open-air firing in Mexico, Russel and Dahlin write that nearly every piece of wood from a 900 m^2 fallowing forest was needed to make only 0.5 m^3 of lime.[177]

Concluding Remarks

The above discussion of architectural production at Kalamianos and the reconstruction of structures 7-X and 4-VI have wrestled with some of the major problems that impact the study of Mycenaean domestic architecture. In particular, the preservation of domestic structures on the mainland, particularly the fugitive building materials, is variable and our knowledge of larger settlements and urban planning is limited. There are certainly practices of building that span the Aegean which are useful in filling in missing information, but we can lose some sense of human variability and choice by relying on comparative data. I have compensated for the unknowns at Kalamianos by drawing on standard, conservative building practices, as well as ethnographic data, and by reconstructing structures 4-VI and 7-X in different ways as a means to explore choices in building practices at the site. Excavation in the future at Kalamianos will certainly refine knowledge of localized building practices and will improve the models I have created here. Despite the gaps in our knowledge, though, the diversity of choices that confronted builders

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[176] Searle (1935, 395–403) discusses appropriate fuels and temperature for lime production.
[177] Russell and Dahlin 2007, 417.

at Kalamianos and the room for variability across different structures is significant, in and of itself. It offers a strong reminder that the process of producing domestic architecture is fundamentally human and that the final product is grounded in the decisions of many cognizant agents who participated in construction. In Chapter 7, the reconstructions and discussion of structure 4-VI's and structure 7-X's production are revisited in order to model how builders organized production in time and space. There, the detailed energetic flowcharts of the production process, which were cross-referenced in this chapter, are created and the temporality of production is addressed through simulation.

CHAPTER 6

THE NORTHEAST EXTENSION OF MYCENAE'S
FORTIFICATION WALL

Background to Mycenae's Fortification Wall

Overview of Mycenaean Fortifications

Across the Late Helladic mainland, large fortification walls were built at a variety of

sites.[1] Perhaps next to Gla alone, the most well-known of these fortifications are found at the

three major sites of the Argolid: Tiryns, Mycenae, and Midea. Built on high hills overlooking the

plains below, these sites were ringed with thick limestone walls strategically pierced by various

gates and passageways. As viewed today, the fortification walls of these three sites reflect an

agglomeration of Mycenaean building phases that culminated in final changes made during LH

IIIB2.[2] Chronologically, the evidence indicates that in the Argolid, Tiryns was fortified first,

when a megaron and circuit wall were built in LH IIIA1.[3] Mycenae followed suit in LH IIIA2,[4]

while Midea was the last, only being fortified in LH IIIB.[5] This chronology, however, is tentative

since later building and the expansion of these citadels has obscured earlier phases of

construction. Habitation at these sites pre-dates the surviving evidence for fortifications, so it

remains possible that one or more of the three were fortified earlier than the LH III remains

suggest.

The fortifications of the Argolid were built in a cyclopean technique, which used

particularly large, unworked limestone boulders as its principal building material. More

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[1] The sites are catalogued by Hope Simpson and Hagel 2006.
[2] There are also Hellenistic alterations to Mycenae's fortification wall.
[3] Iakovidis 1983, 3–20.
[4] Mylonas 1966, 15–33; Iakovidis 1983, 23–72.
[5] Demakopoulou and Divari-Valakou 1999.

specifically, Loader defines the particular Mycenaean expression of the cyclopean technique as "stonework composed of two distinct wall faces of large, unhewn blocks, generally of local limestone and assembled without mortar, but where openings existed they were filled with small stones."[6] Between the exposed wall faces was a core of earth and stones and despite the lack of mortar, layers of mud and clay are attested in cyclopean walls.[7] The scale of construction is summed up by Wright's and Loader's analysis of average block weight and size. Wright estimates that an average cyclopean block can measure 1.5 m long x 1.0 m tall x 1.0 m thick,[8] to which Loader adds that a typical cyclopean facing stone is 1.845 tons.[9] The use of such large stones in wall faces, particularly the exterior faces, has led to a persistent scholarly link between cyclopean fortifications and concepts of monumentality and elite power.[10] Of the walls at Mycenae and Tiryns, for example, Hope Simpson and Hagel say that "[they] were intended to convey the message that their rulers possessed such a formidable power that it would be useless to contend against them."[11]

The Earlier Phases of Mycenae's Fortifications

The earliest fortification wall at Mycenae (Figs. A.84, A.85) — or at least the first archaeologically attested wall[12] — was built along the higher elevations of the hill in LH IIIA2

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[6] Loader 1998, 5.
[7] See also the definition and discussion of Cyclopean fortifications in Wright 1978, 157–240; Iakovidis 1983; Küpper 1996, 31–5; Hope Simpson and Hagel 2006, 23–6.
[8] Wright 1978, 159–160.
[9] Loader 1998, 66.
[10] This is variously expressed throughout Wright 1978; Loader 1998; Hope Simpson and Hagel 2006; Fitzsimons 2007, 2011; Laffineur 2007.
[11] Hope Simpson and Hagel 2006, 23.
[12] See French and Shelton (2005) a for discussion of the citadel's earlier phases.

(Fig. A.86, Mycenae 1).[13] It followed the northern line of the current wall, turned abruptly south near the Postern Gate, and then cut back west along the Khavos Ravine following the natural contour of the hill.[14] A hypothesized gate existed in the western wall, just north of Grave Circle A, which remained outside of the fortified citadel at the time. The wall was founded directly on worked bedrock without the use of any clay or mortar and was approximately 7.0–7.5 m thick.[15] Built in the typical cyclopean style, its exterior face consisted of irregular limestone boulders pried from the citadel's exposed bedrock and amply supported by smaller chinking.[16] The boulders of the wall face occasionally form headers and stretchers and so bond irregularly with the wall's core, which is composed of rock and earth.[17] Later expansion of the citadel altered or destroyed much of the first wall, but the northern and southeastern sections continued in use throughout Mycenae's history.

In a second phase of building, during LH IIIB1,[18] the western wall of the first period was razed and rebuilt 50–60 m downslope (Fig. A.86, Mycenae 2).[19] While the northern and eastern segments of the first wall remained in place, the new western extension now swept further south until it reached the edge of the Khavos Ravine. Here, it turned abruptly north, following the path of the ravine until it linked up with the eastern boundary of the first wall. The exact location of this join and the manner of its construction are not known since this section of the wall has been lost to erosion (Fig. A.85). The new western wall expanded the citadel by 11,000 m^2 and now

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[13] Mylonas 1966, 22–8, 33.
[14] Mylonas 1966, 22–8; French 2002, 52–6.
[15] Iakovidis 1983, 27.
[16] Loader (1998, 27–31) includes these as part of her Type III walls.
[17] Mylonas 1966, 19; Loader 1998, 27.
[18] Mylonas 1966, 28–31, 33.
[19] Mylonas 1966, 28–31; Iakovidis 1983, 29–35; Kalogeroudis 2008, 288–9.

encompassed Grave Circle A.[20] On the western edge, where the wall of the first phase ended and the new wall began, the Lion Gate was built in place of the earlier entrance. The new gate was a pillar-and-lintel construction and was made of conglomerate instead of limestone.[21] Below the gate's uprights, a threshold was set in a bedding trench and the gate's lintel was capped by a limestone relieving triangle decorated with two heraldic lions.[22] Cuttings in the lintel and pillars indicate that the gate was closed by means of a wooden door which could be bolted shut.[23] In contrast to the earlier entrance, the Lion Gate faced to the northwest and was approached by a monumental ramp flanked by a bastion to its south. At the same time as, or perhaps slightly later than the Lion Gate, a second gate, known as the Postern Gate, was added to the north wall. Here, a portion of the surviving first period wall was removed so that an east-west passageway ran through it.[24] In the passageway a post-and-lintel gate was built. Like the Lion Gate, it was bounded on its north side by a bastion.[25] Ashlar masonry was employed around both gates. As with the cyclopean walls, the ashlar blocks faced a more substantial core of earth and stone.

The method of construction in the second period wall was comparable to that of the first period; large limestone boulders were stacked with chinking around a core of rock and earth.[26] Because it was situated at a lower elevation in an area of softer bedrock, however, the cyclopean wall now rested on built foundations. In place of sitting directly on bedrock, shallow trenches were first dug into the rock and then filled with small stones and clay.[27] The first course of the

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[20] Kalogeroudis 2008, 288.
[21] Iakovidis 1983, 30–1.
[22] On the manufacture of this relief, see Blackwell 2014.
[23] Mylonas 1966, pl. 14, 15.
[24] Mylonas 1965, 27–50; Iakovidis 1983, 33.
[25] Mylonas 1965, pl. 8, 9; Iakovidis 1983, 33.
[26] Iakovidis 1983, 34–5.
[27] On types of Mycenaean wall foundations, see Wright 1978, 10–44.

wall and its fill were then set on this bedding. Additional clay was used in the lower fill and

between the joints of the first courses. The liberal use of clay acted as waterproofing and

prevented runoff from destabilizing the foundation and lower course.[28] Part of this second period

wall was dismantled during the Argive sack of 468 B.C.E and later reconstructed in the

Hellenistic period.[29]

The Northeast Extension

Architectural Description of the Northeast Extension

In the third phase of building, a small extension was added to the northeastern citadel

(Fig. A.86, Mycenae 3; Fig. A.87). A short section of the first period wall, c. 20–25 m long, was

disassembled and a new wall was built extending further to the east.[30] This new Northeast

Extension enclosed a small plateau that had previously rested outside of the citadel. To its east

and south the wall ran along the plateau's edge, which drops off steeply. On its north side, the

extension maintained the line of the citadel's existing north wall. The extension measured c. 60

m long and was 5.50–7.25 m thick. The newly enclosed area was quite small, measuring c. 18 x

33 m and adding only c. 600 m^2 to the citadel's habitable space.[31] Despite its removal, the path

of the first period wall remains visible where the bedrock had been worked and where the

occasional block has been left in place.[32] The joints of the Northeast Extension and the first

period wall are clear. Where they meet on the south side, five courses of the first period wall

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[28] Iakovidis 1983, 34.
[29] This is the so-called polygonal tower. See Steffen 1884, map. 2; Tsountas and Manatt 1897, 26–8; Boethius 1923, 415–6.
[30] See Mylonas 1966, fig. 2.
[31] Iakovidis 1983, 35.
[32] Mylonas 1966, fig. 1; Iakovidis 1983, 27.

remain in situ, projecting slightly to the north.[33] On the north side, their meeting point is exposed

by a gap on the exterior face that reveals the curvature of the original north wall.[34]

Like the first period wall, the Northeast Extension was built directly on worked bedrock

without the use of foundation trenches. Plesia clay was employed between the wall's courses.[35]

The wall's exterior face tends to be curvilinear while its interior face is angular.[36] Generally, the

masonry of the extension resembles that of the second period but was "more careless."[37] On its

northern and eastern façade, the blocks are large, which Wright suggests is due to the wall's

visibility along the roads approaching from Zygouries and Berbati.[38] On its southern façade, the

blocks are less well chosen.[39] The stones used measure c. 2.0–2.4 m wide x 1.20–1.35 m tall,

although the largest have a height of nearly 2 m.[40] Gaps up to 0.4 x 0.7 m were sometimes left in

the façade's courses and these were filled with stone slabs.[41] A large amount of chinking is found

in the courses, especially on the southern façade.[42] These chinking stones measure up to 0.2 x 0.5

m.[43] For the interior face, the stones are smaller than the facade and of various shapes. Wright

noted blocks measuring from 0.8 x 0.7 m to those measuring 1.5 x 1.9 m.[44] Some stones also

show signs of hammer dressing and material from the razed first period wall was likely reused

for construction of the Northeast Extension's interior face.[45]

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[33] Iakovidis 1983, 27, pl. 22.
[34] Mylonas 1965, pl. 6a.
[35] Iakovidis 1983, 37.
[36] Wright 1978, 195–6
[37] Iakovidis 1983, 37.
[38] Wright 1978, 194.
[39] Wright 1978, 194–5.
[40] Kalogeroudis 2008, 292.
[41] Mylonas 1965, 146, fig. 89; Iakovidis 1983, 37.
[42] Wright 1978, 195, fig. 127.
[43] Wright 1978, 194.
[44] Wright 1978, 196.
[45] Wright 1978, 195; Iakovidis 1983, 37.

The core of the Northeast Extension was built in layers; up to a height of c. 2 m, the core consists of larger pieces of rubble, but above this small stones and earth are used.[46] Although facing blocks are sometimes set as headers, the core and the facing walls are not well bonded.[47] At least two passageways, often termed "sally ports," were constructed in the Northeast Extension to provide limited exterior access.[48] The first pierces a straight section of wall in the southernmost portion of the extension (Fig. A.88). This southern passageway, or "south sally port," was known in the 19th century and appears on Steffen's map.[49] Although it is prominently visible, it was initially thought to be a hidden gallery through which troops could secretly attack a besieging enemy, but it now seems to have provide access to a built terrace outside of the citadel wall. The passage itself is constructed just above the wall's lowest courses. Since it is slightly raised from the surrounding ground level, a set of limestone steps grant access to it. For its entire length, the passageway is corbelled. It measures c. 1.05 m wide x 2.45 m high, and runs perpendicularly through the wall face for 7.1 m (Fig. A.89).[50] The passage exits onto a ridge which runs roughly northwest-southeast and drops off quickly on its northeast and southwest sides. The remains of a retaining wall to the west of the exit and remnants of fill show that a terrace once existed here.[51] Measuring approximately 10.0 x 23.5 m, the terrace would have offered a view of the southwestern approaches to the citadel.[52] Generally, the stones forming the southern sally port appear to be carefully chosen and more regularly shaped than those in other parts of the Northeast Extension, likely in order to ensure stability.

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[46] Iakovidis 1983, 37.
[47] Wright 1978, 195.
[48] Loader (1996) has suggested that a third, east sally port might have existed.
[49] Steffen 1884, pl. 2.
[50] Iakovidis 1983, 35.
[51] Iakovidis 1983, 35.
[52] Iakovidis 1983, 35

A second passage runs through the extension's northern wall segment (Fig. A.87). This northern passage was only fully uncovered in 1964 by Mylonas.[53] Prior to his work, it was thought to be a drain; however, the presence of thresholds at the passage's entrance and exit, and a built ramp show it was meant for foot traffic.[54] The northern passageway is entered by a ramp to its south. The ramp is built of earth and small stones and is supported on the west by a retaining wall.[55] The north passage is significantly smaller than its southern counterpart, measuring only 0.90 m wide x 0.92–1.02 m high, although at the exit its height increases to 1.95 m.[56] Instead of using corbelling, it is capped with flat stone slabs that exceed the width of the passage. The side walls generally employ large cyclopean blocks packed with chinking. At the exit, two monolithic blocks are capped by a lintel which is worked underneath to give the false appearance of corbelling. The passageway runs obliquely through the wall for 6.9 m, slanting towards the northwest.[57]

West of this northern passage, the Northeast Extension is pierced one final time by the entrance to an underground cistern. The construction of the underground cistern represents the most technically complex aspect of the Northeast Extension and reflects the high degree of skill that Mycenaean builders possessed. In order to secure access to water from within the citadel, the Mycenaeans built a twisting passage that terminated in a deep cistern within a natural fold in the soft conglomerate bedrock (Fig. A.90).[58] The passage was roofed over and covered with earth so that it remained invisible outside of the walls. Water from a natural spring was then piped into

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[53] Mylonas 1965, 153–6.
[54] Mylonas 1965, fig. 92, 93.
[55] Mylonas 1965, 153–6; Loader 1996, 191–2.
[56] Mylonas 1965, 153; Iakovidis 1983, 35.
[57] Mylonas 1965, 153–6; Iakovidis 1983, 35.
[58] Iakovidis 1983, 36.

the hidden cistern. To enter the cistern, an entrance was constructed passing through the

Northeast Extension. Approximately 5 m to the west of the north sally port access is provided by

a set of steps (Fig. A.91).[59] These steps are built of small pieces of limestone and are irregularly

shaped.[60] The steps begin just beyond the fortification's interior face and descend for five or six

steps until they reach the fortification wall.[61] Immediately to the west of these steps is a retaining

wall, c. 11 m long, that was meant to keep debris from washing down the steps and into the

cistern.[62]

Where the steps meet the fortification's interior face, a corbelled tunnel has been

constructed that runs obliquely through the wall's thickness at a northwesterly angle. The tunnel

slopes downward and is c. 1.6–2.0 m wide and c. 4 m high.[63] The walls of the tunnel are built of

well-chosen limestone blocks that are set in roughly even horizontal courses while gaps are filled

with large pieces of chinking. Within the tunnel, the stairs continue for a further 16 steps until

they reach the bottom.[64] Here a 1.6 m high doorway marks the position of the fortification wall's

exterior face. The doorway is capped by a long conglomerate lintel that spans the width of the

tunnel. A relieving triangle was left above the lintel and was filled with limestone rubble.

Originally the lintel block was supported on both sides by the tunnel walls, but the lintel's west

end evidently cracked. To support the damaged lintel, a conglomerate upright just under 1.6 m

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[59] Iakovidis 1983, 36.
[60] Karo 1934, 124.
[61] Karo 1934, 124.
[62] Mylonas 1965, 17–23, fig. 10; 1966, 32.
[63] Iakovidis 1983, 36.
[64] Mylonas (1966, 32) and Iakovidis (1983, 36) counted 16 steps, but Karo (1934, 124) said there were 18 steps.

tall was inserted against the west wall of the tunnel and in the small gap between the lintel and

upright, a flat piece of limestone was inserted.[65]

Beyond the doorway there is a flat landing, which angles slightly to the north and lies just

outside of the fortification wall.[66] The landing is roofed with large, flat limestone slabs and its

side walls are built of cyclopean blocks set in rough courses. Earth covers the slab roof so that

nothing is visible on the surface.[67] The landing ends after c. 2.5 m where it intersects with a

descending passageway that cuts to the west at a right angle (Fig. A.92).[68] The construction of

the passageway's walls and roof follow the construction of the landing, using roughly coursed

cyclopean blocks and long roofing slabs topped with earth. The passageway descends via a set of

20 stairs, each of which measures 0.50 m x 0.15 m and is made of limestone slabs worked with a

saw.[69] At the bottom of the stairs is a second landing that is 2.8 m lower than the first landing.[70]

The landing turns abruptly to the north and, as it does, there are three broad steps. At the third

step, the landing is meet at a right angle by a second descending passageway which runs to the

northeast. Instead of built walls topped by slabs, the passage is now constructed with corbelling.

It is narrower than the first stepped passage, measuring c. 1.4m wide and its height varies

drastically. A set of 54 narrow steps, 0.20–0.23 x 0.18 m, lead downward.[71] Here, the steps and

walls are covered in a layer of plaster, which is wearing away.[72] At the bottom of the steps, 12 m

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[65] Karo 1934, 124–5; Iakovidis 1983, 36–7.
[66] Karo 1934, 124–5; Iakovidis 1983, 36–7.
[67] When first discovered, the landing was exposed, but it was restored to its original condition in the 1960s. Hope Simpson and Hagel (2006, pl. 2A) provide an image prior to restoration.
[68] Karo 1934, 125.
[69] Karo 1934, 125; Iakovidis 1983, 37.
[70] Karo 1934.
[71] Iakovidis 1983, 37.
[72] There are no published measurements to help estimate the amount of clay applied to the walls.

below the second landing, there is a rectangular well-shaft, 3.5 m deep.[73] Above the well-shaft, a

second vertical shaft was built into the stone roof. Spring water was piped to this shaft and

allowed to fill the lower well-shaft and parts of the second descending passageway.

The CAD Model

In reconstructing the original form of the Mycenae's Northeast Extension (Figs. A.93,

6.11), there are problems that limit the details of the model. First, the walls of Mycenae have

been modified in a number of places since the end of the Bronze Age. After the sack of Mycenae

by the Argives in 468 B.C.E. and the dismantling of parts its walls, sections were rebuilt and

repaired in the Hellenistic period.[74] The Polygonal Tower, which was built along the lower

southern elevations of the citadel, is the clearest example of this rebuilding phase, but the

Northeast Extension was also modified in the Hellenistic Period.[75] On Steffen's map, typical

Hellenistic polygonal masonry is marked at the exterior northern face of the extension and at its

northeast corner.[76] Anastylosis, too, has altered the walls of the Northeast Extension. Although

this work allowed Mylonas to explore the interior composition of the walls, it has potentially

altered the walls' appearance in unknown ways. For example, Wright noticed that Steffen,

Tsountas, and Wace each drew the Northeast Extension as a series of straight lines with angular

junctures.[77] In Mylonas' plan, though, the exterior wall face becomes sinuous (Fig. A.86,

Mycenae 3), which could be the result of reconstruction.[78] Whether it was built as a single,

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[73] Iakovidis 1983, 37.
[74] See Steffen 1884, map 2; Boethius 1923, 415–6; Iakovidis et al. 2003, 11.
[75] Iakovidis 1983, 35.
[76] Steffen 1884, map 2.
[77] J.C. Wright 2005, n. 8; see also Mylonas 1965, fig. 1.
[78] Wright says that "Mylonas maintains that Stikas did not restore this area (Mylonas 1962: 144), but the matter needs further study" (2005b, n. 8).

curved wall or as a series of integrated linear sections impacts how we envision the construction process; the latter method, relying on a sectional approach, is typical of other Mycenaean walls[79] and was technically and logistically simpler. In the CAD model, for the sake of ease and consistency with current plans, I have followed the curved form of the walls first depicted in Mylonas and now found in the Mycenae Atlas.[80] Widths are taken directly from these plans, but the wall height must be guessed at since the Northeast Extension is nowhere preserved to its original height. Loader estimates a height of 8.25 m,[81] which is conservative, given that sections of the fortification wall greatly exceed this measure. For this reason, I rely on Loader's estimate in the CAD model. This ignores the distinct possibility of a superstructure, perhaps of mudbrick, built along the top of the walls.[82]

Construction of the core of the wall is divided into two parts. From Mylonas' analysis, it is clear that the lower portion of the wall core employed large stones and the upper portion consisted of small stones and earth. The thickness of the core and wall faces as well as where the construction of the core changes is unclear, though. Mylonas indicates that when the core was explored, the small stones and earth ran from the preserved top of the wall for a depth of 2.4 m before transitioning to larger stones.[83] He does not say what the height of the wall here was, but does say his exploration occurred along the southern part of the wall,[84] a section which was better preserved than the rest of the extension.[85] Iakovidis later published a measure of c. 2 m for the height of the lower core while small stones and earth composed the remainder of the upper

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[79] J.C. Wright 2005.
[80] Iakovidis et al. 2003.
[81] Loader 1998, appendix 2.
[82] There is possible evidence for mudbrick superstructure at Midea; see Loader 1998, n. 10.
[83] Mylonas 1965, 146, fig. 89.
[84] Mylonas 1966, 146, fig. 89.
[85] See, for example, Steffen 1884, map 2.

wall.[86] Because Iakovidis' measure is straightforward, I have reconstructed the large stone core

up to 2 m and the smaller stone and earth core for the remainder of the wall. The approximate

thickness of the core and two faces are not published. In response, I have estimated the thickness

of each face as 1.5 m. This derives from Wright's average measurement of cyclopean blocks of

which his maximum dimensions are 1.5 m long x 1.0 m wide x 1.0 m high.[87] In the case that

blocks were placed as headers, then, a face might approach 1.5 m in thickness, although this is

clearly a subjective estimate for the Northeast Extension and it may incorrectly approximate the

face and core thickness.

The north and south passages as well as the entrance to the cistern are incorporated into

the model, but the ramp and stairs leading to them have not been included. The retaining wall

west of the cistern and the terrace outside of the southern passage are not included. Details of the

underground cistern are derived from Karo's plan and sections.[88] Karo provides a good outline of

the cistern's path and shape, but does not offer information on the thickness of masonry

throughout the cistern. His section C-D (Fig. A.90) shows roofing slabs, perhaps 0.5 m thick,[89] a

measure which I have relied on to approximate the thickness of all masonry in the cistern.[90]

Neither the steps nor the thick clay coating in the lower parts of the cistern are included in the

model because of the difficulties in finding suitable measurements for them. The model of the

cistern, therefore, establishes only the general structural masonry and its spatial relationship to

the wall without including the finer details that one would like. This can be improved upon in the

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[86] Iakovidis 1983, 37.
[87] Wright 1978, 159–60.
[88] Karo 1934, pl. XII, XIII.
[89] Karo 1934, pl. XIII.
[90] At the time of Karo's plan and sections, the roofing of the cistern's passage immediately
outside of the fortification was not intact (see Hope Simpson and Hagel 2006, pl. 2A). It has
since been restored.

future, though, with a more comprehensive restudy of the cistern's architecture. For spatial

reference and a general measure of volume, the old east wall is added into the model (Fig. A.94).

Producing the Northeast Extension[91]

Planning to Build

The incorporation of a secure water source accessible from the citadel's enclosed space is

characteristically identified as the impetus for construction of the Northeast Extension.[92] The

speed with which construction could be completed and the presence of an immediate threat

requiring construction continue to be open questions. Loader, at least, has suggested from her

analysis that many LH III fortification walls were unlikely to have fulfilled an immediate

defensive need,[93] but at the same time, the Northeast Extension does show a wall building

technique which Iakovidis called "more careless" than the construction of the first and second

period walls.[94] At any time, extending one's fortification wall was likely a tense endeavor,

leaving one exposed to potential attack, so any exigency would curtail the ability to plan and

execute an extension's construction well. My own tendency is to envision the extension as a

general shoring up of defensive needs resulting from a perceived weakness, which included not

only the incorporation of the cistern, but also the addition of the southern passageway and terrace

overlooking the Khavos ravine. Any hurried appearance in construction might result from a

feeling of necessity to accelerate the pace of security improvements without the presence of a

menace already at the gates. To remove part of one's wall and extend it required, in any case, a

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[91] The corresponding energetic flowcharts are found in Figures A.121–124. An annotated energetic flowchart that explains how these are read is found in Figure A.11.
[92] Mylonas 1966, 31.
[93] Loader 1998, 72–3.
[94] Iakovidis 1983, 37.

sense that there was no immediate threat to one's defenses. In addition, the presentation of larger stones to the roads from Berbati and Zygouries is a counterpoint to the more careless wall-building technique and implies that reasonable attention was given to planning and executing the extension's northern and eastern facades.

In addition to considering the general safety of dismantling and extending part of the fortification wall, the builders at Mycenae had to assess other factors affecting the successful outcome of this building project. Chiefly, the time to complete the extension and the availability of labor and materials had to be evaluated, at least roughly, before concluding the project was viable.[95] Some of these issues of planning have been discussed above as they apply to Treasury of Atreus' construction,[96] but the need for the builders to perform a quantity survey to estimate time and labor was markedly greater for the Northeast Extension because of the danger posed by project failure. Examples of textually-based architectural quantity surveying are found in the Near East, particularly for mudbrick construction; since they were often formed in standardized sizes, mudbrick walls were ideal for these types of calculations.[97] As G.H.R. Wright points out, by the 3rd millennium B.C.E. quantity surveying was a standard practice in Mesopotamia. It also relied on rules of thumb for quick reckoning, such as assuming that walls would take up 1/3rd of a building's planned footprint.[98] A survey of volumes shows that, based on the CAD model, the demolished eastern segment of the first period wall provided c. 1,140 m^3 of material, including both facing stones and core material. The new extension required c. 5,229 m^3 of material and an additional c. 132 m^3 for the cistern's masonry.[99] Though the razed wall did not provide enough to

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[95] Wright 2009, 11.
[96] supra, p.117–118
[97] Robson 1996.
[98] Wright 2009, 11–2.
[99] See Table B.15 for quantities.

complete the extension, its reuse did offer a reduction in work, not to mention solving the immediate need to dispose of the razed material without transporting it far. Those planning the new wall needed to be sure they could acquire the other c. 80% of materials, including the larger stones for the exterior faces, before they began demolishing the eastern wall segment.

Unlike the careful mathematical consideration given to the Treasury of Atreus or the level of urban coordination seen at Kalamianos, planning the path of the Northeast Extension was less involved since the wall followed the geological contours of the hill. Beyond a quantity survey of the needed materials, the most difficult part in laying out the wall's intended path was anticipating where the extension would link up with the underground cistern that ran beyond the wall's confines. It seems likely that the path of access to the cistern was determined first and potentially that the cistern was even constructed before the Northeast Extension was started. If the cistern was, in fact, the driving force beyond extending the wall, prioritizing its successful construction would make sense; then the wall and passage through it could be structured to link up with the cistern's prebuilt layout. Finally, the effect on daily life in the citadel would have been considered. Although the area of construction was limited, those living or working in the eastern area of the citadel would have been profoundly affected during construction. Immediately adjacent to the area of construction, where the old wall had to be removed, stood Houses Delta and Gamma. Like most of the structures at Mycenae, neither directly abutted the fortification wall, but the space between wall and building was slight; workers razing the earlier wall and moving building materials would have traipsed around the tight spaces at their doorstep. The functioning of the Artisans' Quarter and House the Columns, 50–100 m to the southwest

may equally have been affected.[100] The disturbance of daily functions caused by construction in the eastern area of the citadel was another reason to accelerate completion of the project.

Preparing the Building Site and Foundations

Because of the date of construction, in the later part of LH IIIB2, and the simplicity of materials and tools, as compared to more ambitious projects like the tholoi of Wace's Group III,[101] there was little long-term infrastructure that needed to be built before construction began. With a portion of the material coming from the earlier wall and the remainder of limestone and earth accessible nearby, long distance heavy transport was not an overarching problem. White Plesia clay was the material furthest removed from the construction site.[102] Although it is not feasible to determine the amount of clay added to the fill and between courses,[103] the road network running from the southern clay beds to the citadel[104] meant that wagons and oxen were able to transport the necessary volume in bulk. The acropolis itself, the mountain slopes to the east, and the hills north and south of Mycenae offered abundant places to quarry the needed limestone.[105] Conveniently, roads ran along the slopes of these areas and led to the vicinity of the postern gate, immediately to the west of the construction site. Mylonas says that an excavated section of this road network was paved with earth, clay, pebbles, and sand,[106] which made it suitable for both wheeled vehicles and sledges. In the immediate area of construction, slipways

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[100] This area was used for workspace and storage. For a basic overview of these buildings and their connection with palatial craftsmen, see Wace 1949, 91–7; Mylonas 1966, 72–3.
[101] Wace 1949, 16–9.
[102] It is a few kilometers to the south; see Iakovidis et al. 2003.
[103] For this reason, the clay is not included in any energetic calculations.
[104] Iakovidis et al. 2003.
[105] Higgins and Higgins 1996, 46–7.
[106] Mylonas 1966, 86; Iakovidis et al. 2003, 28.

could facilitate transport of materials from the built roads and assist the movement of heavy materials around the building site, but such infrastructure is meant to be temporary and would be constructed only as needed.

The two major tasks required before masonry could begin going up were the preparation of foundations and the excavation of rock and earth for the cistern and its passageway.[107] The approach to foundations was simple, relying on direct contact between the lowest course of the wall and the bedrock.[108] The builders only needed to hammer away projections of rock and fill in small gaps with stones in order to provide a level perch for the wall. Little else was demanded during this task other than an approximate knowledge of the wall's path and its intended thickness. The preparation of foundations may have been completed all at once, and so used to formally mark out the wall's path, or it may have been approached in sections, as the wall builders progressively set the lowest course. Because it was excavated into softer conglomerate,[109] excavation for the cistern similarly required only simple tools such as picks, hammers, adzes, and baskets. The path of excavation, though, demanded more attention from workers than the extension's foundations. The passage needed to follow a path that was concealable, to slope gently enough that water could be carried up without difficulty, and most importantly to meet the spot where water was piped in from the nearby spring. Because the builders chose a "natural fold in the bedrock"[110] for the passageway, the quantity of overburden and rubble that had to be removed is difficult to estimate, but the final passageway, cistern, and masonry occupy c. 290 m^3 of space. When buried, the cistern was topped by a level of fill,

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[107] The corresponding energetic flowchart is found in Figure 7.26.
[108] Wright 1978, 10–44.
[109] Mylonas 1966, 31.
[110] Iakovidis et al. 2003, 36.

perhaps up to a few hundred cubic meters in volume[111] that was presumably gathered from this excavated material.

Erecting the Cistern and Wall

As mentioned in the previous section, it is possible that much of the cistern was completed before the above ground construction was initiated.[112] The initial portion of the cistern's second section,[113] where the roof is flat, had to be built in tandem with the fortification wall in order to match the two up correctly and ensure the cistern was hidden,[114] but the remainder could have been built independently. There is even the possibility of a chronological gap between part of the cistern and the Northeast Extension, but the use of corbelling in the lowest section, a technique which is found only in the last phase of Mycenae's fortification, implies that the gap would not be too long. Regarding the change in technique between flat roofing in the upper portion and corbelling in the lower, there is a possible structural explanation. Because of the low tensile strength of rock, flat roofing slabs may not withstand large weights placed upon them, while corbelled roofing instead transfers the superimposed weight to bedrock. Since the fill above the cistern became greater as its depth grew, the change in technique may have encouraged stability under the increasing weight.

When the old eastern fortification wall was ready to come down, the task would have been an imposing one for the workers who scaled the wall and wrenched out its stones.

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[111] This is purely a guess. In general, the entire cistern and the process of constructing it warrants future reevaluation.

[112] The corresponding energetic flowchart is found in Figure 7.27.

[113] That is to say, the section immediately outside of the fortification wall; see Iakovidis 1983, 36–7.

[114] This area of the passageway was collapsed when explored by Karo (1934) and was later restored.

Scaffolding, ladders, or ramps were a necessity for workers to move up and down freely,[115] but how they transferred the heavy stones from the wall top to the ground is hard to envision. On the exterior face, they could have simply toppled them over and let them fall, but for the interior face fine control of each stone's descent was desirable so as not to obliterate surrounding houses. There is little information to elucidate the process of dismantling ancient fortification walls, despite the fact that it has been a frequent war-time occurrence throughout history. An Assyrian relief of a siege published by Layard shows two armored individuals using a pry-bar to dig out blocks or bricks from a fortification;[116] otherwise, I have not found further illustrative texts or depictions from the Mediterranean or Near East.[117] Still, an image of the Anastylosis Service published by French[118] that shows four individuals raising a cyclopean block with wooden scaffolding and chains gives a humanized glimpse of the process of razing and re-erecting the walls. Limited to using ropes, pry bars, and ramps, the best we can say about how builders removed the old eastern wall is that it entailed careful choices about which stones to remove first in order that large sections of wall not tumble out at once, and a good sense of how and where each stone would fall or be let down.

Erecting the new extension was similar to wall removal, but undertaken in reverse; it exploited the same tools and material, needed a careful eye for stone placement, and required the technical knowledge to safely manipulate and place each stone where it was desirable.[119] Loader has methodically discussed her interpretation of cyclopean construction and it is profitable to

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[115] Fitchen 1989, 120–8.
[116] Layard 1853b, pl. 13.
[117] Some ancient depictions do show the use of rams to punch through walls, but this is not quite relevant.
[118] French 2002, fig. 18.
[119] The corresponding energetic flowchart is found in Figure 7.28.

draw on her analysis of quarrying, transporting, and lifting stones.[120] Loader includes a summary

of major techniques that could have been used to quarry stone in Mycenae Greece including deep

channeling, wedge-and-feather, and stepped quarrying.[121] As she notes, often these types of

activities produce regular blocks that are unnecessary for cyclopean construction, so the

technique of cyclopean quarrying was likely much simpler. By exploiting natural fractures using

hammers, wedges, and pry bars,[122] blocks could be loosened and fractured to form the unshaped

boulders necessary for fortification walls. Following Wright's average measurements, a normal

facing stone weighed c. 1,845 kg.[123] Quarrying for the Northeast Extension was likely

opportunistic, occurring in a manner comparable to the extraction of surface deposits at

Kalamianos. Along the nearby slopes, where limestone was plentiful,[124] the Mycenae Atlas

marks evidence of quarrying in three locations (Fig. A.95).[125] One of these (C5:05) is possibly a

conglomerate extraction point and while the other two do not mention a stone type, the area east

of the citadel is principally limestone.[126] These latter two locations (D5:04, D6:01) are c. 100 m

north and c. 500 m east of the Northeast Extension. The last of the three (D6:01) was also

marked by Steffen as his *antiker Steinbruch*.[127] It is important to remark that all three extraction

points lie directly on the major roadways emanating from Mycenae; any or all of these could

have provided stone for the Northeast Extension. The existence of good roadways and ample

stone sources to the north and east of the citadel meant that workers could extract stone from

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[120] Loader 1998.
[121] Loader 1998, 50–3.
[122] Loader 1998, 46–9; see also Dworakowska 1975, 99–102; Evely 1993, 1:213–7.
[123] Loader 1998, n. 19.
[124] Higgins and Higgins 1996, 46–7.
[125] Iakovidis et al. 2003, C5:05, D5:04, D6:01.
[126] This area of Mycenae is mostly limestone but between Mt. Zara and Profitis Ilias, at lower
elevations, there are patches of conglomerate; see Higgins and Higgins 1996, fig. 5.5.
[127] Steffen 1884, map 1; Iakovidis et al. 2003.

multiple quarries at once as a way to increase the daily supply and speed construction. Other than ensuring a steady supply of material, coordination between quarry and building site was low since cyclopean stones do not require a fixed size or shape. Selection of appropriately-sized stones and the separation of larger stones for the exterior north and east face would be done on site by the wall builders. This is in great contrast to the high degree of coordination required by the ashlar masonry found in the Treasury of Atreus.

For transportation, oxen and wagons were optimal. With an average weight of under two tons, cyclopean stones were just below the several ton weight limit of ancient axles.[128] Loader suggests that, from the extraction point, workers would have moved each stone a short distance to the wagon where oxen would draw the load to the building site.[129] Approximately four men could lever the stone on to the wagon[130] and if the wagon were four-tons, she suggests a team of at least 14 oxen to draw the total weight.[131] The well-built roads that ran very near the Northeast Extension made this the ideal manner of transportation. Once at the site, the stones could be offloaded and dragged along slipways to the wall face. Raising them into place, though, poses a major issue. Loader discusses in detail the possibilities, including ramps, levering and wooden frameworks, and timber hoisting devices. Ultimately, she argues the best possibility is a wooden ramp with rollers along which stones could be dragged by traction animals.[132] As she mentions, this is certainly a better solution than earthen ramps, which require constant modification as the wall height changed. I am not convinced by the commonly cited use of ancient rollers, but I

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[128] G.R.H. Wright 2005, 41.
[129] Loader 1998, 54–9; see also G.R.H. Wright 2005, 40–3; Shaw 2009, 37–8.
[130] Loader 1998, 71. Compare the illustration in Korres 1995, 37.
[131] Loader 1998, 60.
[132] Loader 1998, 62–4.

agree that an inclined plane of timber is the best theoretical solution at the moment.[133] This need

be nothing more than thick, individual timbers laid together to form a ramp. Its angle would

increase with wall height, but it still offered a pronounced advantage over direct vertical lifting.

The use of traction animals to complete the lifting would be wholly dependent on the suitability

of terrain. For the Northeast Extension, the limited space and roughness of the area suggest that

workers more likely supplied the force to raise the stones, while oxen were limited to

transporting them from quarry to building site along well-built roadways.

Once to height, maneuvering the stones into place may have been easier than one would

expect. The more careless construction of the Northeast Extension that left large gaps between

stones meant there was great leeway in positioning the stones. In addition, the clay employed in

the extension would ease the manipulation of blocks into place. Finally, Seeher's experimental

fortification wall at Hattuša shows that skill gained from experience offers a pronounced

advantage. About the process of laying out a large rubble socle, Seeher writes,

> While young and less experienced workmen would struggle in vain — albeit with much strength and hullabaloo — to slide a stone into the proper position, these craftsmen *[the experienced ones]* — with a comfortable grip and deft leverage — would have it in place in no time at all. Remarkable too is their capability of selecting at one glance the stones ideal for the next step of the work…[134]

As skilled workers maneuvered each block into place, the core stones and earth that were

deposited between faces do not seem to have been a great concern. Wright emphasizes that

construction was "shell-like" and little attention was given to binding core and face.[135] The

greatest difficulty encountered while erecting the walls was corbelling out the cistern's entrance

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[133] G.R.H Wright (2009, 74–5) suggests that parbuckling, in which a rope is wrapped around an object and used to roll it up an incline, may have been used to move cyclopean blocks.
[134] Seeher 2007, 46.
[135] Wright 1978, 195.

and the southern passageway.[136] The south passage was easiest. After the first few courses of the

southern wall were set, a gap was opened in the wall. For a height of three to four stones, the gap

was maintained until a regular course of stones was stepped out slightly. Within the passage, the

gap between the stones on each side was then topped with a single stone, giving it the appearance

of a keystone (Fig. A.96).[137] The corbelling of the cistern, in contrast, was more intensive

because it required that multiple courses of stone be stepped out and because workers needed to

account for the downward slope of the stairway.[138] Like the south passage, this process was

facilitated by laying regular courses of stone, gradually stepping them out until they meet, and

then dressing off the protrusion with a hammer to give the wall face a rough, curved appearance

(Fig. A.92).[139] The greater number of courses that needed to be stepped out and the height of the

cistern's entrance made this procedure more dangerous than building the south passage. A stone

pushed out beyond its center of gravity would kill anyone below and workers falling from the

wall tops would not be uncommon. In modern construction, falls remain the leading cause of

injury and death. Falling objects, too, continue to be a major hazard.[140] Although corbelling does

not require centering like a true arch, wooden shoring could reduce accidents by bolstering

courses as they were stepped out.[141]

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[136] On corbelling in Mycenaean architecture, see Wright 1978, 200; Cavanagh and Laxton 1981, 1988; Maner 2013.
[137] This approach is also found at Tiryns (Wright 1978, 225–6).
[138] There are comparable examples of descending corbelled passages at Tiryns (Wright 1978, 226–8).
[139] The mechanics of corbelling have been discussed in relation to tholos tombs; see Cavanagh and Laxton 1981, 1988.
[140] According to the Occupational Safety and Health Administration (OSHA), in 2014 falls caused 349 of 874 deaths in American private-sector construction.
[141] Fitchen 1989, 97–100; Wright 2009, 132–3.

The Visibility and Order of Construction

The selective display of large stones, which is argued to advertise power through scale and material,[142] is a common practice in Mycenaean architecture, so the choice to place larger stones in prominent locations of the Northeast Extension is expected. Loader rationalizes this approach to fortifications, reasoning that "the appearance of monumental walls is a deterrent against attack. The large blocks of the citadel walls would have been perceived as being impossible to disrupt and, indeed, their massive size must have kept them relatively immovable."[143] Regarding the construction of the Northeast Extension, however, there is an unexplored counterpart to this purposeful monumentality. If through their scale and appearance, the fortifications of Mycenae instilled a feeling of invulnerability, what message was sent when spectators witnessed part of this monumental wall being dismantled to make way for the new extension? The response might cut either way. On the one hand, the façade of power may be strengthened in advertising the ability to both erect and destroy monumental walls, but on the other, the revelation that such walls can be dismantled wholesale may undermine their veneer of impregnability. The visibility and psychological impact of construction *and* destruction at Mycenae are worth exploring in more detail in the future. Nonetheless, in this context, the visibility of the Northeast Extension's construction and the removal of the previous wall were quite limited, a circumstance which may have affirmed to the builders that the partial razing of Mycenae's wall at the end of LH IIIB2 was justifiably safe.

A viewshed from the area of the Northeast Extension shows that, to the inhabitants south and southwest of the citadel, the removal of the earlier wall section and construction of the new

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[142] See especially Wright 1987; Fitzsimons 2007, 2011; Laffineur 2007.
[143] Loader 1998, 21.

233

segment would have remained inconspicuous (Fig. A.96). It is likely that the movement of workers and materials was intermittently visible, especially along roadways approaching the citadel, but the particulars of construction and any gaps in the existing wall would not be seen from this area. Only along those roads approaching from Zygouries and Berbati, where the builders exhibited larger stones in the Northeast Extension, would the process have been visible. Yet, even in this case, the construction of the new wall would have been more evident than the removal of the old wall section, which was both short and largely screened from view to the north by the rest of the first period wall (Figs. A.86, A.94).

Evidence for reuse of the razed wall's material, and the juncture of the Northeast Extension and earlier wall suggest that removal of the old and construction of the new occurred in tandem, further masking exposed gaps in the wall and offering a more secure and efficient construction method. In the interior face of the Northeast Extension, Mylonas noted the small size of the blocks, which he attributed to reuse from the razed wall section.[144] Iakovidis further suggested that razed material was incorporated into the upper part of the eastern section[145] and Wright mentions hammer-dressed blocks in the interior face that may be from the first period wall.[146] Although the area of reuse is not pinned down (and it may not be possible to pin down if blocks were not systematically reused), based on the manner in which the extension and stubs of the first period wall were united, it is probable that workers were immediately shifting blocks from the razed wall to the rising interior face of the extension; the former wall's core of earth and small stones would have been equally valuable in the extension as chinking and for the upper fill. In this way, while the new extension was rising, parts of the old wall still remained in place.

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[144] Mylonas 1965.
[145] Iakovidis 1983, 37.
[146] Wright 1978, 196.

Concluding Remarks

In the above discussion of production and in the creation of the Northeast Extension's model, the generally good preservation of the wall, Mylonas' fortuitous exploration of its construction during anastylosis, and Loader's past work have been integral to my work. Despite the scale of Mycenaean fortification walls, the degree of technical knowledge and places for decentralized choice during production appear limited in respect to what analysis of the Treasury of Atreus and the structures of Kalamianos showed. Like the Treasury of Atreus, greater exploration in the future of Mycenaean quarrying is needed and the problem of lifting large stones, which is also problematic for later periods of Greek architecture, demands ongoing consideration. Finally, accurate measurements and documentation of the cistern's masonry and clay coating are called for. My model and our knowledge of the cistern's production would be greatly enhanced by this. In Chapter 7, the reconstruction and discussion of Northeast Extension's production are revisited in order to model how builders organized production in time and space. There, the detailed energetic flowcharts of the production process, which are cross-referenced in this chapter, are created and the temporality of production is addressed through simulation.

CHAPTER 7

EXPLORING THE DYNAMICS OF ARCHITECTURAL PRODUCTION

Models of Architectural Production

In the following sections, my 3-D reconstructions and hypotheses about the processes of construction discussed in Chapters 4–6 are built into dynamic models of architectural production.[1] These models are founded on the integration and organization of tasks, labor, and materials during the production process. The creation of the models for the Treasury of Atreus, structures 4-VI and 7-X at Kalamianos, and the Northeast Extension of Mycenae's fortification wall are discussed on a structure by structure basis. Measurements of volume and surface area, where required, are first published based on a quantity survey of the earlier reconstructions. Volumes are rounded to the nearest 1 m^3 for the Treasury of Atreus and Northeast Extension. At Kalamianos, because of the smaller quantities of materials, volumes are rounded to the nearest 0.25 m^3. In all cases, surface areas are rounded to the nearest 1 m^2. The measurements from the quantity survey are then combined with tasks-rates to determine the amount of labor builders devoted to the structure's materials and components. The rates for tasks are published in Appendix C and are categorized by five task types: procure (Table C.3–8), transport (Table C.9–12), manufacture (Table C.13–15), assemble (Table C.16–23), and finish (Table C.24–29).

The sources for the task-rates are diverse and include direct experiments, estimates from traditional energetic studies, and early modern construction manuals. As the multiplicity of sources leads to rates that are expressed in differing units, I have standardized the rates so that

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[1] In part, the following paragraphs summarize aspects of the method found in Chapter 3. See pp. 67–78, 85–87 for fuller explanations of the concepts.

they are all listed in units per one person-hours (*x units* / ph). Because transportation rates are a

factor of distance, however, these are expressed as formulas that must be tailored to each use.

For transparency and future applications, the rate as originally published, notes on the source of

the rate, and my interpretation of the rate's applicability to Mycenaean practices are given.

Tables C.1 and C.2 provide the estimated densities of building materials for volume to weight

conversions and the ratios of raw materials to manufactured materials (e.g. earth and temper to

mudbrick).

The procedure of combining my hypotheses about construction, the quantity survey, and

the task rates is facilitated by the creation of energetic flowcharts.[2] These energetic flowcharts

graphically illustrate the components, materials, and tasks of construction, and help to structure

thinking about how these integrate to create a structure. They further detail task-rates, quantities,

and sums of person-hours for each structure. I round all measures of person-hours to the nearest

five to avoid the clutter of decimals and diminutive numbers without any real loss of

information. Because the transportation rates are specific to each structure and based on distance

to resources, the difficulty of terrains, and the method of transportation used, the transportation

rates for each structure are listed in a corresponding table. The logic underlying the

transportation rates is presented in the context of each structure. In specific cases, I make

generalizations or exclude minor materials from the energetic flowcharts for ease of modeling or

due to gaps in the evidence. My reasoning for any such generalizations or omissions is explained

in my discussion of each structure. The final energetic flowcharts for each structure are

employed in two manners. First, their data is tabulated into a traditional energetic format and

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[2] For fuller explanation, see pp. 85–87. For an annotated example of an energetic flowchart, see Fig. A.11.

compared with existing energetics studies in the Aegean. Secondly, and most importantly, I build the components, tasks, and data from the energetic flowcharts into a dynamic model of architectural production with which I explore the organization and temporality of production through simulation; this latter application of the flowcharts as a staging ground for creating, analyzing, and discussing more complex, process-oriented models of architectural production is my driving motivation for creating them.

The Treasury of Atreus

Using the CAD reconstruction of the Treasury of Atreus (Fig. A.26), the volumes and surface area of materials and components have been estimated. Table B.3 breaks down the quantities of the materials employed by the builders. Each listed material provides summed quantities for the entire Treasury of Atreus and a detailed list of quantities required for individual building components. Table B.3 includes volumes in m^3 for all major building components and the surface area in m^2 for those building components that required surface dressing with a hammer or chisel.

Because transportation is a major and potentially limiting factor in construction, it is essential to address the distance and terrain over which the builders transported the conglomerate, rubble, poros, and clay. Since the fragmentary and possibly non-contemporary road network cannot easily be used for this, I analyze the connection between resource locations and the Treasury of Atreus in GIS. To do this, the location of the Treasury of Atreus, the Kharvati Quarry, the area of Monastiraki, and the area of the Plesia Beds were plotted against a 30-meter interval digital elevation model. The least-cost-path between these resources and the building site was then calculated to highlight the ideal path as a factor of distance and slope (Fig.

A.97). The distance and average slope of each least-cost-path are presented in Table B.3. The table gives the distance in meters from each source that is used in transportation rates and shows that, on average, the slope of each path was a moderate, $4 - 4.5°$.[3] Like the surviving road network, which is plotted for comparison, the least-cost-path analysis suggests there were two major approaches to the building site, one which ran along the crown of the Panagia Ridge and another which followed the lower contours between the Panagia Ridge and Mt. Zara. The similarity between the plotted path and actual road remains implies that the Mycenaeans did their best to construct roads which followed the easiest route.[4] The technical knowledge and ability to ensure roads respected the terrain was likely an important precursor to large scale construction, which necessitated transporting cumbersome building materials in a resource-efficient manner.

A breakdown of the Treasury of Atreus' construction is illustrated in a series of energetic flowcharts that show the integration of components, materials, tasks, and labor in a visually descriptive manner (Figs. A.98–A.105). The initial flowchart for the Treasury of Atreus shows the seven major building components required to complete the building project: site preparation, the lower chamber and stomion, the lintels, the upper chamber, the dromos and upper façade, the peribolos, and the tumulus. The isolation of each of these as a distinct component reflects my own thinking about the process of construction as discussed in Chapter 4. For each major component and the Treasury of Atreus as a whole, the summed labor expended by the builders is expressed in person-hours (Fig. A.98). Because of the amount of data required to visually illustrate the process of construction, the details for each major building component are given in

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[3] This a simplification of the surrounding terrain.
[4] For a recent application and discussion of least-cost analysis, see Newhard et al. 2014. GIS analysis shows great potential for future research, especially using the least-cost-path to predict the locations of roadways and to explore these results on the ground.

their own figures whose corresponding figure number is listed in Figure A.98. Each of the

corresponding figures shows the discrete tasks that the builders performed on particular materials

during production of that component. To calculate the number of person-hours builders

expended during each task, the set of standardized task-rates, material densities, and constants

from Appendix C are used. I have built a number of important assumptions and generalizations

into these energetic flowcharts:

1)   Transportation of Materials: Based on the GIS analysis which shows an average

slope of 4–4.5° along roadways, all transportation uses the rate for moderately steep terrain as

found in Appendix C. Any dragged load is thought to have utilized a lubricated surface to reduce

friction. Where loads are small or divisible, the use of wagons is suggested. For large stones,

dragging is assumed. The decrease in block size means that, for the dromos and upper façade,

50% of blocks were dragged and 50% were taken by wagon (see conglomerate in Fig. A.103).

All blocks for the chamber are dragged, although this may misestimate the labor builders

expended transporting blocks in the highest courses.

Distances to conglomerate and clay are discussed above. Limestone rubble is readily

available in the vicinity of Mycenae and an arbitrary distance of 0.5 km is used to account for its

transportation. The same distance applies to the fill needed to complete the tumulus. Spoil

removed during excavation is hypothesized to have been deposited within 100 m, likely to the

east of the Treasury of Atreus in order to build up the terrace (Fig. A.24). The proximity and

terrain require that the spoil be carried in baskets and dumped. For carrying rates, a person is

able to maintain a load of 28 kg.[5] Based on the inferred distances and the transportation methods,

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[5] Based on Ayres and Scheller 2002.

individual rates for the transportation of each material are listed in Table B.5. Each of these rates is used in the energetic flowcharts to determine the labor that builders expended transporting particular materials.

2) <u>Water, Temper, and Mortar</u>: The source of water used for mortar and claybrick is not known. Traditionally, brickyards are close to water sources so that the transportation of water is minimized. For this reason, claybrick and mortar do not account for acquiring and transporting water, and their listed volumes are dry (based on their amount in the finished structure) rather than wet. Mortar is assumed to have been mixed as a rubble or brick wall was assembled, so mortar has no distinct manufacturing stage. The type and source of temper for bricks is, likewise, unknown. Its volume is accounted for so as not to overestimate the amount of clay required, but the task of acquiring and transporting temper is not included. This could be fixed with future study as the tempering of bricks has implications for understanding enchainment with agricultural practices.[6]

3) <u>Ashlar Block Sizes</u>: In Appendix C, three task-rates for ashlar assembly are available based on the estimated size of blocks, whether small (0.1–0.2 m^3), medium (0.2–0.5 m^3), or large (0.5+ m^3). The lower chamber and stomion rely on the large rate; the upper chamber, dromos and upper facade rely on the medium rate; and the peribolos relies on the small rate. This is meant to approximate the changes in block size, but the large rate needs to be refined in the future through experimentation.

For the sake of comparison and to situate this data within previous work in the Aegean, I have summed tasks from the energetic flowcharts in a tabular format that is typical of traditional

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[6] Homsher 2012.

architectural energetics studies. Table B.6 shows the summation of each component and the five types of tasks. The traditional energetics summary shows the breakdown of the 267,570 person-hours that builders expended to complete the Treasury of Atreus. Among the five task types, the assembly of materials is dominant, requiring 43% of the builders' labor. Most of this high labor demand is attributable to raising and setting the abundant conglomerate ashlar. In general, the conglomerate ashlar demanded 60% of the labor expended during construction. Beyond assembly, procurement and transportation account for most of the remainder of labor expenditures, while manufacturing and finishing required only 5% of the total labor devoted by builders.[7] The summed person-hours and volumes for the Treasury of Atreus can be briefly compared to Fitzsimons' study of the Mycenae tholoi and Cavanagh and Mee's previous estimates for building the Treasury of Atreus.[8]

Fitzsimons provides a measure of the volume of excavated spoil needed to build each tholos at Mycenae. In total, he estimates that 2,9515.15 m[3] of fill needed to be removed for the Treasury of Atreus.[9] Based on my detailed CAD model, I reached a total measure of 2,885 m[3] of spoil removed during excavation of the site (Table B.3). The difference of 30.15 m[3] between these measurements is negligible. This offers a good point of confirmation that the estimates made by Fitzsimons[10] and those made in this study are both sound and replicable. Cavanagh and Mee's study of labor-costs for the Treasury of Atreus, in contrast, offers measures that deviate from my own; their overall estimate of 20,280 man-days is strikingly different than my own summed measure for the Treasury of Atreus. Although it is difficult to know precisely how many

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[7] The structural emphasis of the reconstruction in Chapter 4 means that final decoration is not included. This is an area for future addition.
[8] Cavanagh and Mee 1999; Fitzsimons 2011.
[9] Fitzsimons 2011, table 5.7.
[10] Fitzsimons 2011.

person-hours their "man-days" translate into, it likely ranges from 101,400 to 162,240 person-hours based on a five- to eight-hour work day found across traditional energetic studies.[11] My measurement of 267,570 person-hours is 165–264% greater than this. The source of this discrepancy may be attributable to fundamental differences in volumes and disagreements on appropriate task-rates for quarrying, transporting, and assembling building materials, but again, it is hard to isolate the exact discrepancies in their study; a few examples, however, do stand out as the likely culprits.

While our volumes for the peribolos and its materials are comparable,[12] my measurements for the conglomerate ashlar; its backing of rubble, mortar, and claybrick; and the tumulus diverge from Cavanagh and Mee's estimates. For the conglomerate ashlar of the dromos and chamber, Cavanagh and Mee estimate a volume of 1,400 m^3, approximately 71% of my measurement of 1,960 m^3.[13] The discrepancy is primarily due to their very conservative estimate of the dome's masonry.[14] Since my own model relies on good data about the nature of the dome and uses the published thickness of the masonry at both the lowest and uppermost course, my own measurement is better supported. For the limestone and claybrick backing of both dromos and dome, Cavanagh and Mee estimate 350 m^3 and 400 m^3, respectively.[15] In contrast, I have measured 1,235 m^3 of mortared rubble and 1,510 m^3 of claybrick backing the walls of the dromos and dome. Based on Wace's sections behind the dromos,[16] there is an archaeologically

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[11] As expressed numerous times above, scholars must publish labor in person-hours first or they undermine their own metric's comparative value by obfuscating its true measure.
[12] Cavanagh and Mee 1999, 97.
[13] Cavanagh and Mee 1999, 96.
[14] They suggest about 735 m^3 for the dome, stomion, and lintels combined (Cavanagh and Mee 1999, n. 33).
[15] Cavanagh and Mee 1999, 97.
[16] Wace 1940, fig. 1, 2.

corroborated volume of c. 495 m^3 of rubble and 555 m^3 of claybrick here alone. As these are close to Cavanagh and Mee's estimates and the authors acknowledge the uncertainty about the dome's backing materials, it may be that they estimated only the dromos' backing, although they imply otherwise.[17] Finally, their estimate of 4000 m^3 for the tumulus[18] is about 54% of my measurement of 7,425 m^3. Since the tumulus' pinnacle has shifted over the millennia and eroded away, the difference may partially be due to how I envision the tumulus' original form, but because their estimate is not explained, it is not possible to offer a better reason for the discrepancy. Taken together, these three substantial variations in volumes are likely the driving force behind the difference of Cavanagh and Mee's "man-day" estimate and my own person-hours. Since my measurements originate from a CAD reconstruction that is built on published measurements, plans, and sections, I would argue that my own measurements are more accurate, although certain elements such as the backing of the dome do require more study in the future. Combined with my use of well-sourced data on time-rates,[19] my discussion of its production, my measurements, and my person-hours are a revised point of reference for future work on the Treasury of Atreus.

The Harbor Town of Kalamianos

Using the CAD reconstructions of structures 4-VI (Fig. A.66) and 7-X (Fig. A.67) at Kalamianos, I have estimated the volumes and surface area of the buildings' materials and components. Table B.7 and B.8 break down the quantities of the materials employed by the builders for the two structures. Each listed material in the tables provides a summed quantity for

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[17] Cavanagh and Mee 1999, 97.
[18] Cavanagh and Mee 1999, 97.
[19] All rates are found in Appendix C.

the entire structure and a detailed list of quantities required for individual building components. This includes volumes in m^3 for the major building components and the surface area in m^2 for those building components that required surface treatment with mud or lime plaster. Although the CAD reconstruction of 7-X and its surrounding ground line suggests that some fill was used to level out the southern floor of the building, this is not included among the quantities or in the energetic flowcharts; the volume is, at most, a few cubic meters and I hypothesized that the fill was likely detritus from foundation leveling and stone working activities so that it has little effect on volumes or person-hours.

I have combined the volumes listed in the preceding tables and the discussion of construction in Chapter 5 into a series of energetic flowcharts that illustrate the process of construction. The person-hours for each energetic task derives from the set of standardized task-rates, material densities, and construction constants published in Appendix C. The energetic flowcharts present a breakdown of structure 4-VI (Figs. A.106–112) and structure 7-X (Figs. A.113–120) into their major components. Additional charts break down the major components to highlight how raw materials progressed through various tasks. To ease creation of the energetic flowcharts, I have incorporated the following assumptions and generalization:

1)   Transportation of Materials: Because distances to material sources are a significant factor in building, these have been estimated for structures 4-VI and 7-X. The major materials (earth and stone) are readily available within 50 m of the building sites. It is estimated that 250 m is sufficient to collect the branches and vegetation needed for floors and roofs, while the major timber required at least 750 m to reach sufficient trees.[20] For 7-X, the distance to water

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[20] The limitations of our knowledge regarding timber are discussed in Chapter 5.

is negligible because of the nearby fissure, but for 4-VI, it is estimated that 50 m is a reasonable distance to reach nearby fissures. The area of brick production for 7-X is hypothesized to have been in the polje (see Fig. A.48), 150 m to the building's north. All transportation methods at Kalamianos rely on carrying, either as a group for larger loads or as an individual for smaller loads. The group carrying rate from Appendix C means a slower speed due to the fact that heavy stones and logs required the coordination of multiple people at once. For all carrying rates, a person is able to maintain a load of 28 kg.[21] Based on the inferred distances and transportation methods, individual rates for the transportation of each material are listed in Tables B.9 and B.10. These rates are used in the energetic flowcharts to determine the labor that builders expended transporting particular materials.

2)   Minor Tasks and Materials: Some tasks are negligible because of the small volumes of material involved or the proximity of the material to the site. For example, the transportation of water is often not included in the energetic flowcharts when it would be on the order of a few person-hours. This does not imply it is an unimportant aspect of production, only that from the perspective of modeling the construction process, that it is trivial. Similarly, there are no tasks included for procuring branches and vegetation. Only a transportation rate is used and this assumes branches and vegetation are collected informally, as needed. The tempering used in the mudbrick and lime plaster for 7-X are likewise assumed to be readily available and do not incorporate a procurement or transportation rate. Minor materials are occasionally listed in the model for clarity, though, to illustrate how raw materials are brought together by builders to form manufactured materials or to illustrate areas requiring future exploration.

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[21] Based on Ayres and Scheller 2002. Because of the shorter carrying distance, this may underestimate the sustainable weight; see Cotterell and Kamminga 1990, 194 table 8.1.

The energetic flowcharts for structures 4-VI and 7-X are illustrated in Figures A.106–112 and Figures A.113–120, respectively. For the sake of comparison and to situate this data within previous work in the Aegean, I have summed the tasks from the energetic flowcharts for both structures in a tabular format that is typical of traditional architectural energetics studies. Tables B.11 and B.12 show the traditional summation of each component and the five categories of tasks for structures 4-VI and 7-X. Respectively, the summaries show the breakdown of the 4,380 person-hours builders expended constructing structure 4-VI and the 5,930 person-hours expended constructing structure 7-X. Based on Devolder's analysis of Minoan architecture, this places the two structure from Kalamianos roughly on the order of structures found at Mochlos and Pseira.[22] Comparatively, the two traditional energetics summaries are distinct because of the suggested differences in construction techniques found in the structures; however, despite these differences, the breakdown by task category is similar as builders expend most of their labor assembling components, especially walling.

The combined procurement and transportation of building materials are moderate in both cases, accounting for 22% of structure 7-X and 26% of structure 4-VI's total labor requirements. The ready availability of materials at Kalamianos, discussed in Chapter 5, accounts for this modest percentage. This can be contrasted with the tedious procurement and long-distance transportation of materials for the Treasury of Atreus, which the traditional energetics summary (Table B.6) shows required 52% of the builders' time and labor. The reduced energy that builders had to spend procuring and transporting materials at Kalamianos was a significant factor

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[22] On Pseira, Building BS/BV (4,625.31 ph) and Building AB (6237.27 ph), and at Mochlos, Building B (5229.91 ph) and Building C3 (5743.78 ph); see Devolder 2013, 116.

in their ability to produce thick and substantial walls, since these less demanding tasks left them room to devote approximately 50% of their energy to assembling walls from rubble and mudbrick.[23]

Building walls of mudbrick was especially demanding because it required additional transportation and manufacturing steps when compared to rubble wall building. The traditional energetics summary for structure 7-X suggests the difference in the average hourly labor expended at Kalamianos for mudbrick masonry when compared to rubble masonry was about two to one.[24] Although this is a generalized comparison which would be impacted by builders' choices and local factors of construction, particularly resource locations and wall thickness, it implies that choosing to build in mudbrick at Kalamianos came at an added effort. Devolder reached a similar conclusion in her study of Minoan architecture, finding that mudbrick walls required approximately one and a half times the labor of rubble walls.[25] Since Devolder's and my own generalized rates of mudbrick construction differ little, the discrepancy in our ratios is due almost wholly to her higher labor estimates for rubble walling. This is expected though, since the reduced rate for rubble walling at Kalamianos, about two thirds of Devolder's rate, is a factor of the prevalent availability of limestone. In the future, it is all the more important, to isolate the structures at Kalamianos where builders opted to employ mudbrick or mix mudbrick and rubble; since it was a more demanding choice of building material than the readily available rubble, it may provide clues to local social organization, chronology, and building function.

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[23] This also may be reason to expect added time was spent on refinements like painted plaster.
[24] The average of 7-X is approximately 1 m^3 / 10.18 ph for rubble masonry and 1 m^3 / 22.48 ph for mudbrick masonry.
[25] She publishes a rate of 1 m^3 / 24.52 ph for mudbrick walls and 1 m^3 / 16.66 ph for rubble walls (Devolder 2013, 121, 138).

In both structure 4-VI and structure 7-X, the builders expended a moderate amount of their laboring on interior and exterior plastering. For the most part, the 16% of labor expended on plastering structure 7-X and the 20% on structure 4-VI was a structural necessity; without some form of plastering, the mortared rubble and mudbrick would be prone to decay and ultimately destabilize the buildings. The interior lime plastering of structure 7-X was only minimally demanding, suggesting that from the perspective of time and energy, lime plastering was an obtainable enhancement for many structures at Kalamianos[26] and would be limited only by the availability of experienced individuals to manufacture and apply it.[27] In the case of both mud and lime plastering, regular maintenance was required[28] so the associated tasks, especially for finishing the exterior surfaces, and the concomitant labor required, should be seen as a recurring obligation for builders to preserve structures at Kalamianos. It is hard to say how frequently maintenance of plastering occurred since it is a factor of weather and use, but the initial 860 person-hours and 930 person-hours for structures 4-VI and 7-X, respectively, would have to be continuously reinvested to renew the surfaces. Once this maintenance became impractical due to reduced time or population, the process of decay would begin, eventually leading to roof and wall collapse.[29]

For the sake of order of magnitude, which is valuable in traditional energetics comparisons, it is useful to roughly approximate the overall labor requirement for the major structures of Mycenaean Kalamianos and to assess their maintenance cost as well. There are a

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[26] Structure 13-II at Stiri, which has been cut by a modern road, shows evidence for lime plaster.
[27] See Brysbaert (2008) for thorough discussion of plastering, skill, and social identity.
[28] Carelli (2004, 117–8) includes "maintenance" as an additional task type in his traditional energetic discussion of Copan.
[29] On the process of house decay and the formation of the archaeological record, see for example, Friesem et al. 2014.

number of ways this could be calculated, such as reconstructing the cubic meters of walling for the buildings and applying the average person-hours for rubble and mudbrick mentioned above. An easier way for Kalamianos, though, is to use an average person-hour cost per m^2 and apply this to the buildings' footprints. This glosses over some of the problems that arise when looking at cubic meters of walling, such as reconstructing wall heights and dealing with collapse, and it makes the calculation easier to complete with a two-dimensional GIS map (see Figs. A.49, A.50). I apply this method to a total of 23 structures, all of which have defined rooms and walls, but the results do not account for every possible structure nor do they include fortifications or terracing;[30] the results are meant only to approximate the major buildings with rooms that the Saronic Harbors Archaeological Research Project identified. To each of these 23 structures, I apply the per square meter rate for structures 4-VI and 7-X. Structure 4-VI, the one story rubble building, has a footprint of 195 m^2 or a labor rate of 1 m^2 / 22.46 ph and structure 7-X, the two-story mudbrick building, has a footprint of 105 m^2 or a labor rate of 1 m^2 / 56.48 ph. The results are presented in Table B.13. The total shows a range of 89,953–226,204 person-hours depending on whether each structure is built as a single story with rubble or a double story with mudbrick, like structures 4-VI and 7-X. The average result of 158,079 person-hours is the best estimate since it allows for variability in construction practices across the site. To return briefly to Devolder's study of Minoan buildings, this total measure is approximately ten times as much as the Royal Villa or South-East House at Knossos, and approximately four to five times as much as the South House or Unexplored Mansion at Knossos.[31]

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[30] Kvapil (2012) has previously analyzed the terracing at Kalamianos.
[31] Royal Villa (15,126.17 ph), South-East House (16,592 ph), South House (30,799.64 ph), Unexplored Mansion (43,525.24 ph); see Devolder 2013, 116 table 15.

For approximating the maintenance cost of the site, the labor that builders expended plastering is estimated based on the average person-hours derived from structure 4-VI and 7-X. The results are listed in Table B.14 The range for plastering all structures is 18,258–36,744 person-hours with an average of 27,502 person-hours. If limited to the exterior alone, the range is 8,208–13,793 person-hours; the difference between the upper and lower numbers is primarily due to whether there is one story or two. As high-level, tabular overviews typical of traditional energetics these metrics should be read as macroscopic overviews of human behavior, but the numbers do reasonably suggest the magnitude of labor that inhabitants expended to renew the plastering of the site's major structures. If the exterior plastering was gradually renewed over the course of roughly a decade, inhabitants might expend 1,400 person-hours yearly completing this task. Renewing the interior as well would mean perhaps twice as much labor. Neither case is especially onerous for a moderately-sized population, especially when broken up over a year or even a single season, but if there were a population crash, the remaining inhabitants would have to selectively renew exterior plastering while abandoning many structures to the elements.

The Northeast Extension of Mycenae's Fortification Wall

Using the CAD reconstruction of the Northeast Extension (Figs. A.93, A.94), I have estimated the volumes and surface area of the project's materials and components. Table B.15 breaks down the quantities of the materials employed by the builders. Each listed material provides summed quantities for the entire structure and a detailed list of quantities required for building components. This includes volumes in m^3 for all major building components or phases and the surface area in m^2 for those building components that required surface treatment. In this case, this is only the area of bedrock worked for the purpose of improving contact between the

251

lowest course of the cyclopean wall and bedrock. I have combined the listed volumes and discussion of construction in Chapter 6 into a series of energetic flowcharts that illustrate the process of construction. The person-hours for each task derives from the set of standardized task-rates, material densities, and constants published in Appendix C. The energetic flowcharts present an overall breakdown of the structure into its major components and then breaks down each component to highlight how raw materials progress through various tasks. To ease creation of the Northeast Extension's energetic flowcharts, I incorporate the following assumptions and generalizations:

1)   <u>Transportation of Materials</u>: As with the situation at Kalamianos, the material necessary for the Northeast Extension was locally available. There is no single extraction point, though, that can be isolated as the source of limestone blocks and rubble. As discussed in Chapter 6, the known extraction areas occur to the northeast and sit along major roadways leading to the citadel (Fig. A.95). Any number of extraction points along these roads may have been exploited by builders at once in order to maintain the progress of construction. As an equitable average distance for transportation, I use a measure of 500 m for limestone and rubble, which accounts for the likely mix of longer trips, such as the c. 1.5 km trip to draw from the lower slopes of Profitis Ilias, and shorter trips such as the c. 100 m trip to extract stone around the citadel itself.[32] Spoil from excavating the cistern and stone from the razed first period wall are transported an approximated 50 m. For the newly extracted blocks and rubble, the roadway was adequate for transportation by wagons and oxen. The short distance and terrain for the reused material suggests that the material was carried and either dumped or reused in the new

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[32] Compare D6:01 and D5:04 (Fig. A.95).

wall. For all carrying rates, a person is able to maintain a load of 28 kg.[33] Based on the inferred

distances and transportation methods, individual rates for the transportation of each material are

listed in Table B.16. These rates are used in the energetic flowcharts to determine the labor that

builders expended transporting particular materials.

      2)   The Razed First Period Wall: The material of the razed first period wall was

reused in construction of the new extension. This process is simplified in the energetic

flowcharts by suggesting the 1,140 m^3 of razed material was added to the new wall face;

however, it may have been divided in a more complex manner between the new wall faces and

wall fill. Portions of the old material may also have been discarded.

      3)   Foundations and Clay: The amount of preparation required before setting the

lowest courses of the wall is hypothetical. The wall's footprint is 632 m^2 and I suggest about

25% of this area needed to be worked with a hammer in some way to remove projections or

otherwise dress it to safely transfer the wall's superimposed weight to bedrock. Despite reports

of clay in the wall, none is included in the energetic flowcharts because its manner of application

and volume are unknown.

      4)   The Cistern: It is proposed that excavation of the cistern occurred while the

builders were preparing the site, and likely before any wall construction began. The volume

taken from the CAD reconstruction, 289 m^3, is used as the excavated volume.[34] If it were built in

a preexisting crease in the rock, the volume of material removed may have been less; however,

the 289 m^3 does not account for removal of overburden. It only estimates the volume of the

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[33] Based on Ayres and Scheller 2002. As for Kalamianos, the shorter distance might mean this
underestimate the sustainable weight; see Cotterell and Kamminga 1990, 194 table 8.1.
[34] The rate of excavation does not account for increasing depth and the added difficulty of
removing materials.

finished cistern, so I believe it is a reasonable middle ground. There is no question that a thick layer (or layers) of waterproof clay was applied to the lower section of the cistern. Details of its application and its measurements require future study, though. I have added it to the energetic flowchart (Fig. A.123) with a question mark to stress that it as an important unknown that can be filled in with future study.

The resulting energetic flowcharts of the Northeast Extension are illustrated in Figures A.121–124. For the sake of comparison and to situate this data within previous work in the Aegean, I have summed the tasks from the energetic flowcharts in a tabular format that is typical of traditional architectural energetics studies. Table B.17 shows the traditional summation of each component and the five categories of tasks for the Northeast Extension. The summary shows a breakdown of the 44,875 person-hours builders expended constructing the Northeast Extension. From the traditional energetics summary, the builders expended 75% of their energy assembling the new cyclopean wall, as would be expected. Comparatively little time is spent procuring materials, in part because of reuse from the former wall; however, our knowledge of Mycenaean quarrying and stone extraction is mostly speculative, originating from Minoan, Hittite, or Egyptian evidence. Study of Mycenaean quarries is desperately called for and would potentially change this number. Transportation, at 15% of the total, is modest due to the use of oxen on well-prepared roads for most of the building materials. Among the major components, it is notable that the cistern, often cited as the impetus for construction, required a miniscule 2% of the builders' overall labor for the masonry[35] and 3% for excavation, so that it gives the impression of a minor undertaking if considered only from the perspective of labor expenditure.

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[35] Here, too, we need better experimentation with building in large stone masonry.

Although the steps of the cistern are not included, even if this doubled the number, the total would still be small.

The summed person-hours and volumes for the Northeast Extension can be compared to the summed energetics found in Loader's study of Mycenaean fortifications.[36] Loader presents energetics calculations for transporting one face of stone to build the walls at Gla, Tiryns, and Midea. Based on her average count of blocks in one wall face per site, for the three she publishes a total of 139.53 years, 55.26 years, and 13.82 years respectively.[37] The meaning of these numbers, which are irregularly expressed in years, is clarified when she explains that they derive from assuming that four men transport a single cyclopean block in 11.19 hours and work eight hours per day year round. We can, therefore, convert these years to person-hours by multiplying each by 11,680, the total person-hours per year that her number masks.[38] The results are that transportation of stone for one face of Gla takes 1,572,011.2 person-hours, for one face of Tiryns takes 645,436.8 person-hours, and for one face of Midea takes 161,417.6 person-hours. A second set of numbers, again in years, is presented for transportation with oxen instead of men. The results for Gla, Tiryns, and Midea are respectively 16.5 years, 5 years, and 1.25 years.[39] Multiplying these by 2,920, the total person-hours per year, converts them to total person-hours.[40] The result is that to transport stone for one face of Gla takes 48,180 person-hours, for one face of Tiryns takes 14,600 person-hours, and for one face of Midea takes 3,650 person-hours. This latter set of numbers is the better of the two for comparison with my own since I

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[36] Loader 1998.

[37] Loader 1998, appendix 3.

[38] That is to say 4 men working 8 hours for 365 days (4 x 8 x 365 = 11,680 person-hours / year).

[39] Loader 1998, 69.

[40] That is to say 1 man working 8 hours for 365 days (1 x 8 x 365 = 2,920 person-hours / year). This does not include any sort of oxen-hours.

hypothesize transportation for the Northeast Extension relied on wagons and oxen. The energetic flowchart in Figure A.124 shows that 1,478 m^3 of the Northeast Extension, a bit over the amount of stone in one face,[41] required 1,330 person-hours to transport by oxen. Since one face of Midea's wall employed c. 2,727 m^3 and one of Tiryns's used c. 10,641 m^3, the person-hours expended for one face of the Northeast Extension falls at the bottom of the continuum of fortifications in the Argolid, when viewed at a highly abstracted level.[42]

Thinking Through the Energetic Flowcharts

The energetic flowcharts created to graphically describe architectural production offer a valuable counterpoint to traditional architectural energetics. As traditional energetics is quick to sum up numbers and push upwards, towards the level of macroscale interpretation, the energetic flowcharts keep analysis grounded in the smaller details that sustain larger social, economic, and political models. As an end in themselves, future scholars should consider using such flowcharts within traditional architectural energetics. If coupled, this provides one means to think across multiple scales and this stresses the importance of macro-, meso-, and microscale evidence. The balance provided by the closer range details of energetic flowcharts is an important improvement in this regard. In fact, this is exactly the type of multiscalar analysis that agency studies[43] and the chaîne opératoire necessitate. If we return to the film metaphor used to describe the chaîne opératoire approach,[44] the tasks and materials of the energetic flowcharts are the chaîne

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[41] This volume is the amount of new material hypothesized to have been used in combination with the reused material of the first period wall.

[42] The volumes for Midea and Tiryns are based on Loader's suggested number of blocks in each face multiplied by the average size of a cyclopean block (Loader 1998, appendix 3).

[43] See especially Pauketat and Alt 2005.

[44] Desrosiers 1991.

opératoire's scenes in which actors use knowledge and tools in particular contexts to transform raw materials; across the energetic flowcharts these actor-oriented scenes enchain, over time converging into larger processes, material components, and eventually leading to the final structure itself. In traditional energetics, it is easy to lose sight of these scenes and their enchainment, but with the energetic flowcharts it is possible to move up and down a specific chaîne opératoire from finished structure to small-scale tasks and more explicitly envision how individuals devoted their labor and integrated within one another during construction. Viewing "construction" in this manner is what I have preferred to call *architectural production* since this term places emphasis on the individuals and processes while moving away from the historically passive and stylistic approaches to which studies of ancient construction often confine themselves.

A second benefit that these energetic flowcharts provide is the explicit inclusion of volumes, task-rates, and person-hours. Not only does this quantify the small scale aspects of architectural production, but these are the numbers that are rolled up in traditional energetics. When working with so many numbers, tables are necessary but they can become densely-packed, hard-to-read, and error-prone. Graphically representing these numbers and their hierarchical summation supplements tabular content. High-level tables also lack the energetic flowcharts' detailed picture of volumes and labor, and do not provide information on how tasks integrate before reaching a final sum of person-hours. The energetic flowcharts bring in ideas of complexity, as well, that balance out traditional energetics' sometimes myopic focus on "labor-cost." Although a group of structures can fall into the same range of person-hours, the energetic flowcharts describing each structure better highlight why they fall into such ranges and whether these ranges are, in fact, meaningful. For example, the flowcharts can help to isolate similar and

disparate production processes within a single group of structures. Concomitantly, the social,

political, and economic nature (*i.e.* the complex-embedded nature) of these processes can be

explored to scrutinize the broader meaning of traditional energetics groupings and to dissect elite

power strategies or sociopolitical typologies. In the context of this study, the energetic flowcharts

are a stepping stone in the overall modeling process, but they are an equally valid stopping point

for future research of architectural production and the chaîne opératoire.[45]

Simulating Production: Precedence Diagrams and Labor Ranges

Using the energetic flowcharts as a staging point, the groupings and tasks of each

structure have been entered into Microsoft Project and the relationships between tasks have been

established.[46] The types of relationships between tasks, as discussed in Chapter 3, are finish-to-

start (FS), start-to-start (SS), finish-to-finish (FF), and a combined relationship which is both a

start-to-start and finish-to-finish. Since this last relationship cannot be directly expressed in

Microsoft Project, placeholder tasks, labeled "*FF*", are added where a combined relationship is

warranted.[47] A good example of this is between many of the procure and transport tasks. The

combined relationship between these two types of tasks ensures that transportation starts after

procurement and does not finish before procurement. In effect, the placeholder tasks labeled

"*FF*" make sure that the start and finish of two tasks sync up in a logical way.

The precedence diagrams for each of the four structures under study are published in pdf

format in the supplementary content (Supplements 1–4).[48] The predecessor tables for the

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[45] Compare the use of sequence models in lithic studies; see Bleed 2001.
[46] In part, the following paragraphs summarize aspects of the method found in Chapter 3. See p. 72–83, 91–93 for fuller explanation of these concepts.
[47] Refer back to their graphical representation in Figure A.2.
[48] Their size prevents their inclusion in this chapter's figures.

structures, which list each task and its relationship to preceding tasks, are found in Tables B.18–21. These contain the same information as the precedence diagrams. The predecessor tables give a unique ID for each task, an outline number showing how the tasks group into systems that are related to the energetic flowcharts, and the IDs of each task's predecessor. The type of relationship between the task and its predecessors is abbreviated next to the predecessor's ID.[49] Any lag or lead is listed after the abbreviated relationship as a "-" or "+" followed by the amount of lag or lead. For use, criticism, and modification in future researcher, this data may be directly pasted into Microsoft Project to scrutinize how I have diagrammed the production process.

Within the precedence diagrams, most of the relationships between tasks are built on hard logic, that is physically inviolable rules, for example that foundations must be built before the superstructure; however, soft logic, that is rules based on the thoughtful interpretation of the building process and the ideas raised in the previous narratives of construction, is also a factor at key points. Across all four precedence diagrams, lag and lead times based on soft logic have been included to model a realistic delay between overlapping tasks. In modern project management, the amount of lag or lead between tasks rests heavily on past experience and practical knowledge of how work should be staggered. For the four structures under study, I have applied lag and lead so that it offers a reflection of past behaviors, but simplifies an otherwise complex modeling process. For tasks of shorter duration, a lag or lead of 5% has been added where called for.[50] For tasks of longer duration, the lag or lead is set at 1%. There are a few other occurrences of soft logic incorporated into the precedence diagrams that must be pointed out.

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[49] SS (start-to-start), FF(finish-to-finish); No abbreviation (finish-to-start).
[50] This means that the tasks will add a lag or lead of 5% of its predecessor's duration.

For the manufacture of claybrick or mudbrick, as found in the Treasury of Atreus and structure 7-X at Kalamianos, there is an absolute lag time of seven days between manufacturing and transporting the bricks. This absolute lag makes sure that one week of time passes for bricks to dry before they can be transported.[51] For structures 4-VI and 7-X at Kalamianos, major components of the buildings are logically staggered so that the procurement of materials for a future building component does not begin too early. For example, hard logic dictates that earth for the roof could be procured, transported, and stockpiled at the site as soon as construction began. Because of the limited space at Kalamianos and the smaller duration of many of these tasks, however, it is more likely that such a task was closer in time to the creation of the roof. The precedence diagrams for both structures reflect this logic and model building materials being procured and transported nearer to the time when they will be employed. This logically prevents the building site from becoming choked up with unneeded materials or crowded with groups transporting materials at times when they are unnecessary. Finally, for the Northeast Extension, the precedence diagram is arranged so that the assembly of the cyclopean fortification wall does not start before the assembly of the cistern has finished, although preparation of the cyclopean wall's foundations may begin earlier in the model. This is based on the possibility, raised earlier, that parts of the cistern antedate the creation of the fortification wall. The effects that logical relationships in the precedence diagrams have on the models of construction are discussed in the context of the simulation data, as the strengths and weaknesses of each precedence diagram become clearer in light of the results.

To complete the dynamic models of architectural production, labor ranges have been hypothesized for each task in the precedence diagram. The ranges for each structure are listed in

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[51] This is a conservative drying time; see McHenry 1989, 86.

Tables B.22–25. The name and outline number for each task corresponds to the precedence tables and diagrams. The established range of labor for a task is a set of three numbers: a low, middle, and high number of individuals. The range of three numbers is similar to PERT (Project Evaluation and Review Technique), a project planning technique which uses three numbers to simulate task durations in construction simulations.[52] In this setup, the low and high numbers reflect hypothesized minimum and maximum numbers of laborers that might operate at once at a given task. The middle number reflects a reasonable number of workers between the two extremes. The thought behind this tripartite approach is that labor is more likely to fall near the middle number than to fall at the extreme minimum or maximum. Therefore, as in PERT, these three numbers are fed into a statistical function that weights the middle number.[53] The resulting distribution forms a smooth curve (Fig. A.125) that can be sampled during a simulation to estimate the amount of laborers working at a task. Wherever possible, the chosen ranges rely on physical constraints and comparative data. In each table of labor ranges (Table B.22–25), I give an explanation for the range. None of the ranges is perfect and it would be unreasonable to expect perfection. The numbers do, however, offer an expedient and realistic way to explore human behaviors during the construction process and to draw attention to the extents and limits of our current knowledge. Because some of the tasks and labor ranges have a greater effect on timeframes of construction and some of the ranges are more conjectural than others, after simulation, I utilize statistical sensitivity analysis to isolate the most important tasks and to stress where future experimentation, better estimation, and archaeological fieldwork is needed.

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[52] Baldwin 2014, 142–3.
[53] The mathematical nature of the distribution is detailed in Goodpasture 2003, 41–5; Mun 2008, 906–7.

For each model of construction, which consists of the precedence diagram combined with the statistical distributions of laborers working at each task, a simulation is performed to generate schedules of construction and statistical metrics about the construction process. Each simulation is run for 1,000 iterations. During an iteration, Palisade @Risk, a Monte Carlo simulation tool, assigns a number of workers to every task based on the statistical labor distributions and then generates schedules for construction in Microsoft Project. Because scheduling tasks is a complex job that typically requires human input, each iteration schedules a given task to start as soon as physically possible. This means that some scheduled tasks have a float time that would allow them to start later than scheduled or run longer than scheduled. Many of these floating tasks are significant; because they offer room for decision-making during the construction process, their occurrence can highlight the choices during architectural production that confronted ancient builders.

The result of each simulation is 1,000 schedules of construction based on different labor configurations, a set of statistical data showing patterns in completion time and variations in peak labor, and sensitivity data suggesting which tasks and labor ranges have the greatest impact on the simulated timeframes of project completion. In the following section, I discuss the results from each structure's simulation, first at a general statistical level. I then bring closer range examples and reasonable schedules of construction to the fore. Finally, I perform sensitivity analysis to isolate areas for future model improvement.

The Temporality of Architectural Production

The Treasury of Atreus

A graph of the time to complete the Treasury of Atreus and the relative frequency of simulated schedules that generated this time is published in Figure A.126. Time is expressed in

absolute days of eight working hours.[54] In the best and worst case scenarios, simulated schedules gave a completion time of 463 to 938 working days. The mean result is 643 days with a standard deviation of 72.83 days. The probabilistic distribution of days to complete construction shows that the shortest 90% of schedules finish in under 742 days, the shortest 50% finish in under 634 days, and the shortest 10% under 559 days. The peak number of individuals working on site during the simulated schedules is given in Figure A.127. The peak number of individuals is time-scaled by the month of construction, consisting of 30 eight-hour days. The blue line shows the peak among all 1,000 simulated schedules, the red line the peak among 90% of schedules, and the yellow the mean of all 1,000 schedules.

The feature of this graph that is immediately apparent is the steep rise and plateau that, across all schedules in red, first appears in the seventh month and runs until the twenty-first month. This drastic change in the peak number of individuals on site is the "lintel bump," the time when an especially large group must be called upon to move the interior lintel, estimated to require 412 individuals, and to a lesser extent, the exterior lintel, estimated to require 75 individuals.[55] The duration of the plateau across all schedules reflects the various times this act occurs in the simulations. Among 90% of schedules, however, the transportation and installation of the lintel occurs during a much shorter window of time, between the ninth and fourteenth work month of construction. This plateau is ill-defined in the mean because of the loss of resolution that is inherent in averaged data.

Outside of the lintel bump, the data across all schedules and 90% of schedules shows peak monthly labor ranging from approximately 50 to 250 individuals. Whereas the lintel bump

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[54] Allbaugh (1953) found that eight hours was a standard working day on Crete in the 1940s. This measure does not include breaks or the time to get to work.
[55] See Table B.22.

shows a peak of laborers that must be organized and supported for a very brief period of construction, this range is more revealing of the steady number of laborers that will be working at any given time. Even at this general level of statistical data, the advantage of studying construction as a dynamic process by using the method advocated in this dissertation is apparent. Unlike flattened pictures that can emerge from traditional energetics studies, which often present generalized hypotheses such as twenty laborers working for nine months, more realistic pictures of the variable administrative and labor needs that the construction process required materialize here in greater clarity. Moving to the level of individual schedules sharpens this picture.

In the case of the Treasury of Atreus, whose timeframe for completion has ramifications for our understanding of social, political, and economic organization at Mycenae, it is constructive to begin by looking at the longer simulated timeframes of construction. Figure A.128 and Table B.26 show in a Gantt chart and tabular format a summarized schedule of construction that is completed in 742 days, the number under which 90% of simulated schedules completed. This 90% mark provides a convenient rule-of-thumb for examining a longer but still realistic schedule from the simulation data, and it cuts off the less realistic outliers that appear at the upper edge of the timeframe in Figure A.126. The 742 days to complete construction in this schedule is a representation of absolute working days of eight hours. It is important to note that this does not account for breaks in construction or seasonality, issues which are difficult to discuss with certainty, but, nevertheless, should be considered. If there were a working season of 90 days per year, this number in the upper range of the simulated data would suggest the Treasury of Atreus was realistically completed in under nine years. If reduced to 50 days per year, this would place completion within 15 years.

In this longer simulated schedule, the peak labor on site shown by month (Fig. A.128) has the expected lintel bump occurring during the 13th month of construction, or 384 work days into construction (see Table B.26). The peak, though, is quite short lived, just a few working days (Fig. A.129). Even if this estimated time to move the lintels is overly generous and the task's duration were multiplied, installing the lintels would still occupy only a small fraction of the 742 working days devoted to the project. Better study of Mycenaean quarries and future experimentation with conglomerate quarrying and transportation will refine this important issue. Once builders moved the lintels from the quarry into their position in the tomb's chamber, the simulated schedule's peak labor settles to 234–241 individuals. A portion of this still large amount is due to the fact that during the 16th month of construction, starting on working day 473, the upper chamber, dromos and upper façade, peribolos, and tumulus are worked on simultaneously, requiring large numbers of individuals to perform discrete tasks concurrently. The simulated start of the peribolos' construction at this time, however, is highly flexible. It may alternatively be started at a later time, for example, after the upper chamber is completed on working day 505, or its duration may be extended by employing fewer workers. A decision to start the peribolos later or to take longer to build it would reduce the peak labor between months 15 and 17 and increase that of month 19 and after. This flexibility in building choices is important during construction because it provides a convenient way for builders to handle uncertainty. If materials for the peribolos do not arrive on time, if skilled workers are absent, if individuals must be shifted to other tasks, or if major accidents occur, the final date on which construction is completed might not be delayed, so long as the peribolos is completed before the dromos and upper façade are done on working day 718. That is to say, because it is relatively

disconnected from other construction elements, construction of the peribolos has a large amount of float time that can be called upon as necessary by administrators and builders.

The tumulus, too, has leeway in this regard, but unlike the peribolos, the tumulus is a driving factor behind the date of completion. To speed up construction, the builders might take two different approaches to the tumulus: labor could be drawn away from less pressing tasks, such as building the peribolos, and assigned to procuring and transporting material for the tumulus, or builders could start these tasks earlier in time than the present schedule and current model allow. This last possibility is archaeologically intriguing. The model of construction assumes that hidden elements, such as the rubble and claybrick backing of chamber and dromos, must already be substantially completed before most of the tumulus is heaped up. This supposition may be erroneous, though. Heaping up the tumulus earlier in the project's life, such as in tandem with the upper chamber, which begins in this schedule on working day 385, would spread labor more evenly across the project and speed up the completion date. The distinct layers of stratigraphy along the so-called Great Poros Wall around the Tomb of Clytemnestra might indicate that an extended or piecemeal approach was taken to tumuli.[56] Future non-invasive, subsurface study of the Treasury of Atreus' tumulus would help address this question of construction and staging.

In contrast to the rush of building at the end of this 742-day schedule, at its start, labor is sometimes quite low. During months 1 and 2, a peak of 87 individuals work to dig out the site and quarrying conglomerate for the lower chamber and stomion. In working month 3, when masons and helpers begin to install the ashlar walls of the chamber, labor dips to 35 and the pace of construction further drops in working months 5 through 12 as construction of the lower

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[56] Taylour 1955b, fig. 5.

266

chamber slowly progresses. The 15 workers on site assembling the lower chamber may be an underestimate, but we should also be wary of underrating the technical knowledge and ingenuity of the Mycenaeans by assuming brute force and high numbers of laborers were always needed during large construction project. Within the labor model, though, 15 workers in the chamber does fall under the suggested middle range of 20 workers (Table B.22 Outline #3.1.3). On the other hand, for much of the chamber only a single block could have been set and worked at any one time, a task which can be accomplished by a small but steady number of laborers. The central point to take from this low number of laborers is the contrast it provides with the lintel bump. Even in the largest projects, there will be lulls in the pace of construction and labor demands can dip. From an administrative perspective, this means that while at times, such as transporting the lintel, there is a need for intensive centralization, at other points, a small group of skilled builders and helpers can operate rather independently with less oversight. Looking at a schedule of median duration from the simulation offers some points of comparison and indications of how the builders could speed the pace of construction.

A summary schedule taking 643 working days, the point under which 50% of simulated schedules are completed, is given in a Gantt chart and tabular format in Figure A.130 and Table B.27. Here, the lintel bump happens in the 10th month of construction, starting on working day 282. The major difference in this faster schedule is the organization of labor at the start and end of the project. Whereas the slower schedule relied on a small group of workers building the lower chamber over a longer duration, in the median schedule the lower chamber is completed more quickly. During the first eight months of construction, peak labor on site is much higher than in the previous schedule, showing a range of 26–81 individuals. This higher number of peak individuals is a significant factor in completing the lower chamber by working day 295 in

contrast to working day 395 in the previous schedule. Like the preceding schedule, though, there is a lull in construction activity during months 7 and 8, when the lower chamber is going up. The peak of 26 individuals on site during this period again reflects the variation in administrative and organizational needs during construction and like the preceding schedule, this number stands in stark contrast to the peak of 566 individuals working when the lintels are transported.

Another factor which speeds along this schedule is the additional labor working on the tumulus during the last months of construction. As mentioned before, procuring and transporting materials for the tumulus is an important choice point for the builders since it has an immediate effect on the completion date of the project. Together, the high and median schedules suggest that by focusing more skilled labor on the completion of the lower chamber and unskilled labor on the tumulus, the completion time for construction could be significantly reduced. The prerequisite for this decision, though, is that a larger pooler of workers was available and sustainable. Compared to the longer schedule, at the project start the minimum peak of laborers in the median schedule is 50 instead of 35 and at the end of the project 83 individuals work on the tumulus instead of 47. Like the high schedule, in the median schedule, the peribolos is flexible and can be delayed to decrease the peaks of 186–190 laborers seen in months 13 to 16. A close up of the peribolos' construction shows how work might be delayed or completed more slowly by builders.

Figure A.131 shows the scheduling of the peribolos' major tasks grouped by building material. The blue bars show the start, duration, and end of the task in work weeks of seven working days. The bars underneath each show the associated float time, that is how much time the builders could delay or extend work without affecting the project's completion date. Since construction of the peribolos is an integrated system of tasks, delaying or extending any one of

268

these, such as taking longer to procure and transport rubble, will push other tasks further in time as well. The high degree of float associated with this system means that all rubble does not need to arrive at the site until work week 84 and that the finishing of the peribolos' ashlar masonry can happen anytime until the end of the project. Figure A.132 details how the simulation has organized labor for the peribolos in this particular median schedule. For the rubble, mortar, and poros, the two numbers reflect the laborers procuring and the laborers transporting the materials, respectively. For all three of these tasks, labor could be reduced and builders could move to more pressing tasks as needed. The number of workers quarrying ashlar is particularly high and because it finishes well before assembly, if possible, reducing the number of quarriers and increasing the number of masons would be advantageous. The assembly of rubble and the ashlar facade also might be reasonably delayed to a future time.

The Harbor Town of Kalamianos

A graph of the time to complete structure 4-VI at Kalamianos and the relative frequency of simulated schedules that generated this time is published in Figure A.133. Time is expressed in work days of eight hours. In the best and worst case scenarios, simulated schedules produced a completion time of 42 to 90 work days. The mean result is 57.818 days with a standard deviation of 7.247 days. The probabilistic distribution of work days to complete construction shows that the lowest 90% of schedules finish in under 67 days, the lowest 50% finish in under 57 days, and the lowest 10% under 49 days. The peak number of individuals working on site during the simulated schedules is given in Figure A.134. The peak number of individuals is time-scaled by the work week of construction, each consisting of seven eight-hour work days. The blue line shows the peak among all 1,000 simulated schedules, the red line the peak among 90% of

schedules, and the yellow the mean across all 1,000 schedules. All three lines show a relatively steady amount of peak labor on site until the final weeks of construction when the number reaches a maximum of 45 across all schedules and 36 across 90% of schedules. Figure A.135 shows a graph of the time to complete structure 7-X at Kalamianos and the relative frequency of simulated schedules that generated this time. In the best and worst case scenarios, simulated schedules produced a completion time of 64 to 141 work days. The mean result is 91.913 days with a standard deviation of 13.594 days. The probabilistic distribution of work days to complete construction shows that the lowest 90% of schedules finish in under 109 days, the lowest 50% finish in under 90 days, and the lowest 10% under 76 days. The peak number of individuals working on site during the simulated schedules is given in Figure A.136.

For both structures, the peak number of individuals working is consistent; both show labor during 90% of schedules peaking at 36 individuals and the peak of 45 individuals across all schedules for structure 4-VI is only slightly higher than the peak of 41 individuals for structure 7-X. The maximum of this peak, though, occurs at a different point in time for the two structures. For structure 7-X, the peak is witnessed around weeks 2–4 of construction. This jump in peak labor occurs at the time the second story floor is going in and mudbrick manufacture is beginning, so that a variety of tasks are overlapping here. Since the reconstruction of 4-VI lacks mudbrick, a comparable bump at this time is absent. Instead, the peak number of laborers for structure 4-VI reaches the maximum around weeks 7 and 8. This reflects the time at the end of construction when interior and exterior walls are being plastered. A similar bump is seen for structure 7-X, particularly in the line showing peak labor across 90% of schedules. The smaller surface area that needed to be plastered in 7-X, however, means this bump in labor was less significant during simulation than it was for structure 4-VI. Like the poros wall or the Treasury

of Atreus, the act of plastering is a good choice point for builders. Since plastering can be completed by just a few workers, the builders might choose to take longer at this task while concentrating on other building tasks. This offers an easy way to reduce one peak in laborers during the project and spread labor demands out more evenly. Because plastering is a driving factor in the completion date of construction, this choice comes at the expense of delaying the completion date. As protection from the elements, the choice of plastering would depend heavily on seasonality and weather.

Two median schedules of construction for structure 4-VI and 7-X illustrate a reasonable pace of construction at Kalamianos. The median schedule of structure 4-VI (Fig. A.137, Table B.28) finishes on work day 57 and the median schedule for structure 7-X (Fig. A.138, Table B.29) finishes by work day 90. Both schedules show some linearity in the construction of the major building components. This is, in part, a factor of the model of construction and the hypothesis that materials must be transported nearer to when they are used due to limitations of space on the building site. If this assumption in the model is too strong, it may be that workers begin certain components earlier in the construction process, which would reduce completion times but lead to larger amounts of labor on site and increase the complexity of the process. For 7-X, strong overlap is seen between procuring, transporting, and installing the second story floor and the start of production for the second story's mudbrick during the 3rd week of construction. The installation of the stairs, as well, falls during construction of the second story. For both structures, interior and exterior plastering overlaps in time and begins while the roof is still being finished. This is where the plastering bump, discussed before, arises. During construction of structure 4-VI, there are peaks of 18–35.25 people working to finish the roof and the plastering. For structure 7-X, peaks of 18–28 workers complete these tasks. The appearance of decimals

here in the labor is important to make note of. This is a result of small scale tasks, like gathering earth and water, that require very little labor. The decimals designate one or multiple people working part time at a task. This part-time work is more apparent if we look closely at plastering in structure 4-VI.

Figure A.139 shows the interior plastering of 4-VI's basement rooms, which runs from work day 48 to work day 57, the last day of the project. The close-up illustrates that one or two individuals could work ¼ to ¾ time procuring earth, transporting it, and then gathering water to supply the plasters. This rate of work, despite already being low, could be reduced even further since all three of these tasks have a float of one or two work days. The plasterers who are finishing the basement's walls, on the other hand, have no room for delay; the completion date of the project hinges on them. The low labor needed to gather sufficient materials for plastering and the large float of each associated task suggests that builders could employ a few organizational strategies. The first would be a stock-piling approach. One person working full-time, perhaps taken from another task, could quickly gather up all the materials needed and leave them on site for later use. This could certainly work for something like the earth for plastering, which would not take up much space,[57] but storing the water on site makes less sense; this is something that really needs to be gathered for immediate use. As another strategy, then, one of the plasterers might stop working, gather a small amount of materials, and return to use them until more is required. Finally, a last possibility is that children performed these small scale tasks. Because gathering meager amounts of earth and water needs very little energy and because there is so much lag time for error or slow speed, children could easily take on these tasks without the possibility of impeding the building process. Moreover, it would free up adults to work on the

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[57] This task uses 4 m^3 of material.

more pressing tasks. As a general rule, I would argue that non-driving, individualized tasks that demand low skill are excellent points to consider the integration of children in the building process.

The Northeast Extension of Mycenae's Fortification Wall

A graph of the time to complete the Northeast Extension and the relative frequency of simulated schedules that generated this time is published in Figure A.140. Time is expressed in absolute work days of eight hours. In the best and worst case scenarios, simulated schedules produced a completion time of 89 to 370 work days. The mean result is 154.56 days with a standard deviation of 36.57 days. The probabilistic distribution of days to complete construction shows that the lowest 90% of schedules finish in under 195 days, the lowest 50% finish in under 147 days, and the lowest 10% under 116 days. The peak number of individuals working on site during the simulated schedules is given in Figure A.141. The peak number of individuals is time-scaled by the work week of construction, consisting of seven work days of eight hours. The blue line shows the peak among all 1,000 simulated schedules, the red line the peak among 90% of schedules, and the yellow the mean across all 1,000 schedules. The peak labor for construction reaches a maximum in weeks 8 to 10 of construction. These maximum numbers are reached in each case after a relatively steady climb in peak labor from the start of the project. The increase and maximum here is due to a fundamental change in the nature of construction. The initially lower peak labor corresponds to the construction of the cistern and the preparation of foundations. Peak labor climbs to its maximum when workers start to remove parts of the old cyclopean wall and begin quarrying and transporting new cyclopean blocks in volume.

Interestingly, the simulated data shows a large amount of variation in both completion date and peak labor on site. This suggests there was a fair amount of room for variation in the organization of construction. It also has implications for whether the Northeast Extension could have been built for an immediate defensive need or not. Certainly, with 50% of schedules falling above 147 working days and a minimum completion time of 89 working days, this becomes difficult to support. Although this does not account for issues of seasonality or the culturally defined work week, even at a full seven days a week, thirty days a month, this means 50% of schedules fall above five continuous months of construction. In the worst case scenario of 370 work days, slightly more than a year of continuous daily work is needed. Looking at a schedule of construction which highlights the processes of building offers perspective on this issue of time.

To explore how quickly the wall might be reasonably built, an example of a faster schedule, requiring 116 work days, the mark under which 10% of schedule fall, is given in Figure A.142 and Table B.30. As would be expected, the schedule shows that much of the time is devoted to the cyclopean wall, while the cistern and site preparation are completed in the first 20 work days of the project. Generally, the peak labor is steadier across the project than seen in simulations of the Treasury of Atreus or Kalamianos. When construction of the cyclopean wall and its accompanying tasks pick up on day 18 and until its finish on day 116, the peak labor on site ranges from 35 to 81 individuals. Weeks 7 through 14 reflect the core push of construction with very consistent peak labor, ranging from 63 to 81 individuals, while the final weeks drop to a peak of 35 laborers. If we keep in mind that the cistern may have been partially built at another time, and just look at the cyclopean wall, then a few weeks might be shaved off of the 116-day

schedule; however, the completion time would still hover around 100 work days, hardly a short amount of time if there were an immediate military need.

Figure A.143 shows the details of the construction of the cyclopean wall in this schedule. After the cistern is completed and site preparation is done, in week 3 the reused rubble is immediately transported from the old wall face as it comes down and reassembled into the new wall face while the larger stones of the lower fill are deposited.[58] By the end of week 5, the old wall is completely removed and new cyclopean rubble is steadily arriving by wagon for the wall faces. Both the arrival of the new facing materials and the assembly of the faces has a float time of up to a few weeks. The deposition of the large amount of wall fill here sets the pace of construction. Because of the float, some changes in labor organization could speed construction up slightly. If workers move from wall faces to quarrying and assembling wall fill, construction will finish earlier, but only by a work week or two at most. The peak labor on site during the last weeks of construction will also even out somewhat. So, under a rosier scenario, if the cistern is built separately and construction of the wall is more efficiently organized, the builders might rush construction and finish in just under 100 days. In an even less likely occurrence, the builders might hit the minimum timeframe established by simulation of 89 work days, still three months of continuous daily work. To put these very idealized schedules into perspective, at this rate of progress, a vertical meter of new walling is going up every one to two weeks. The labor to achieve this rate of construction, though, pushes up against the space available for workers. Returning to the schedule in Figure A.142, at the apex of wall construction up to seven oxen-

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[58] The connection between removal of the old wall and construction of the new is complex and uncertain. Parts of the old wall remained standing as the new wall was erected since the lower courses of the two abut one another and then bond in higher courses. This issue requires further examination in the field.

drawn wagons are hauling stones to the building site and up to 62 individuals are engaged in assembling the wall faces and fill. This optimistic picture of so many working at once, speeding along wall construction, seems unlikely.[59] Not only does this argue against an immediate defensive need, but it suggests that a best case scenario for the construction of the wall will be closer to a median 147-day schedule from simulation and that a practical group of builders and administrators, taking account of uncertainty, might expect to take up to a full year to complete the Northeast Extension.

Sensitivity Analysis and Model Refinement

As a way to model complex processes, the energetic flowcharts, task-rates, precedence diagrams, and labor ranges are simplifications of past behaviors. This simplification is a part of all model creation, but in some cases, the simplifications do questionably influence the outcomes of simulated schedule durations. Sensitivity analysis of the modeled tasks' impact on simulation outcomes helps to pin down where future work can be done to improve these models and knowledge of ancient building processes in general. Using Palisade @Risk, the linear correlation between a task's duration and the timeframe to complete each project is measured using a regression coefficient.[60] The regression coefficient shows the amount of change in the project's completion time in relation to an increase in the number of laborers working at a given task. A larger regression coefficient suggests a stronger linear relationship between the task and the completion time of a project. The negative sign before a coefficient means that an increase in

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[59] The fact that only 10% of simulations fall within this timeframe is an indication that the simulated schedules are practical reflections of past behaviors.
[60] For detailed description of regression analysis in project planning, see Goodpasture 2003, 217–25.

labor decreases the completion time of the project. In many cases tasks do not show meaningful correlation based on the simulated data. Those that Palisade @Risk returns as having a degree of correlation with the time to finish the project are listed in Tables B.31–34.

For the Treasury of Atreus, the strongest correlation with the completion time exists in the assembly of the lower chamber, the assembly of the dromos and upper façade, and to a lesser extent the removal of spoil during site preparation. For structure 4-VI, data suggests that the pace of wall assembly for both the basement and first story as well as procuring earth for wall mortar are well correlated with the speed of completion. This contrasts with structure 7-X, where the mortared rubble construction shows significantly less correlation with completion time than does the assembly of the second story walls in mudbrick. Finally, transporting rubble for the wall faces and upper fill of the Northeast Extension, which constitutes the majority of wall material, correlate well with project completion time. Since the duration of each of the statistically correlated tasks is a factor of material quantity, task-rate, and labor range, the validity of all three must be scrutinized.

In the case of material quantities, the conglomerate found in the lower chamber, dromos and upper façade of the Treasury of Atreus are persuasively supported by data from Wace; I would argue that there is always room for further study, but that these numbers are precise. The volume of material removed during site preparation is based on published measurements; as mentioned earlier, it further agrees with Fitzsimons' independent volumetric analysis, which differs by only 30.15 m^3 or about 1%.[61] The task-rate for digging out the area is equally backed by its use in construction manuals and its basis in actual experience.[62] The rate of assembly of

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[61] Fitzsimons 2011, table 5.7.
[62] See Appendix C, Table C.6.

the conglomerate walls, on the other hand, is more questionable. The rate derives from published

construction rates for ashlar assembly,[63] but the block size in the Treasury of Atreus is

significantly larger than traditional ashlar. The difficulty of maneuvering and shaping these

blocks during assembly and its effect on the proposed task-rate requires more exploration. In

general, experimentation with quarrying, moving, and transporting conglomerate would benefit

studies of Mycenaean architecture. Experimentation with large stones has been fruitful in Egypt

and Northern Europe,[64] and data from these regions is often relied upon elsewhere. Localized

experimentation in the Argolid will improve our knowledge and can add hands-on, experiential

data to archaeological discussions of Mycenaean building practices. Their basis in smaller block

sizes likely means that the rates of ashlar assembly used here are an underestimation since more

labor would be required to maneuver blocks.

For the structures at Kalamianos, the strength of volumetric measurements is variable. In

structure 4-VI, the volume of rubble in the basement's walls is based on direct observation, but

assumptions have been made about the height of the first story. The proposed height affects the

volume of rubble, but not excessively; a change of 0.5 m in the height would add or subtract 35

m^3 of building material and would change the overall person-hours by a few hundred. The

volume for the mudbrick in structure 7-X is less well supported. Its presence and volume have

been hypothesized based on comparanda as one means to explore variability at Kalamianos and

ultimately to extend this to discussions of variability in the production of Mycenaean

architecture; however, building practices at Kalamianos require significant future exploration

through controlled excavation. The task-rates for mudbrick and mortared rubble,[65] on the other

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[63] See Appendix C, Table C.19–C.21.
[64] For example, see Thorpe et al. 1991; Lehner 1997; Edwards 2003; Stocks 2003.
[65] See Appendix C, Table C.16, C.18.

hand, are convincing; both of these wall building techniques have long histories and continue in use.

Finally, like the Treasury of Atreus, the reconstructed quantity of stone in the Northeast Extension is well supported. Although the exact height of the wall will always remain questionable, the estimation of 8.25 m is reasonable and measurements of the wall's thickness are accurate. The transportation rates for the cyclopean stones, nonetheless, need future refinement. Once again, experimentation with large stones in Greece will be constructive, but the particulars of Mycenaean wagons and traction power are likely to always remain speculative. I would argue again that the rate for wagon transportation[66] is an underestimate, though, since it does not account for the loading and unloading of the blocks.

Concluding Remarks

Modeling architectural production and simulating timeframes for completion offers a unique way to explore human behavior at various levels, by zooming in and out on acts of production and exploring particular aspects of planning and labor organization in real time. Its reliance on visual diagramming and modeling techniques that originate in construction management means that assumptions are made explicit so that they can be revised and critiqued in the future; any or all elements in the energetic flowcharts, precedence diagrams, and hypothesized labor ranges remain open to modification as our knowledge evolves and future discussions of Mycenaean building practices unfold. For all four structures, the individual schedules drawn on above and the graphed changes in peak labor illustrate how buildings are the result of a complex intersection of processes, people, and materials that change over time. The

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[66] See Appendix C, Table C.9.

models and simulations are one way to explore these issues of temporality and change; they are tools for thinking that attempt to illuminate the black box in which hides "the temporality of practices embodied in the process of making."[67] The bumps and dips in workers that emerge during construction are important reflections of human behavior. Each change embodies different groups of people with different skills working together and changes in labor can signal changes in the spatial configuration of production. In the following chapter, data about the production of the Treasury of Atreus, the structures of Kalamianos, and the Northeast Extension are coupled with larger archaeological and textual datasets to tackle problems at the intersection of architecture and economy in the Mycenaean period.

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[67] Richards 2004, 74.

CHAPTER 8

ARCHITECTURE AND ECONOMY IN MYCENAEAN GREECE

Monumentality and the Power of Architectural Production

Classical and Experiential Monumentality

Two strands of thinking about monumentality and the connected issue of architectural power run through Mycenaean scholarship. The first draws on classical notions of power and architecture that interpret large scale or public architecture as both a marker for sociopolitical organization and a driver of sociopolitical change.[1] Osborne remarks that this is, in fact, one of the most common interpretations of architecture in the archaeological literature.[2] Such analyses of architecture tend to take a long-term outlook, focusing on quantitative, formal, or symbolic changes. This has been particularly true of transformations in mortuary architecture at Mycenae, where Wright and Fitzsimons have written on the development of building practices from the shaft graves in the late Middle Helladic to the last tholoi in the LH IIIB period.[3] Changes in the scale of construction, the types of masonry, and the choices of building materials, especially the emergence and expansion of conglomerate in conspicuous locations, are linked to the appearance of elites at Mycenae and the eventual centralization of state power in the Argolid. The striking changes in Mycenae's architecture over the centuries are spoken of as both purposeful tools of change, utilized by elites for their advancement, and at the same time, archaeological signposts

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[1] See Trigger 1990.
[2] Osborne 2014, 4–6.
[3] Wright 1987; Fitzsimons 2007, 2011, 2014.

that alert us to the sociopolitical conditions of the time, so that architecture is read as both the vehicle for elite power and the advertisement of that power.[4]

An ancillary thread in this classical strand of monumentality and power in Mycenaean architectural studies traces the development of the megaron as a structure of power and in this regard, it hinges more on the interpretation of architecture as a sociopolitical marker and less on the competitive nature of architecture found in mortuary discussions.[5] Most telling of this thread is Kilian's union of the megaron, the model of Mycenaean sociopolitical structure derived from the Linear B tablets, and the monolithic interpretation of Mycenaean economy, in which control is highly centralized. For Kilian, the early megaron form was the "beginnings of an ideology centered on the *wanax*"[6] and functioned as the emerging center of a redistributive economy, from which point the megaron evolved into a developed LH III form in tandem with the radical centralization of the *wanax*'s power.[7]

The second strand of thinking about monumentality and power has emerged more recently in studies of Mycenaean architecture. This newer perspective interprets architecture from a spatial and experiential point of view by envisioning structures as settings for human action.[8] This approach intersects with broad theoretical trends that have emerged from post-processual archaeology, including a focus on agency and materiality. Often, these studies are flagged by the term "built environment," which discloses an interest in architecture as an active participant in human behavior or as Rapoport says, an interest in environment-behavior

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[4] This approach is also variously expressed in the earlier work of Voutsaki (1995, 1998, 1999, 2010) where architecture complements her analyses of burial goods and conspicuous mortuary display. Voutsaki (2012) is now more critical of the theory behind her past interpretations.
[5] On the megaron and its form, see in general Werner 1993; Darcque 2005.
[6] Kilian 1988, 298.
[7] Kilian 1987a, 1987b, 1988. For a recent and more nuanced perspective, see Pantou 2014.
[8] See especially Maran 2006a, who summarizes this trend and its origins.

interactions with an eye towards the question, "Who does what, where, when, including or excluding whom (and why)?"[9] To answer this, ideas about how people actively moved through space and how space, both inside and outside of structures, enables or constrains movement have appeared in Mycenaean scholarship. Maran employed this approach to propose that Mycenaean citadels were performative spaces in which social action, particularly the procession of visitors, was crucial;[10] through the constraints of the built environment and the encoded cues individuals encountered during procession, existing social order and power structures were expressed and actively reaffirmed.[11] A similar approach was taken by Cavanagh, who examined open spaces and courtyards, and envisioned these as active arenas for rulers "[to] make a show of their power in public."[12] Another thread in this experiential strand of monumentality and power has more explicitly looked at the configuration of space through space syntax analysis. Such is the case in Thaler's analysis of the palace at Pylos which identified ways that the palace's form structured social acts and power and Nagle's exploration of Mycenaean spatial and social organization.[13]

That both strands of thinking, what I have called the classical and the experiential, remain strong is affirmed in two recent examinations of early Mycenaean mortuary architecture and early Mycenaean corridor buildings by Fitzsimons and Pantou.[14] Respectively, the two authors speak of architecture as a reflection of power and sociopolitical organization through the lens of labor investment or as an integral participant in the creation of power and sociopolitical relationships through the lens of symbolic meaning and the organization of space. Despite

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[9] Rapoport 1990, 9.
[10] Maran 2006b.
[11] Maran 2006b, 85.
[12] Cavanagh 2001, 130. Similar ideas appear in Bendall 2004.
[13] Thaler 2006; Nagle 2015.
[14] Fitzsimons 2014; Pantou 2014.

emerging from differing schools of archaeological thinking and engaging different vocabularies to describe the complex relationships between architecture and power (and monumentality), the classical and experiential strands are not mutually exclusive and the vocabularies of each may freely entwine.[15] In fact, cross cutting both strands of thinking is the semiotic interpretation of architecture which views power as either reflected or recreated by systems of meaning built into a structure. Within both, too, are undercurrents that discern that the construction process and not just the finished building may be equally meaningful in reflecting or creating power. Pantou has very explicitly stated this position,[16] that the building process was as much a venue for social negotiations as the finished structure, but others have equally touched upon its relevance. In discussing power and labor investment, Laffineur makes an especially accurate observation that labor was only visible during the construction process and that "this is a major objection to the symbolic value of the investment as emphasizing the power of the ruling class - unless it is kept in the collective memory."[17]

The Concept of Productive Monumentality

The producer-oriented view taken in this study is an important step in elevating the building process to the level of archaeological study where these issues of monumentality and power can be explored, and it represents a third strand in thinking about monumentality and power. My argument that construction is really architectural production, a term that brings with it an active sense of the creation of society, polity, and economy through human and material interactions, and my use of a rich inferential and quantitative modeling approach that explores

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[15] See, for example, Wright 2006a.
[16] Pantou 2014.
[17] Laffineur 2007, 120.

temporally and spatially situated productive processes complements the preceding classical and experiential strands of thinking that weave through Mycenaean scholarship. From the perspective of architectural production, issues of labor, scale, material choices, and human movement in time and space become enmeshed; however, unlike the classical and experiential perspectives, which situate architecture's power along a continuum that, at its poles, sees power as either permanent or continuously recreated through inhabitation, the monumentality and power created during architectural production is more fleeting. When production is over, it is over and though future acts can engage the meaning of past acts, the unique processes of architectural production cannot hold permanent meaning nor can they ever be directly reenacted. It is only after creation that these ideas of static power or recreation through inhabitation take over in the finished structure. Otherwise, what remains of architectural production exists in memory through the recollection and narration of the acts of production and through their mnemonic associations with parts of the landscape, especially areas of resource exploitation, paths and roads along which individuals and materials moved, and of course, the finished structure itself.[18] From this perspective, the acts and memories of architectural production are unavoidably impermanent and their meaning can be repurposed or can fade over time. Examining movement in the landscape over time and viewing acts of production as performance are key to exploring this novel strand of "productive" monumentality and its connection to anthropological concepts of power.

Performance is an increasingly popular topic in archaeological theory[19] and it has surfaced in recent Mycenaean scholarship; major subjects that have engaged performance

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[18] Compare Galanakis' (2011) study of landscape and memory in Messenian mortuary traditions.
[19] DeMarrais 2014; Inomata and Coben 2014.

include mortuary rituals,[20] hunting,[21] processions,[22] feasting,[23] and animal sacrifice.[24] The central point that emerges from these diverse topics is that visible actions situated in time and particular spaces were a vital instrument for social change or the reaffirmation of social hierarchy during the Mycenaean period and that the development and maintenance of Mycenaean society is heavily rooted in specific types of performances. The production of Mycenaean architecture, which scholars like Pantou have hit upon as significant in negotiating social roles,[25] should be firmly added to this list of performative arenas.[26] The temporal and spatial organization of labor during the production of the Treasury of Atreus and the structures of Kalamianos offers insights into the performative nature of architectural production in the Mycenaean period and the role these productive performances could have played in shaping monumentality and relations of power.

Based on the simulated timeframes for the completion of the Treasury of Atreus which produced 643 working days for a mean schedule of completion and 742 working days for 90% of schedules, I suggested previously that, taking into account seasonality, this would work out to approximately 9–15 years for construction. Given this long timeframe of construction, the impact of individuals and materials moving through the landscape was significant. From the perspective of inhabitants and visitors to Mycenae, the yearly repetition of visible productive acts was momentous. To humanize the temporal impact of construction, data on the lifespan of

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[20] Papadimitriou 2011; Boyd 2014.
[21] Harris 2014.
[22] Cavanagh 2001; Maran 2006b.
[23] Hruby 2008; Nordquist 2008.
[24] Hamilakis and Konsolaki 2004.
[25] Pantou 2014.
[26] The idea of architecture as performance has already taken hold in other regions; see, for example, Love 2013.

Mycenaeans is informative. Analysis of skeletal remains from the vicinity of the Palace of Nestor show that the majority of deceased individuals were younger adults, aged 25–30, and that very few were older than their late 40s.[27] In East Lokris, a somewhat longer lifespan was found, with males averaging 32–42 years of age and females 31–43 years of age.[28] Given these numbers, the duration of Atreus' construction might equate to 1/3rd or 1/4th of a healthy individual's lifetime. For the people witnessing construction, the movement of workers, oxen, stone, clay, and rubble to the site of the Treasury of Atreus would, therefore, have become a routine part of life. If we factor in the phasing of resource exploitation, the scale of these acts across the landscape and their visibility to the surrounding population becomes clear.

From the excavation of the tomb and the installation of its conglomerate masonry to the final construction of the peribolos and heaping of the tumulus, over the 9- to 15-year timeframe suggested by the seasonally-adjusted simulation results, large numbers of workers, wagons, and materials circulated throughout the area south of the citadel. The roadways running from the Panagia Ridge to the points of resource extraction to the south were especially important as areas of visibility and interaction (Figs. A.30, A.31). Along these roadways, we should envision not only builders and wagons habitually moving materials, but also inhabitants moving through their daily business or visitors progressing to the citadel. In this way, the landscape itself was interwoven with the creation of the Treasury of Atreus and individuals in that landscape, whether active in construction or not, became entangled with these acts.[29] Because of the spatial and temporal scope of this project, the acts of production associated with the Treasury of Atreus

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[27] Schepartz et al. 2009a, 165–6.
[28] Iezzi 2005. The two numbers represent Iezzi's separate analysis of coastal and inland skeletal remains.
[29] Compare the landscape of construction created on Easter Island by the quarrying of Moai (Hamilton et al. 2008).

would have been imprinted on the daily lives of individuals and later retained in the memories of

viewers and participants. These would be especially linked to particular parts of the landscape

where the repetitive movements of workers were common.

The interior lintel is, of course, a good example of how these productive acts marked the

landscape and how monumentality or power was created through the entanglement of the

landscape and the surrounding populations, and the memories of productive acts.[30] For the

lintels, without entanglement and memory the symbolism and importance of moving them would

vanish, as scheduling suggests, after a matter of days or at most weeks. Recollection of the

gathering of so many people and their movement in the landscape, though, could convert such a

short lived event into a long-term impact. The often noted importance and scale of lintels in

Mycenae's tholoi,[31] beyond being to some extent structural necessities, indicates that the

Mycenaeans were aware of the importance of these events and the memories they created.

Like other performative acts, the production of architecture and its movement in the

landscape was likely a point of control where agents, whether typologically elite or non-elite,

could renew or reform their sociopolitical position and create new interpersonal relationships.

There are certainly many ways this could be done, but from the perspective of both participants

and those who were entangled with construction as witnesses, I would broadly propose that these

acts might be internalized in two contrasting ways. On the one hand, there is the oppressive

impact which is at the heart of classical thinking about monumentality; and on the other, there is

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[30] Laffineur, in fact, points out that the labor-cost for transporting the interior lintel was not perceivable after construction; since it was visible only during the act, he cites this as an objection to the "symbolic value of the investment as emphasizing the power of the ruling class" (2007, 120).

[31] See especial the discussion of tholoi in Fitzsimons 2007, 2011, 2014.

a unifying impact, which argues that these acts create shared group identities and benefit participants.

Two recorded examples of moving large stones provide a representation of the oppressive or unifying impact that productive acts can have. In the case of the former, the oppressive impact is illustrated in Spanish accounts of long distance Incan stone transport. These Incan transportation projects are said to have been "made-work" which was meant to keep the peasantry busy. As a results, they were especially onerous.[32] One drawing made by Guaman Poma de Ayala in 1615 is illustrative. The drawing shows an elite named Inga Urcon standing on a rock that is dragged by peasants.[33] From it, he shouts, "Keep moving sheep," while the stone itself weeps blood. Associated Spanish chronicles recount the story that this stone grew tired from its laborious journey, spoke, and then cried blood while refusing to move any further;[34] the stone was being dragged from Cusco to Huanuco, over 1,000 km to the north. In contrast, an example stressing the unifying impact of productive acts comes from Indonesia. Here, in 1993, von Saher recorded the transport of a 46-ton megalith on a sledge made of tree trunks.[35] He was told that 1,500 different men participated in transportation (not at the same time). He states that, to these men, no payment was given, but "all participants were provided with food, music, entertainment and *a sense of belonging during the entire operation*" (my italics).[36]

The opposition of these two examples is clear, and it is the latter impact, as well as the many shades of grey between the two, that needs to be more often considered in interpretations of Mycenaean architecture. In the case of the Indonesian example not only was the benefit of

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[32] Ogburn 2004.
[33] Compare the depictions of stone movement in Egypt and the Near East from Chapter 4.
[34] Bauer 1998, 56–8.
[35] von Saher 1994.
[36] von Saher 1994, 70.

food, particularly abundant meat,[37] gained by participants, but through their collective actions, moving the stone generated a sense of group identity.[38] How construction of the Treasury of Atreus and movement of its lintels impacted the population cannot be so easily categorized as either oppressive or unifying, and it is likely that productive acts impacted each person in a distinct way,[39] but it is important to recognize that individuals can gain through participation in productive acts and that these acts cannot simply be read as elites wastefully consuming the energy of others,[40] a view that the thermodynamic interpretation at the root of traditional energetics and classical monumentality promotes. As a complex web of processes that employed individuals with differing skillsets and engaged inhabitants in the wider landscape, a single building project is likely to have created diverse relationships including relationships of power over others and relationships of shared power expressed in group identity.

Future productive acts could further eradicate earlier memories of production and the relationships they created or they could purposefully engage previous acts of production. As one example, the second phase of Mycenae's fortification wall has been cited for its appropriation of the past through the enclosure of Grave Circle A and the use of conglomerate ashlar that is similar to the Treasury of Atreus' dromos. Rather than creating a purely stylistic link between the palace and the Treasury of Atreus, we should also consider that building with conglomerate ashlar appropriated memories of previous productive acts. The quarrying of conglomerate at Kharvati, its transportation northwards to the citadel and past the Treasury of Atreus, and the

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[37] Feasting was likely an important way to gather architectural workers during the Mycenaean period; see Dietler and Herbich 2001; Wright 2004a; Hitchcock et al. 2008.
[38] Santillo Frizzel (1997) provides another documented example of the creation of group identity through the movement of large stones.
[39] See Pauketat and Alt 2005; McFadyen 2013.
[40] Trigger 1990.

similar coursing and final dressing of the blocks at the Lion Gate was a reenactment of the production of the Treasury of Atreus' dromos, not to mention it was completed in a highly visible area that engaged the population to the south of the citadel. Not only was the finished product a visual link to an existing monument, but the act of production itself was a performance which purposefully mimicked the past through its engagement with the surrounding landscape.

At Kalamianos, architectural production, its impact on the landscape, and the creation of monumentality through production was different than in the production of the Treasury of Atreus. First, the temporality of construction was distinct. The simulation data for structure 4-VI and 7-X gives a timeframe of 67 to 109 days for 90% of both structures' schedules. In contrast to many seasons of building for the Treasury of Atreus, this number of working days runs up against what we might expect is the upper limit of workdays in a single dry season. There is also little opportunity to pause construction of a structure at Kalamianos once it has begun; it is improbable that mortared foundations, half-finished rubble or mudbrick walls, or an unroofed structure could be left exposed for a period of months without damage. One choice the builders could have made to overcome this seasonal limitation was to build in small modules so that a structure grew by accretion over multiple building seasons. Structure 4-VI, especially based on the abutment of its southern rooms (Figs. A.51, A.81), may have been constructed in such a manner,[41] but this is a shakier possibility for structure 7-X whose smaller floor plan offered less opportunity for modular building (Figs. A.58, A.82). A second choice, which finds good archaeological support at the site, was to take an industrialized approach to building. If multiple structures were tackled at once, then workgroups focusing on specific tasks like foundations, flooring, or plastering, could rotate from structure to structure as needed. Instead of gathering

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[41] Tartaron et al. 2011, 592–4.

materials for a single structure at a time, groups could acquire, manufacture, and transport

materials like timber or mudbrick in bulk. The uniformity of building layouts across parts of

Kalamianos are, I think, a good archaeological correlate of such an approach (Figs. A.72, A.73);

that areas of the site were built in coordination during punctuated periods of time fits with this

"assembly line" production.[42] This is, furthermore, practical from a labor perspective; the

simulation shows that larger numbers of workers were needed to finish the plastering on

structures and to manufacture and build mudbrick walls while fewer were needed in other phases

of construction. By staggering workgroups, multiple structures could be worked on at once by

small crews, while larger crews rotated (or were formed from smaller crews as necessary) to

confront more demanding, time-sensitive productive acts like exterior plastering.

During these punctuated episodes of building at Kalamianos, movement throughout the

landscape would have been significant as numerous groups worked on particular building tasks,

but the distances to acquire and transport most materials were very limited in contrast to those

used in the Treasury of Atreus.[43] Moreover, whereas the Treasury of Atreus was being built in an

already inhabited and active human landscape, the first acts of architectural production at

Kalamianos were on a blank canvas,[44] so to speak. Other than some ceramic indicators of limited

LH IIIA activity, the extensive Mycenaean architectural remains were imposed on the landscape

in LH IIIB,[45] likely in bursts of intensive building activity as suggested previously. If the

settlement of Kalamianos was linked to the palaces of the Argolid, as seems likely,[46] the first acts

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[42] See Pullen 2013b, 253–6.
[43] Timber is an exception to this and could have require significant forays inland.
[44] There are, however, FN/EH remains in the region (Tartaron et al. 2011; Tartaron 2013, 253–7).
[45] Tartaron et al. 2011; Pullen 2013b.
[46] Pullen and Tartaron 2007; Tartaron 2010; Tartaron et al. 2011; Pullen 2013b.

of architectural production would have been an especially visible performance that was viewed across the Saronic Gulf. The movement of people, clearing of the landscape, and rising structures would all be witnessed as novel activities in an area that was previously dormant.

Together, the performative impact of producing the Treasury of Atreus and the structures of Kalamianos suggests that we need to explore more deeply the posited link between labor-costs, monumentality, and power. The connection is more nuanced. Power and monumentality in architecture are complexly related to visible actions during production, the memories of these actions in the landscape, and the final built form, including how it structures human activity and employs particular symbolism. My argument that architectural production is a performative arena for the negotiation of relationships and creation of monumentality, is what, I believe, the classical strand of thinking about power and monumentality is really aiming for by looking at labor as a direct metric of power; the intricacies of this productive monumentality and power, though, are muted in classical thinking by too willingly accepting the Marxist theory that labor is a direct measure of value and by too often reading long-term changes in labor metrics teleologically rather than exploring the diverse processes behind labor metrics and seeking explanations for the (re)creation of sociopolitical structures in these processes. The concept of productive monumentality is also hinted at in the experiential strand of thinking when the building process is cited as an active arena of negotiation, but the particulars of these negotiations need to be fleshed out by close range analysis and given higher status in scholarly discussion. This study takes a major step in this direction and demonstrates the value of studying architectural production and its role in creating monumentality and power through performance in the Mycenaean period.

Individuals and Interactions During Architectural Production

As building projects move through the landscape and progress through time, differing groups of builders with differing skillsets are engaged in the process. While the simulations demonstrate that the peak number of workers on site at any time varies, sometimes considerably as the nature of production changes, underneath these changes in peak labor are changes in the types of individuals, their interactions, and their spatial organization. The integration of these disparate groups during acts of architectural production returns to the larger idea of coproduction discussed earlier.[47] Recall that coproduction is a subtype of multicraft production in which different types of craftsmen collaborate to produce a composite good.[48] While Brysbaert has studied multicraft production at Tiryns, in which different craftsmen worked in close proximity but produced typologically different goods,[49] the idea of coproduction has not been explicitly drawn into discussions of Mycenaean productive activities. Furthermore, a major change that the study of architecture brings to the definition of coproduction is that the term craftsmen needs to be dropped. In its place, I have favored the general terms of builders, individuals, or groups of individuals; since the skillsets employed during building projects are so diverse, we cannot immediately attach the baggage of "craftsmen" to all those participating.

Furthermore, an important characteristic of architectural production is that skilled laborers or "craftsmen" necessarily interacted with individuals who are typologically speaking, non-elite and unskilled, or what we might even call "anti-craftsmen." Moreover, the scale of architectural production, and consequently, the scale of these interactions was considerable when

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[47] supra, pp. 38–42.
[48] Shimada 2007.
[49] Brysbaert 2014.

compared to the production of single-medium goods.[50] For example, Whitelaw has shown that perhaps two full-time potters supplied the needs of the Palace at Pylos and at the regional level, he suggests 450–500 potters working part-time.[51] Architectural production at sites like Mycenae and Kalamianos, though, could engage much greater segments of the population, albeit for punctuated time periods. At 32 hectares and with a population density of 200 individuals per hectare, a high estimate for Mycenae's population might be 6,400 individuals.[52] For the movement of Atreus' lintels, which required 580 individuals, nearly 10% of the surrounding population might be necessary, while for smaller palatial construction projects, like the Northeast Extension, peak labor demand might reach 1–2% of the surrounding population. These segments of the population taking part in architectural production must also be seen as mixed and encompassing different skill levels. Granted that areas in the Argolid and Corinthia, where Mycenae gradually extended its influence during the LH III period,[53] would offer access to additional populations,[54] the production of palatial architecture engaged more individuals in more intensive episodes of production than did traditional, single-medium craft goods.

The myopic archaeological interest in economic models based on the study of single craft goods, like pottery and lithics, was noted in the introductory chapters of this study, as was the resulting strict delineation of craft goods that excludes the significant acts of Mycenaean architectural production that form the core of this study. A subordinate characteristic of this

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[50] By "scale" I mean the size of the production unit (i.e. the number of producers working at once) and not the volume of output.
[51] Whitelaw 2001; see also Hruby 2013.
[52] French 2002, 64; French suggests that this population density is high.
[53] Wright 2004b; Cherry and Davis 2001.
[54] The study of construction and labor catchment areas has been fruitful in the Americas (Bernardini 2004). This approach offers strong potential for future analysis at Mycenae where architectural production can be studied against the backdrop of territorial expansion through labor catchment analysis.

myopia, though, that has not yet been fully expressed is that the favoritism shown to single craft goods and craftsmen is part of a larger archaeological avoidance of the many non-elite, unskilled, "anti-craftsmen" who inhabited the past.[55] Partially, this is an issue of material visibility. In the Mycenaean world, the palaces and their environs, the multitude of palatial wealth goods, and the Linear B tablets have always been compelling topics of study and will continue to be so because of their considerable importance. From the perspective of Mycenaean economic models, though, the intense focus on the palace centers and palatial elites drove the creation of the monolithic model that argued for the primacy of the palace. The two-sector model eventually offered a more balanced understanding through the addition of a non-palatial sphere, but as its name implies, this "sector" was defined by its material opposition to the palace; the non-palatial was everything Mycenaean elites did not care for, did not monitor, and did not use to advance themselves. As scholarly thinking now stresses mixed economic strategies, the role of agency, and a networked approach to human interactions, the dichotomy of palatial and non-palatial is being pulled apart. The organization of labor during the production of the Treasury of Atreus, the structures of Kalamianos, and the Northeast Extension exposes further weaknesses in the palatial and non-palatial divide by demonstrating how traditionally-defined non-elite, non-palatial, "anti-craftsmen" and traditionally-defined elite, palatial, craftsmen interacted with another.

Workgroups, Skills, and the Configuration of Production

The labor and timeframes for each of the three projects in this study are quite different (Figs. A.126, A.133, A.135, A.140) as is the spatial configuration of production (Figs. A.144–A.150). As a result, each of the three shows differing intensities of interaction among distinct

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[55] See Dietler and Herbich 2001.

groups. Within all of the simulation results there is room for human choices that can reshape these interactions, but the general phasing of each projects stresses likely points of interaction. Graphically breaking down the phasing and spatial configuration of tasks for the three projects in this study shows where workers were spatially interacting or isolated during production. A graphical breakdown is shown in Figures A.144–147 for the Treasury of Atreus, Figure A.148 for structure 7-X at Kalamianos, and Figures A.149–150 for the Northeast Extension. It is impossible to assign every task in these phases to a single, discrete group of individuals --- part of the point of looking closely at production is to stress that individuals do not fit neatly into rigid categories --- but applying a continuum of skilled, semi-skilled, and unskilled to tasks, although admittedly a rudimentary and subjective categorization of humans, does provide a sketch of the groups of individuals and their interactions with one another.

For the Treasury of Atreus (Figs. A.144–A.147), we might isolate three sets of highly skilled tasks involving the installation of the conglomerate chamber, the conglomerate dromos, and the ashlar peribolos.[56] A mix of unskilled tasks supports these skilled activities, such as excavating earth, collecting rubble, and dragging stones, while a number of tasks falls in the gray area of semi-skilled. These include making and installing claybrick or mortared rubble, and especially quarrying conglomerate and ashlar. The last two require further thought as more is learned about Mycenaean quarries,[57] but the technique clearly relies on a mixture of the skill to pick out and size up blocks appropriately, and the brute force to extract and maneuver them from the quarry. I would label the transportation of materials by wagon as both unskilled and semi-skilled. Transporting smaller loads of materials, like clay, would not be especially different than

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[56] Decoration is, of course, another highly skilled area of work, but it has not been included in this study or its models.
[57] Morgan et al. 2011.

any common agricultural task, but large stones which stressed the limits of a wagon would require greater experience and knowledge.[58]

Among this mixture of tasks that phased in and out during production, general areas of group interactions can be isolated. First, there is a clear spatial isolation between those working at resource extraction points, particularly the conglomerate and poros quarries, and those working on the tomb's masonry. The tools used between the two tasks, such as stone hammers and chisels, do overlap, but the masonry requires greater knowledge to produce. The unfinished obelisk at Aswan shows that quarrying large, regular blocks required a few overseers with great technical knowledge and a large number of workers pounding away stone wherever they were directed.[59] The spatial isolation of these tasks contrasts, though, with the high degree of information sharing between them; to achieve the fine masonry and appropriate block sizes, the progress of both had to be strictly coordinated. Acting as spatial intermediaries between the quarriers and masons were the transporters moving blocks by sledge or wagon. With the rising of the upper chamber and dromos, the masons, quarriers, and block transporters had the added difficulty of coordinating with the bricklayers and masons working in mortared rubble, who themselves depended on individuals forming bricks, collecting clay and rubble, and transporting these materials. Again, in these skilled tasks, there is a degree of spatial isolation between those extracting raw materials and individuals on the building site, while those transporting move repetitively between the groups.

To sync these tasks up in space and time required ongoing administration and the continuous movement of administrative workers throughout the landscape of construction. Such

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[58] We might think about the variety of specialized vehicles developed for large stone transport in historical Greece.
[59] Engelbach 1923.

administrative positions need not be entirely separated from productive positions; a skilled

mason might also oversee work at the quarry and travel back and forth as needed to ensure

standards are met, but given the diversity of tasks and workers that had to be coordinated, there

was also pressure for segregated administrative positions. Individuals in these positions had to

make daily, high-level decisions about the pace and quality of work, and had to manage multiple,

perhaps conflicting workgroups to ensure the smooth progress of construction. The need to

coordinate so many activities, of which many were spatially isolated and performed by different

groups, also increased the potential that failures or unforeseen problems would impede

construction. It is important to recall that, while we as archaeologists view buildings in their

finished state, there was no guarantee of success when a building project was started; to get to

the final building required active human decision making and the remediation of unforeseen

setbacks.[60] The more complex the process of building in terms of duration, spatial organization,

task differentiation, and number of workers, the more room for failure (and need for

administration to counteract it) there was. The success and continued structural stability of the

Treasury of Atreus is all the more striking in light of this and the remains of the tomb suggest

builders took active steps to lessen the dangers of uncertainty.

The layout of the tomb using a standardized foot of c. 30 cm[61] was a major step in

coordinating spatially discrete activities and lessening uncertainty. Although the details of the

Mycenaean system of linear measurements need much deeper exploration, its application

provided a standardized way to communicate between the quarries and building site as well as

rough out the amount of materials that were needed for construction. This use of linear

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[60] See especially Richards 2004
[61] The details of this foot are discussed supra, pp. 118–120

measurements is a milestone in the history of Greek architecture and it acted as a simple

information sharing mechanism that facilitated complex planning and coordination. Secondly,

major stopping points in construction were worked into the Treasury of Atreus that provided

leeway in the case of uncertainty or what we might loosely call "cost overages," by which I mean

the failure to accurately quantify labor and materials beforehand. Some of these ideas have been

discussed previously in the context of particular schedules, so that, for example, choice points

existed where builders might begin a task earlier or delay it without affecting the project's end

date. Other choice points existed, though in terms of major stopping points at which time the

entire project could be halted.[62]

For the Treasury of Atreus, these stopping points existed between the three major skilled

activities: building the chamber, the dromos, and the peribolos. The masonry and tools used for

each suggests that the composition of workgroups changed at these stopping points and that

temporal gaps were possible. As noted previously, the break in masonry quality between the

chamber and dromos is especially striking, given the movement away from strictly measured

courses in the chamber to the moderately successful attempt at coursing in the dromos; in the

case of the large block in the dromos' north wall, recall that the workers did not even bother to

finish dressing it before installation (Fig. A.39). The transition to the peribolos then represents a

wholesale transformation in workers and skills; the material change to softer poros brings with it

smaller blocks, the peculiar wooden dovetail clamps, and the use of metal tools (Fig. A.23).

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[62] On the importance of time relationships in chaîne opératoire analysis, see Benfougahl (1991),
who categorizes three types of relationships between the start and stop of tasks: free, necessary,
and impossible. The points isolated here would fall into the free category.

Furthermore, this does not factor in the coping stones that capped the wall, but are atypical of Mycenaean architecture.[63]

As the chamber, dromos, and peribolos do not bond and the style of each is distinct, I believe that the change in workgroups and skillsets between them were built in as a safety mechanism at the start of the project. Given the suggested 9- to 15-year timeframe for construction, even if construction were continuous, a large gap in time between the start of the chamber, of the dromos, and of the peribolos existed. If these elements were interdependent and no gap in time between their construction were possible, then starting on day one of construction, the builders would need to know with certainty that a particular group of skilled workers would be present many years in the future. Because of the variation in peak labor of approximately 50 to 250 individuals across 90% of schedules (excluding the lintel bump), builders would also need to know that they could muster specific numbers of people at an exact time in the future; this type of preplanning is impractical and the project would be especially prone to failure. Gaps between skilled tasks, though, allowed workers to be assembled under uncertain future conditions without a threat to project completion. The resulting types of masonry, I would argue, were, therefore, not necessarily preplanned but were the result of the types of skilled workers that could be assembled at each point in time. With the linear system of measurements, a general plan of action and layout was fixed at the project start and then, the chamber was first built in strict courses. Afterwards, the dromos and peribolos were built in a more *ad hoc* fashion, following the initial plan but allowing the details to be resolved by the workgroups available at the time. Given the strong connection of the Treasury of Atreus to the building practices of

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[63] Admittedly, I am still not sure what to make of these coping stones.

Crete,[64] the Near East and Asia Minor,[65] and its similarity to the Treasury of Minyas as well, the

incorporation of stopping points and the stylistic changes that accompanied them may be related

to the unpredictable movements of itinerant builders.[66]

Compared to the Treasury of Atreus, the groups of individuals, skillsets, and

configuration of production at the site of Kalamianos offers a different picture of architectural

production. Foremost, the various productive activities are spatially close to one another. Figure

A.148 shows the spatial configuration of labor during the construction of structure 7-X; in the

case of structure 4-VI, the activities are even more centered around the building since no

mudbrick is included in the reconstruction. Compared to the complexity of the Treasury of

Atreus, there are limited changes in activity areas during production at Kalamianos. The only

tasks that are removed from the immediate area of the final structure are the harvesting and

transportation of timber. Where this happened is an open-ended question, but it does offer one

means for the building process to integrate with interior regions that were otherwise

disconnected from the process. The spatial proximity of tasks may also support the idea,

suggested by similar room and building layouts across swaths of the site, that production was

organized by cycling workgroups who concentrated on particular building components, like

foundations or mudbrick walls. In addition to the already cited advantage of stockpiling materials

and transporting in bulk, the proximity of structures meant that groups could easily rotate and

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[64] The evidence of a connection is strong. It includes the use of a foot also found on Crete; the alignment of the tomb, citadel, and peak of Profitis Ilias; the use of poros ashlar with wooden clamps; the incised branch signs on the dromos' blocking wall; and the decoration of the tomb's façade with a bull scene in gypsum.

[65] The best evidence for transportation using a sledge and lever comes from the Near East. It has come to my attention that a good parallel for the coursing of the dromos and use of hookstones is found at Troy.

[66] Cline 1995; Bloedow 1997; Brysbaert 2008.

could readily communicate with one another to coordinate their activities. In contrast to the dispersed activities required to produce the Treasury of Atreus, for much of the building process this required a less formalized administrative mechanism; however, the initial acts of planning the layout of multiple buildings and the establishment of workgroups required greater oversight and ongoing coordination. Additionally, although the modularity of tasks (i.e. the separation of foundations, walls, floors, etc.) allowed different work groups to cycle across buildings, unlike the Treasury of Atreus, long stops between stages of construction were not permissible. From a preplanning and administrative perspective, when a foundation was started there needed to be a degree of confidence that workers would complete the structure during that building season.

Among the tasks and associated workgroups at Kalamianos, most can be loosely categorized as unskilled and a few as semi-skilled. Foremost, the tasks of procuring the raw materials, particularly earth, water, and timber are comparable to tasks we should expect Mycenaeans to have encountered in daily life as part of an agriculturally based society. The use of limestone rubble in foundations and walls is also common enough in Mycenaean architecture, but the scale of these tasks at Kalamianos and the size of stone used is atypical. For this reason, I would label the stone elements as semi-skilled, since it is likely that a few knowledgeable masons familiar with large stone construction worked collectively with less skilled individuals to extract and erect foundations or mortared rubble walls.

The most likely area for highly skilled workers was during initial planning, where a few individuals needed to set building layouts, and during final decoration, particularly lime plastering, again where only a few individuals were needed. As a result, over the course of construction, most interactions would occur between groups at the lower end of a generalized continuum of unskilled to skilled workers. Because the planning and plastering were temporally

separated from most of the building process, skilled workers may not have interacted as frequently with other workgroups during architectural production. The segregation of skilled workers during the building process, though, is counterbalanced by the small size of the site and the possible cycling of workgroups, all of whom would have certainly seen one another while working. A second point to make is that, because Kalamianos was established in a new area, rather isolated from existing sites,[67] the builders of the site were likely also inhabitants so that many individuals would have interacted in daily life outside of the building process. This makes the situation at Kalamianos distinct from architectural production in a larger inhabited environment, like Mycenae, where workgroups that interacted during the building process might return at the end of the day to spatially and socially discrete areas of habitation. As a result, the performative aspects of production at Kalamianos might be especially meaningful arenas of competition, particularly when the first structures were imposed on the landscape; the builders were literally creating the built environment which would structure their own sociopolitical interactions. This may have meant that there was greater room for social, political, and economic competition and the negotiation of identities during architectural production, and the opportunity to participate in structuring your own built environment, in itself, could have been a major enticement for individuals to work and settle at Kalamianos.

Like Kalamianos, the spatial configuration during production of the Northeast Extension changes very little (Figs. A.149, A.150). There is really no alteration in the type of resources or the building techniques for the duration of the project, granting that it is possible construction was halted between the initial creation of the cistern and the replacement of the old wall with the new extension. So, although there were certainly different types of workgroups procuring,

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[67] The exact relationship with the site of Stiri needs further exploration.

transporting, and assembling stone, their composition did not need to change; administratively, this meant there were predictable skillsets required for the life of the project. This consistency was an important counter to future problems that might arise under more uncertain conditions, such as needing to count on the availability of skilled labor well in advance.

Most of the skills for the Northeast Extension fall into the grey area of semi-skilled, because they relied on a few skilled actors integrating with a large number of laborers providing the brute force to maneuver stones. A few skilled individuals would have sufficed to plan and direct the layout of the cistern and the assembly of the new wall. With a median duration of 147 working days and 90% of schedules finishing in under 195 days, workers could have extended construction over a few building seasons, especially given the regularity of skillsets, but because of its necessity in defending the citadel of Mycenae, it was likely completed without regard for seasonality. Coupled with the steadier labor needs and limited amounts of skilled labor, this suggests that at the time of construction, planners knew they had access to a fixed supply of workers who could provide the brute force needed continuously for at least five months.

Decision Making and Decision Makers

Across all three projects, we should consider the scale of decision making that was necessary to maintain the organization of production and to advance production towards to the finished structure. Each of the projects under study here shows a variety of choice points that required calculated and well-informed human input, but the amount of choice and centralization of these choices were different for each project. For the Treasury of Atreus, a system of linear measurements was employed to constrain the layout of the project, but within this system purposeful stopping points were integrated so that new groups of builders could work out the

details of each building component according to their skills and experience; the result was a proportionally designed tholos tomb which followed well-established Mycenaean layout practices, but employed very distinct types of masonry for different building components.

At Kalamianos, too, groups of buildings were well-planned within a gridded layout that was a product of both geological and human demands. After this planning, though, multiple choice points existed during the process of construction. I have highlighted the distinct choice of using mudbrick or mortared rubble for the superstructure, and the impact this choice had on the organization of production, but numerous other choices, as well, existed; these included the height of stories, the incorporation of stairwells and their layout, the isolation or integration of rooms via doors and passageways, and the interior and exterior finishing of the structure. Many of these choices were likely influenced by a combination of the structure's intended function and the personal choices and skill level of workgroups. The result should be a noticeable amount of variation in the details of structures. At least among the remains of the rubble walls and foundations, there is such variation, as indicated by the size of stones, the treatment of corners, the thickness of walls, the presence of orthostates, and the width of doorways. These different choices are certainly the result of a complex intersection of needs, skills, and limitations during the building process, and future chronological refinement will help to pin down how and why builders made these choices during punctuated episodes of construction.

For the Northeast Extension, choices were very limited and the wall's layout was constrained by the physical demands of the terrain and the placement of the cistern, which was geologically dictated. The most difficult aspect of construction, the corbelling of the south sally port and the passage to the cistern through the wall, did offer room for choice at a high level and, as with all choice points, the danger of failure. The most important choice made by builders to

reduce the danger of failure was to build corbelled passages in roughly even courses. This ensured a fixed height across the passage and assured that weight was reliably transferred to underlying bedrock.[68] There is no evidence that these regular courses followed a fixed system of measurements, so they were likely set by an individual or small group of individuals during construction while other workers simply followed suit. Unlike Kalamianos and the Treasury of Atreus, the impact of choices made by most workgroups and builders during the procurement of resources and construction of the masonry, though, seems to have been minimal.

The diversity of groups and tasks, the incorporation of stopping points, the complexity of tasks, and the centralization or dispersion of decision making are part of larger social, political, and economic structures at the time of construction. Literature on organizations and their internal structures offers some helpful points when dealing with architectural production, which like an organization is a complex integration of multiple parties working towards a common end. Both the element of communication, such as between resource extraction and the building site, and the areas of choice during construction have been emphasized above; these issues are similar to problems of information processing with an organization, specifically how much information must be processed and coordinated, and how and by whom it is processed and coordinated.[69] The models of production and the use of the energetic flowcharts, therefore, not only represent the material stages of production and the interaction of individuals and groups through material transformations, but they also represent flows of information between productive groups. Like raw materials during the building process, "information is an important resource, and both the

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[68] Compare the corbelling at Tiryns, where regular courses are well preserved in the south gallery (Schnuchel 1983; Küpper 1996, 33–8).
[69] See Palaima (2003) who addresses information processing in the Linear B records.

307

lack of information and the inability to process and distribute it constrain behavior."[70] As the amount of information and its sources multiply, Moore notes that there is a pressure towards the hierarchical or horizontal segregation of information.[71] Johnson even suggests that once a group reaches six individuals, positions of within-group leadership begin to emerge in response to the growing amount of information that must be processed.[72]

The analysis of production in this study suggests that the organization of information processing and administration were distinct for the Treasury of Atreus, the structures of Kalamianos, and the Northeast Extension. In all three cases, directing authorities were responsible for the initial planning and start of construction, but afterwards information and decision making were variably handled. In the Treasury of Atreus, decision making seems to have frequently rested with groups of skilled masons, whose work dictated the requirements of resource extraction and the pace of transportation. At Kalamianos, the interaction between semi-skilled and unskilled workers as well as the plethora of individualized choices required for each structure suggests that many decisions could be resolved in a decentralized manner during construction, but that these decisions were bounded at a higher level by the planned layout of the site and likely by the intended function of a structure. Finally, the process of decision making during production of the Northeast Extension seems to have been strongly centralized with little room for meaningful decision making by the majority of participants.

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[70] Moore 1983, 187
[71] Moore 1983.
[72] Johnson 1982.

Administration, Compensation, and Architectural Production

Although the administration of architectural production is only tenuously evidenced in the Linear B texts, with builders listed in just a few places,[73] when interpreted broadly, the Linear B texts do show strategies of production monitoring, labor recruitment, and compensation that are revealing. Granted that the Mycenaean palace centers emerged under distinct regional conditions and approached industries differently,[74] among those items that intersected with palatial interests, there is a rough division into goods whose production was in some way monitored and goods which were acquired without concern for their production.[75] In the case of the former, the texts show both close monitoring of certain productive acts and a dispersed approach which is concerned more with inputs and outputs rather than the minutiae of production. Perfume manufacture at Pylos is a major example of the close monitoring of spatially centralized production.[76] The complexity of the process, numerous raw materials, and presence of a few, high status 'unguent-boilers' in the Pylian texts may explain why and how production was directly monitored.[77] Halstead has argued for the direct production of select agricultural goods, as well,[78] and the Knossos harvest records certainly bear out significant palatial involvement.[79] The textual evidence for direct palatial intervention in agriculture is less certain elsewhere and most agricultural production may have instead fallen under the purview of local communities, who shared their crops in exchange for loans of palatial oxen.[80]

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[73] Montecchi 2011, 2013; Nakassis 2012.
[74] Bennet 1985, 2001; Shelmerdine 1999; Galaty and Parkinson 2007b, passim.
[75] Bennet and Halstead 2014, 273.
[76] Shelmerdine 1985; Killen 2001, 171–2, 174–5.
[77] Killen 2001, 171–2, 174–5; Knappett 2001, 87.
[78] Halstead 1992, 2001, 2007.
[79] e.g. KN F 852.1 *da-wo / a-ma , e-pi-ke-re* GRA 10300.
[80] Killen 1992, 2004; de Fidio 2001.

A spatially decentralized approach to monitoring production which relies heavily on intermediate managers is attested by the *ta-ra-si-ja* system. The *ta-ra-si-ja* system is found at Mycenae, Knossos, and Pylos, specifically in the production of cloth, bronze working, and to a very limited extent, the manufacture of chariot wheels.[81] Unlike the direct production of perfumed oil, a large, dispersed workforce, often consisting of low status workers,[82] is characteristic of the *ta-ra-si-ja* system.[83] In a good summary of the administrative mentality behind the *ta-ra-si-ja* system, Nosch has isolated five levels of monitoring: 1) the target level, where a desired amount of output is fixed; 2) the collection of raw materials, such as bronze from villages in the PY Jn series; 3) the distribution of materials to individuals or groups 4) the receipt of finished goods from individuals or groups; and 5) the difference between receipts and targets listing what is owed.[84] The system is really a piecemeal approach to production which assigns fixed work with the expectation of a certain return based on established standards of production.[85] The system is overwhelmingly monitored by a single scribe at Knossos (scribe 103) and at Pylos (hand 2), but its operation engages a number of named managers or entrepreneurs, such as the collectors whose reach extends into sheep rearing, wool, and textile manufacture.[86]

The idea of spatial centralization and dispersion that plays into the direct monitoring and the piecemeal *ta-ra-si-ja* system may be drawn into the discussion of the control and monitoring of architectural production. First, I would caution that the complexity of architectural production

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[81] Killen 2001; Nosch 2006

[82] Although named smiths at Pylos may be high status individuals (Nakassis 2013, 74–102).

[83] Chadwick 1988; Killen 1988, 2001; Nosch 2006.

[84] Nosch 2006, 170.

[85] This is very much like the textual monitoring of construction in the ancient Near East and Egypt as well as modern construction management practices.

[86] On the collectors, see especially the extensive discussion in Rougemont 2009, 249–524.

demonstrated by this study means that centralized or palatial control of projects was likely highly variable, but given this, the work assignments characteristic of the *ta-ra-si-ja* system are interesting. First, the piecemeal production of architecture, in which targets are set, materials allocated, and work deficits calculated, is found in records of architectural production in the Bronze Age Near East and Egypt.[87] Classical Greek records, too, show piecemeal work taken on by individuals as part of the diverse negotiations and payments that characterized building projects.[88] Of course, a direct record of piecemeal architectural production does not exist in the Linear B, which are chronologically restricted and topically quite narrow, but Nakassis' analysis of architectural labor in PY Fn 7 is evocative.[89]

Based on PY Fn 7, which lists twenty wall-builders, five sawyers, and one all-builder, preceded by two named individuals, Nakassis presents a few key arguments. First, he suggests that labor was organized in workgroups so that four masons were paired with one sawyer, and a total of five such teams operated under the all-builder, a type of foreman. Second, he argues that the named individuals, *qa-ra₂* and *pa-ka*, were responsible for the provision of unskilled laborers who supported the teams of masons and sawyers. Based on the standard ration of Z 3 per day in the Linear B texts,[90] *pa-ka* could have provided 240 person-days of labor with his suggested allotment of HORD and *qa-ra₂* could have provided 480 person-days so that, for the month, 24 supporting workers could be supplied.[91] If we wanted to take this person-day approach a bit further, we could add in the labor time of the masons, sawyers, and all-builder. Since they are all provisioned for one month, these workers are sustained for a total work equivalent of 780

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[87] Simpson 1963, 1969; Robson 1996; Ezzamel 2004; Heimpel 2009.
[88] Burford 1969.
[89] Nakassis 2012, 275–8.
[90] Palmer 1989.
[91] Nakassis 2012, 277; see also mention of PY Fn 7 in Nakassis 2015, 595–6.

person-days. Coupled with the implied labor gathered by *pa-ka* and *qa-ra₂,* PY Fn 7 might

support 1,500 person-days of architectural work. Needless to say, this is a significant amount of

work. If we factor in an eight-hour work day, as I have used in this study, this tablet provisions

five workgroups and a foreman who will complete an estimate 12,000 person-hours of work. For

the most complex Mycenaean buildings projects, like the Treasury of Atreus, the fortifications of

Gla, or the drainage works of the Kopais, this may be a trivial amount, but in light of the

structures at Kalamianos, the sustenance of this work is considerable; PY Fn 7 shows enough

labor support to build both structure 4-VI and 7-X (about 10,310 person-hours combined) with

room to spare. Of course, the temporal component of construction here is relevant since

simulation shows that the median completion time for structure 4-VI is 57 work-days and for

structure 7-X, it is 90 work-days; however, the 'assembly-line' approach to production at

Kalamianos that I have suggested intersects with the tablet's provisioning of multiple

workgroups, who in an environment like Kalamianos, could work on multiple structures at once.

Given Nakassis' conversion of rations to work-days, it is interesting to reverse this and

convert the person-hours from Chapter 7 into a rough measure of rations as a way to think about

the recruitment and compensation of architectural labor. Again, accepting a work day of eight

hours and a standard male ration of Z 3, a measure of 1.2 liters,[92] then we can suggest the overall

consumption of grain during production. For the Treasury of Atreus, which required builders to

expend 267,570 person-hours (Table B.6), this is about 33,446 daily rations or 40,315 liters.

While structures 4-VI and 7-X have been mentioned above in light of PY Fn 7, as a whole, the

labor expended on the major structures of Kalamianos is loosely estimated at 158,079 person-

hours (Table B.13); this is approximately 19,760 daily rations or 23,712 liters. We can also

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[92] Palmer 1989.

include here the suggested cost of continuously renewing the structures' plastering, which roughly required 27,502 person-hours, about 3,438 daily rations or 4,126 liters. Finally, the Northeast Extension's estimate of 44,875 (Table B.17) corresponds to approximately 5,610 daily rations or 6,731 liters. It is very difficult to time-scale this data because of the inherent variability in labor during construction and the uncertainty of the duration of construction, but these numbers can be interpreted in the context of Nakassis' quantitative evaluation of staple finance as well as Mycenaean agricultural practices.

In his study of staple and wealth finance in the Pylian texts, Nakassis broke the textual evidence for staple finance into four categories: feasting texts, which record palatially sponsored feasts; collection texts, which are generally related to feast preparations; payment texts, which list the direct distribution of staple goods; and unknown texts, which lack sufficient data.[93] For his category of payment texts, the term he used for what are often called ration texts, he calculates that the Pylian texts recorded staple distributions that were equivalent to 55,000 daily rations.[94] Given the turnover of Linear B texts, Nakassis posits that, although the maximum duration covered by these texts could be one year, it is probably much shorter and "perhaps a single month or even less."[95] To rephrase this in terms of labor, based on the standard ration rate, the Pylian texts show staple distributions that could have supported 55,000 person-days of work in perhaps a single month. This situation is admittedly difficult to extend directly to the situation in the Argolid and related coastal area of the Corinthia where Kalamianos is situated. The political development of the two regions followed different paths,[96] and the textual data from

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[93] Nakassis 2010.
[94] Nakassis 2010, 134–5.
[95] Nakassis 2010, 136.
[96] Voutsaki 1998, 2010; Wright 2004b.

sites in the Argolid is both sparse and poorly preserved.[97] Still, Nakassis' quantification does offer some measure of scale when compared to the amount of daily rations I have calculated for architectural production. The volume of staple payments monitored by the palace at Pylos for perhaps a month well exceeds the equivalent daily rations that would be consumed during any of the architectural projects studied here; from the perspective of staple finance, architectural production may not have been especially burdensome. Moreover, the "startup cost" to feed a group of workers who might begin construction is small compared to the quantitative scale of rations in the Pylian records, particularly the amount of subsistence rations devoted to supporting cloth manufacture.

The suggested daily rations consumed in these architectural projects can also be weighed against the amount of land needed to produce an equivalent amount of grain. This tactic encounters some difficult obstacles, including the question of how we interpret the HORD and GRA signs from the Linear B texts,[98] and the very nature of Mycenaean agricultural practices. Palmer, though, has collected a number of measurements that estimate the productivity of land in Greece, both ancient and modern.[99] In ancient Greece, she suggests a rate of 10 hectoliters of wheat per hectare of land.[100] For the largest architectural project studied here, the Treasury of Atreus, this implies that the grain produced on 40 hectares of land could pay basic rations in wheat for the entirety of the project. To add some context to this number, Palmer notes that in 1921, 40,613 hectares of wheat were planted in the Argolid.[101] An interesting addendum to this

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[97] For a basic overview of the Linear B texts, including their findspots and chronology, see Driessen 2008.
[98] Palmer 1992; Halstead 1995.
[99] Palmer 1992.
[100] Palmer 1992, table 1.
[101] Palmer 1992, table 2.

strikingly low amount of land, is to consider if building activities at Kalamianos were

agriculturally self-sufficient. Kvapil has studied both the abundant Bronze Age terraces around

Kalamianos and discussed cultivation practices in the region.[102] She estimates terraces created

approximately 150,000 m^2 of land for cultivation.[103] From Palmer's rate, this would produce

around 15,000 liters of wheat per year. Given that I suggest a total consumption of 23,712 liters

during construction of the major structures and that the terraced land was only a part of the

cultivable land in the region, once the initial push of construction and cultivation had been

made,[104] this suggests that Kalamianos may have been agriculturally autonomous and that it was

able to sustain ongoing construction, at least from the perspective of staple resources; the initial

external push to get to this point of self-sufficiency might look very much like the situation in

PY Fn 7.

The limited agricultural demand of building projects suggests that systems of staple

finance were not essential to large scale architectural production. In itself, this may be why so

few builders appear in the texts.[105] Small allocations of rations are able to sustain intensive

building projects[106] and, as in PY Fn 7, named individuals may be accountable for much of the

unskilled labor so that it is not easy to identify in the texts. Given the rapid cycling of ration

texts, as well as the small amount of rations required for large projects, the scant mention of

builders at Pylos, Thebes, and Knossos may not just be happenstance; it may actually reflect the

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[102] Kvapil 2012.
[103] Kvapil 2012, 202.
[104] This measure does not include creation of the terraces themselves. If we accept the numbers from Kvapil (2012, 200), then the terraces might roughly be an additional 8,650 days of work or another 10,500 liters of grain.
[105] They appear at Knossos, Thebes, and Pylos in just a few texts (James 2002; Montecchi 2011, 2013; Nakassis 2012).
[106] See also Montecchi 2011.

degree of palatial involvement in architectural production from the perspective of subsistence

allocations. Much of the sustenance required by builders, particularly unskilled builders, may

have been either managed by named individuals or it could have fallen to local communities to

sustain workers,[107] which does not seem especially demanding. From a broader perspective, the

argument that large staple payments were not necessary to support Mycenaean building activities

also fits with the ongoing identification of labor intensive architecture in egalitarian or non-

agricultural societies.[108]

The limited importance of staple finance in Mycenaean architectural production, though,

must be contrasted with the managerial complexities of production and the need for a variety of

semi-skilled and skilled workers who integrated with unskilled laborers. Rather than simply

accepting that all workers received rations[109] and following classical thinking about

monumentality that envisions architectural production as exploitive, the compensation and

recruitment of individuals in a building project was likely complexly related to the diversity of

tasks, the requisite skill levels, the forms of administrative oversight, and the ability of groups to

meaningfully participate in decision making about the building project. This is a further caution

against reading summed labor-costs as a reflection of a particular recruitment mechanism or a

specific form of labor compensation.[110] Beyond rations, recruitment and compensation during a

single project might also engage feasting, employ systems of wealth finance, or offer the

enticement of landholding or other productive opportunities.

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[107] Discussion of the integration of palace and local communities is given by de Fidio 1987, 2001.

[108] Ortmann and Kidder 2013; Notroff et al. 2014; see also Kaplan 1963.

[109] The distributions of wine and grain to builders at Thebes are, in fact, irregular; see James 2002; Montecchi 2011.

[110] See, for example, Kolb 1997; Abrams and LeRouge 2008

Feasting is especially well suited to short-lived bumps in labor demand, such as those modeled for the lintels in the Treasury of Atreus and the intensive periods of plastering at Kalamianos. As a means of drawing people together, feasts are also a way to integrate with new groups and to expand networks of interaction that can attract skilled labor.[111] On the LH III mainland, there is certainly an abundance of evidence for feasting.[112] From the perspective of state finance, at least at Pylos, Nakassis noted that more than half of the textually attested staples were consumed in feasts rather than distributed as rations. This, he argued was "a more direct method of securing allegiances among the community than converting these staples into wealth."[113] The variety of textual evidence, including the Pylos Ta series and the Theban nodules, reveals both the complexity of arranging these feasts and their importance from an administrative perspective.[114] The ceramic and faunal remains, too, bear out the role of feasting in the Mycenaean Argolid and Corinthia.[115]

The utilization of wealth goods has also been frequently noted as part of Mycenaean strategies for engaging skilled workers and integrating with networks of people via localized elites. In his model of Mycenaean palatial mobilization, Halstead notes that palatial finance was a mixture of both staple and wealth finance, each employed to different ends.[116] Wealth goods, whose raw materials were acquired via taxation and exchange, were particularly used to mobilize goods or people over a larger distance than staple goods allowed.[117] At Pylos and Knossos,

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[111] The anthropological literature on feasting is extensive. Dietler and Herbrich (2001) is a good overview of feasting and labor. Hayden (2014, 233–346), also, offers recent discussion on this issue.

[112] On feasting in the Aegean, see the papers in Wright 2004c; Hitchcock et al. 2008.

[113] Nakassis 2010, 139.

[114] Aravantinos 1990; Killen 1994; Palaima 2004b; Wright 2004a.

[115] Dabney et al. 2004; Wright 2004a; Lis 2008; Shelton 2008; Walberg and Reese 2008.

[116] Halstead 2007.

[117] Halstead 2007, 70–1.

records of the manufacture of cloth, typically from wool, but likely also from flax,[118] are

indicative of the importance of wealth finance and exchange. At Mycenae, too, there is evidence

that suggests an essential role of cloth in the functioning of the palaces; Varias Garcia identifies

36 tablets at Mycenae, about 43% of the Mycenae corpus, that are related to cloth production.[119]

The allocations of wool in the Mycenae texts are further linked with standard types of

Mycenaean cloth and fit within the operation of the *ta-ra-si-ja* system that the Mycenaean

palaces used to produce certain wealth goods.[120] Beyond engaging local or regional networks of

people,[121] wealth goods like cloth and perfumed oil also functioned within long distance

exchange networks that could be used to attracted skilled builders or to stimulate networks of gift

exchange across the Mediterranean.[122] In the latter case, the Near Eastern and Egyptian records

show that such gift exchange networks could include not only high status goods, but the

individuals who manufactured these goods themselves.[123] The stylistic similarities in the painted

plaster of different regions is a compelling piece of archaeological evidence for the movement of

such workers.[124]

 Finally, beyond the role of wealth and staple goods in recruiting and funding builders

with different skillsets, there are mixed benefits that builders might have gained by participating

in largescale construction projects. Based on evidence from the Pylian tablets, it is implied that

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[118] Foster 1981; Halstead 2001, 44–6.
[119] Varias Garcia 2012, 155.
[120] Nosch 2014, 375–6.
[121] On the significant role of wealth goods in integrating networks of people in Messenia and the Argolid, see especially Voutsaki 1995, 1998, 1999, 2010; Schon 2007, 2011; Aprile 2013.
[122] Kelder 2009; Fappas 2011.
[123] Hitchcock 2005, 693–4; see also the discussion of exchange networks and craftsmen in Cline 1995; Bloedow 1997; Sherratt 2001; Abell 2014.
[124] Brysbaert 2008, 77–85, 189–95; Barnes 2013.

certain labor services were owed to the palace in relation to holding plots of land.[125] Particularly

in the context of settlement at Kalamianos, one incentive for builders to move and work there

may have been the right of landholding and the guarantee of collective labor during the harvest.

Kvapil circumstantially dates a threshing floor at the site to the Late Bronze Age and this fits

with the intensive agricultural exploitation of the surrounding area that is indicated by Bronze

Age terracing.[126] More broadly, participation in large scale projects may have offered

"networking opportunities" for a variety of participants. In this regard, market exchange and

entrepreneurship may be part of acts of architectural production.

Participation in collective work events,[127] like architectural production which drew

together many parties, could have offered one means for goods to circulate via heterarchical and

voluntary exchange outside of the purview of Linear B texts. Large, punctuated gatherings of

people for architectural work were both visible gatherings in the landscape[128] and, to function,

had to be predictably administered; quite simply people needed to know when and where to

show up. In the case of the Argolid, the integration of networks of people, especially through the

exchange of wealth goods, may not only have led to the incorporation of regions in a hierarchical

manner with Mycenae ultimately emerging at the top;[129] it may also have fostered the very

networks of human interaction and information sharing required for forms of market exchange.

Certainly the gatherings of people during peaks of labor in architectural production offered one

predictable, spatially centralized arena for such exchanges. The attendance of diverse peoples in

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[125] Chadwick 1987; Nakassis 2012, 269–74; Palaima 2015, 621–9.
[126] Kvapil 2012, 232–5.
[127] Dietler and Herbich 2001.
[128] Making these productive acts visible and well-remembered was an essential part of what I have called productive monumentality.
[129] Voutsaki 1995, 2010.

the vicinity of centers like Mycenae in order to work on collective acts of production might be one way goods, such as pottery produced in specific workshops,[130] circulated in the larger region. Beyond rations, feasting, and other incentives, architectural production may have offered participants access to networks of domestic goods and such assemblies of people might have functioned in the sense of temporary markets of exchange.

We should also consider the participation of unfree or uncompensated workers alongside other types of workers. This category of labor is necessarily wide and could include slaves, indentured workers, apprentices, soldiers, and even children. Unfree labor is, at least, hinted at in the Linear B tablets by the term *do-e-ro(-a)*[131] and group of textile workers designated by ethnics.[132] The ongoing, steady pace of the Northeast Extension, its military importance, the lower skill required of most participants, and the limited room for meaningful decision making outside of a few directing individuals might reflect the participation of individuals in this category of labor. Needless to say, though, our understanding of this category of labor in Mycenaean Greece is meager.

Architectural Production, Human Action, and the Mycenaean Economy

If nothing else comes from this study, it should be clear that the process of creating architecture is complex. It draws together diverse groups who interact through the transformation of materials while over the course of production the spatial configuration and scale of human and material interactions shifts, sometime drastically. The material transformations that underlie architectural production, moreover, are not merely economic, but they are equally social and

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[130] Shelton 2010; Pullen 2013a.
[131] Individuals with this designation, though, may be high status religious personnel contrary to the later implication of the word δοῦλος (Nakassis 2013, 14–5).
[132] Ventris and Chadwick 1973, 155–68; Efkleidou 2004.

political actions which hold meaning for participants and witnesses. The overlap of these traditionally separated spheres was expressed earlier in the theory of complex embeddedness, which posits that whether something is economic, political, or social is entirely based on the subjective interpretation of individuals. At the center of these subjective assignments of meaning, though, is human action, as found in the interaction of human and human, and human and material. What I have called architectural production is just one dynamic network of human actions that holds the particular goal of building some structure. The analysis and diagramming of these actions and the simulation of how architectural production may have played out temporally is a remarkably valuable way to examine this network and enliven the otherwise static material remains of architecture; it moves the area of study from the finished building to the important human processes of building. Furthermore, the networks of action studied here represent only part of the larger picture.

Countless other networks of human actions and their material components unavoidably intersect with architectural production; this is articulated in the chaîne opératoire through the idea of enchainment, that multiple chains of material production and consumption intersect and overlap. For architectural production, not only do the wealth and staple goods, the land or the feasting items, or the voluntary exchanges, that formed part of recruitment and compensation tie in, but so do innumerable other elements of daily life. This includes such categories as tools, animals, scaffolding, rope, clothing, pottery, lithics, administrative objects, and even medicines. How diverse networks of action and materials goods entwined is not so easy to say; like the human actions at the heart of architectural production, it would be highly situational and the intersection of networks would be mediated through diverse individuals. Archaeologically, extracting the situational nature of such actions and interactions, and the subjective meaning

attached to them is difficult. Behind the material remains of a single structure, we can have

distinct groups of individuals who each have varying abilities to act freely and make choices

during production, and beyond this are the many other groups of individuals who are materially

enchained with architectural production. Even if we just assign everyone to a single typological

group, such as administrators, skilled and unskilled workers, and "others," architectural

production still presents a multifaceted web of interactions. This web of interactions, though, is

really the point. *This web is the Mycenaean economy*. So, how do we disentangle this web in a

way that renders it intelligible?

In this study, I have taken a producer-oriented, agentive approach to individual structures

to study one important portion of the web. Rather than taking on the impossible task of

understanding the whole web, that is the whole Mycenaean economy (which is really

unbounded), I would argue that this type of focused attack on the material record is the best way

to advance. One major effect of this intensive line of inquiry, though, is that strictly typological

thinking and higher level dichotomies such as palatial and non-palatial break down. This is not to

say such typological thinking is inappropriate; on the contrary, it has always been a core feature

of archaeological analysis and should remain as such, but when viewed at a close range, the

boundaries between categories tend to become fuzzy; humans and their actions are not so neatly

pigeonholed. To work from the material remains up requires that we weaken typological

boundaries that may appear fixed at a high level. In fact, any study of agency really mandates

this. To concurrently hit the larger picture and not become mired in purely microscale analysis,

though, I think that we can balance this weakened typological approach in the future by not only

taking a multiscalar approach but also a mutlitheoretical approach that tacks back and forth

between strong, prescriptive typologies at a high level and typologically weaker, descriptive and

explanatory methods at a closer level. Together, the two can help us to understand the past writ large (in the sense of the structural web of society, economy, and polity) and writ small (in the sense of the human agents who constituted these webs through their interactions with the material world and with other human agents).

Emerging models of the Mycenaean economy need to better envision the importance of multiple categories of objects, multiple groups of individuals, and the enchainment of networks of objects and people that constituted higher level structures. The implication of enchainment is especially momentous for future study. It means that data from the close range study of particular goods can also add to our understanding of other goods, so that the impact of human actions in one area of production may radiate outward through enchainment. From this perspective, large scale acts of architectural production can have a ripple effect on other practices, such as farming, domestic organization and storage practices, the exchange of staple and wealth goods, and even the movement of skilled workers in pan-regional systems. This runs the other way, too; a change in any of these can impact particular acts of architectural production. While single craft goods, particularly "palatial" goods, have dominated models of the Mycenaean economy, this networked model of the Mycenaean economy requires that we study diverse material remains in their own right and embrace the fact that none of these remains existed in isolation.

Concluding Remarks and Future Directions

In this study, I have demonstrated the importance of studying Mycenaean building projects at a close range where the dynamics of human action and choice matter. I have strongly argued that the term architectural production should be used in order to place architecture on an equal footing with the production of traditional craft goods that dominates current scholarly

discussion. Through rigorous analysis and the modeling of three major architectural projects in the Argolid and Corinthia, I have shown that acts of architectural production are complex; they engage larger numbers of people and require the interaction of more diverse groups of people than traditional craft production. Because of the temporal and spatial scale of architectural production and its heavy reliance on the cooperation of typologically dissimilar groups, namely skilled and unskilled workers, the production of Mycenaean architecture was a significant part of the Mycenaean economy and must be accounted for in future economic models alongside exchangeable goods, like pottery, metals, and lithics.

For Mycenaean archaeology in general, I believe that future engagement with interpretive archaeology and novel economic theory will be valuable. The discipline of Mycenaean archaeology is currently struggling to cope with the dissolution of old ideas and to process a quickly growing body of data. The strands of interpretive archaeology which accept that past individuals and their actions were diverse and complex can, in my opinion, help to build up new theoretical models. The concept of complex embeddedness that I drew from Austrian economic theory is important in this regard; it provides one way to emerge from the failure of the formalist-substantivist debate. In the future, the value of complex-embeddedness as a theoretical basis and its focus on human action needs to be explored more deeply within specific Mycenaean material contexts.

Individual lives, too, must be studied in light of the networked Mycenaean economy and the human actions at the center of production. Following in the footsteps of Hodder's study of Ötzi,[133] Mycenaean skeletal remains will be an important source of future knowledge. Data on the lives of individuals who participated in architectural production, especially those who

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[133] Hodder 2014.

supplied the brute force or who have been historically overlooked, would add to our understanding of general labor practices and would help to address who participated in construction and why they may have done so. Already recent osteological and DNA analysis is offering new and intriguing information on individual Mycenaeans.[134] Looking for tell-tale musculoskeletal markers and evidence of occupational injuries, like broken collar bones and ribs, crushed digits, and back injuries, is one way to learn more about the individual Mycenaeans upon whose shoulders so much of the construction process fell. Additionally, women and children may have played a greater role in Mycenaean building projects than acknowledged. In the Ur III period Garšana texts, at least, women acted as brick-carriers and overseers of brick-carriers.[135]

The comparative, close-range, and diachronic study of traditional craft goods and the production of large scale architecture is warranted. The production of architecture, as this study has shown, is different in many ways from traditional craft goods, especially because of its complexity, but we also need to understand how diverse productive processes integrated and overlapped through enchainment. As part of enchainment, there are points where individuals could exert control or could attempt to constrain the production or exchange of goods. Studying these productive chains, the exchange points between them, and the points of control and choice within them offers a promising way to model specific parts of the networked Mycenaean economy while highlighting how production and exchange played into the emergence of hierarchy and palatial institutions, or lack thereof, in different regions.

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[134] Iezzi 2005, 191–9; Bouwman et al. 2008; Nafplioti 2009; Schepartz et al. 2009b.
[135] Heimpel 2009, 65–72.

Finally, the method that I have used in this study needs to be applied to more structures in order to develop a deeper understanding of architectural production and the strengths and limitations of the method. A greater body of energetic-flow charts and timeframes for the completion of structures will be comparatively useful to study similarities and changes in building and labor practices over time and across regions. One clear place to apply this method in the future is mortuary architecture, particularly tholoi. Although these have been repetitively implicated in competitive display and the emergence of centralization, exploring and comparing the production of tholoi in detail will better illuminate how exactly tombs functioned in elite competition and how this competition changed over time. In Messenia, this would be particularly interesting given the presence of external influences in building practices, the diversity of tholoi, and the knowledge of sociopolitical organization gleaned from the Linear B tablets. In the Argolid, too, the close analysis of tholoi at Mycenae may bring striking conclusions. Particularly, I think longstanding arguments for the linear evolution and the chronological ordering of Mycenae's tholoi could be tested by exploring each tholos through the lens of architectural production. The palatial megaron would also be fruitfully studied using this method. Analysis of the skills, time, and workers needed to build a megaron will complement studies which have emphasized the megaron as a structure of power.
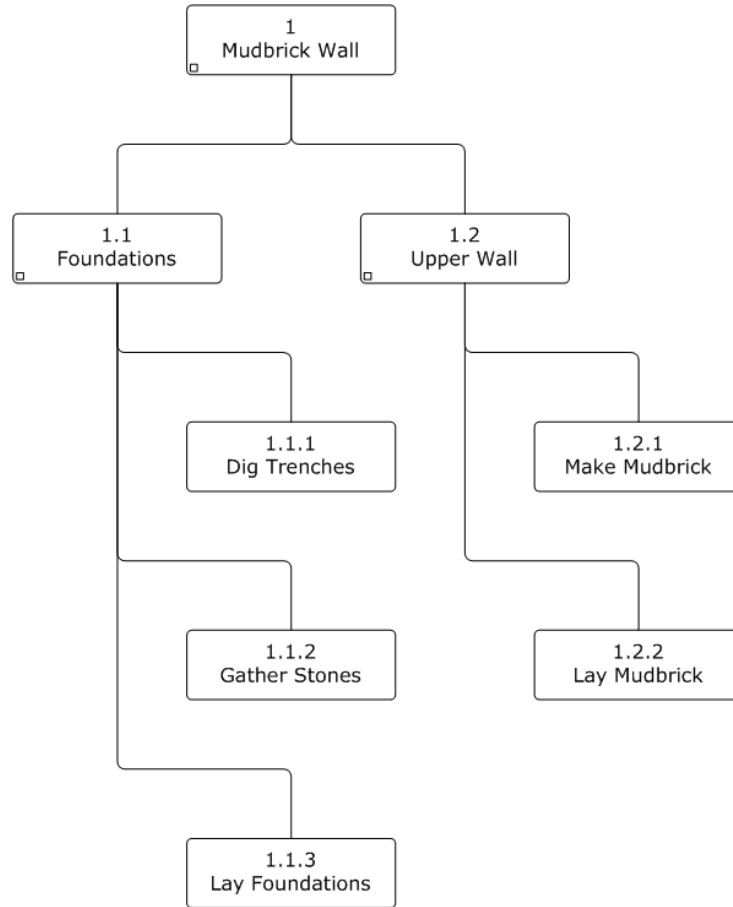
Figure A.1 A hypothetical Work Breakdown Structure (WBS) for a generic mudbrick wall consisting of mudbrick on stone foundations.
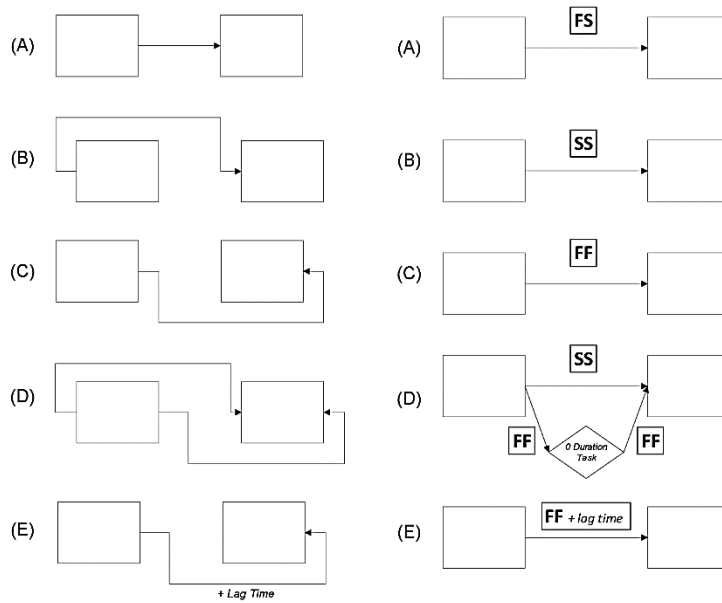
Figure A.2 Four types of relationships used in precedence diagramming: (A) finish-to-start, (B) start-to-start, (C) finish-to-finish, (D) combined relationship, and (E) a finish-to-finish relationship illustrating the placement of lag time.
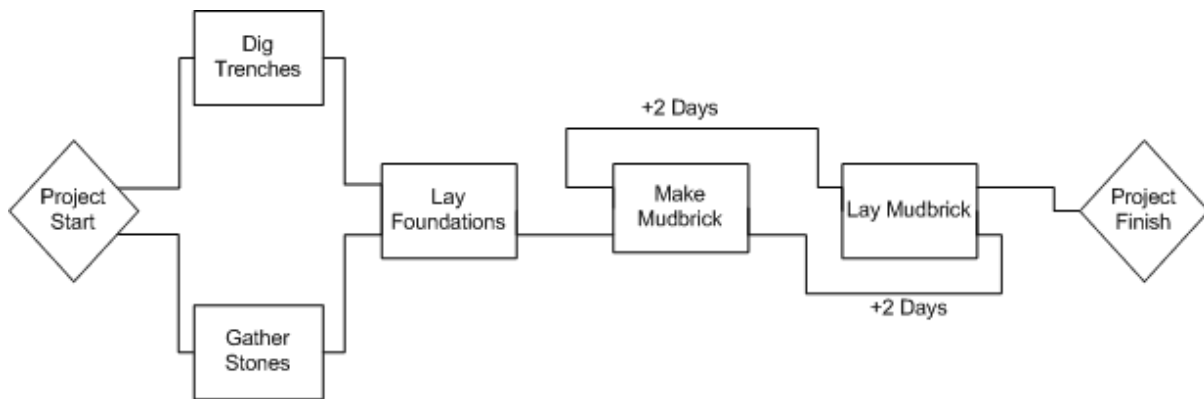
Figure A.3 A hypothetical precedence diagram showing one possible way to create a mudbrick wall. Note that the diagram shows relationships based on both hard and soft logic. The lag of two days between making and laying the mudbrick indicates a minimum wait time before the laying of mudbricks can begin.

328
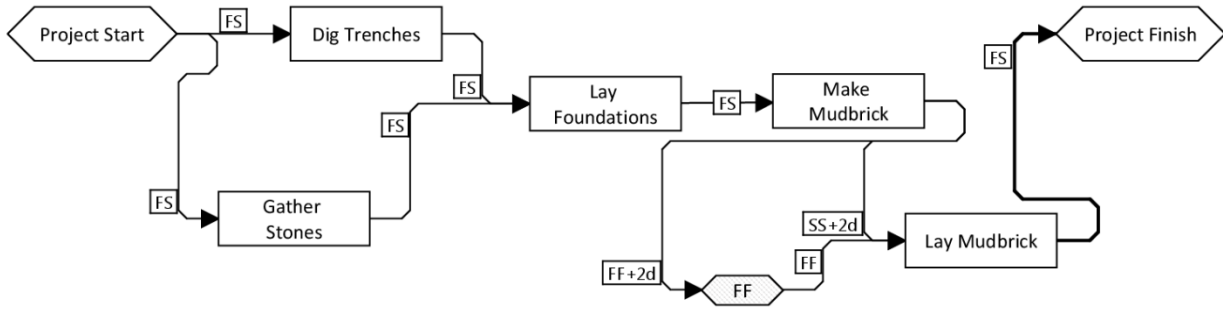
Figure A.4 A hypothetical precedence diagram showing one possible way to create a mudbrick wall. This is a version of Figure A.3 using Microsoft Project's notation. Note the "FF" placeholder between "Make Mudbrick" and "Lay Mudbrick" in order to capture the combine relationship seen in Figure A.3.

Figure A.5 The layout of each task's data in a precedence diagram.
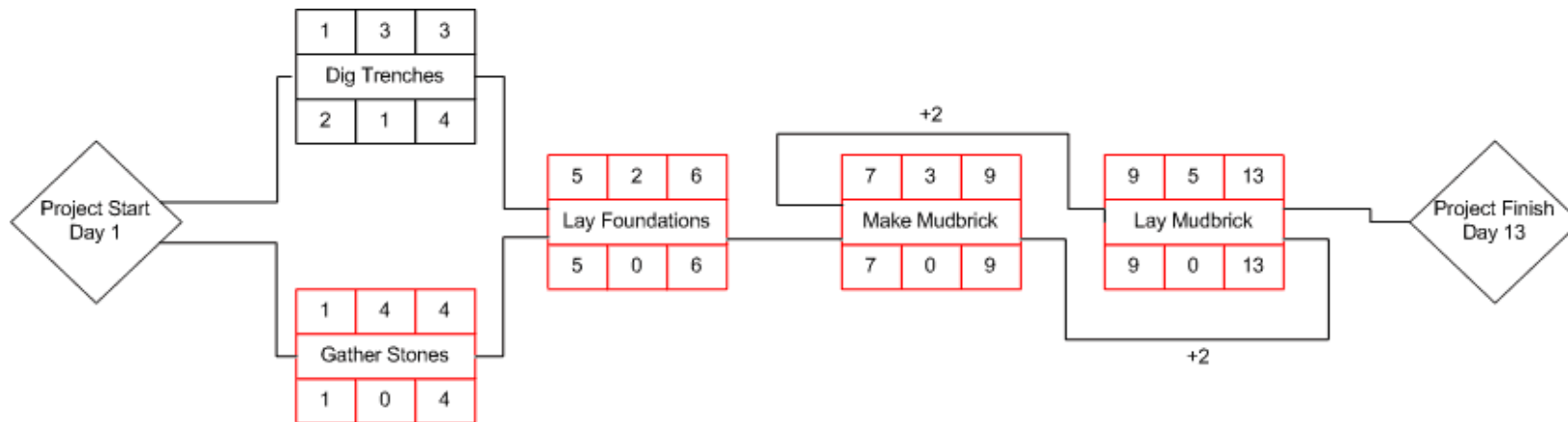
Figure A.6 A hypothetical schedule for the construction of a mudbrick wall established using the Critical Path Method. Red indicates the critical path of construction.
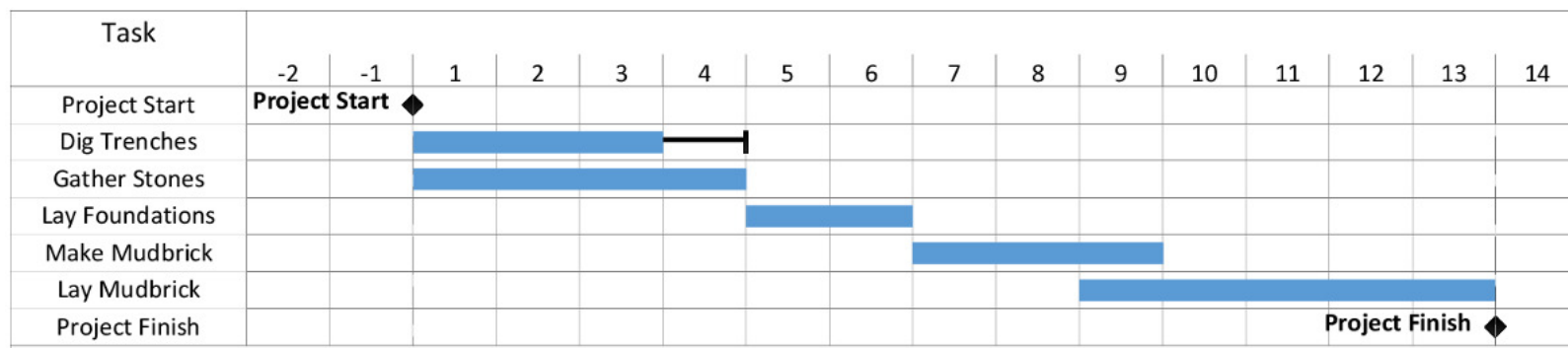
Figure A.7 A hypothetical schedule for the construction of a mudbrick wall displayed in a Gantt chart. The line and bar on "dig trenches" indicates the task has a float of one day.

Task	-2	-1	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Project Start	Project Start ◆															
Foundations	Foundations															
Dig Trenches																
Gather Stones																
Lay Foundations																
Superstructure						Superstructure										
Make Mudbrick																
Lay Mudbrick																
Project Finish													Project Finish ◆			
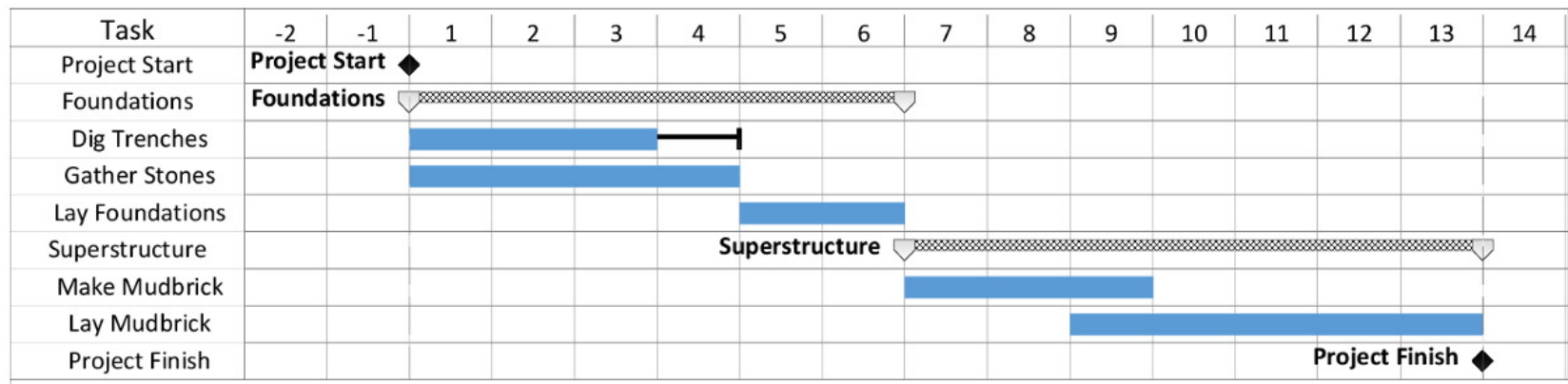
Figure A.8 A hypothetical schedule for the construction of a mudbrick wall displayed in a Gantt chart. Summary bars that group tasks into major components have been added.
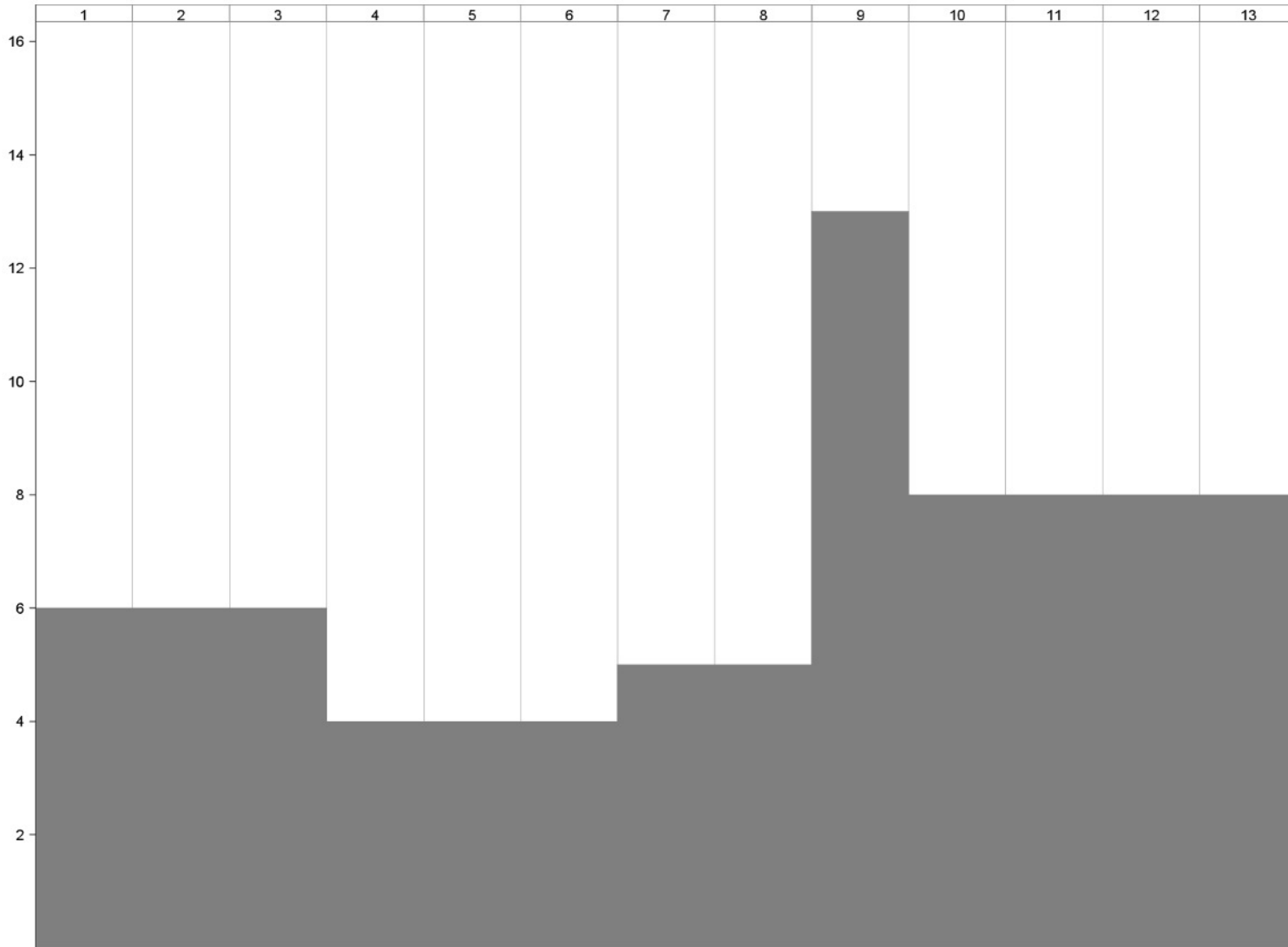
Figure A.9 A time-scaled histogram showing the number of workers on site on the vertical axis and the day of the construction schedule on the horizontal axis.
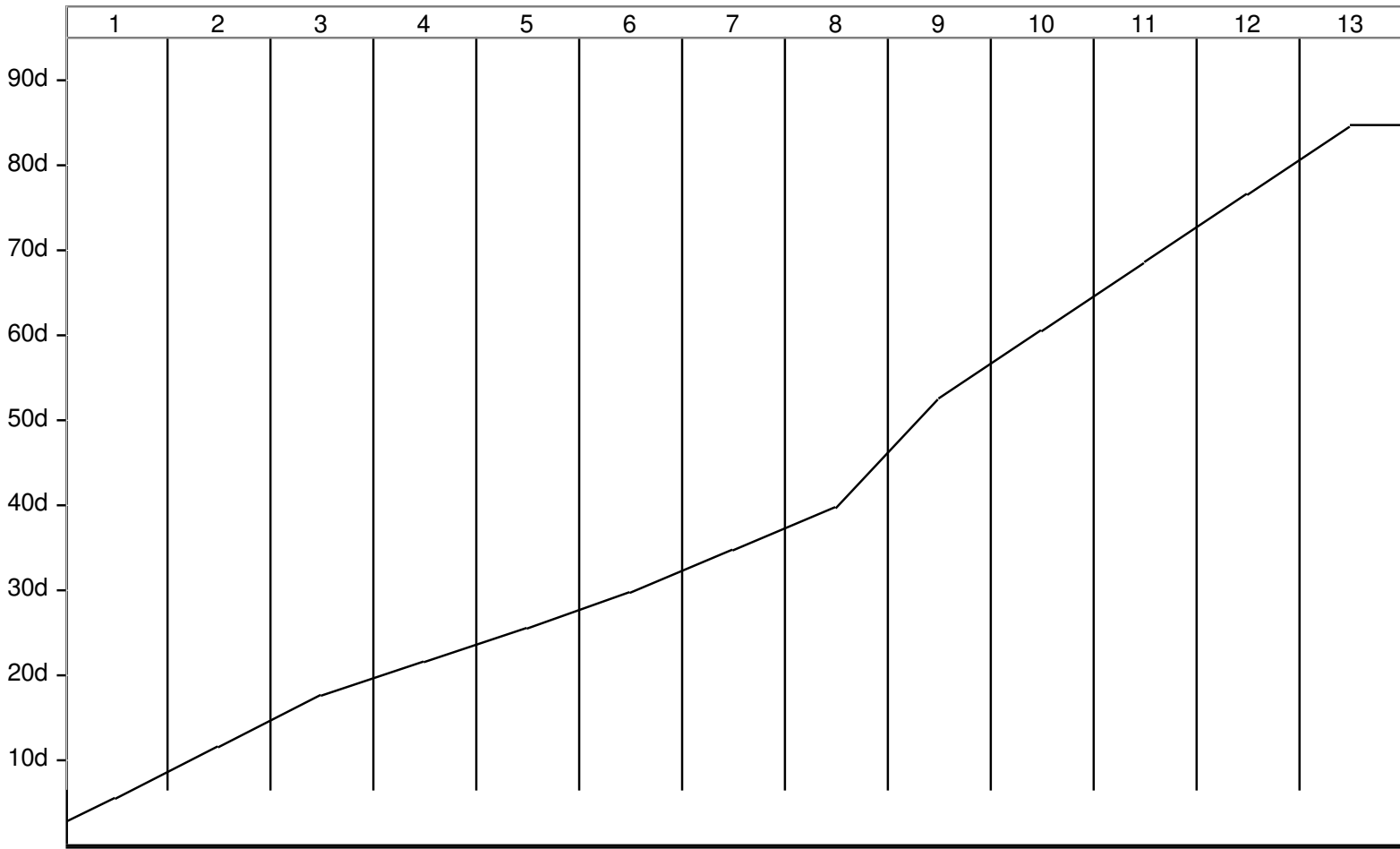
Figure A.10 A time-scaled graph showing the cumulative energy in person-days (12 hour) expended during construction on the vertical axis and the days into construction along the horizontal axis.
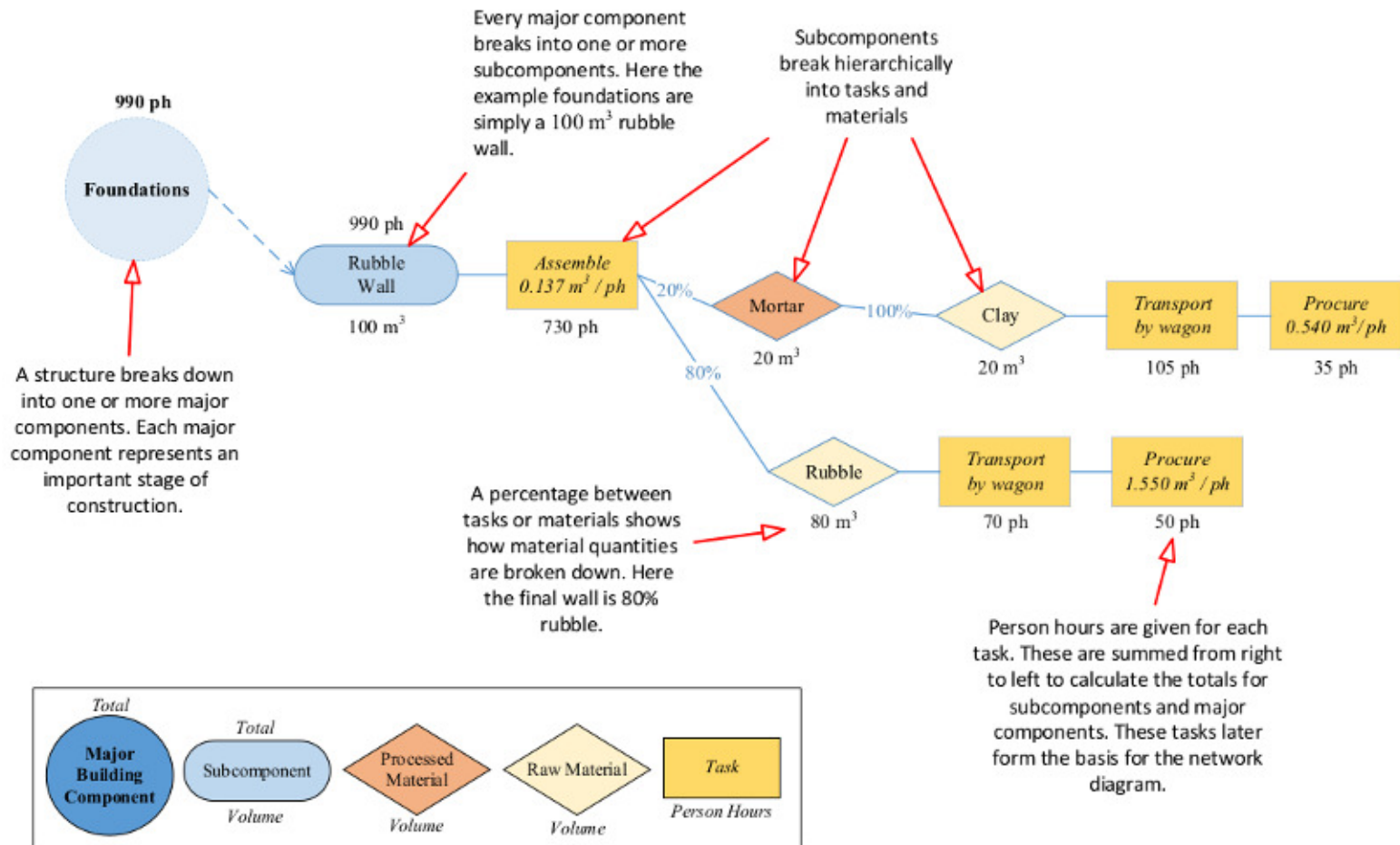
Figure A.11 An example of an energetic flowchart with annotations explaining its format.
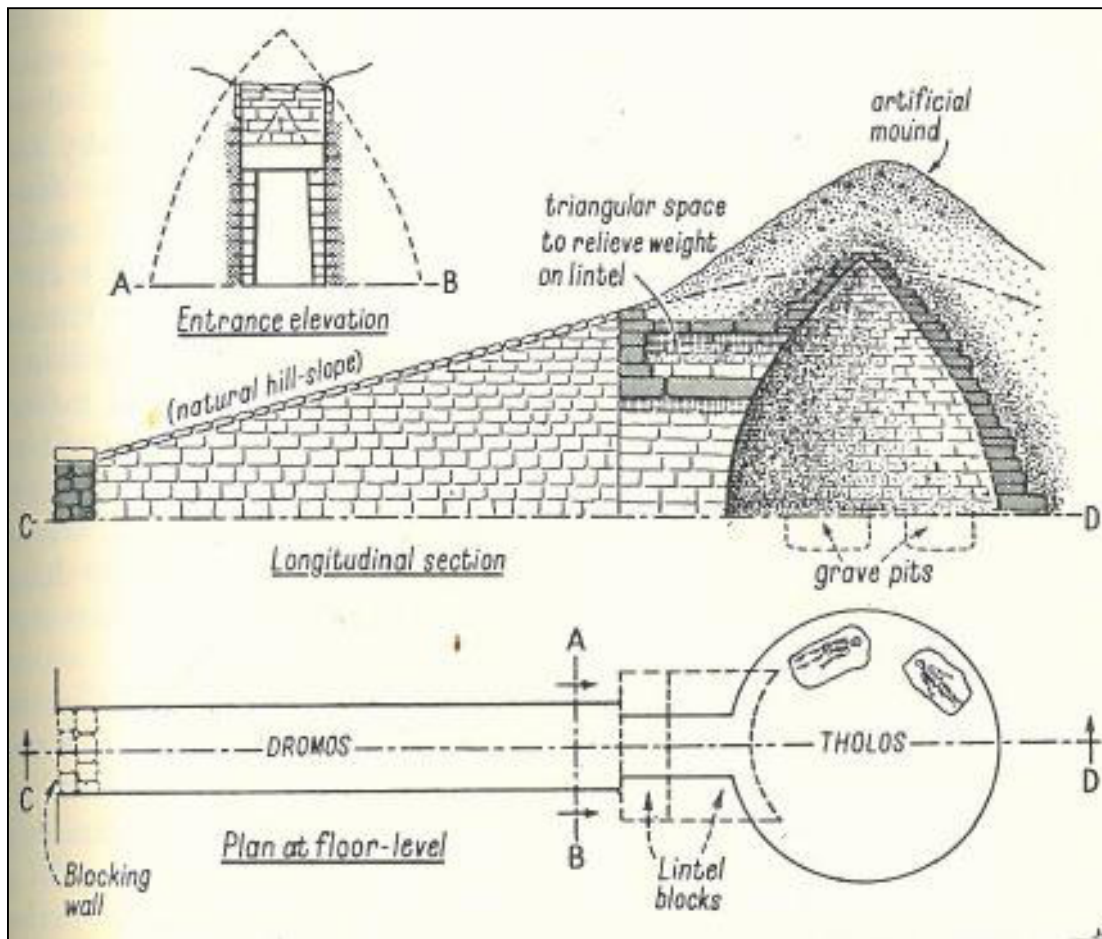
Figure A.12 Generic Plan and Section of a Mycenaean Tholos Tomb (Mylonas 1962, fig. 49).
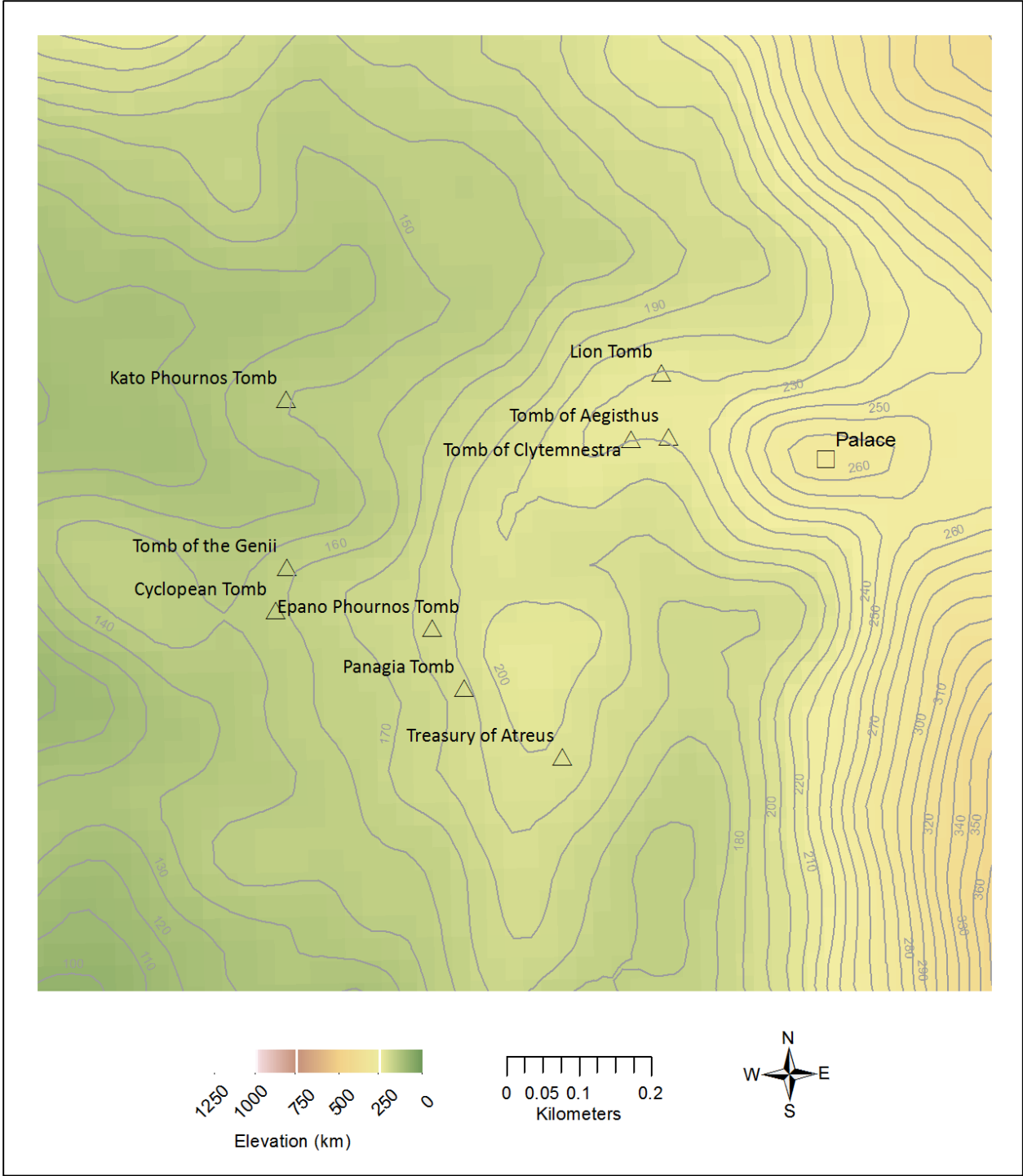
Figure A.13 The location of the nine tholoi at Mycenae.
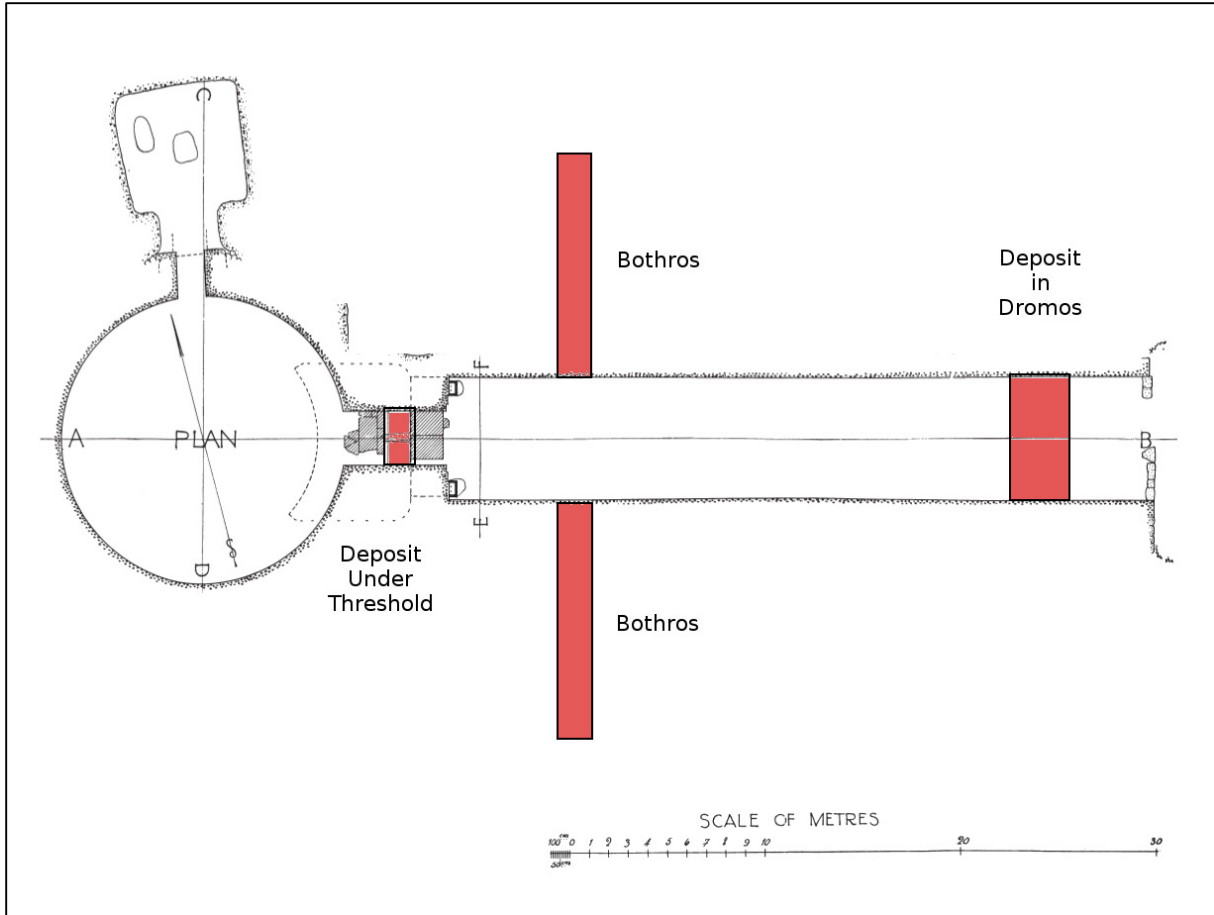
Figure A.14 The approximate locations of the three major deposits which help to date the Treasury of Atreus (Modified from Wace 1921-1923b, Pl. LVI).
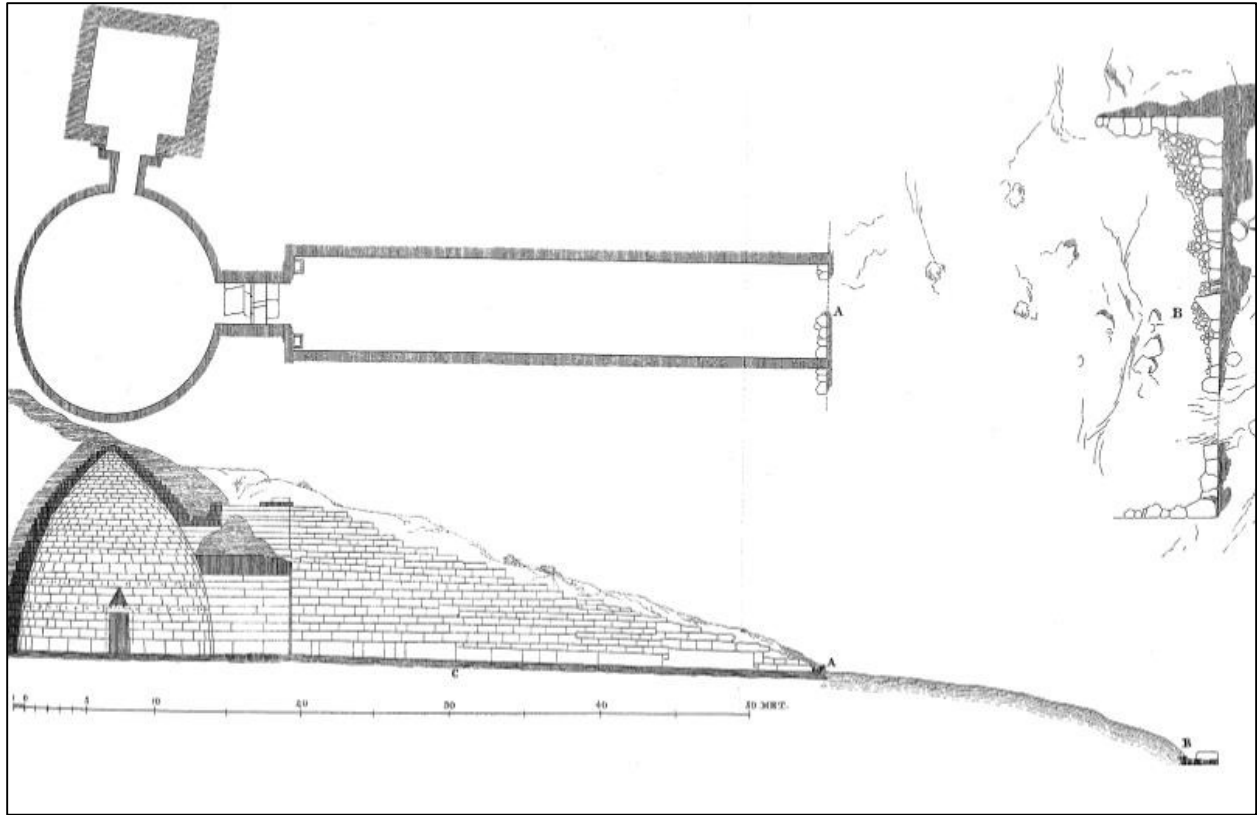
Figure A.15 Plan and section of the cyclopean platform east of the Treasury of Atreus' dromos (Thiersch 1879, pl. XIII).
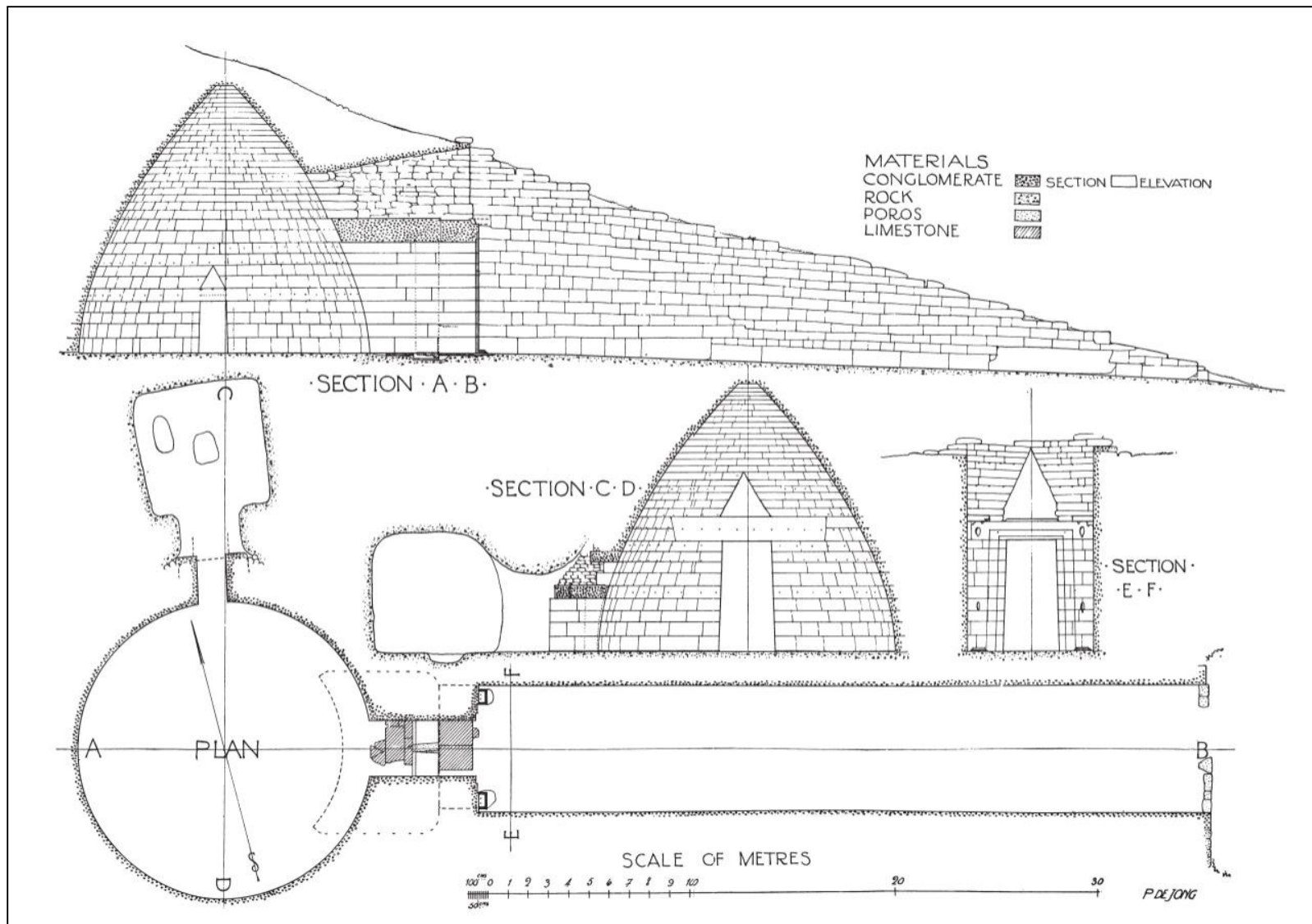
Figure A.16 Plan and sections of the Treasury of Atreus (Wace 1921–1923b, pl. LVI).

Figure A.17 The north dromos wall of the Treasury of Atreus c. 14 m from the façade showing L-shaped blocks or "hookstones" and rounding of block edges and corners.

Figure A.18 Excavations behind the south dromos wall of the Treasury of Atreus showing a mortared rubble and claybrick backing (Wace 1940, pl. II).
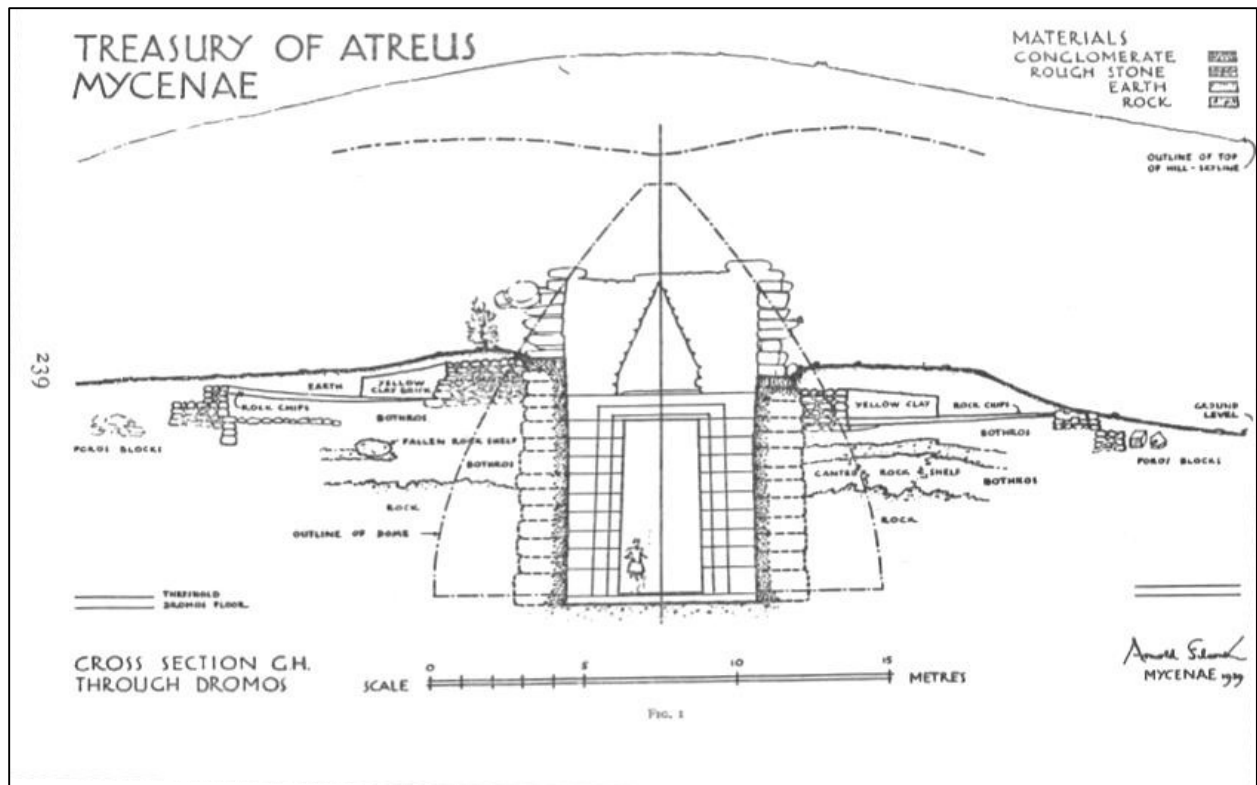
Figure A.19 Section G-H dug by Wace in 1939 showing the Atreus Bothros and the backing of the dromos (Wace 1940, fig. 1).

Figure A.20 The dromos and façade of the Treasury of Atreus.

Figure A.21 The south dromos wall and façade of the Treasury of Atreus.
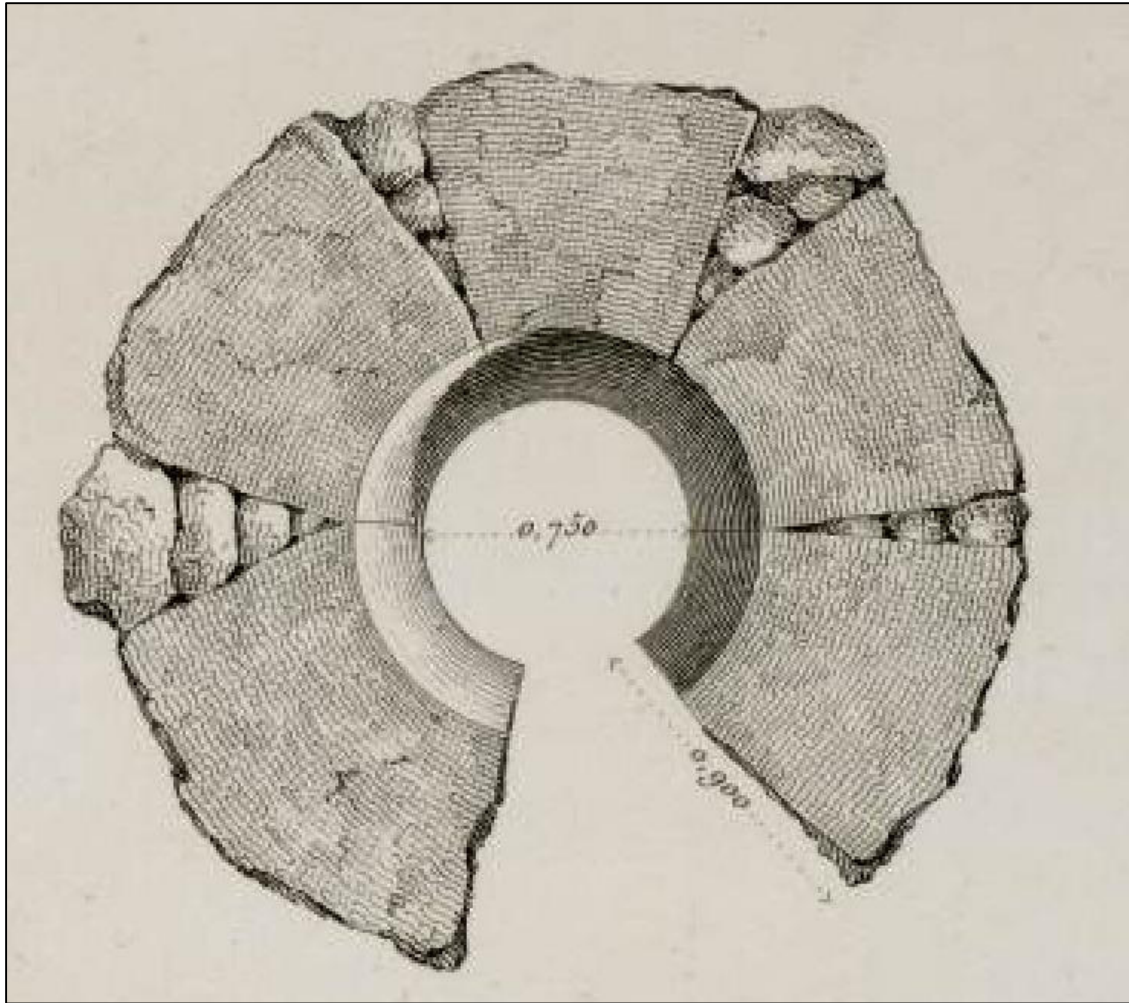
Figure A.22 Drawing of the upper course of the Treasury of Atreus (Blouet 1833, pl. 66).

Figure A.23 Poros blocks from the peribolos of the Treasury of Atreus (Wace and Desborough 1956, pl. 25 d).
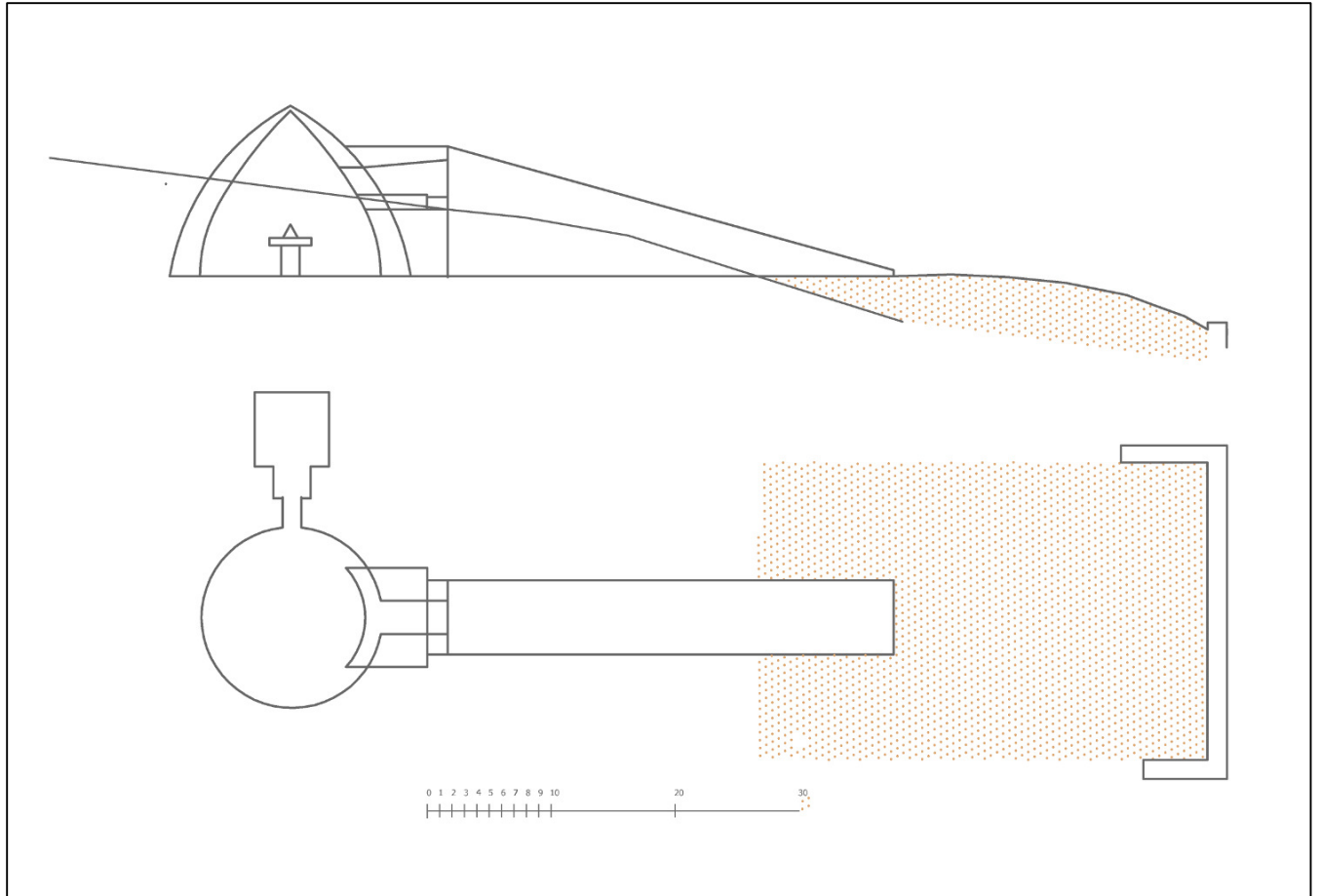
Figure A.24 Schematized plan and section showing the suggested slope of the bedrock and the possible area of fill west of the cyclopean retaining wall (Adapted from Thiersch 1879, pl. XIII; Wace 1921–1923b, pl. LVI; Como 2007, fig. III.8).
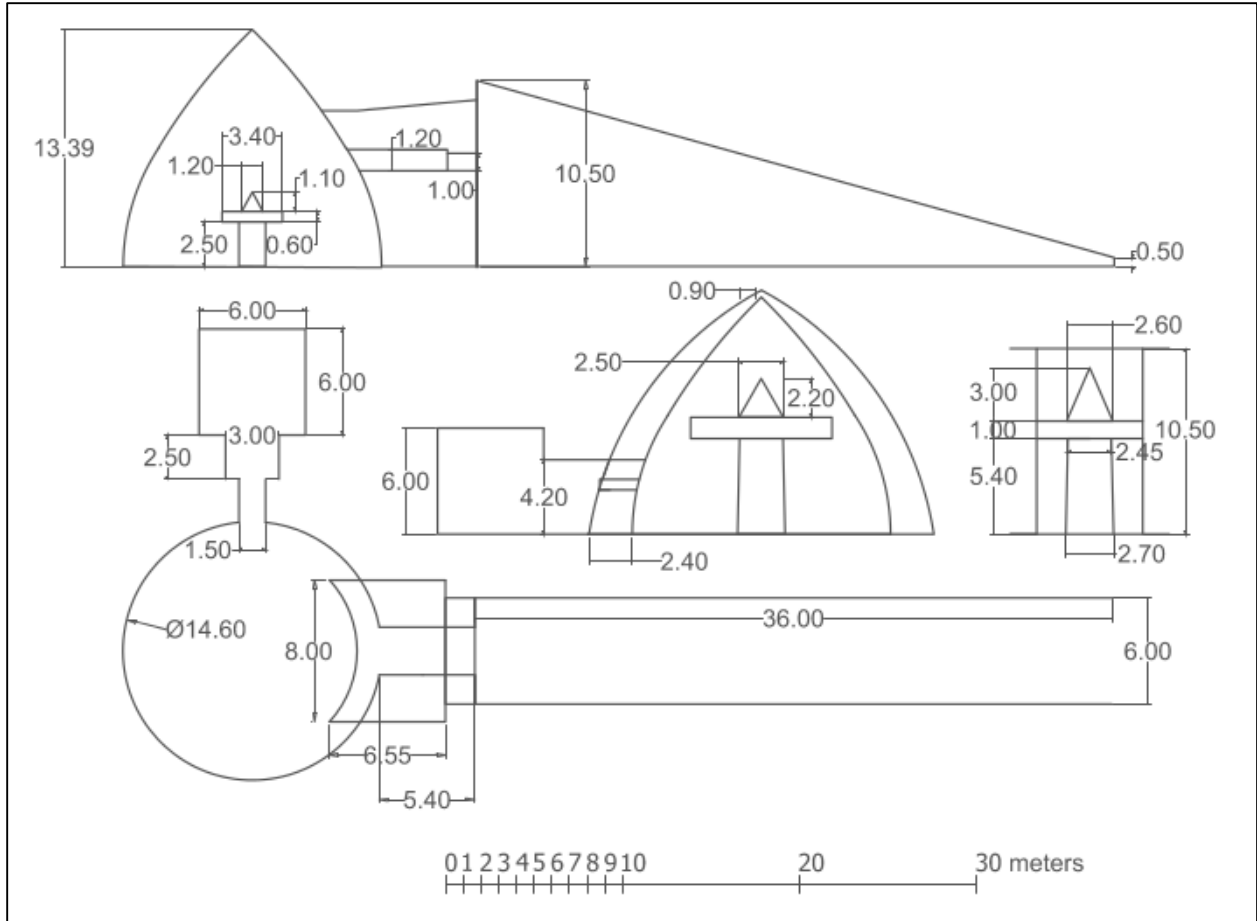
Figure A.25 Schematized plan and sections of the Treasury of Atreus with the dimensions in meters used for the CAD model (Adapted from Wace 1921–1923b, pl. LVI).
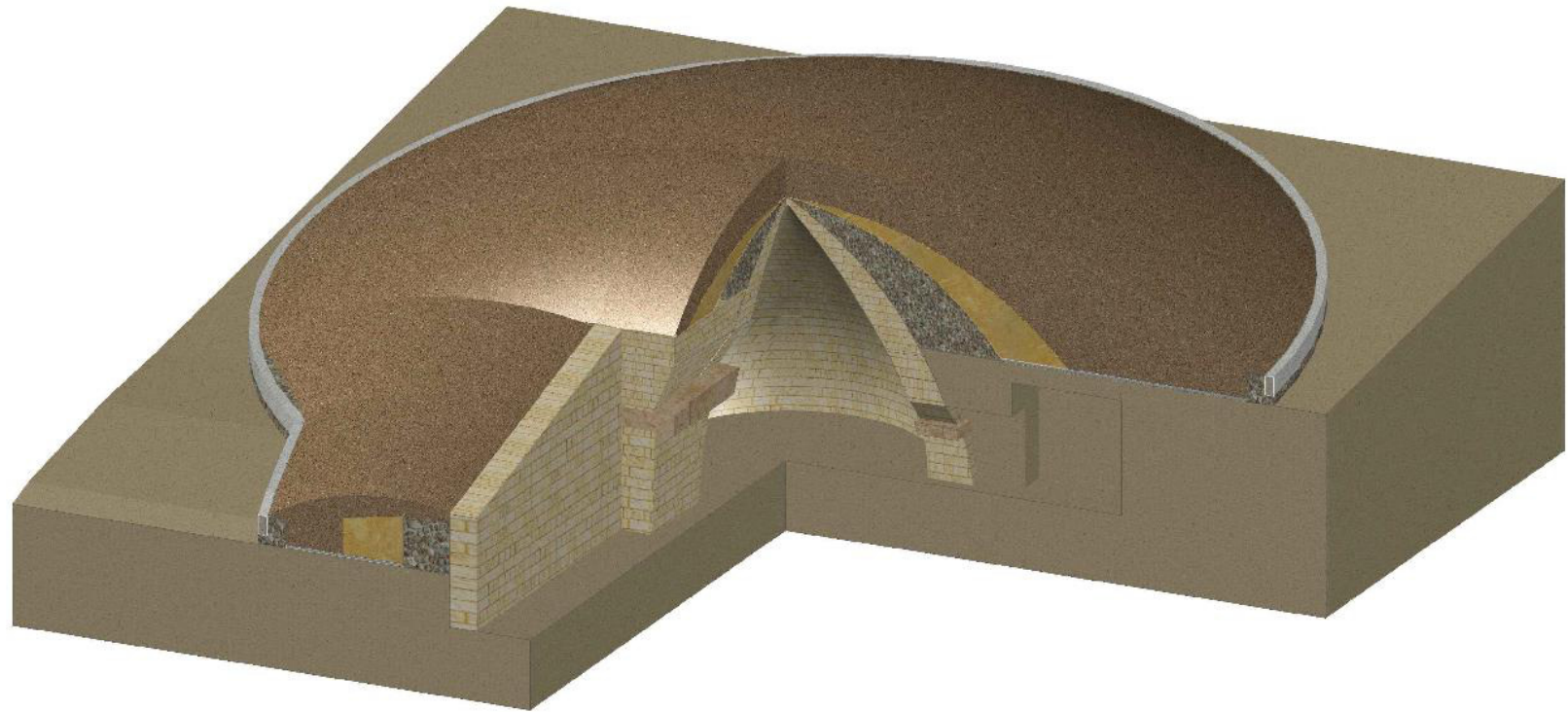
Figure A.26 Cutaway of the CAD model of the Treasury of Atreus showing all construction elements.
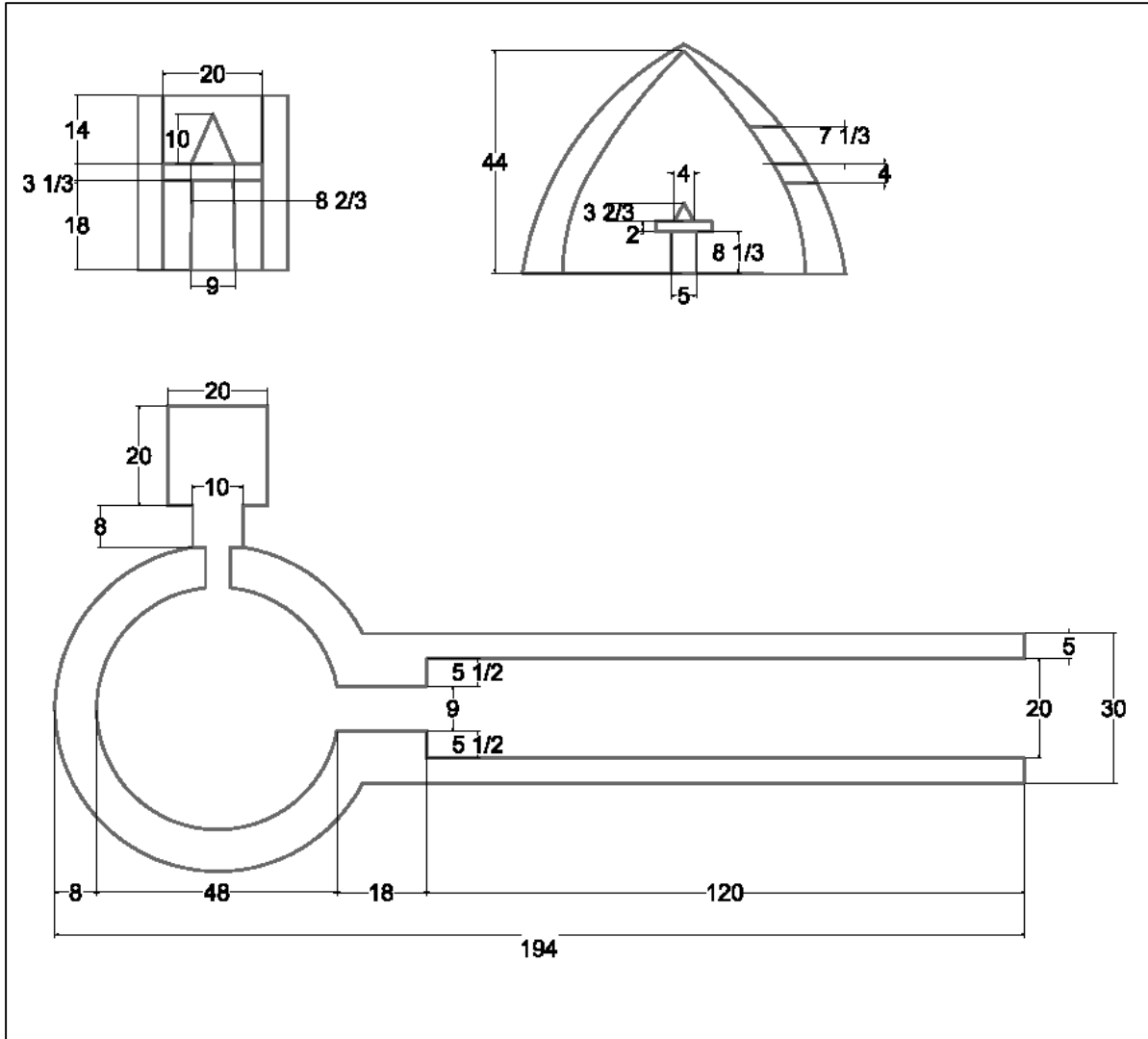
Figure A.27 Schematized plan and section of the Treasury of Atreus showing measurements in Mycenaean feet of 30 cm (Adapted from Wace 1921–1923b, pl. LVI).

Figure A.28 View towards the citadel and Mt. Profitis Ilias from the ridge over the Treasury of Atreus.
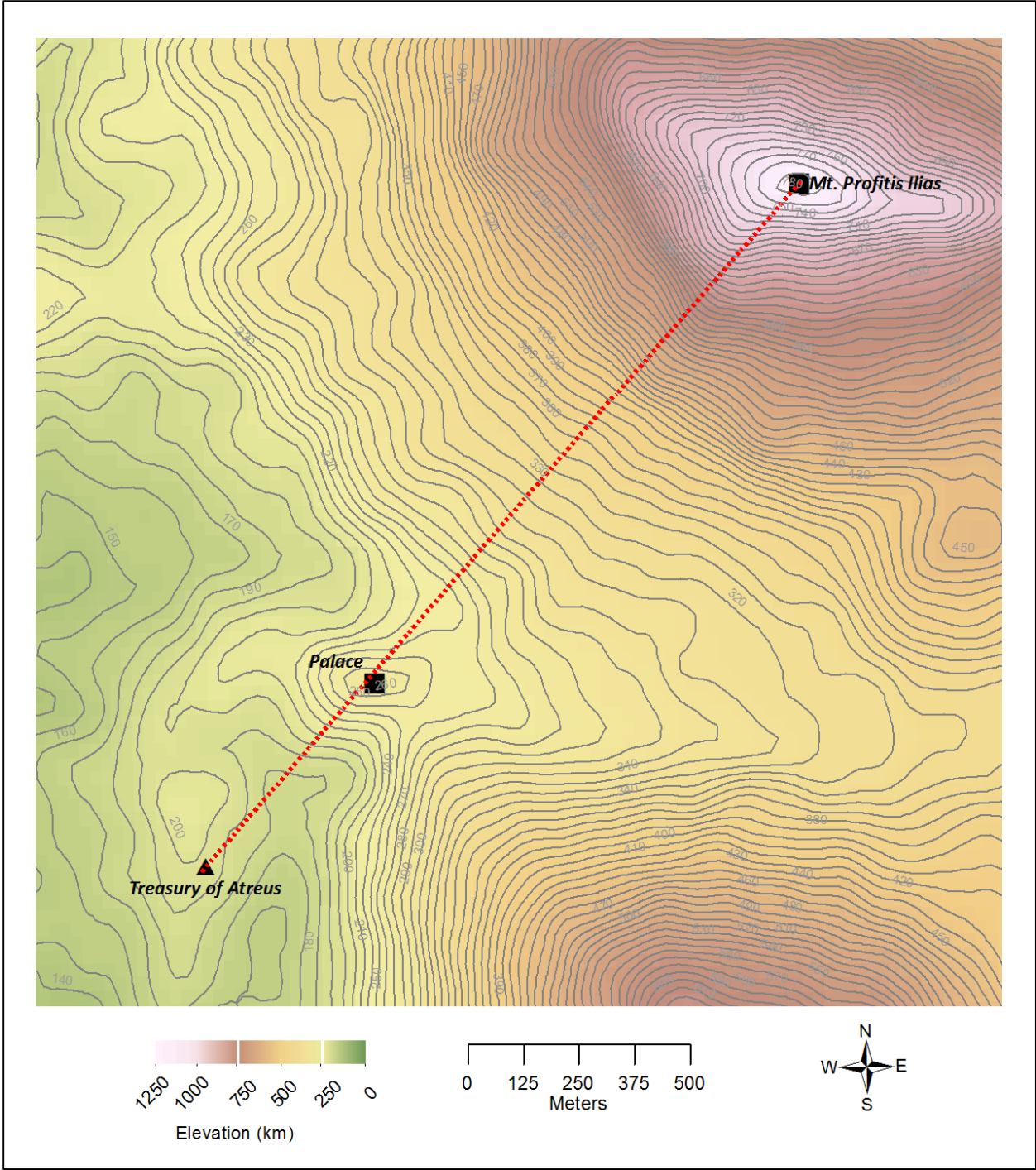
Figure A.29 The alignment of the Treasury of Atreus, the palace, and the peak of Mt. Profitis Ilias.
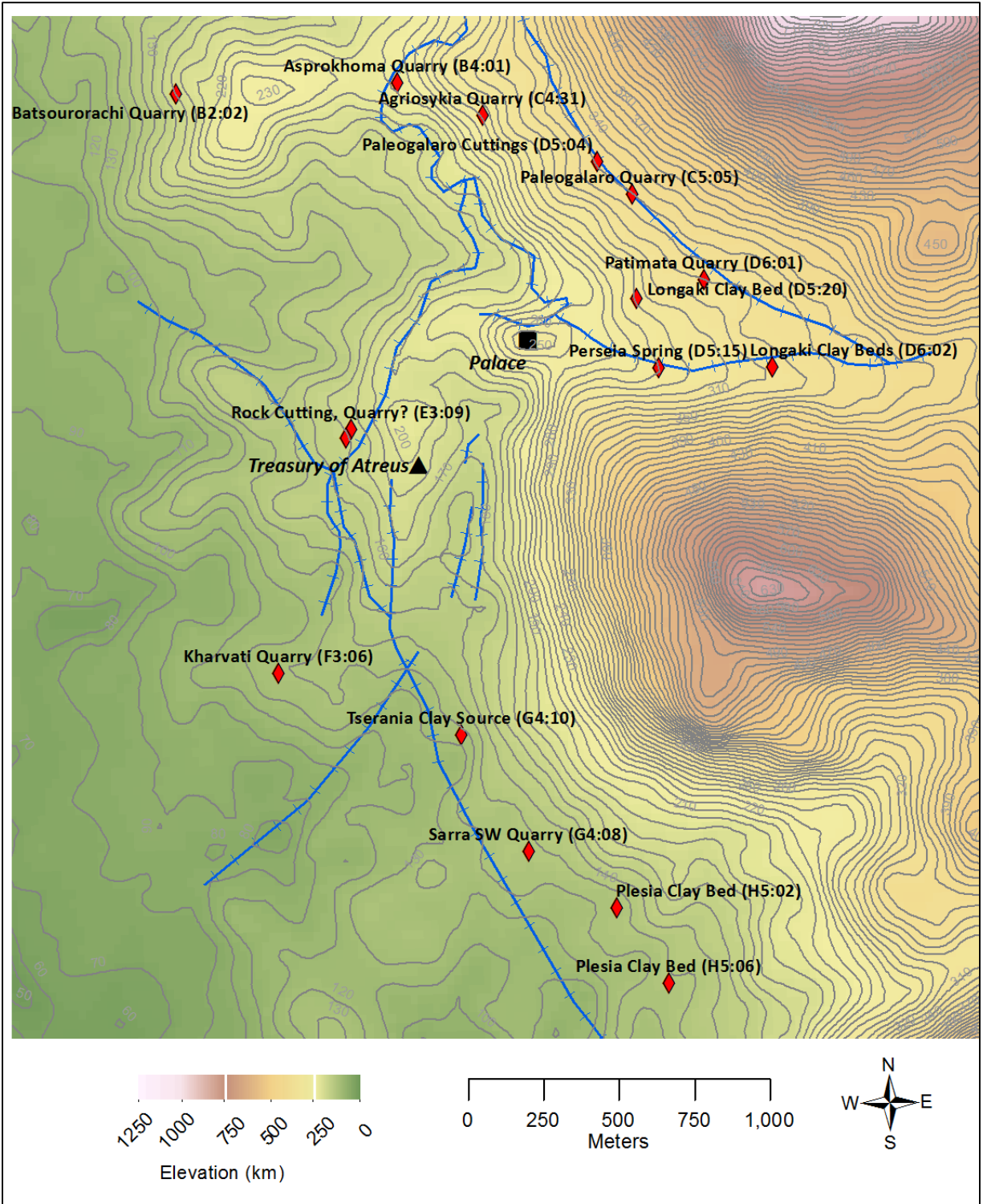
Figure A.30 The resources and road network surrounding the Treasury of Atreus. Designations in parentheses correspond to the Mycenae Atlas.
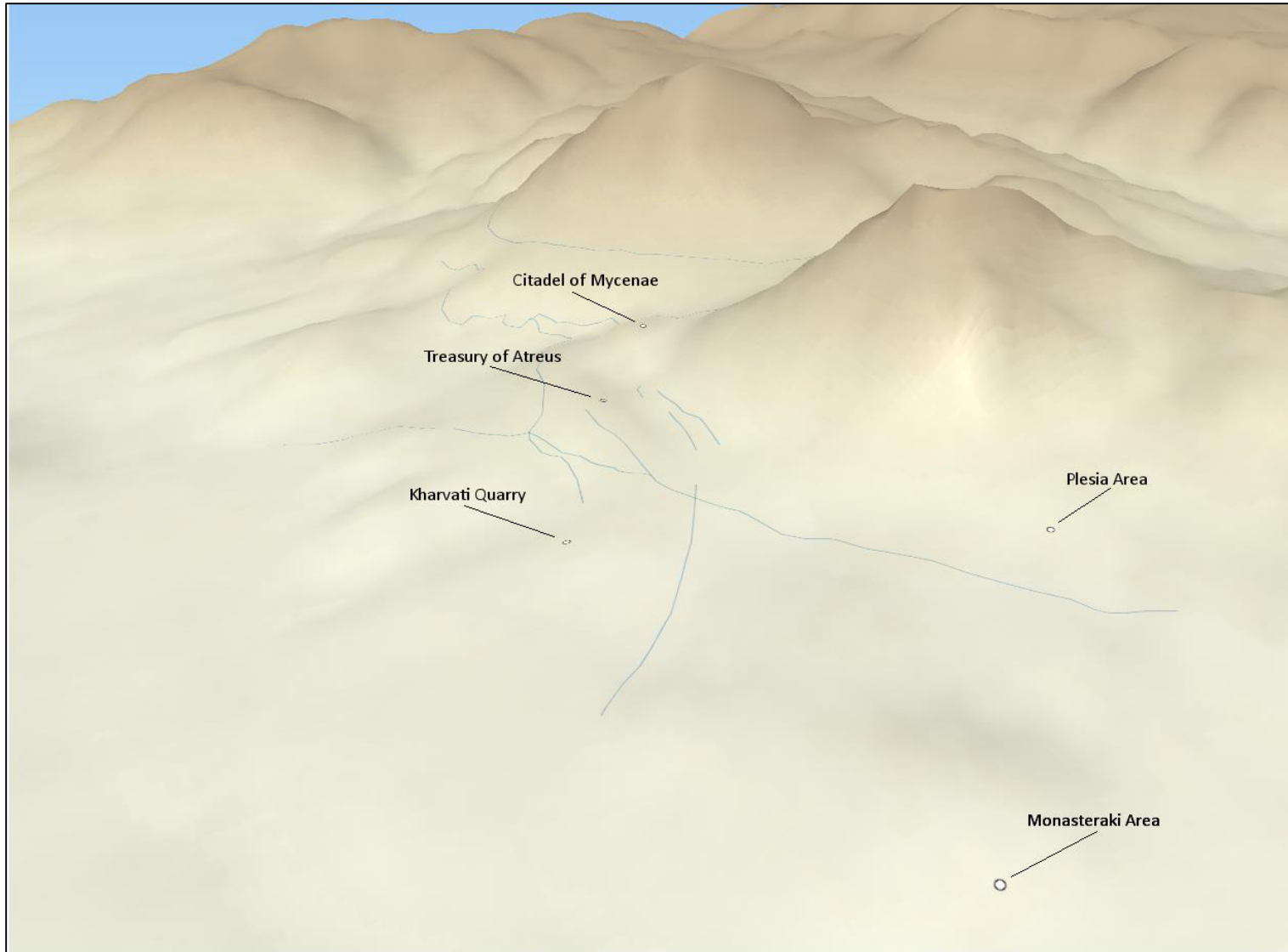
Figure A.31 Areas of resource exploitation in relation to the Treasury of Atreus. Light blue lines are the remains of roads.
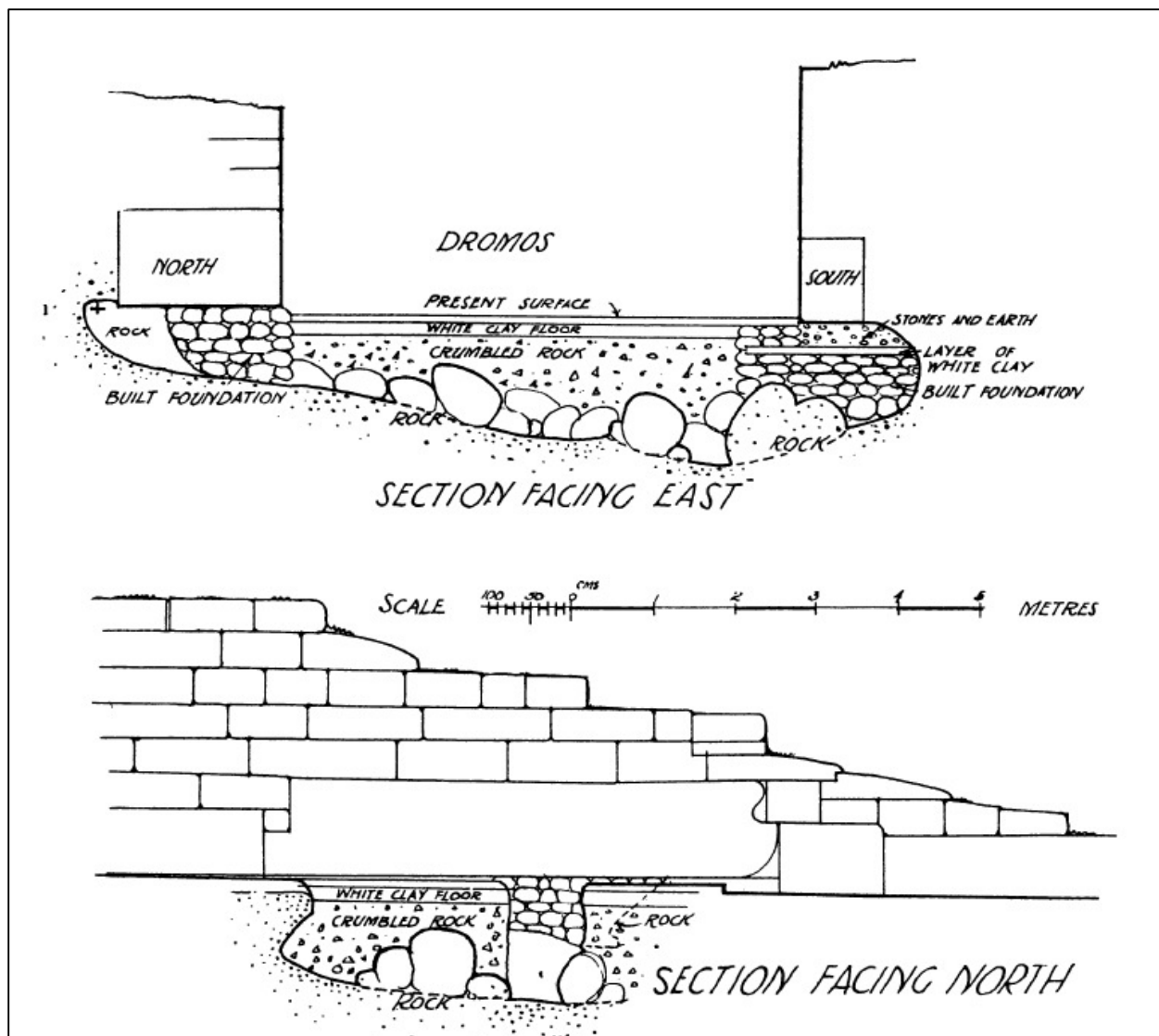
Figure A.32 Section under the eastern dromos showing how gaps in the rock were filled (Wace 1921–1923b, fig. 70).

Figure A.33 The western wall of the Tomb of Aegisthus' dromos showing how the dromos was excavated into the hill.

Figure A.34 A view into the Tomb of Clytemnestra's relieving triangle showing unworked conglomerate stones.
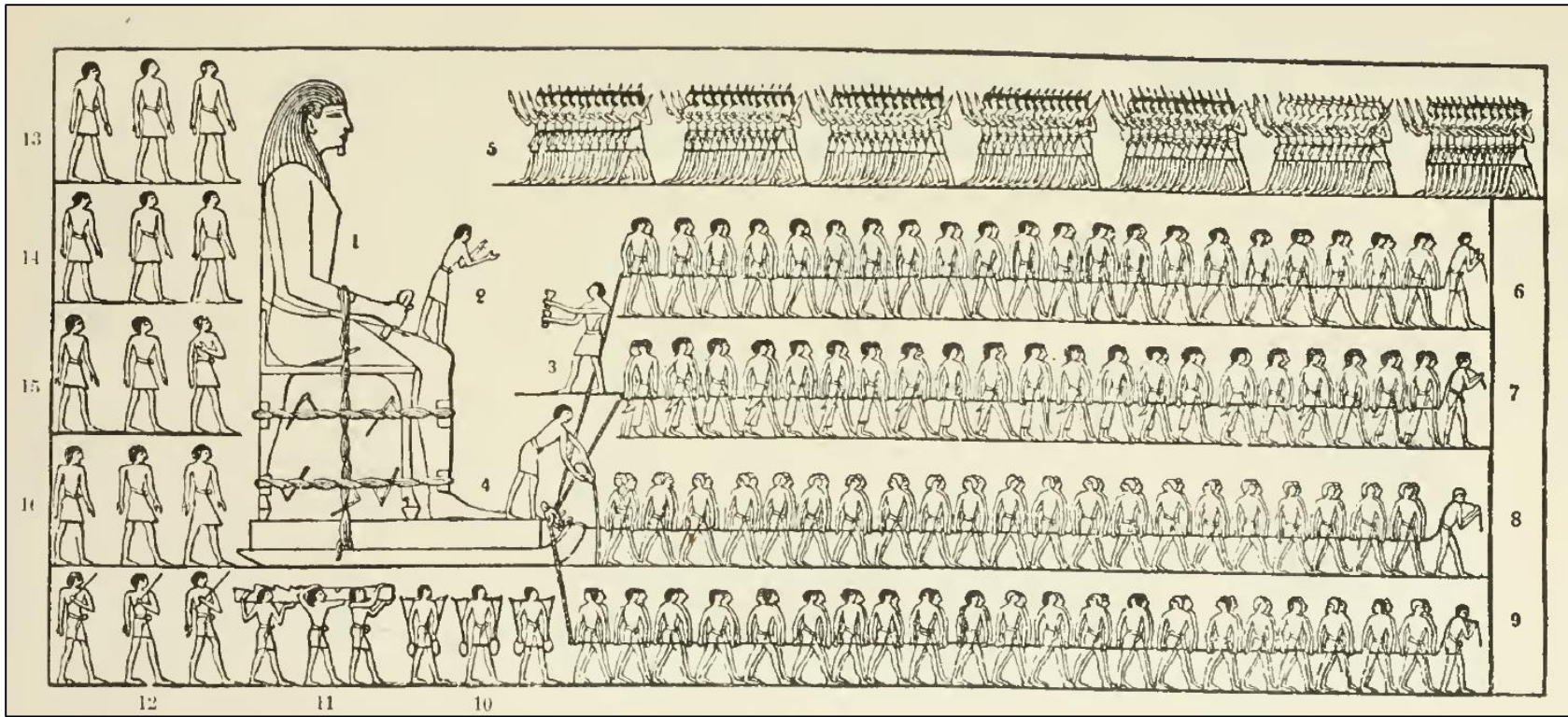
Figure A.35 The movement of a statue from the Tomb of Djehutihotep (Wilkinson 1878, 305 no. 429).
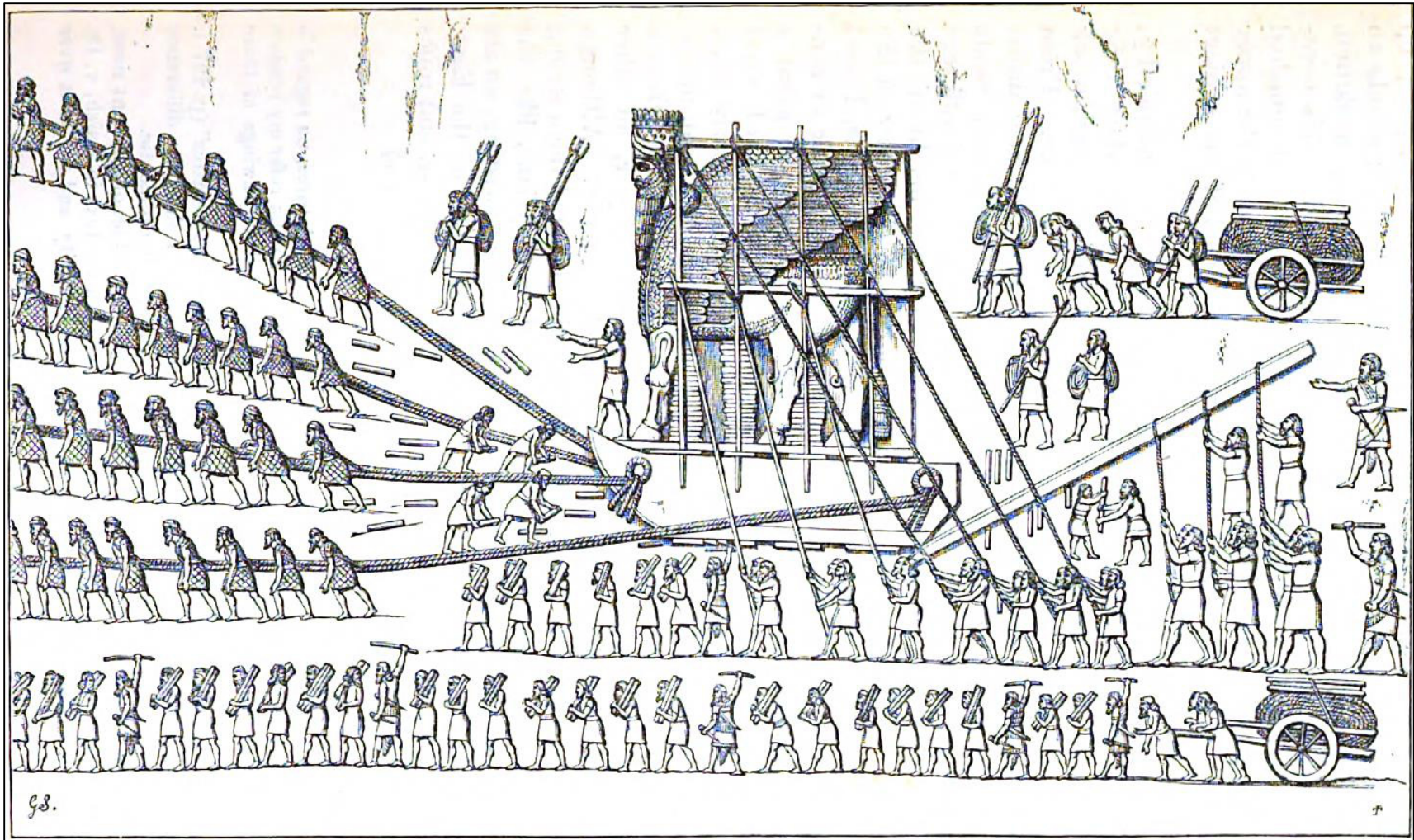
Figure A.36 An Assyrian colossus being transported to King Sennacherib's palace, 7th century B.C.E. (Layard 1853a, 113).
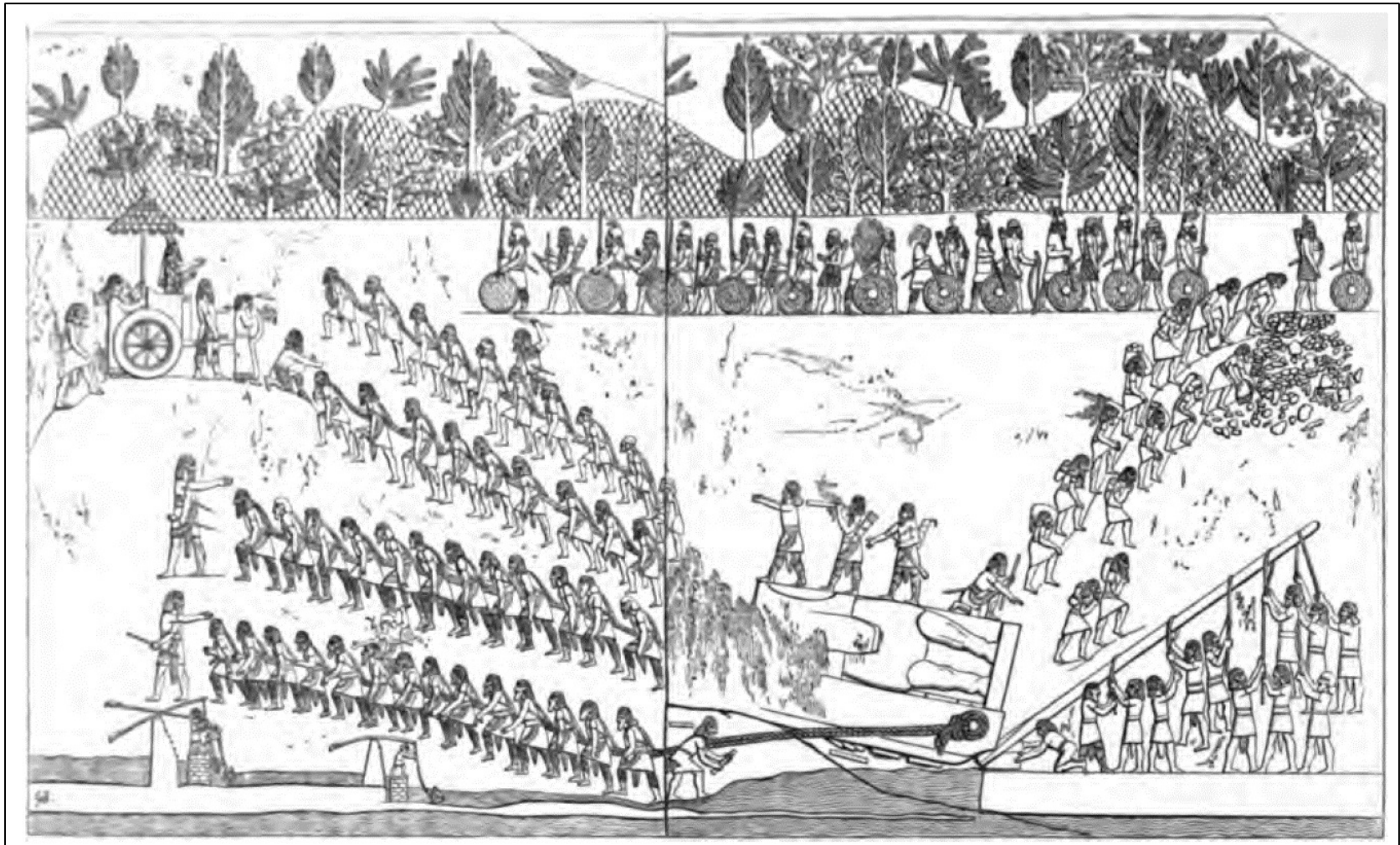
Figure A.37 Assyrian colossus being transported to King Sennacherib's palace, 7th century B.C.E. (Layard 1853a, 111).
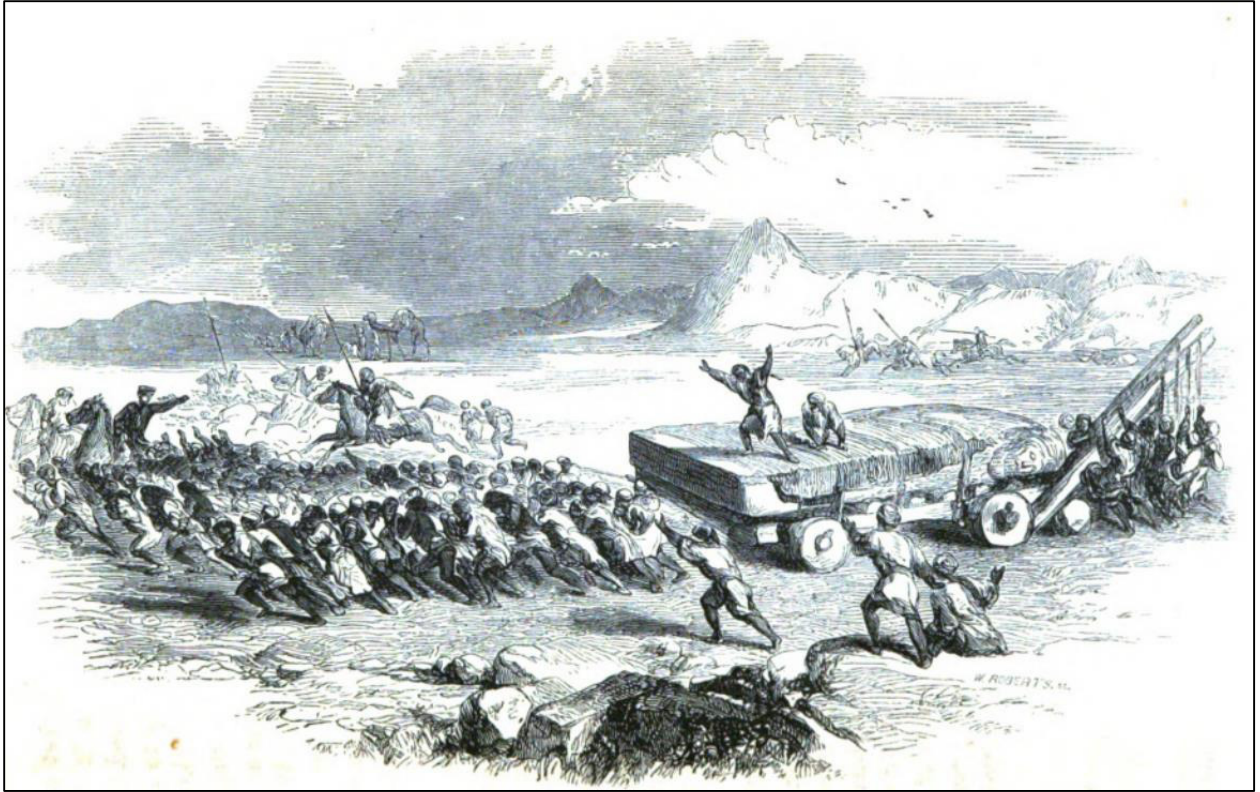
Figure A.38 Layard removes a colossal statue from Nimrud (Layard 1852, 296–7).

Figure A.39 The large block in the north dromos wall of the Treasury of Atreus. The block is worked to receive a rope and lever.

Figure A.40 Closeup of the large block in the north dromos wall of the Treasury of Atreus showing the location for a rope and lever.
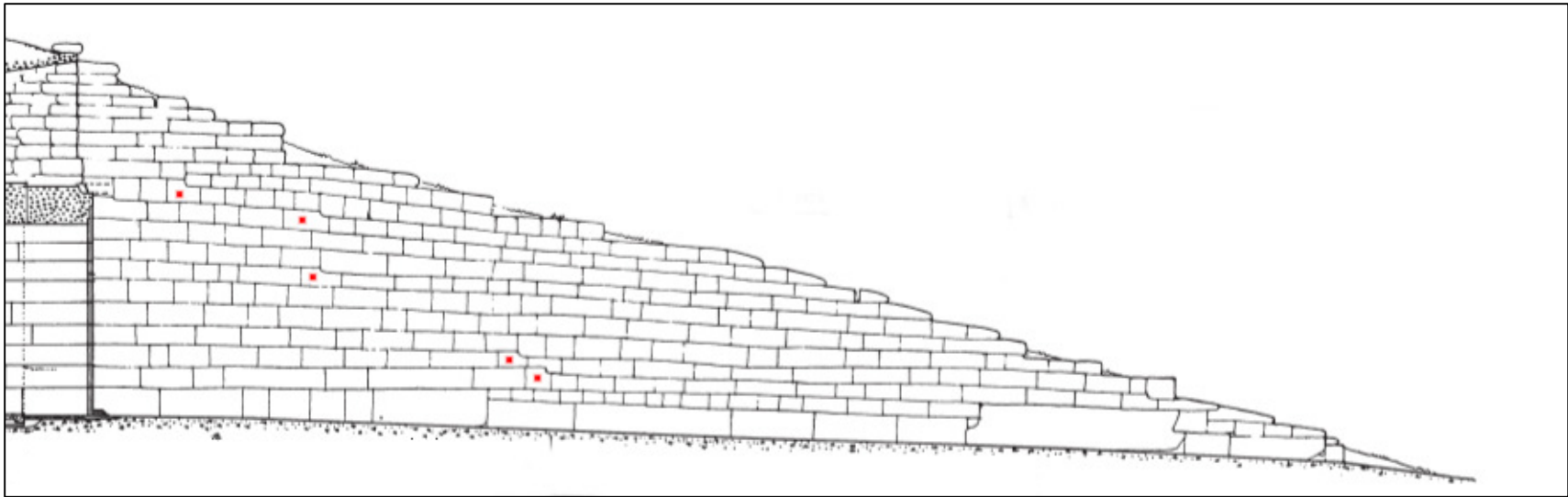
Figure A.41 The northern wall of the Treasury of Atreus' dromos showing the location of "hookstones" marked in red (Modified from Wace 1921–1923b, pl. LVI).

Figure A.42 The meeting of the south dromos wall and the upper façade in the Treasury of Atreus.

Figure A.43 A roughly dressed coping stone from the Treasury of Atreus' dromos, showing the use of chinking
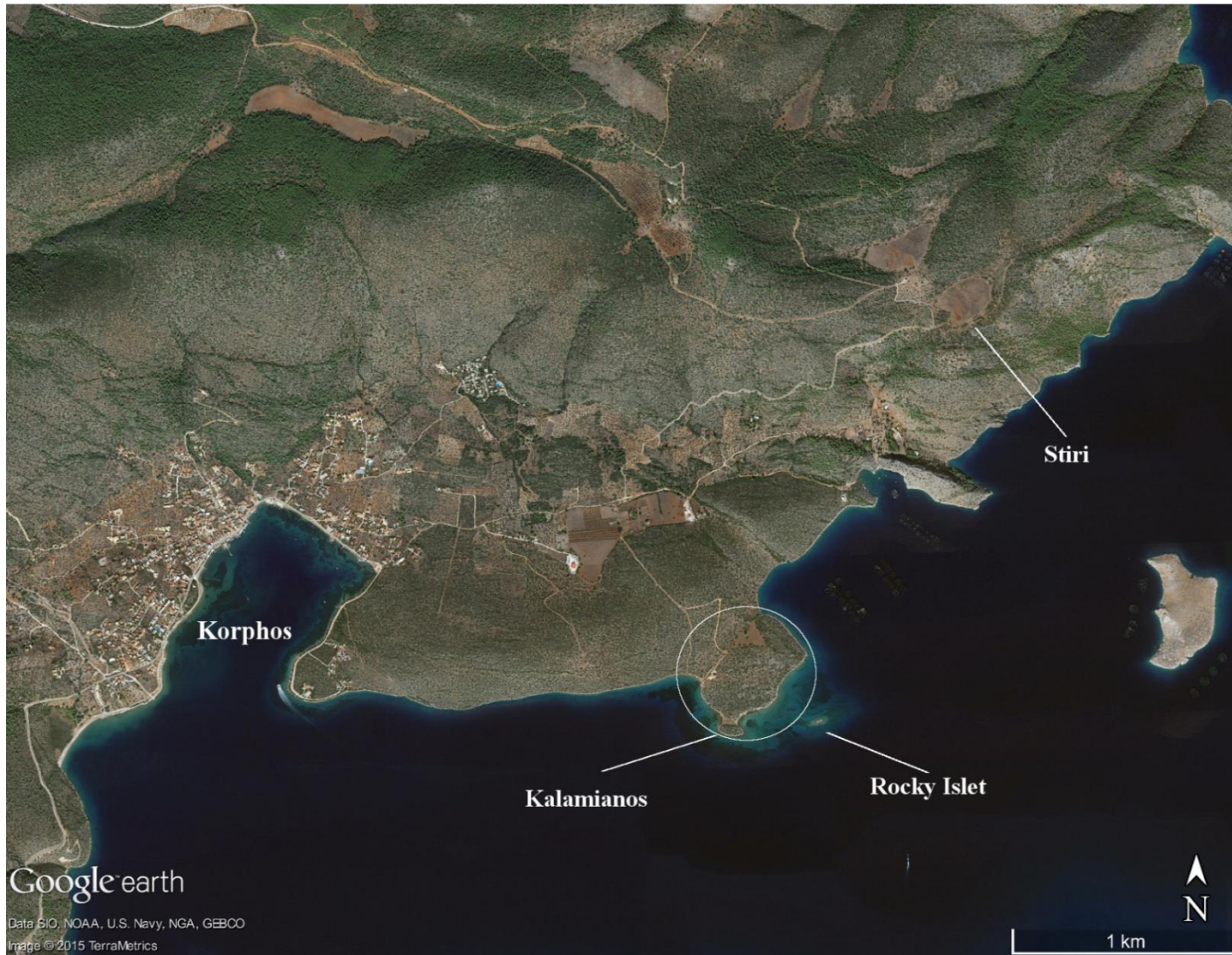
Figure A.44 Kalamianos and its immediate region.
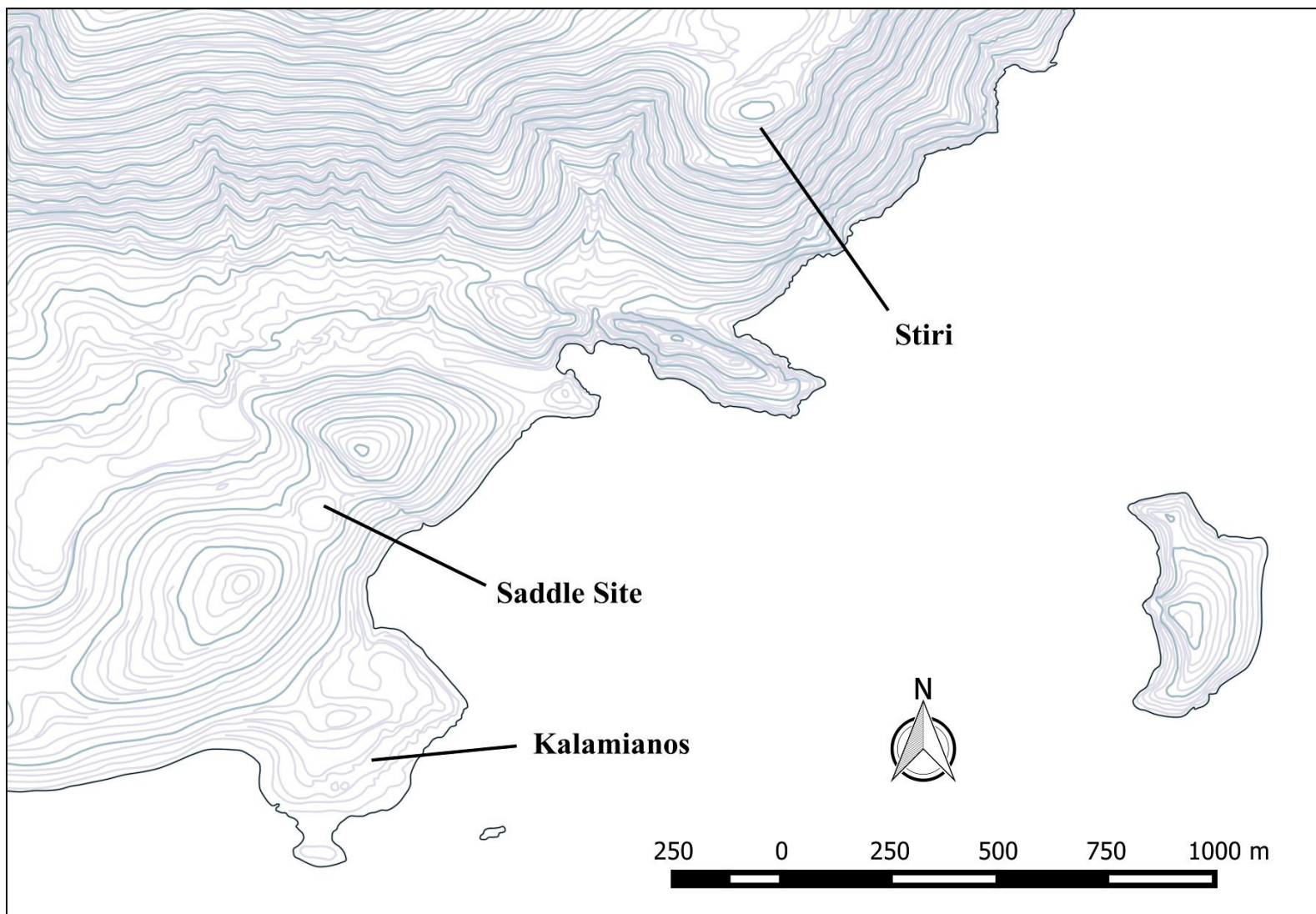
Figure A.45 A map of Kalamianos, the Saddle Site, and Stiri.
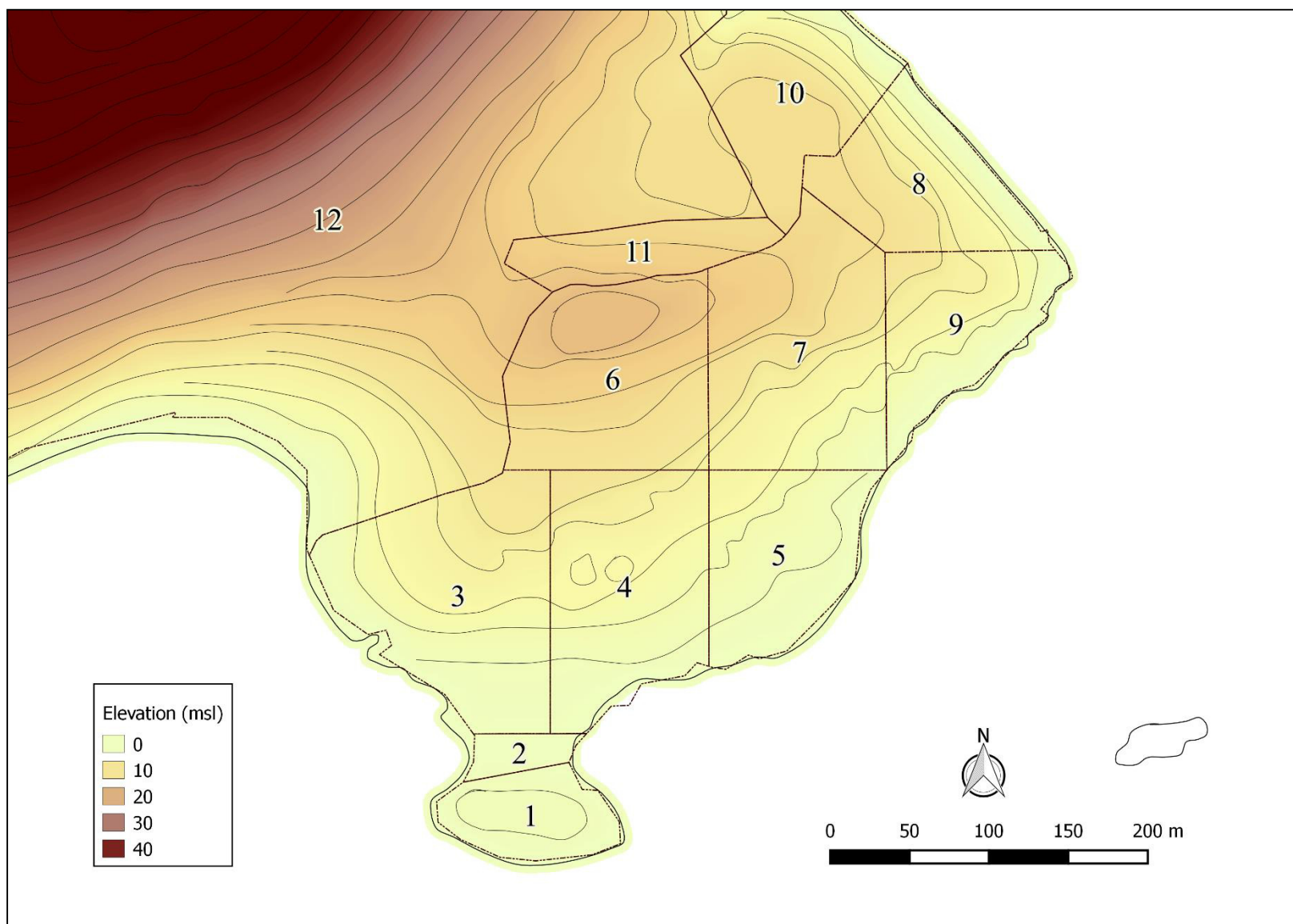
Figure A.46 The division of Kalamianos into sectors
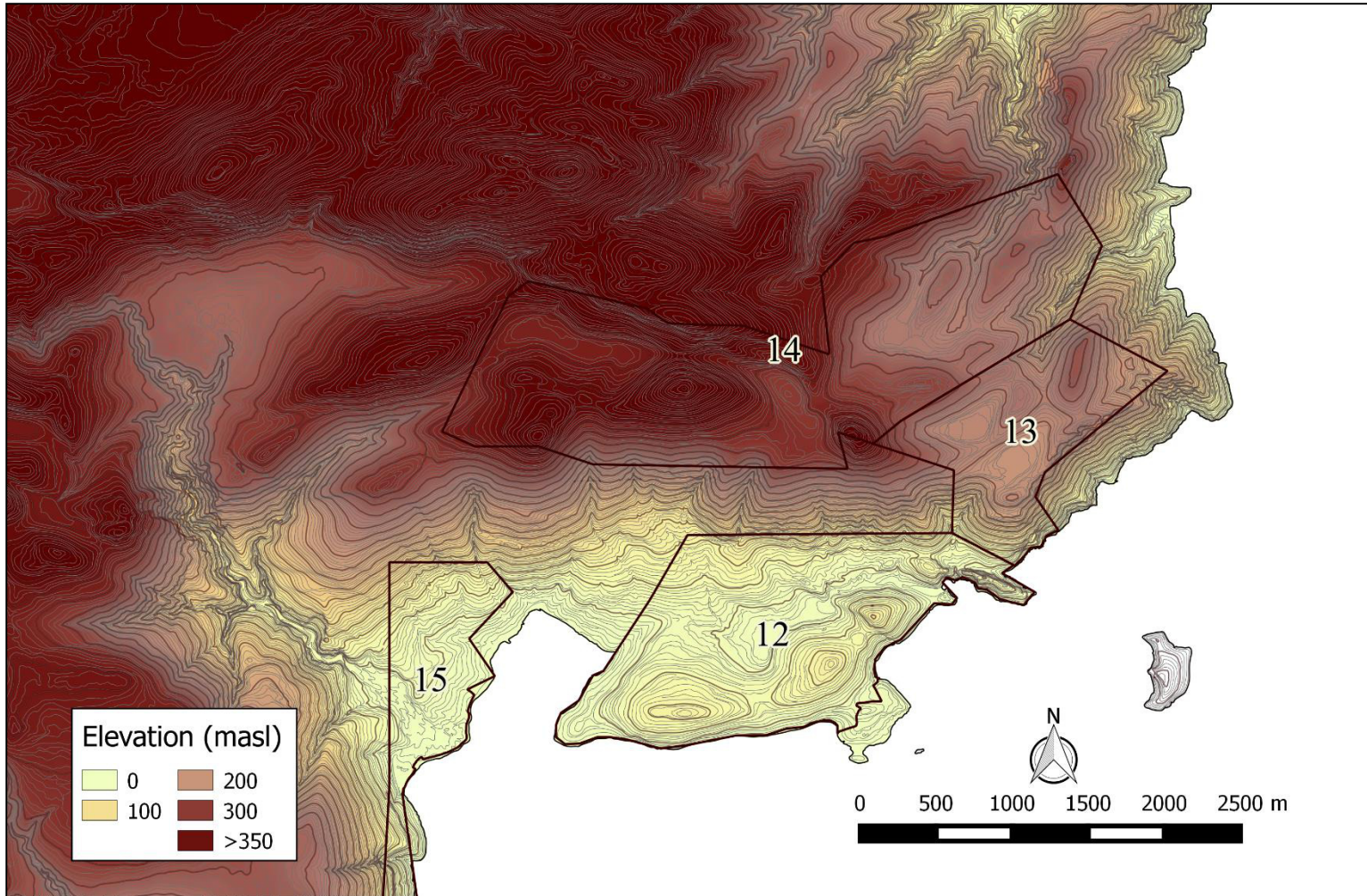
Figure A.47 A map of sectors 12–15.
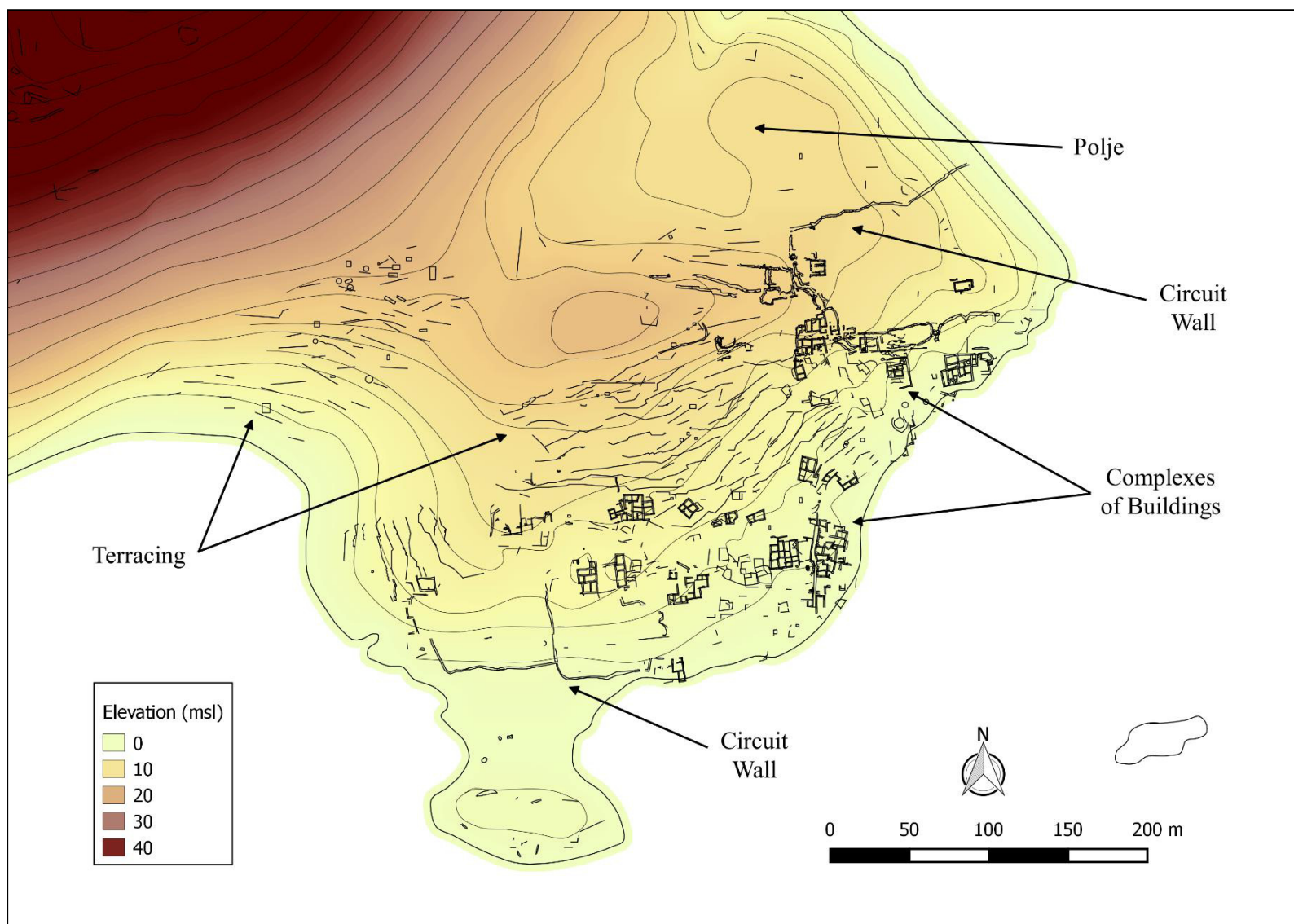
Figure A.48 The architectural remains at Kalamianos.

371
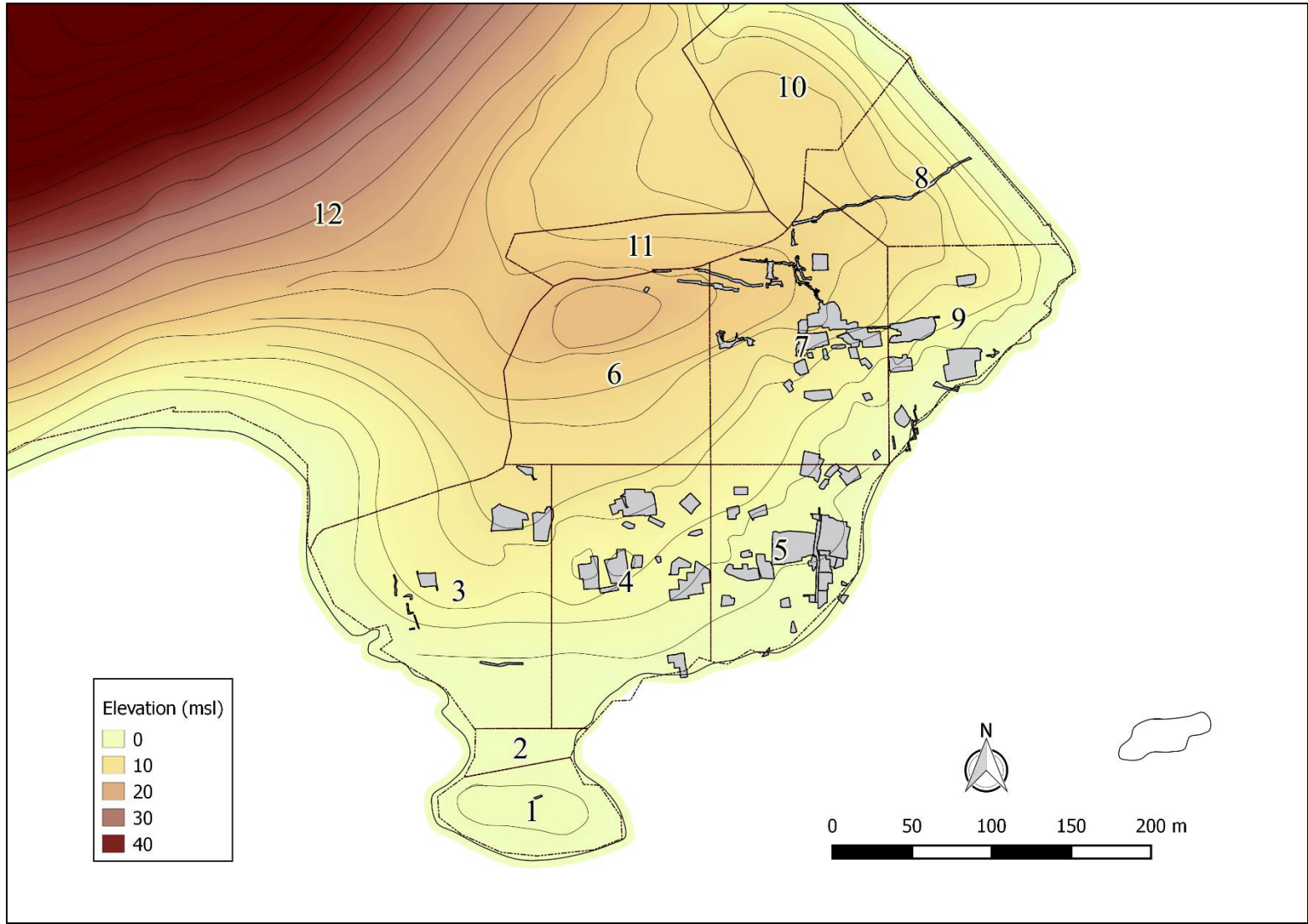
Figure A.49 Outlines of the major identified structures at Kalamianos.
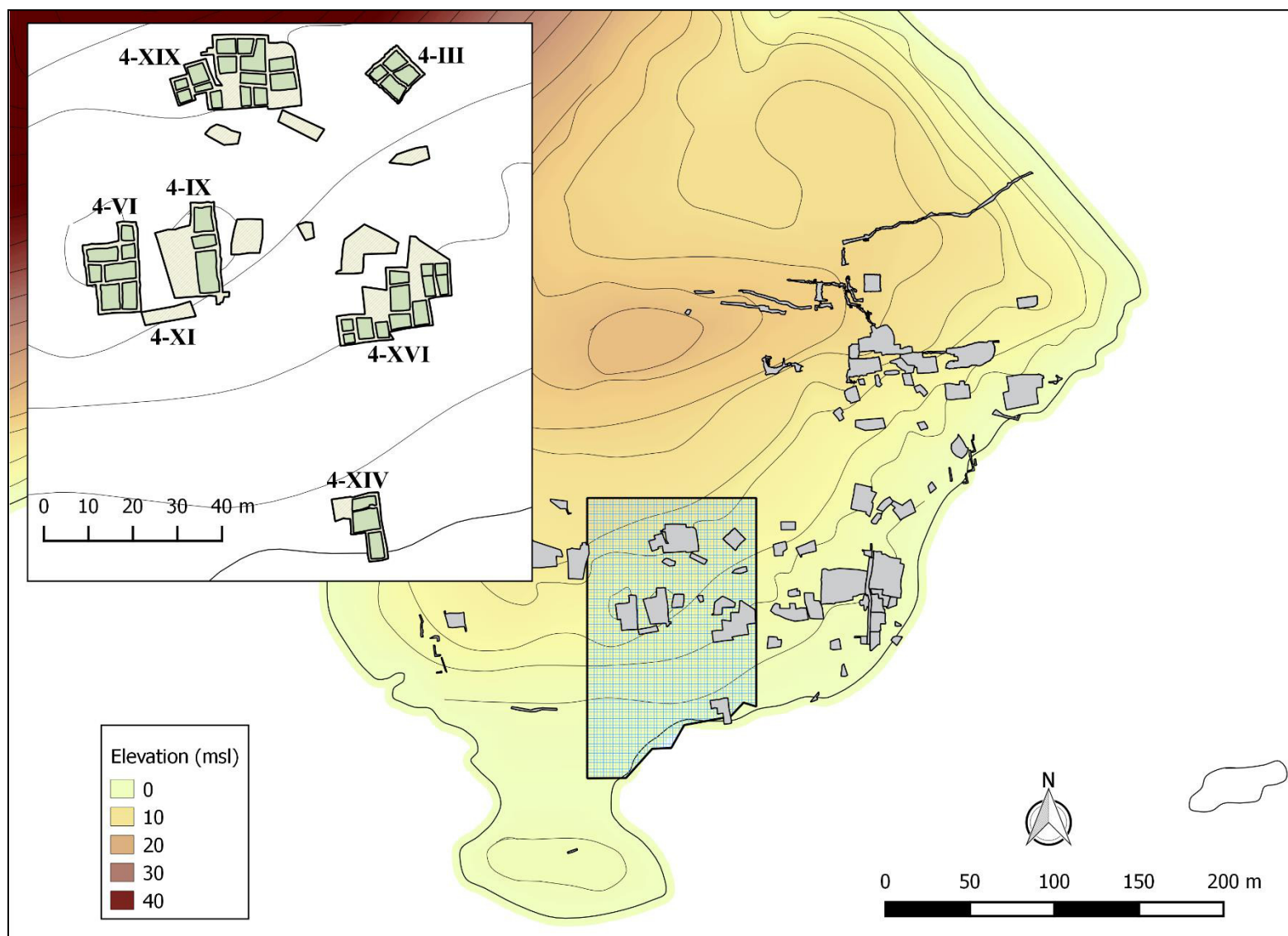
Figure A.50 Closeup of the structures and rooms in sector 4.

Figure A.51 Stone-by-stone drawing of structure 4-VI.

Figure A.52 Exterior face of wall 403 in structure 4-VI showing how courses were set on flattened bedrock with small leveling stones inserted.

Figure A.53 Western portion of wall 408 in structure 4-VI facing east showing typical wall construction.

Figure A.54 Western face of wall 403 in structure 4-VI showing the use of chinking between larger, irregular stones.

Figure A.55 A large corner block at the southwestern corner of wall 408 in structure 4-VI.
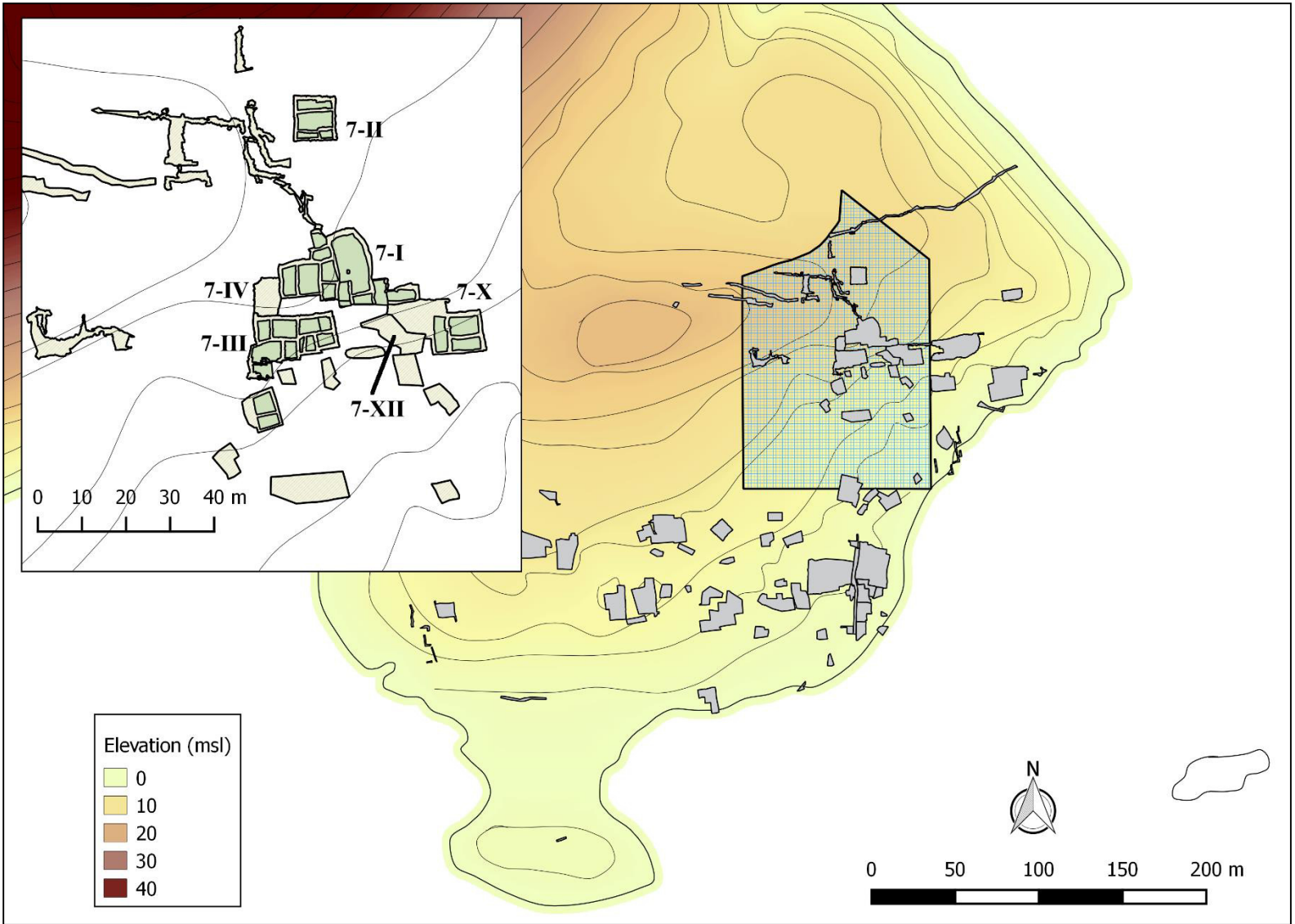
Figure A.56 Closeup of the structures and rooms in sector 7.
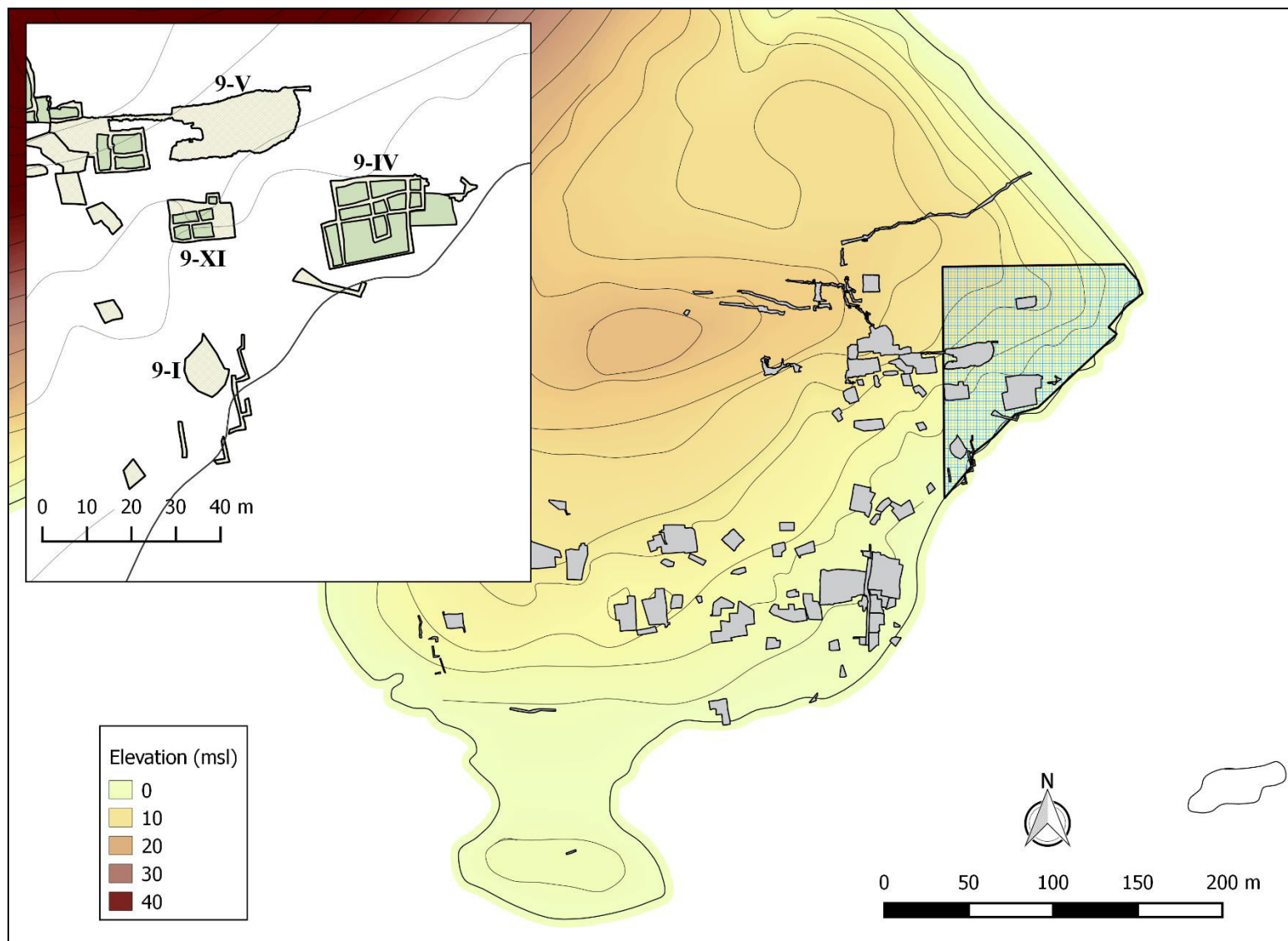
Figure A.57 Closeup of the structures and rooms in sector 9.

Figure A.58 Structure 7-X stone by stone drawing.

Figure A.59 The entrance to 7-X that runs through wall 270.

Figure A.60 The antae blocks on the north end of 7-X's main entrance.

Figure A.61 The doorway to space 2 in structure 7-X, with a possible blocking wall added later.

Figure A.62 A tumbled section of wall 271 in structure 7-X showing flattened bedrock used as a foundation.

Figure A.63 Overview of wall 270 in structure 7-X facing south showing the manner of wall construction.

Figure A.64 The exterior face of wall 272 in structure 7-X at its southern end showing the manner of wall construction.

Figure A.65 The exterior corner of walls 271 and 272 in structure 7-X.

Figure A.66 The reconstruction of 4-VI sectioned and viewed from the east.
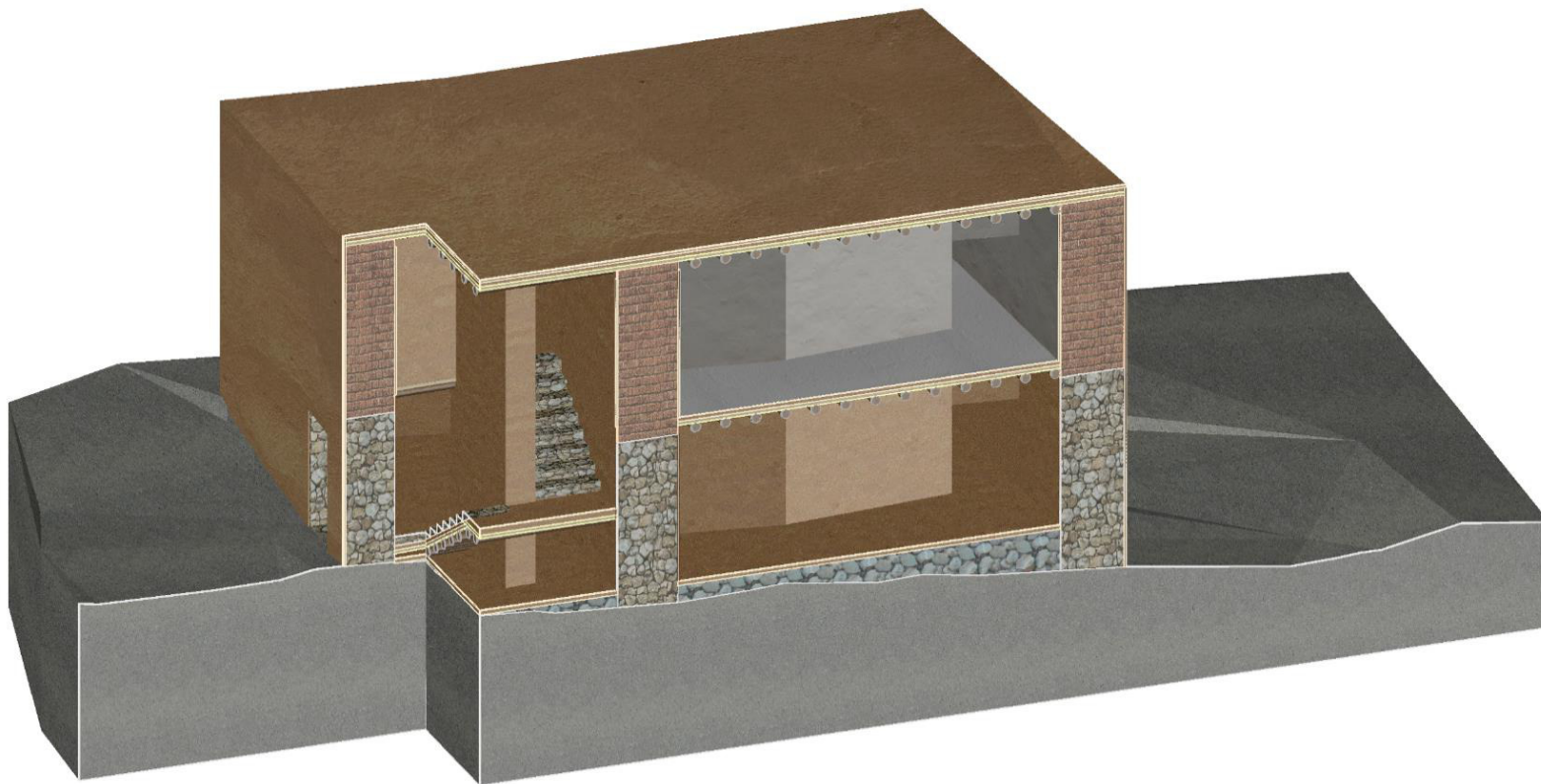
Figure A.67 The reconstruction of 7-X sectioned and viewed from the south.

Figure A.68 Room 10 of Structure 7-I showing a large piece of unworked bedrock along the eastern edge of the room.

Figure A.69 A premodern house at Korphos made of rubble and locally-derived mortar.
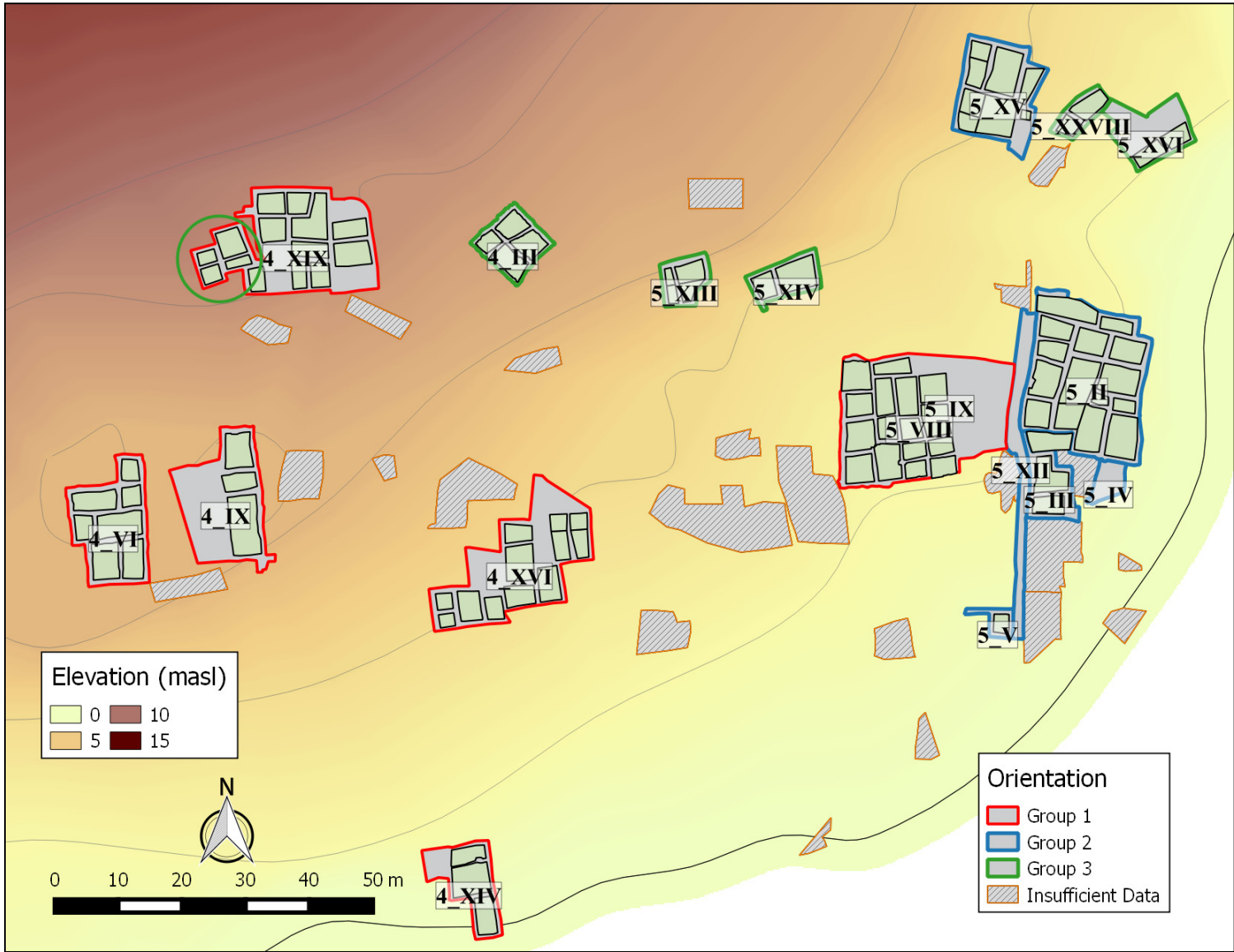
Figure A.70 The orientation of buildings in sectors 4 and 5.
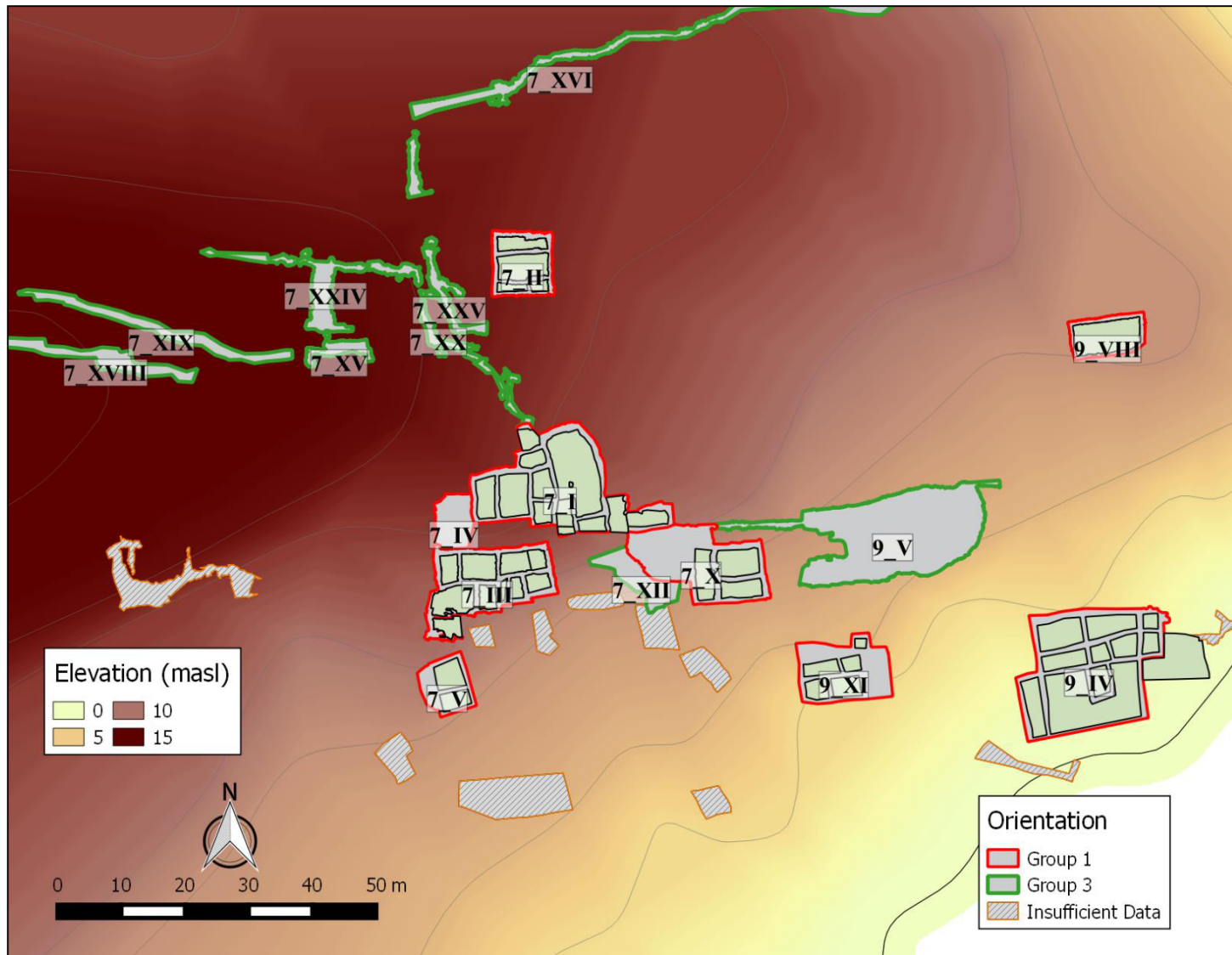
Figure A.71 The orientation of buildings in sectors 7 and 9
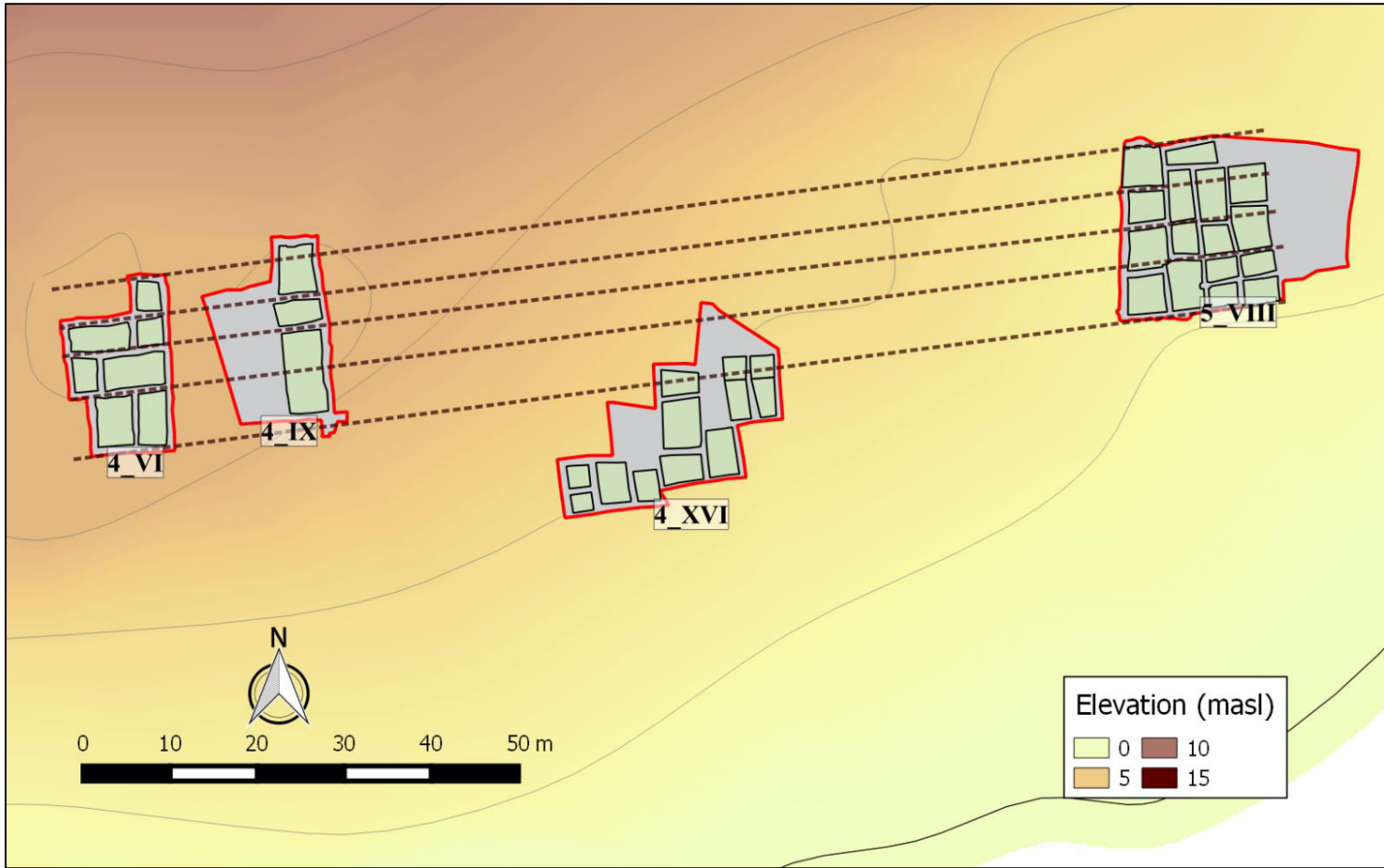
Figure A.72 The gridded layout of 4-VI and surrounding structures
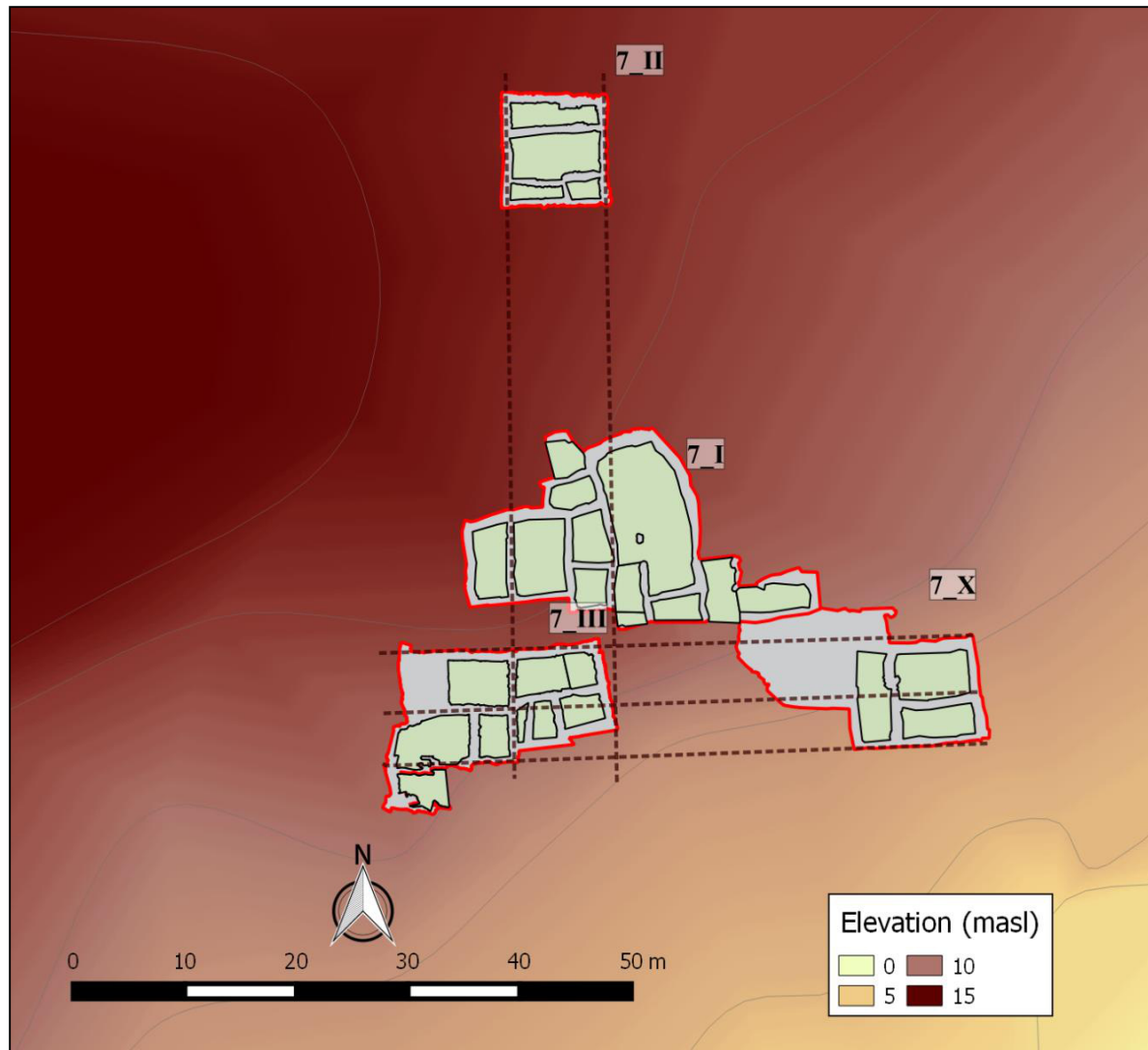
Figure A.73 The gridded layout of 7-X and surrounding structures.
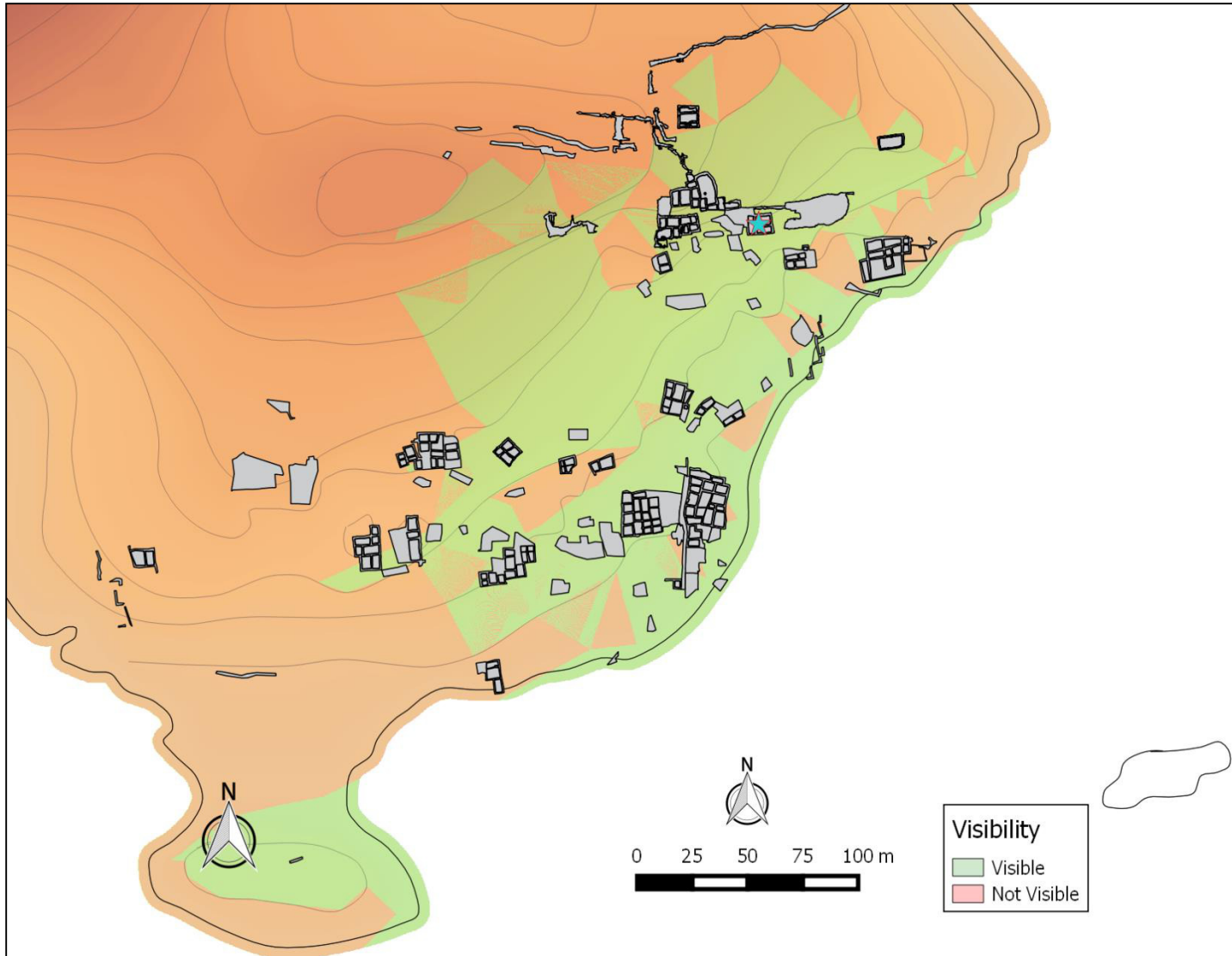
Figure A.74 Visibility from structure 7-X at a height of 3 meters.
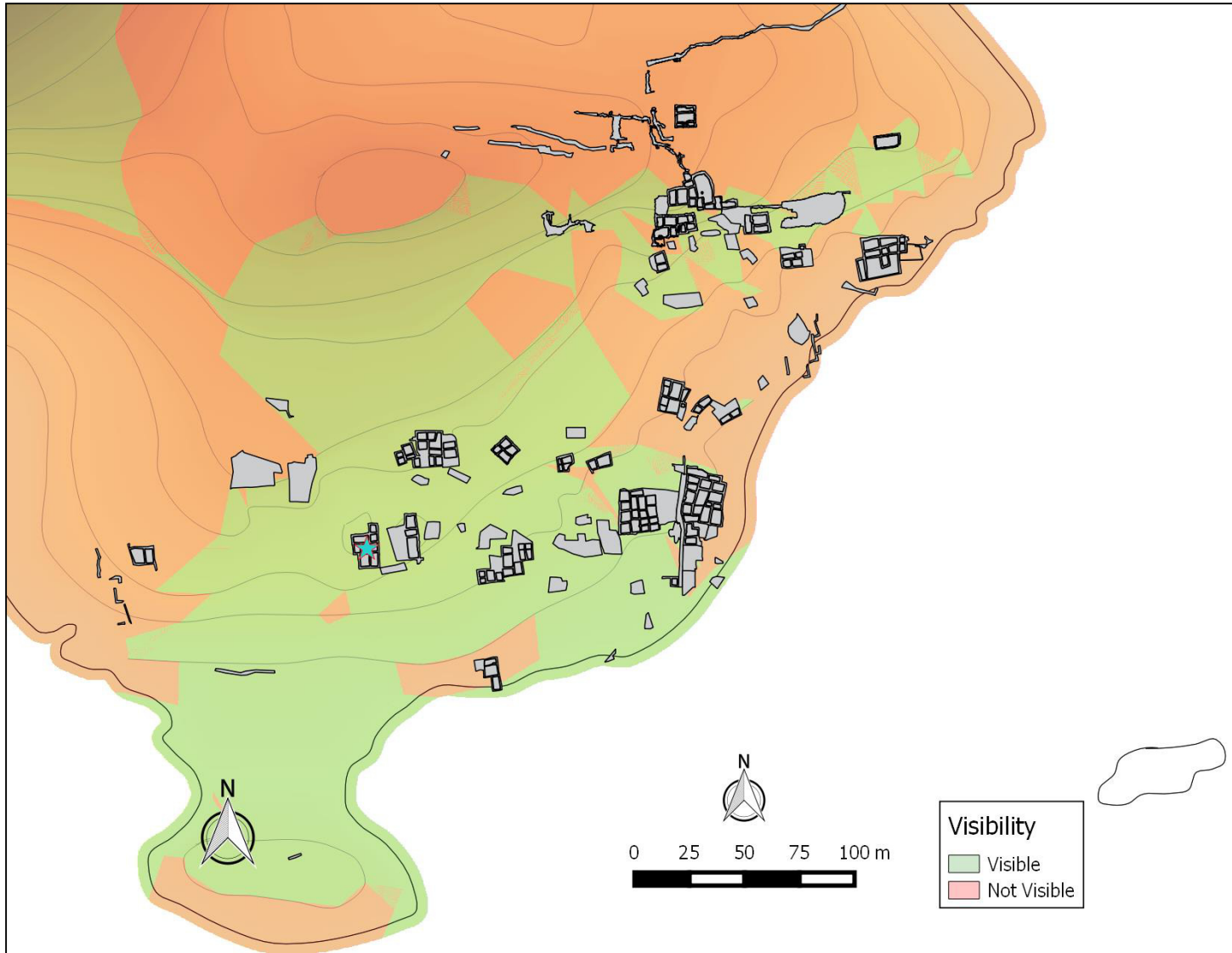
Figure A.75 Visibility from structure 4-VI at a height of 3 meters.
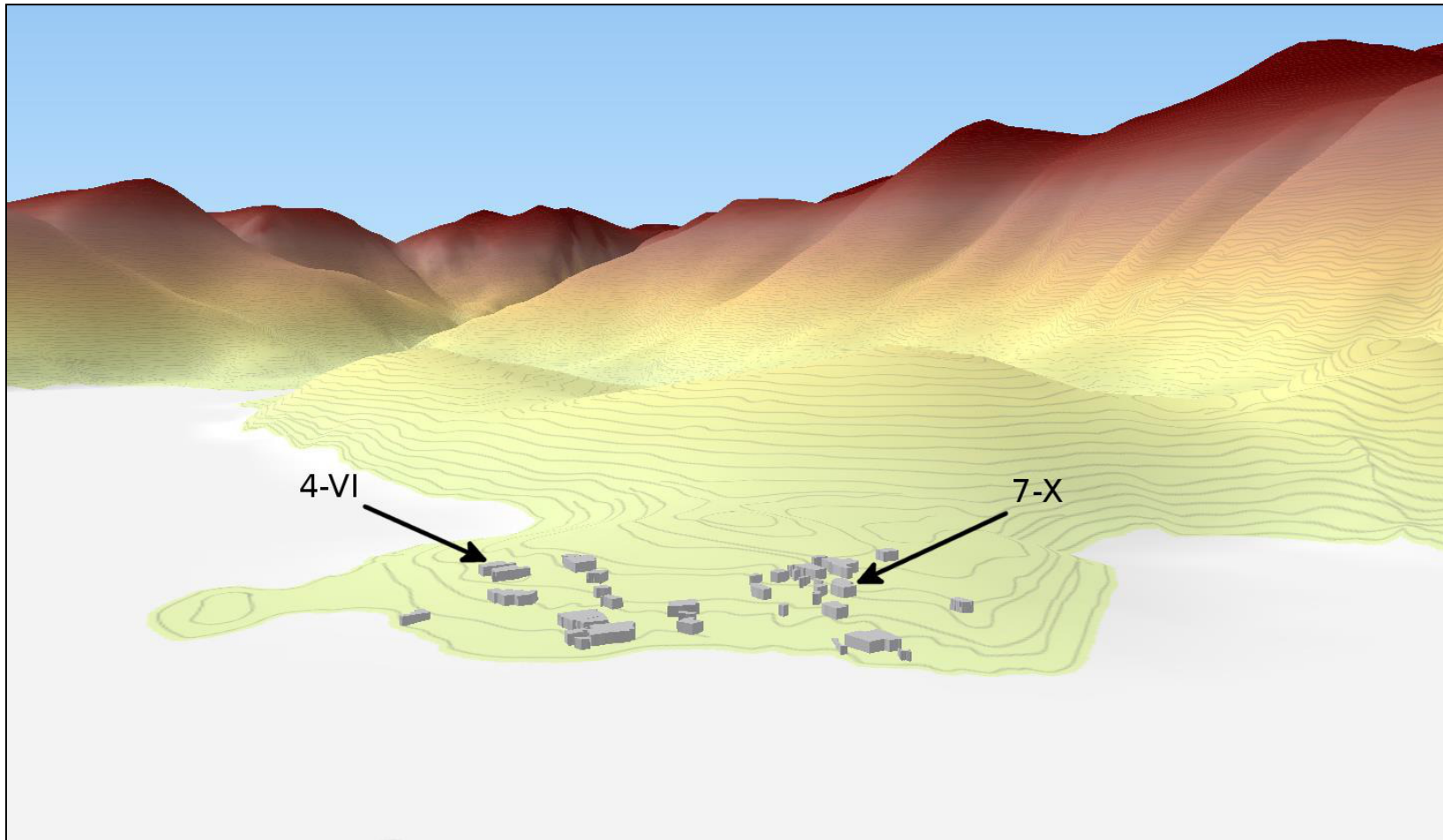
Figure A.76 A 3-D rendering of Kalamianos from the east with major structures (excluding circuit walls and paths) extruded 3 m from the surface.

Figure A.77 Unworked bedrock and terrain to the north of structure 7-X.

Figure A.78 An example of the exposed bedrock covering the terrain south of structure 4-VI.

Figure A.79 A piece of limestone split along fracture lines using a modern chisel.

Figure A.80 The northwestern area of structure 4-VI with evidence of quarrying.
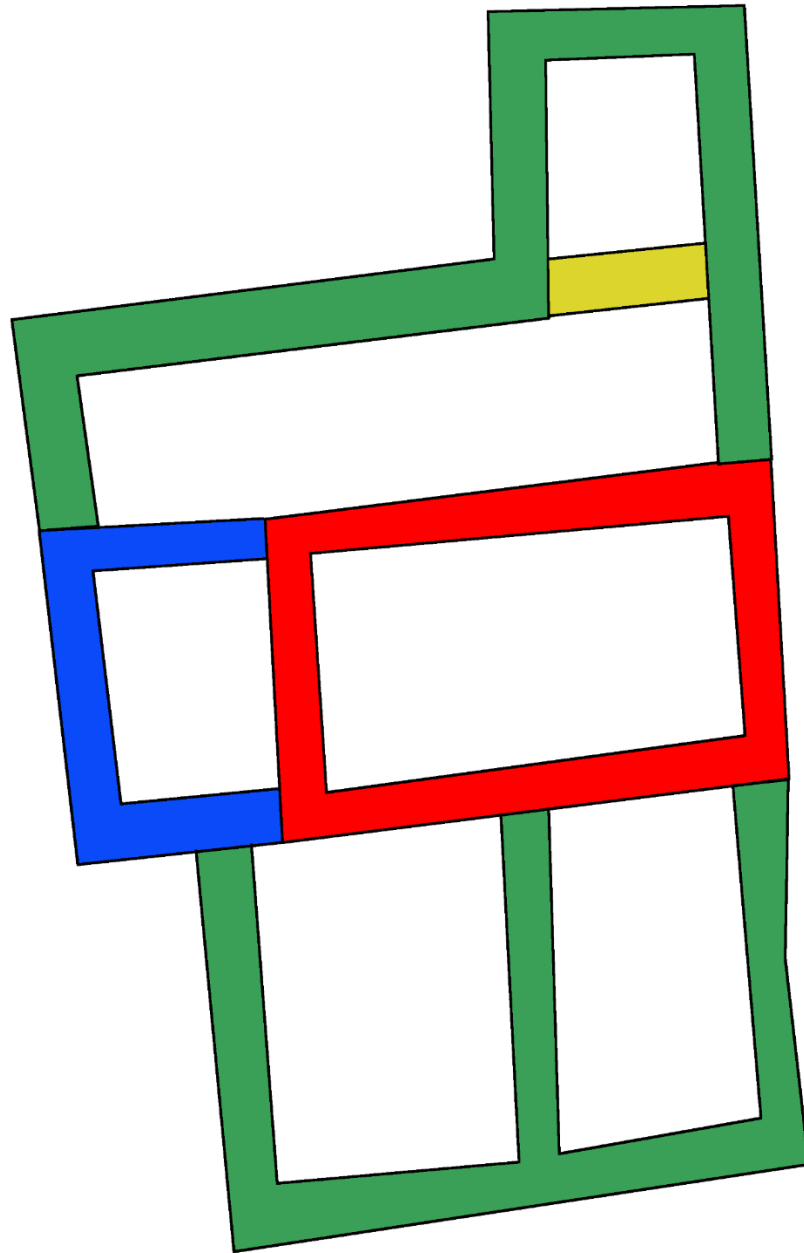
Figure A.81 The hypothesized staging for the construction of structure 4-VI.
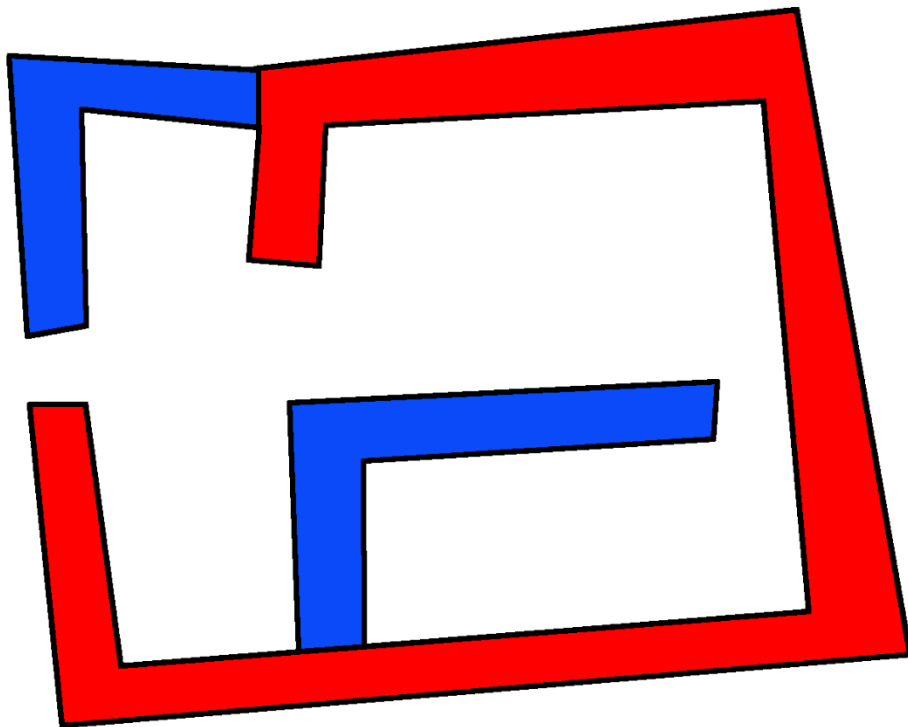
Figure A.82 The hypothesized staging for construction of structure 7-X.

Figure A.83 Structure 13-II at Stiri which has been cut by a modern road revealing fill and a floor level.

Figure A.84 The citadel of Mycenae from the southwest.

Figure A.85 The citadel of Mycenae showing the current state of the fortification wall (Iakovidis et al. 2003).

3. Mycenae. Sketch plan of first citadel. (A) Grave Circle A. (E) Main entrance. (C) Postern gate. (BB) Ravine Chavos (drawing Garvey)

5. Mycenae. Sketch plan of second citadel
(A) Grave Circle A. (LG) Lion Gate. (P) Palace. (S) North staircase (PG) Postern gate. (HC) House of Columns. (ST) Southeastern tower (drawing Garvey)

7. Mycenae. Sketch plan of third citadel. (A) Grave Circle A. (LG) Lion Gate. (PG) Postern gate. (W) Underground cistern in northeast extension. (S) North staircase. (P) Palace area. (HC) House of Columns. (ST) Southeastern tower. (drawing Garvey)

Figure A.86 The three major phases of Mycenae's fortification wall (Mylonas 1966, fig. 3, 5, 7).

409

Figure A.87 Plan of the Northeast Extension of Mycenae's fortification wall (Iakovidis et al. 2003, map 9).

Figure A.88 The south sally port in the Northeast Extension, Mycenae.

Figure A.89 A view looking through the south sally port in the Northeast Extension, Mycenae.
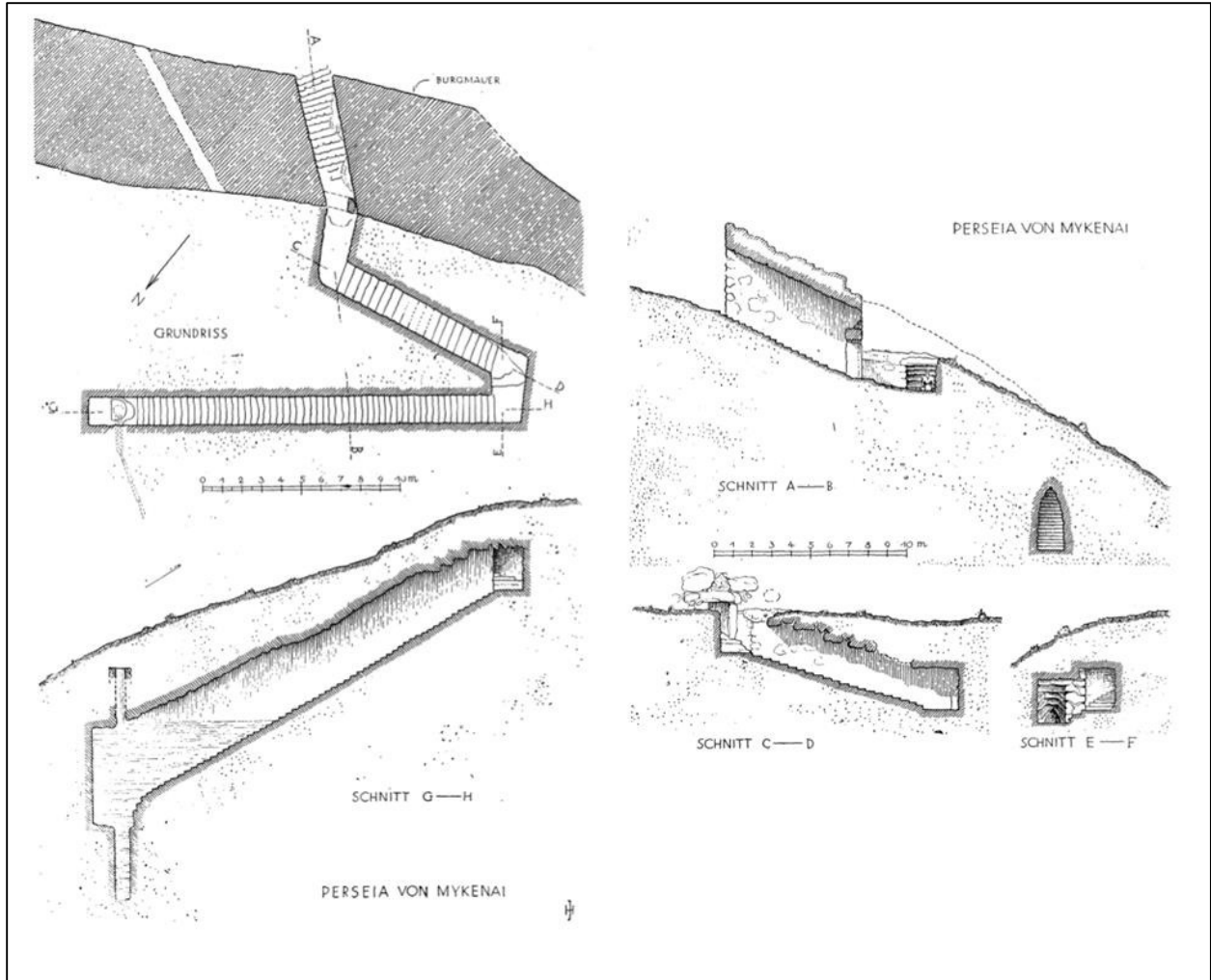
Figure A.90 Plan and sections of the underground cistern, Mycenae (Karo 1934, pls. 12, 13).

413

Figure A.91 The corbelled entrance to the underground cistern in the Northeast Extension.

Figure A.92 The stepped passage of the underground cistern, descending to the west from the first landing.
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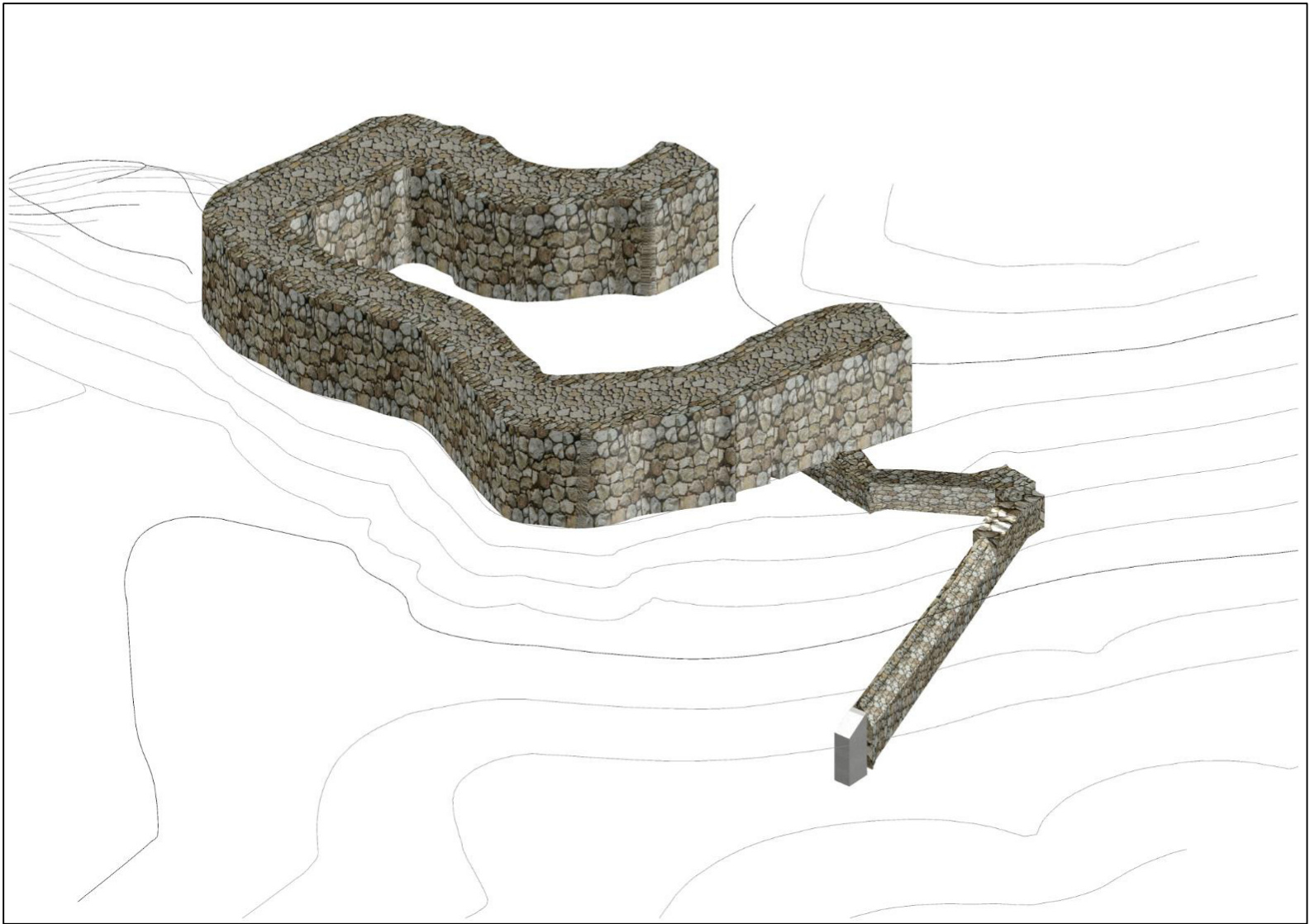
Figure A.93 The reconstruction of the cistern and Northeast Extension of Mycenae's fortification wall viewed from the northeast.
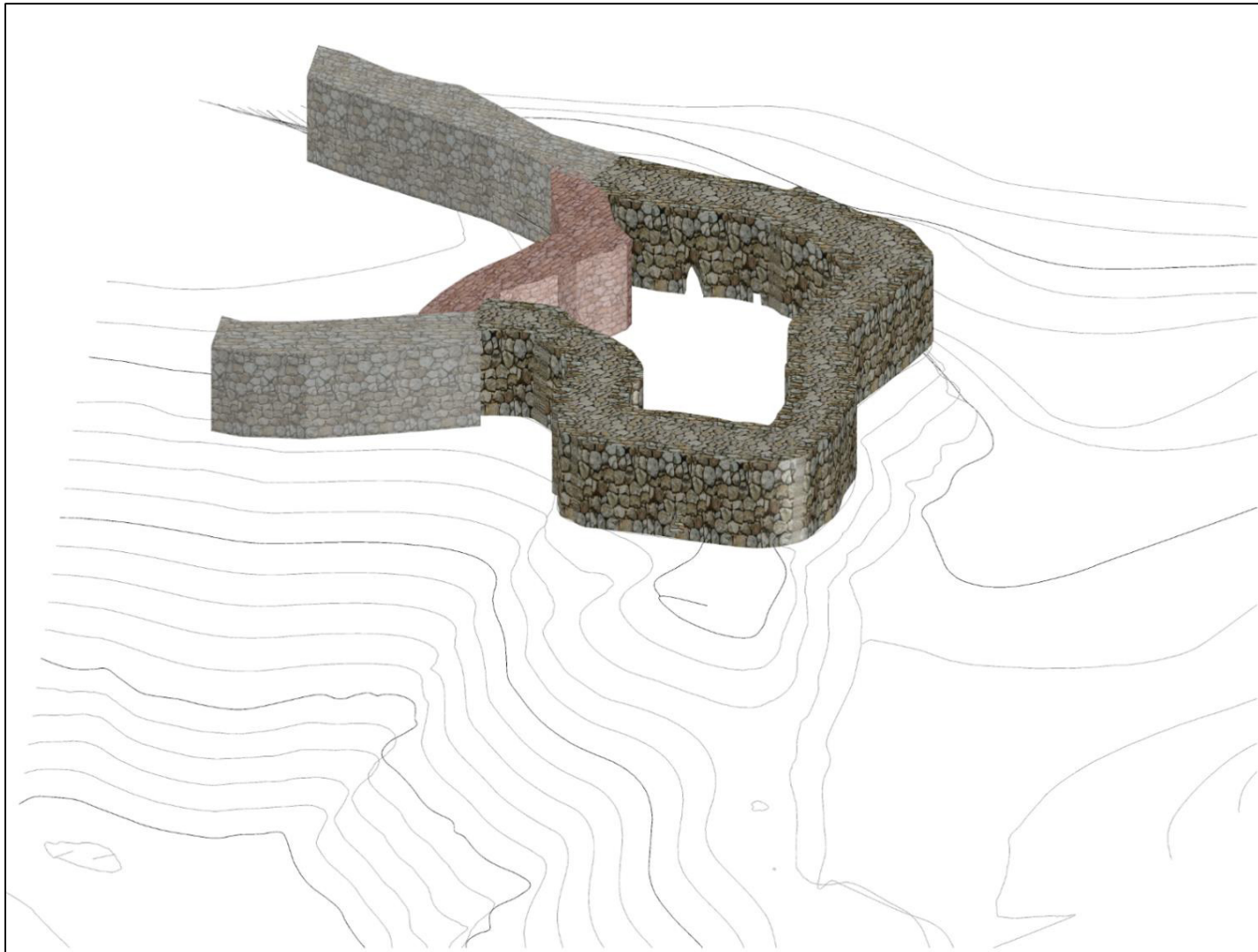
Figure A.94 The Northeast Extension in relation to the intact (faded grey) and removed (faded red) sections of the first period wall viewed from the southeast.

417
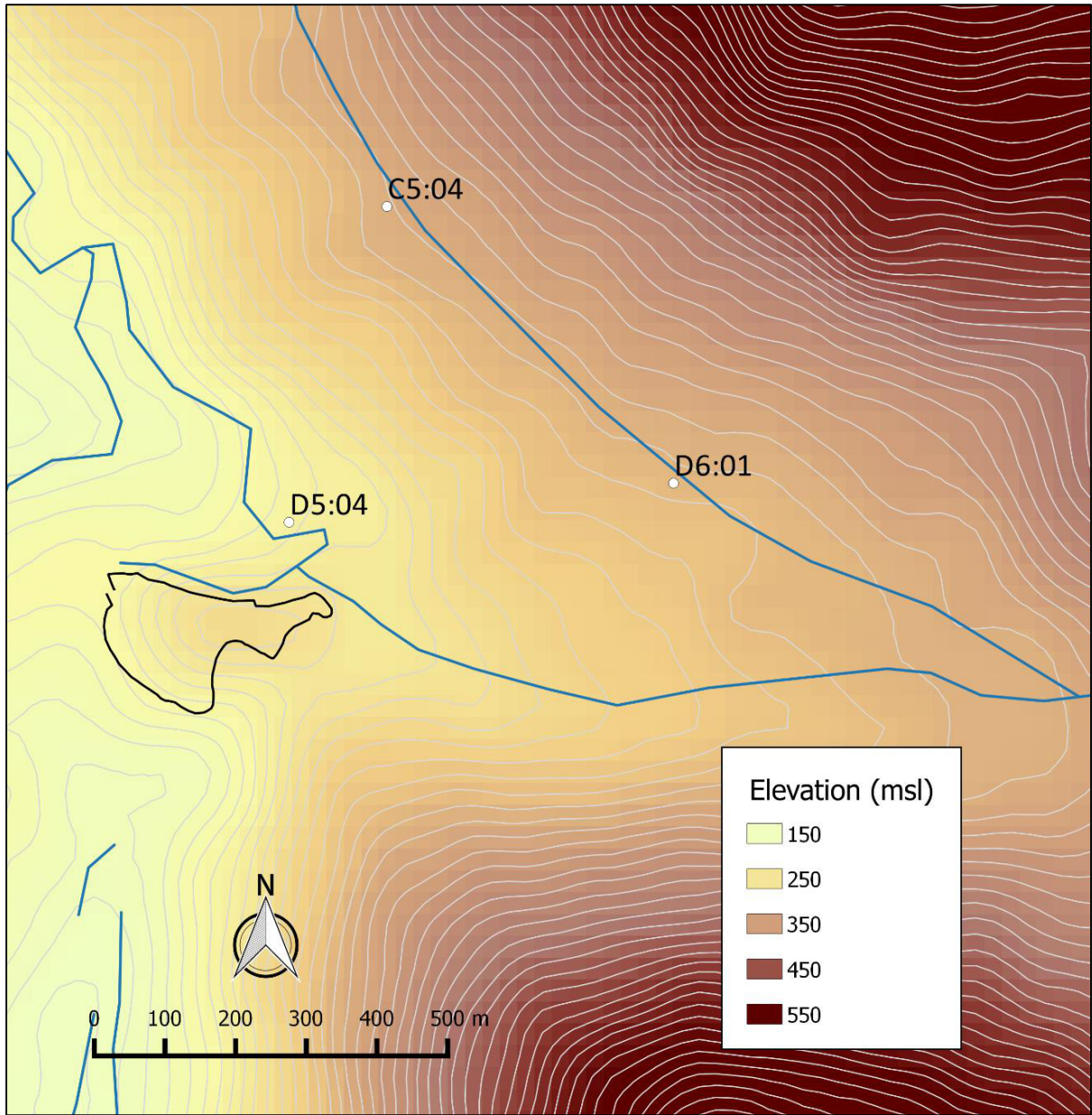
Figure A.95 A map of Mycenae's citadel showing the road network in blue and nearby stone extraction areas marked in the Mycenae Atlas.
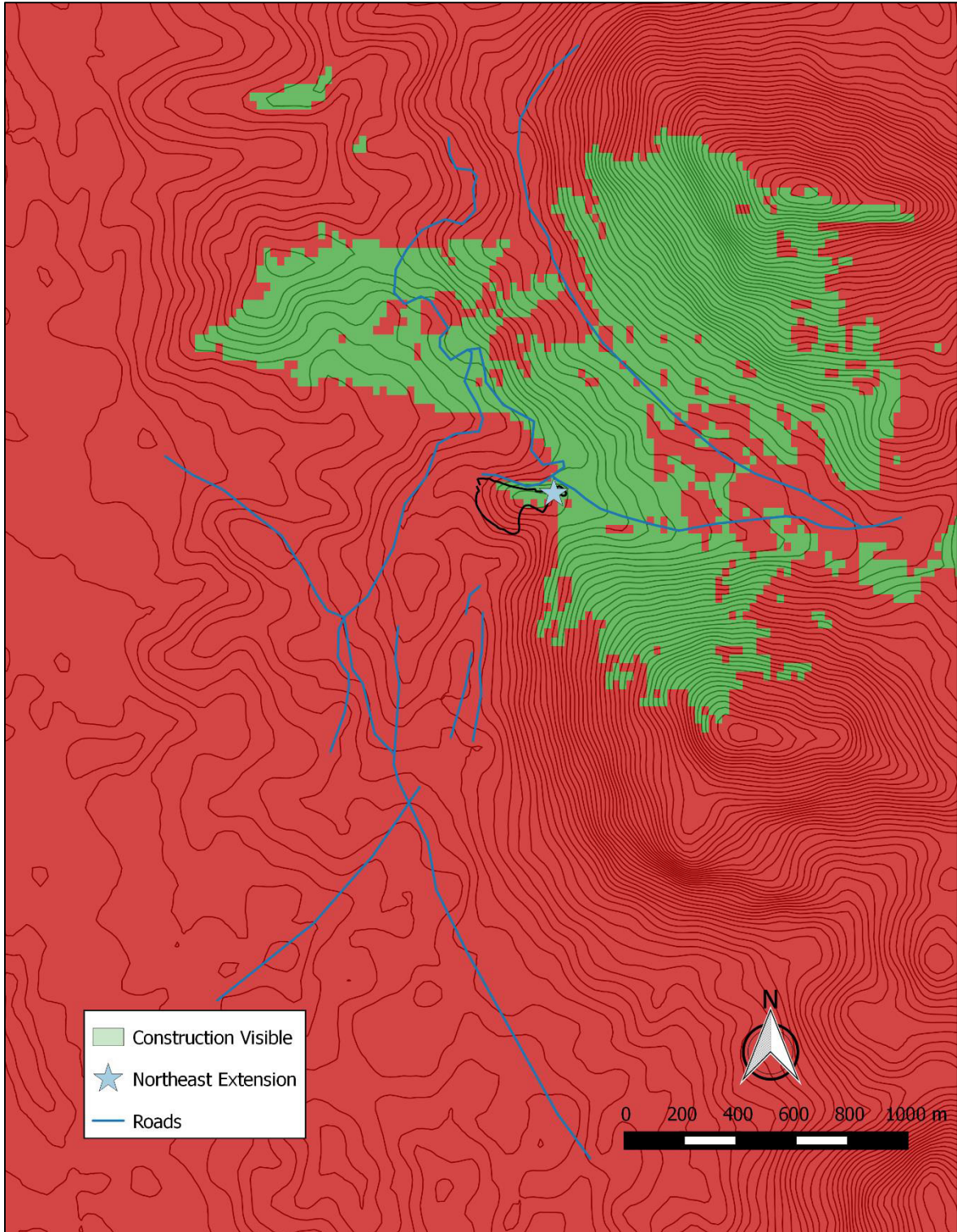
Figure A.96 Viewshed from the area of the Northeast Extension at a height of 8.25 m.
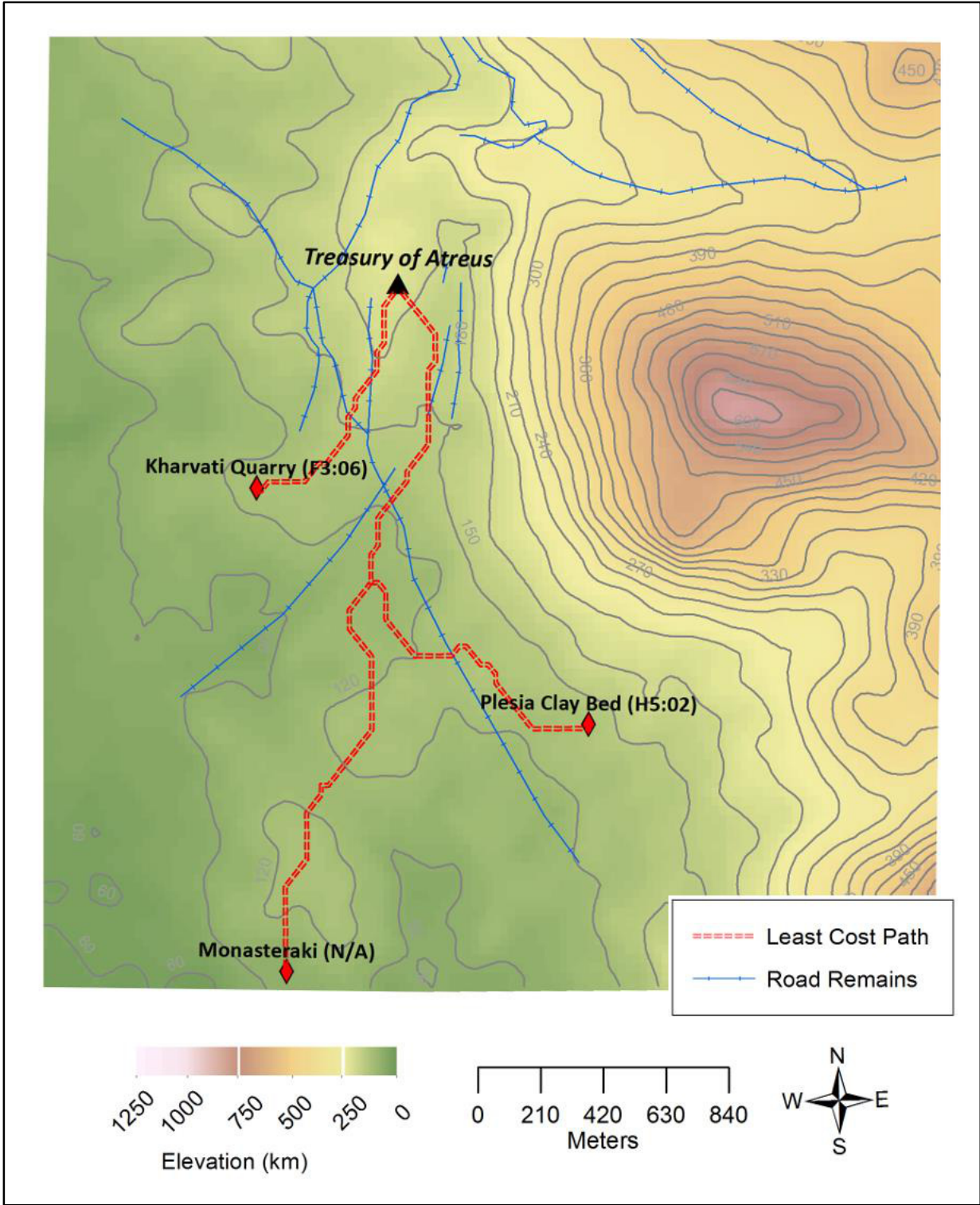
Figure A.97 The least cost path between resource locations and the Treasury of Atreus, and road remains at Mycenae.
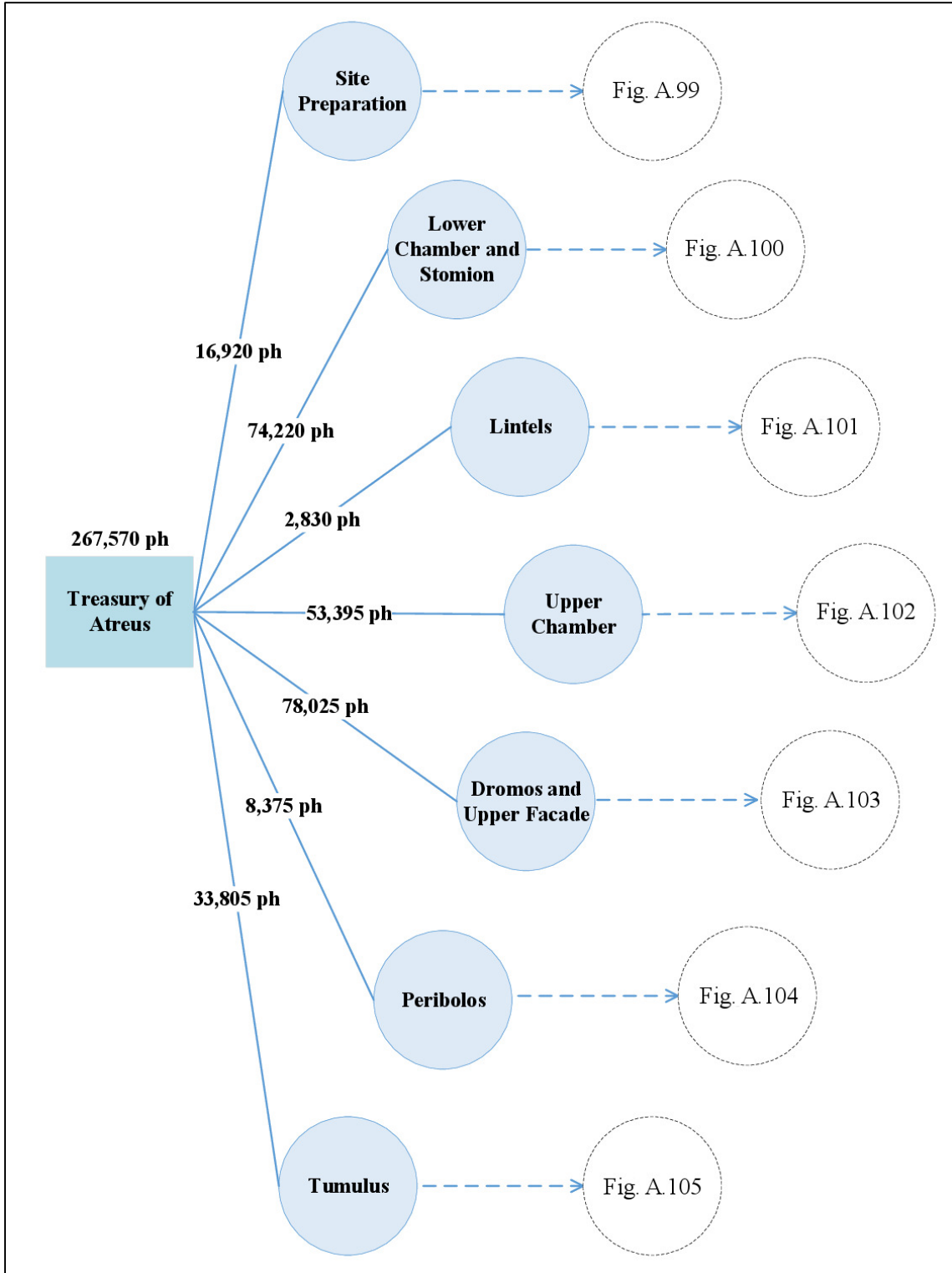
Figure A.98 A flowchart breaking the Treasury of Atreus into its major building components and listing the person-hours for each. Each component is broken into an individual energetic flowchart illustrated in the given figure.
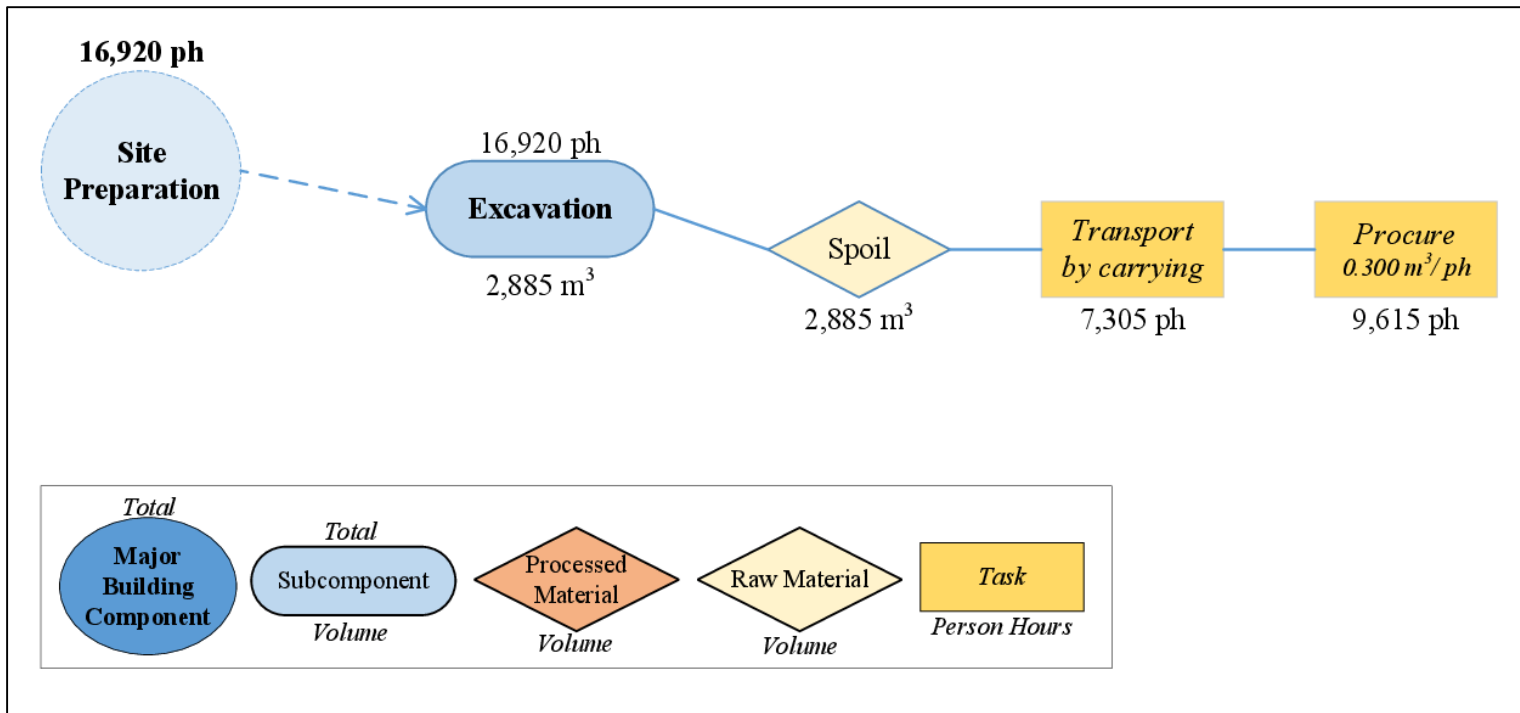
Figure A.99 An energetic flowchart breaking down the elements of site preparation.
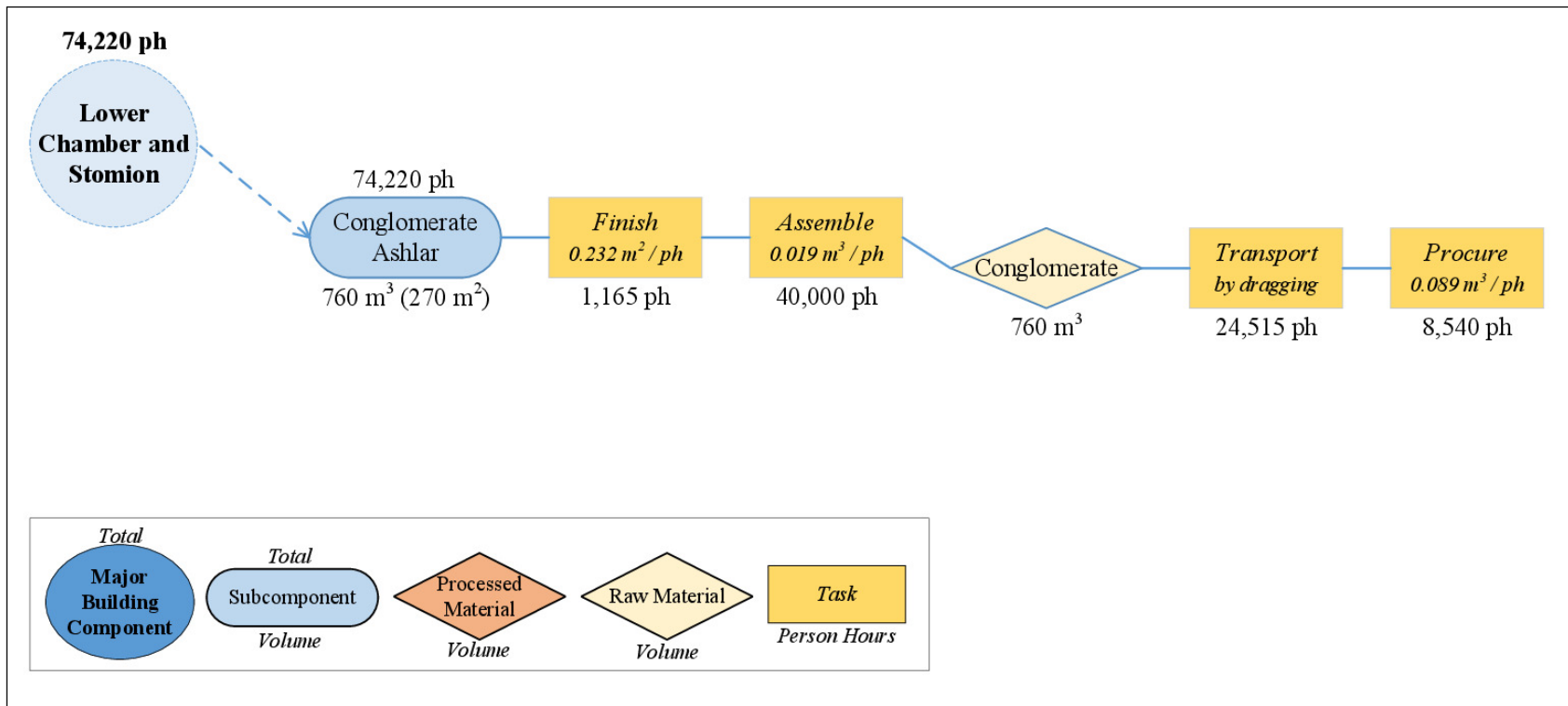
Figure A.100 An energetic flowchart breaking down the elements of the lower chamber and stomion.
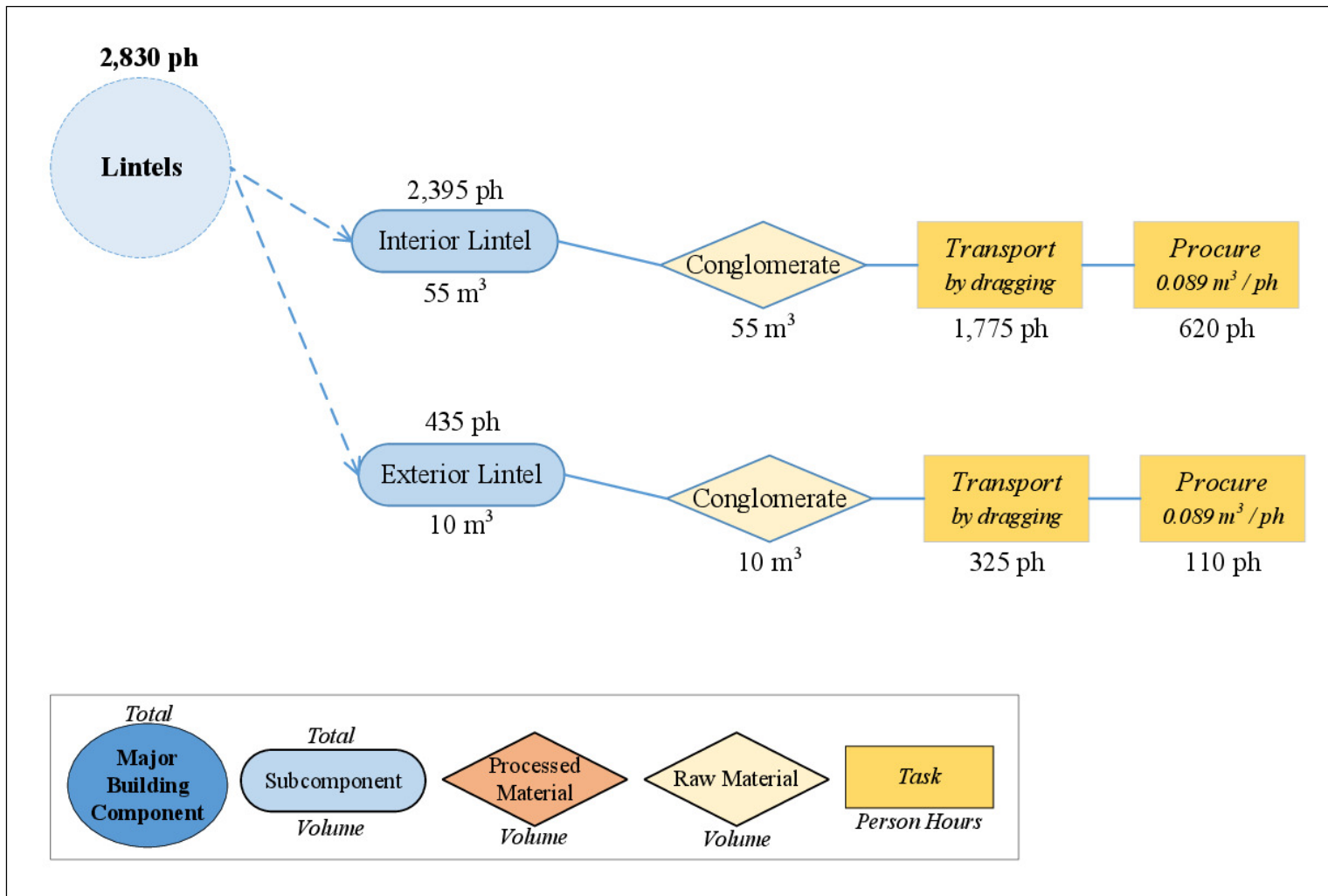
Figure A.101 An energetic flowchart breaking down the elements of the lintels.
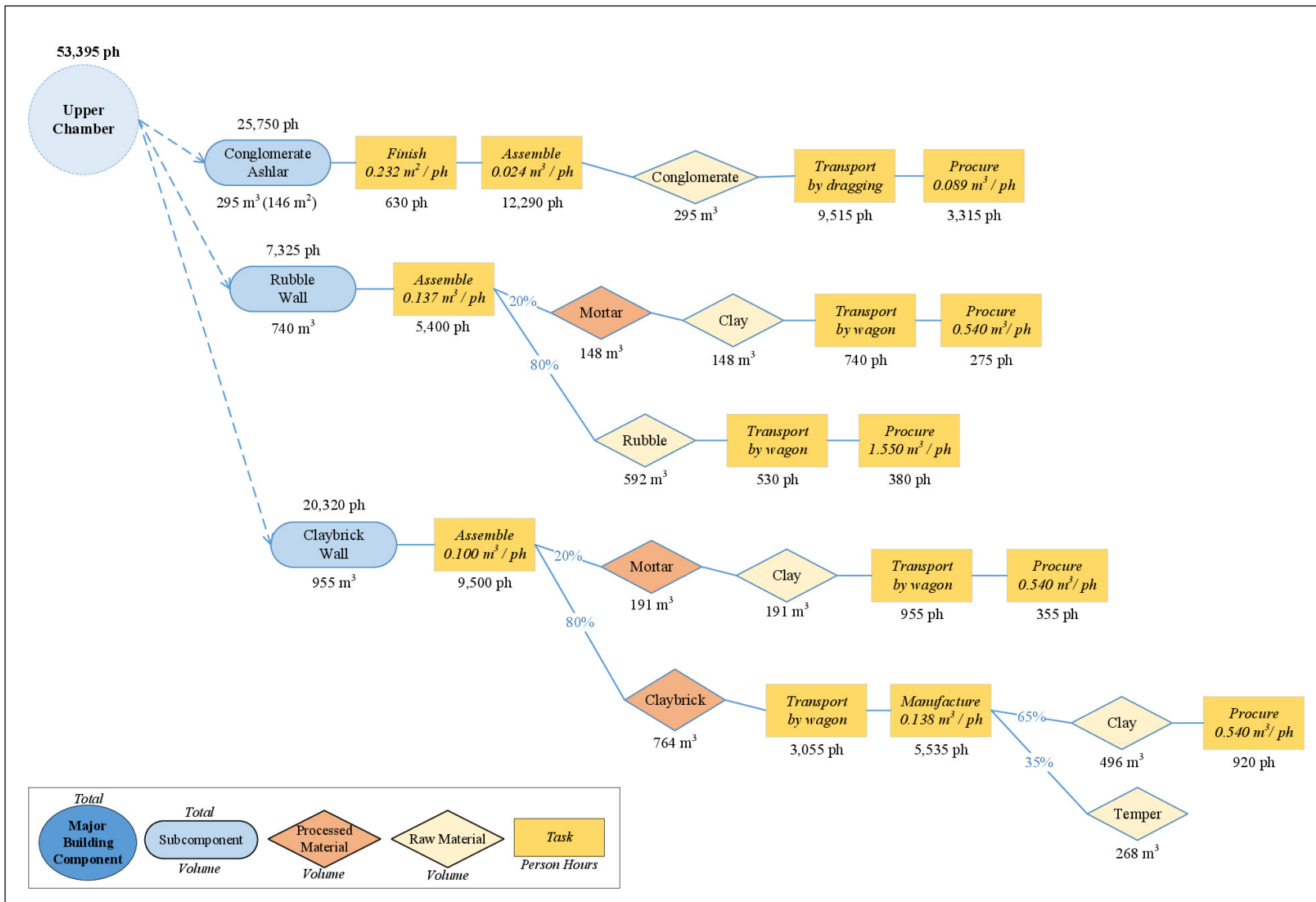
Figure A.102 An energetic flowchart breaking down the elements of the upper chamber.
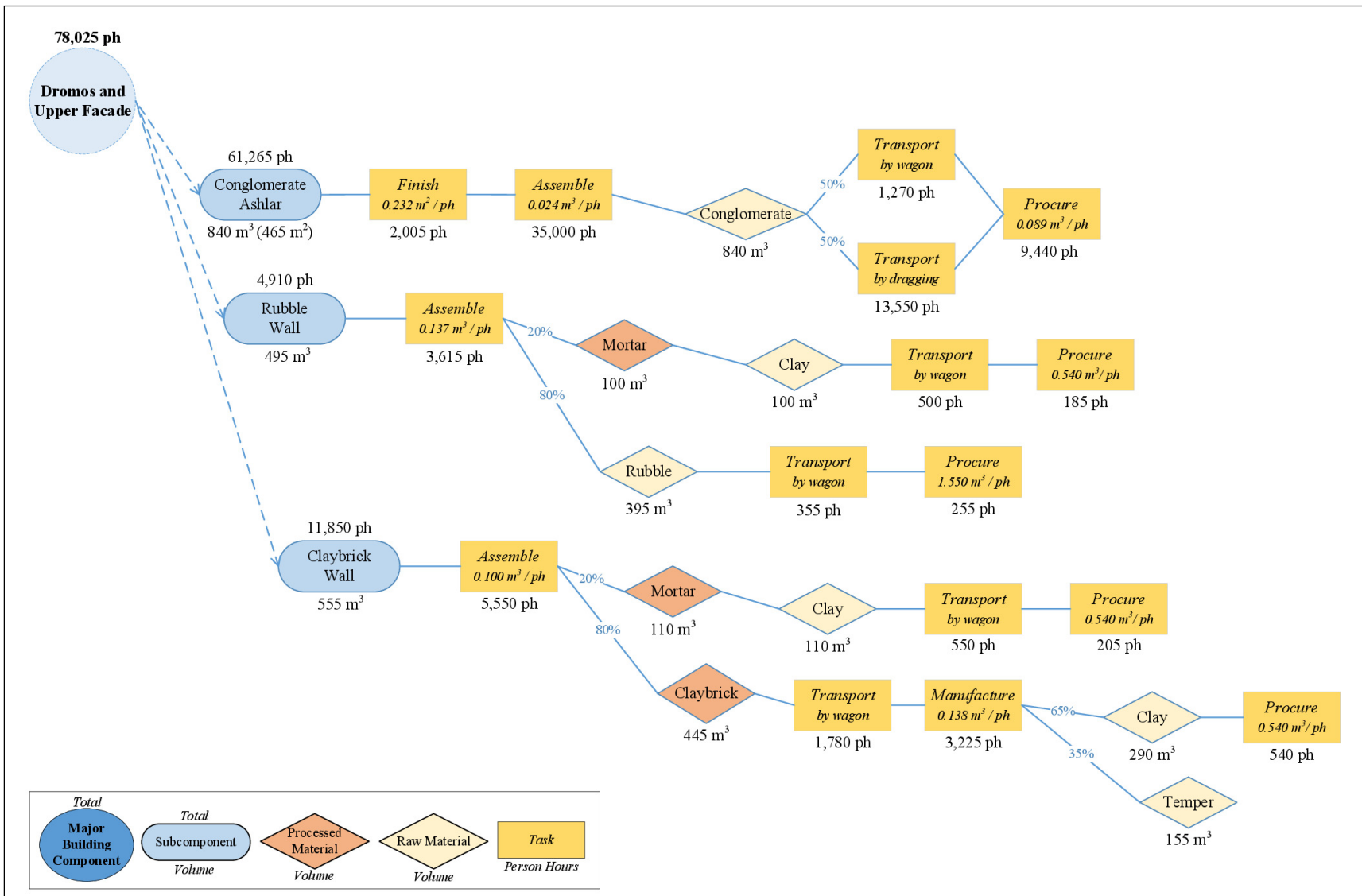
Figure A.103 An energetic flowchart breaking down the elements of the dromos and upper facade.
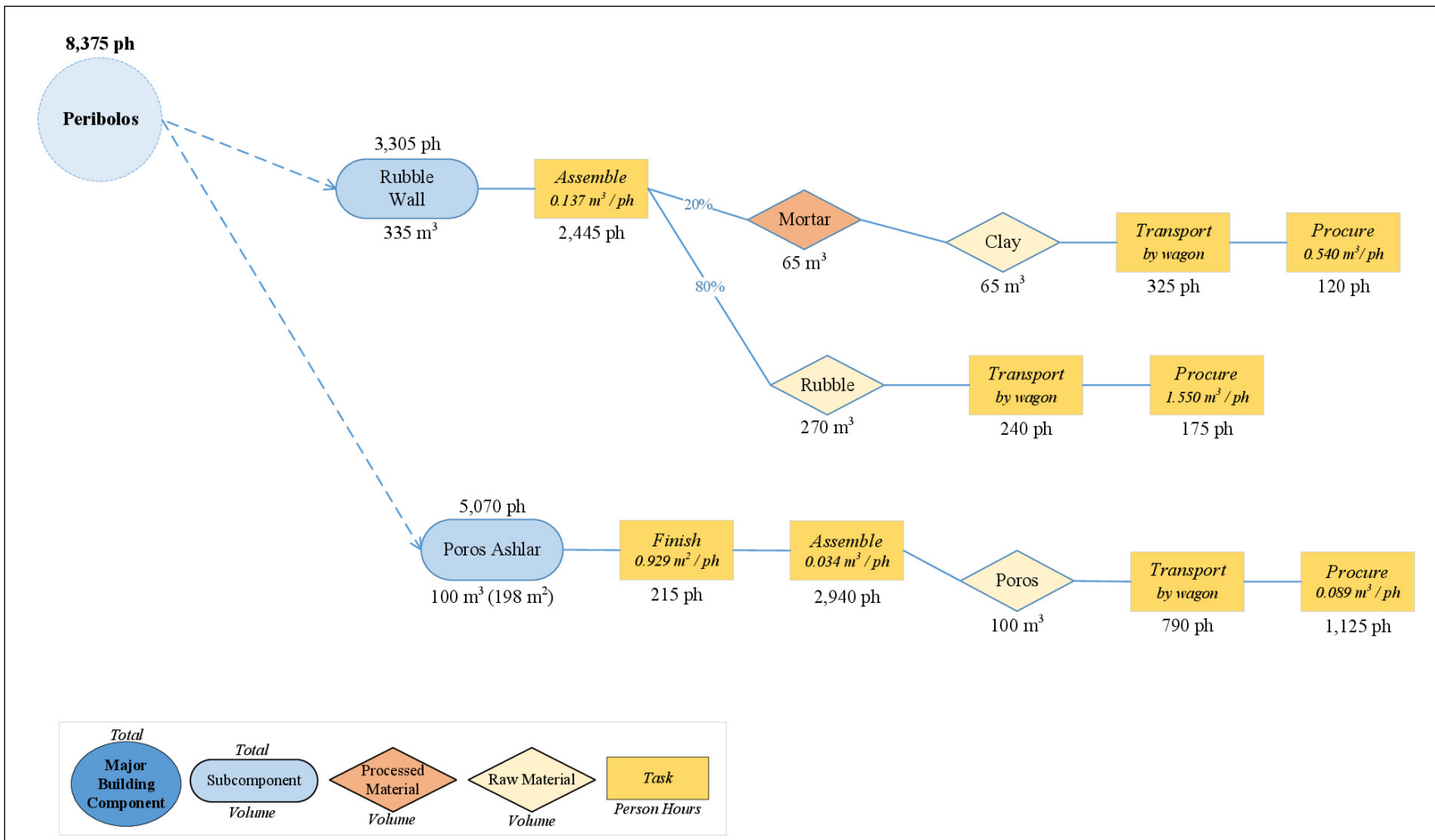
Figure A.104 An energetic flowchart breaking down the elements of the peribolos.
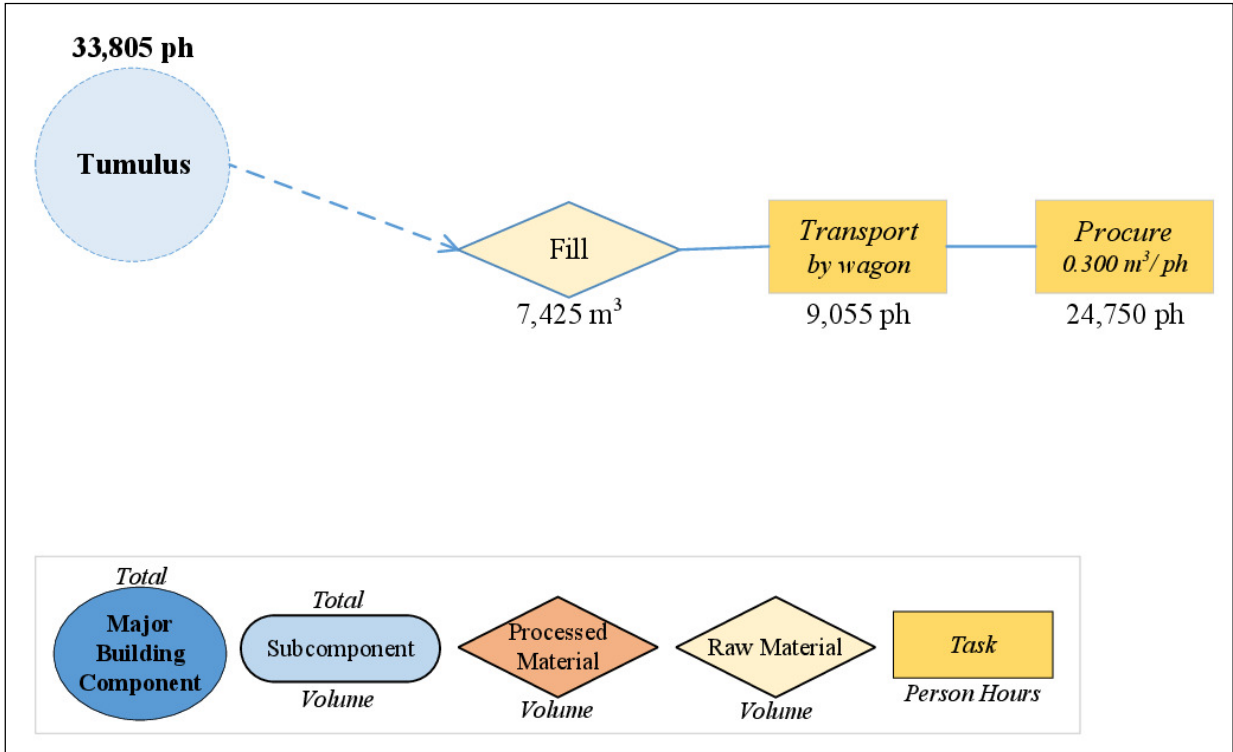
Figure A.105 An energetic flowchart breaking down the elements of the tumulus.
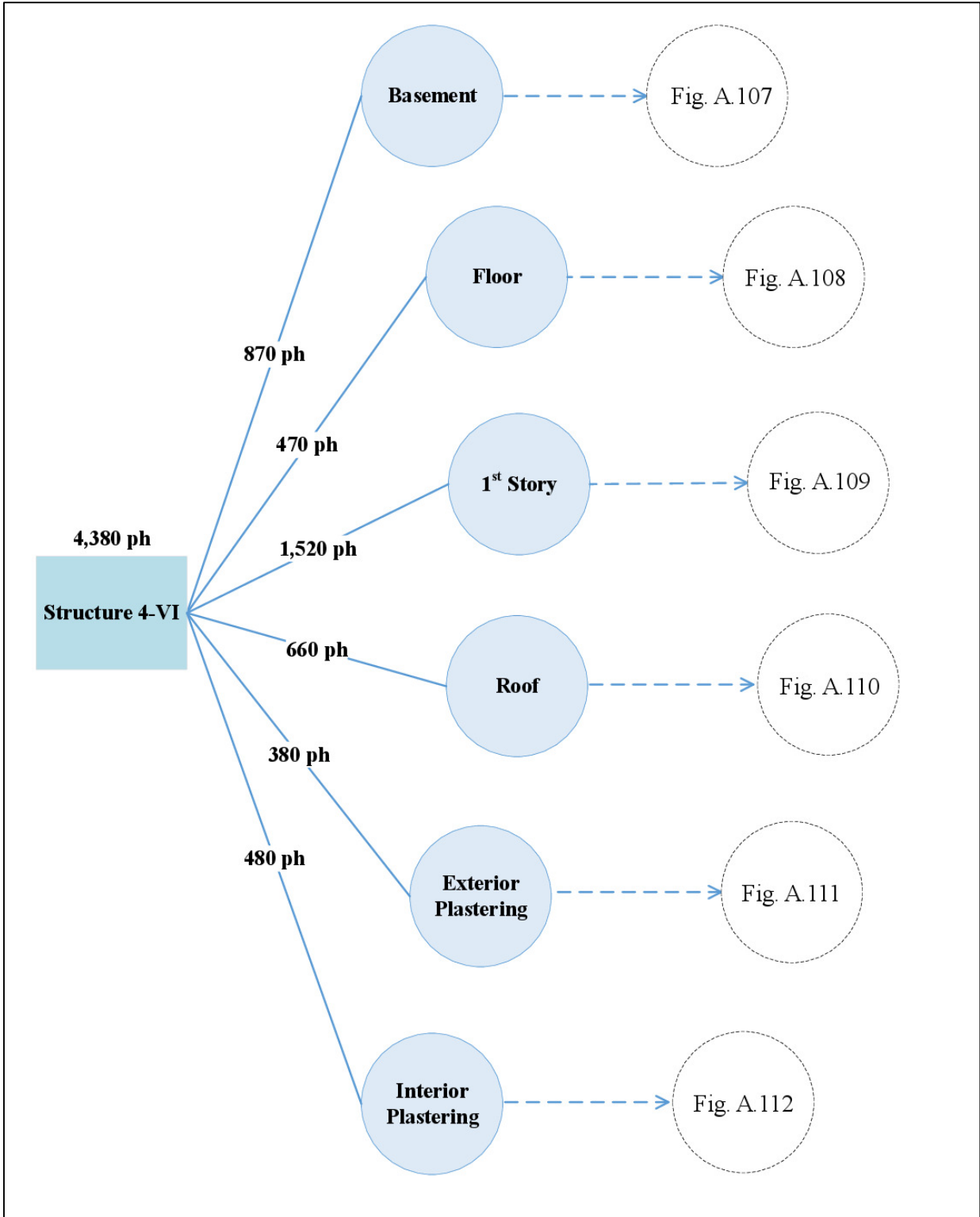
Figure A.106 Energetic flowchart for structure 4-VI.
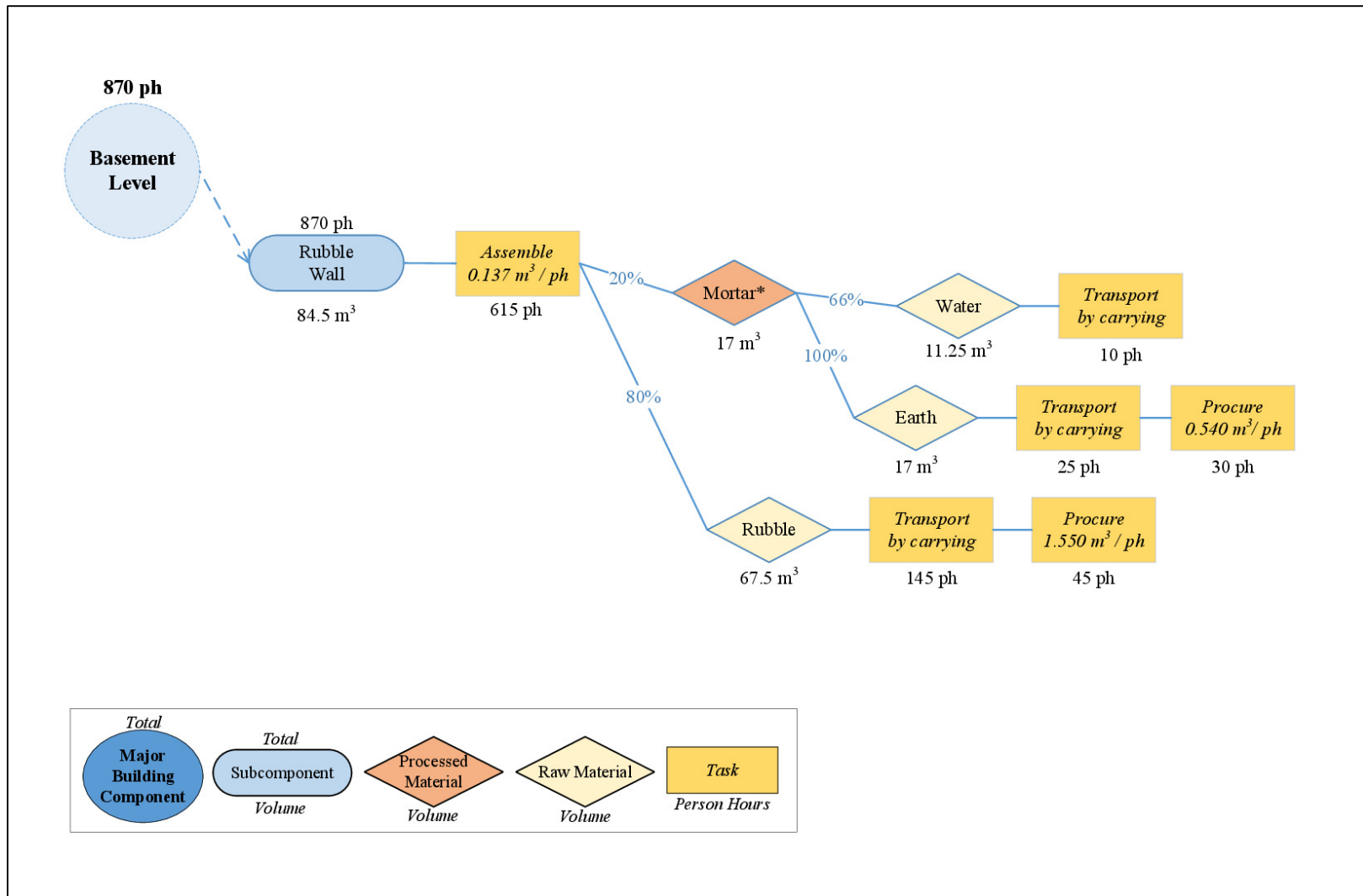
Figure A.107 Energetic flowchart for structure 4-VI, basement level.
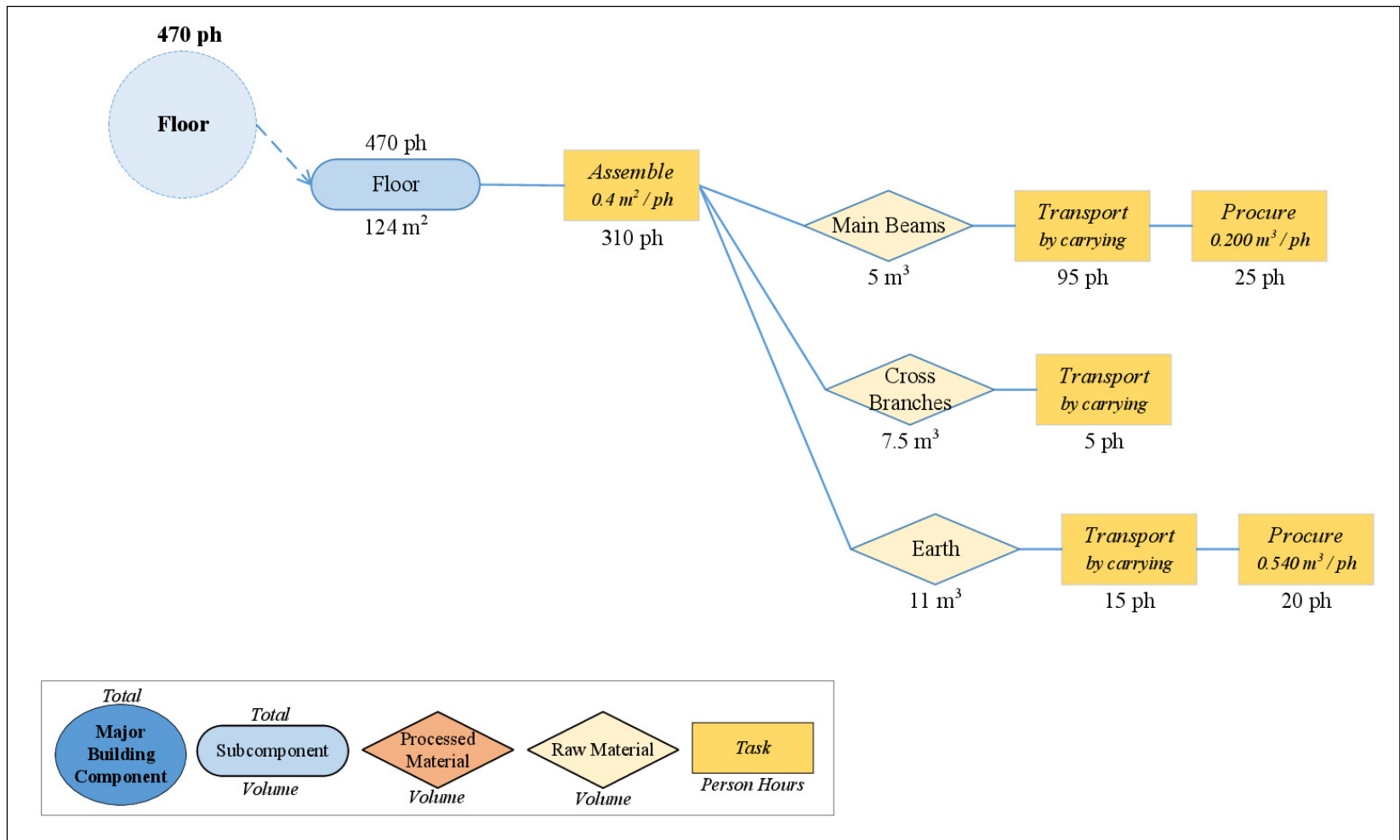
Figure A.108 Energetic flowchart for structure 4-VI, floor.
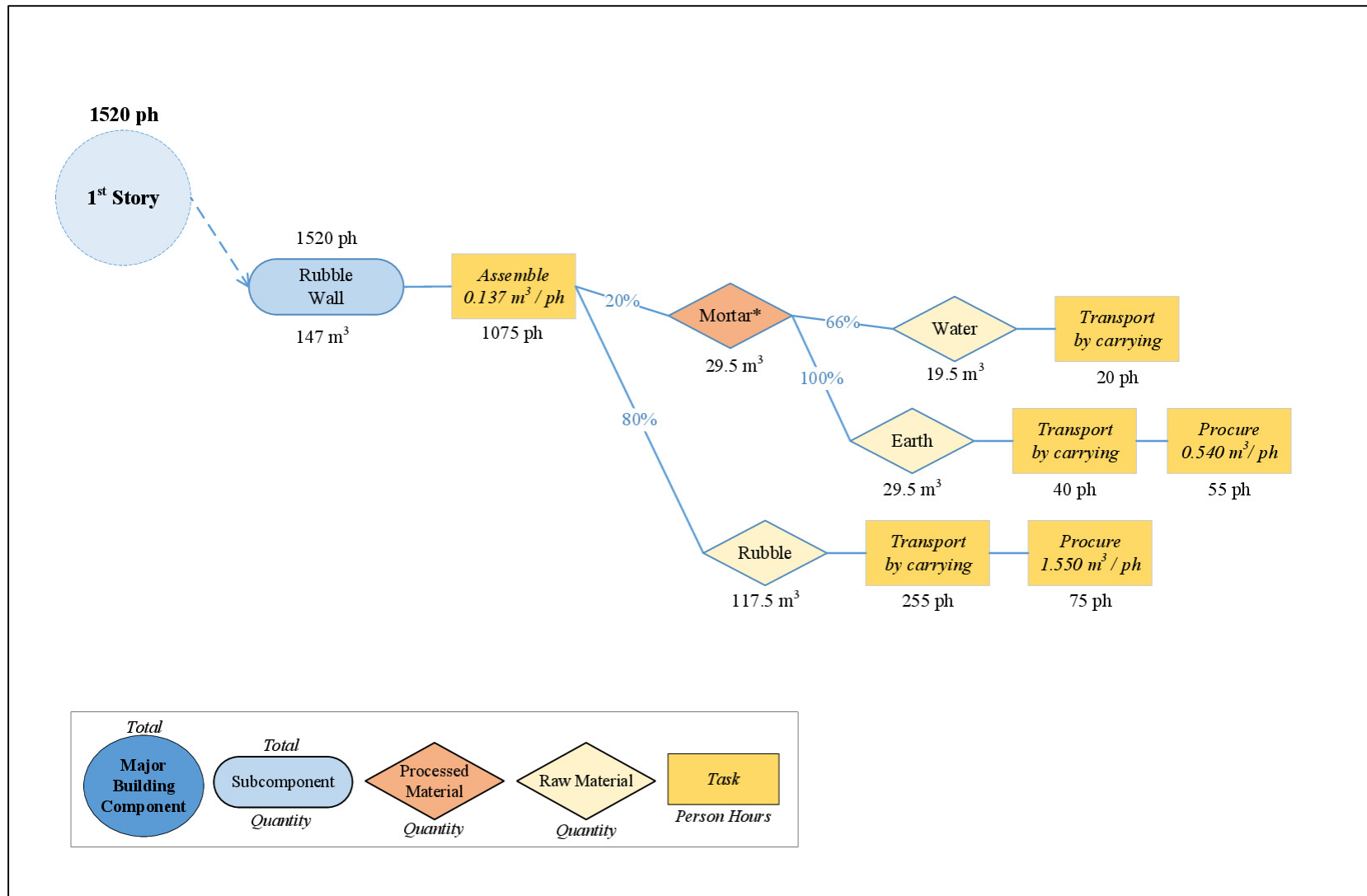
Figure A.109 Energetic flowchart for structure 4-VI, 1st story.
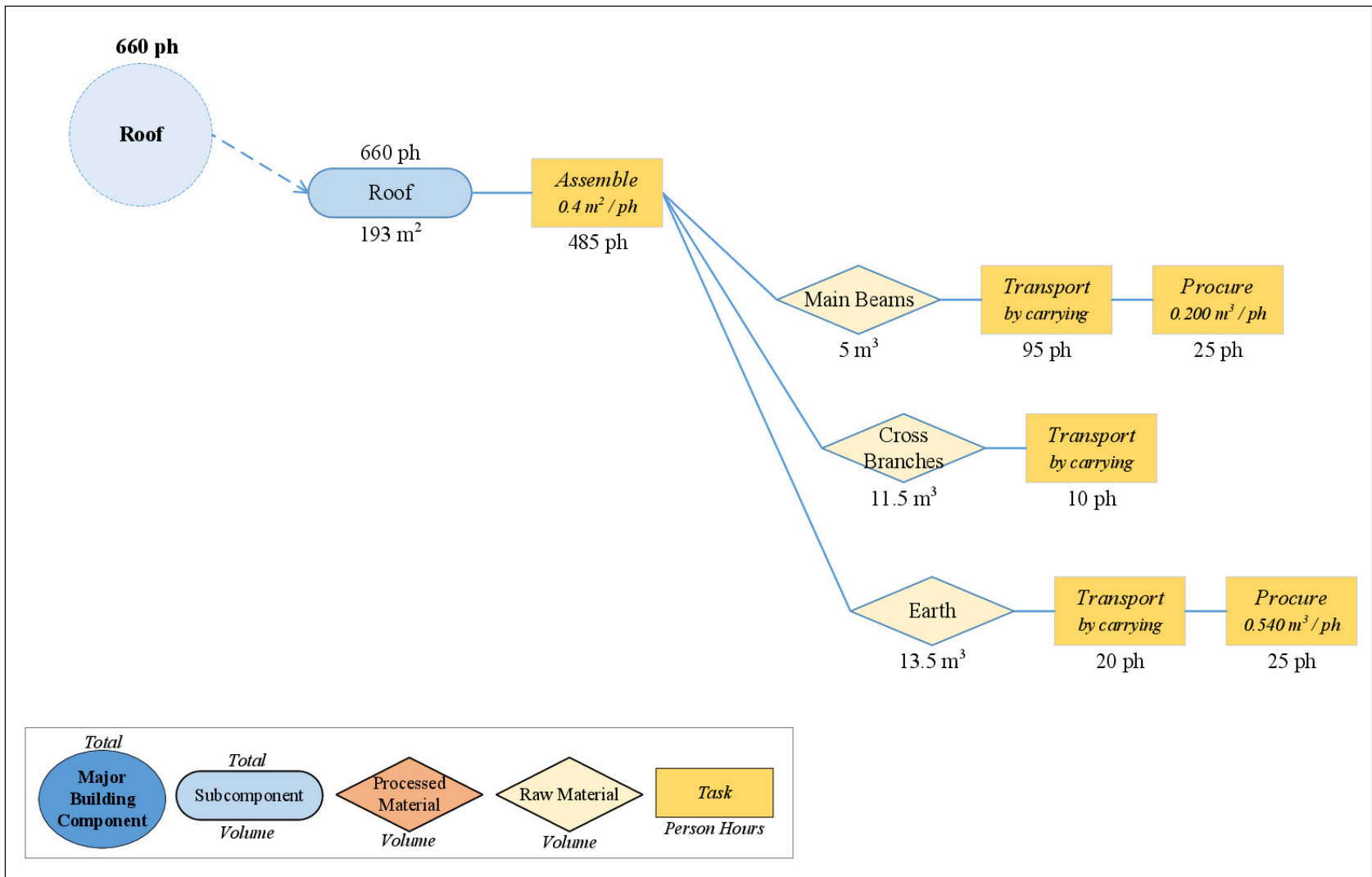
Figure A.110 Energetic flowchart for structure 4-VI, roof.

380 ph

Exterior Plastering

315 ph

Walls

226 m^2
(Exterior faces)

Finish 0.80 m^2 / ph

285 ph

Mud Plaster

9 m^3

66%

100%

Water

6 m^3

Transport by carrying

5 ph

Earth

9 m^3

Transport by carrying

10 ph

Procure 0.540 m^3/ ph

15 ph

65 ph

Roof

193 m^2
(Upper surface)

Finish 5.69 m^2 / ph

35 ph

Mud Plaster

7.75 m^3

66%

100%

Water

5 m^3

Transport by carrying

5 ph

Earth

7.75 m^3

Transport by carrying

10 ph

Procure 0.540 m^3/ ph

15 ph

Total

Major Building Component

Total

Subcomponent

Quantity

Processed Material

Quantity

Raw Material

Quantity

Task

Person Hours

Figure A.111 Energetic flowchart for structure 4-VI, exterior plastering.

434
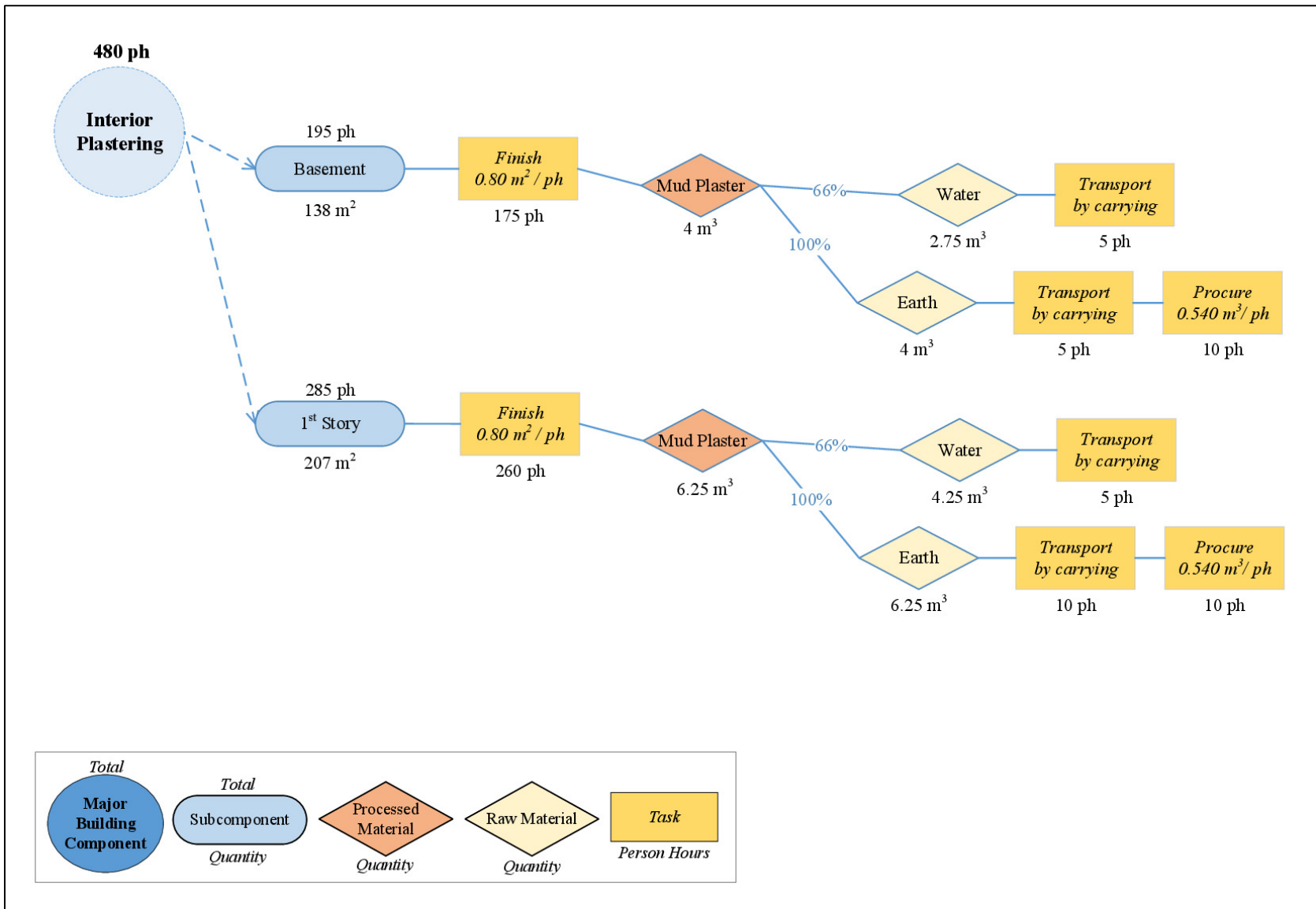
Figure A.112 Energetic flowchart for structure 4-VI, interior plastering
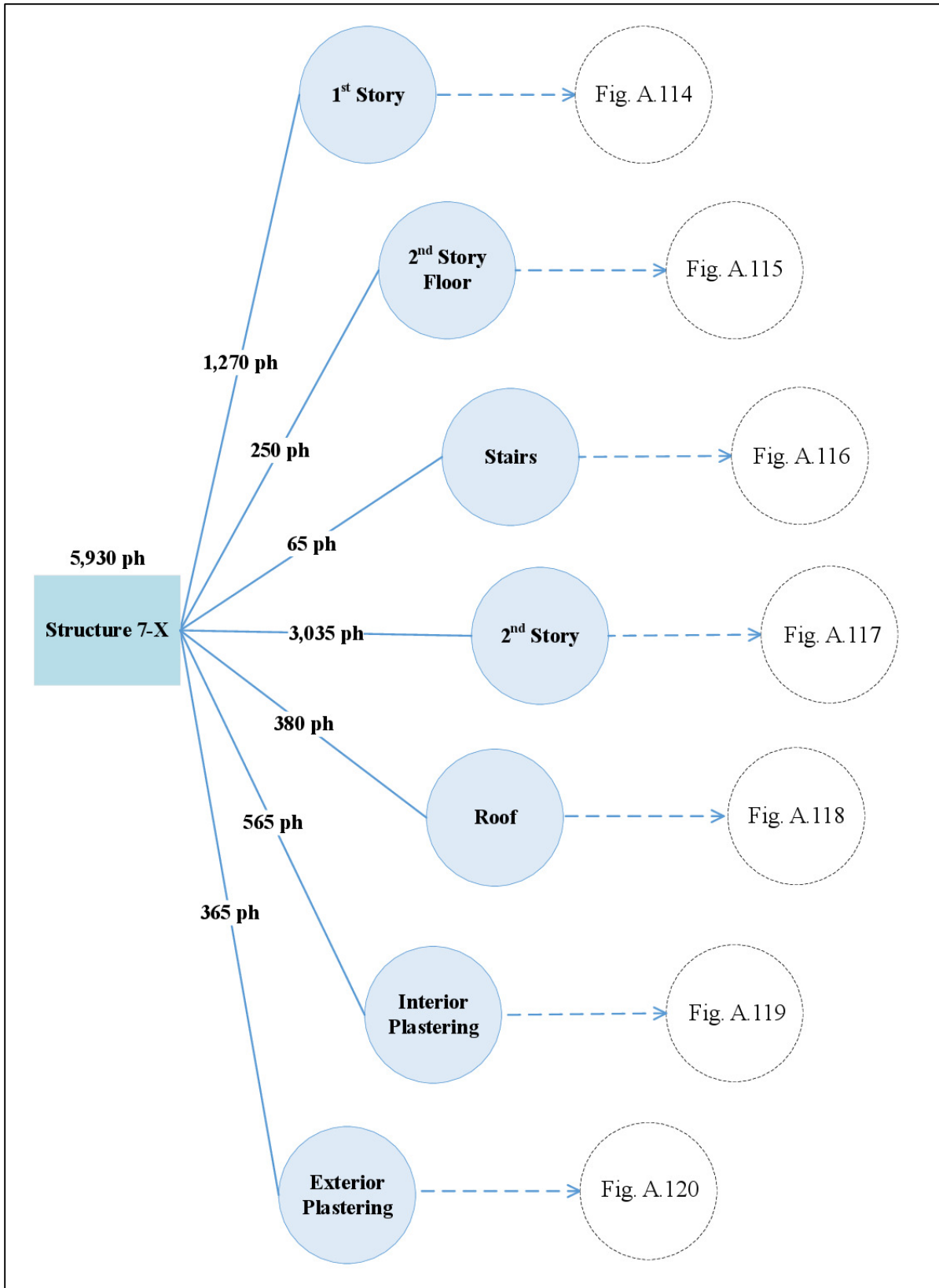
Figure A.113 Energetic flowchart for structure 7-X.
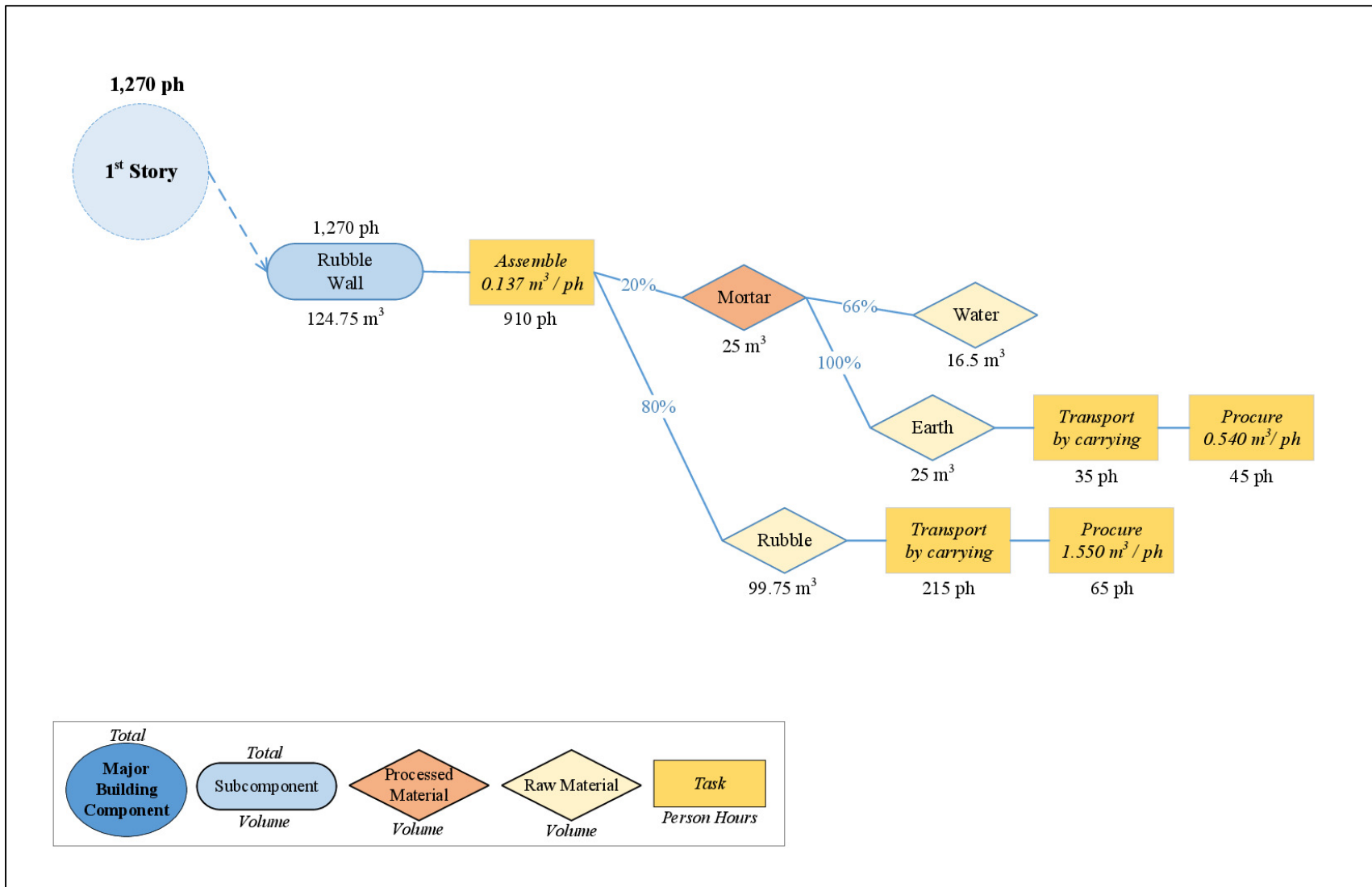
Figure A.114 Energetic flowchart for structure 7-X, 1st story.
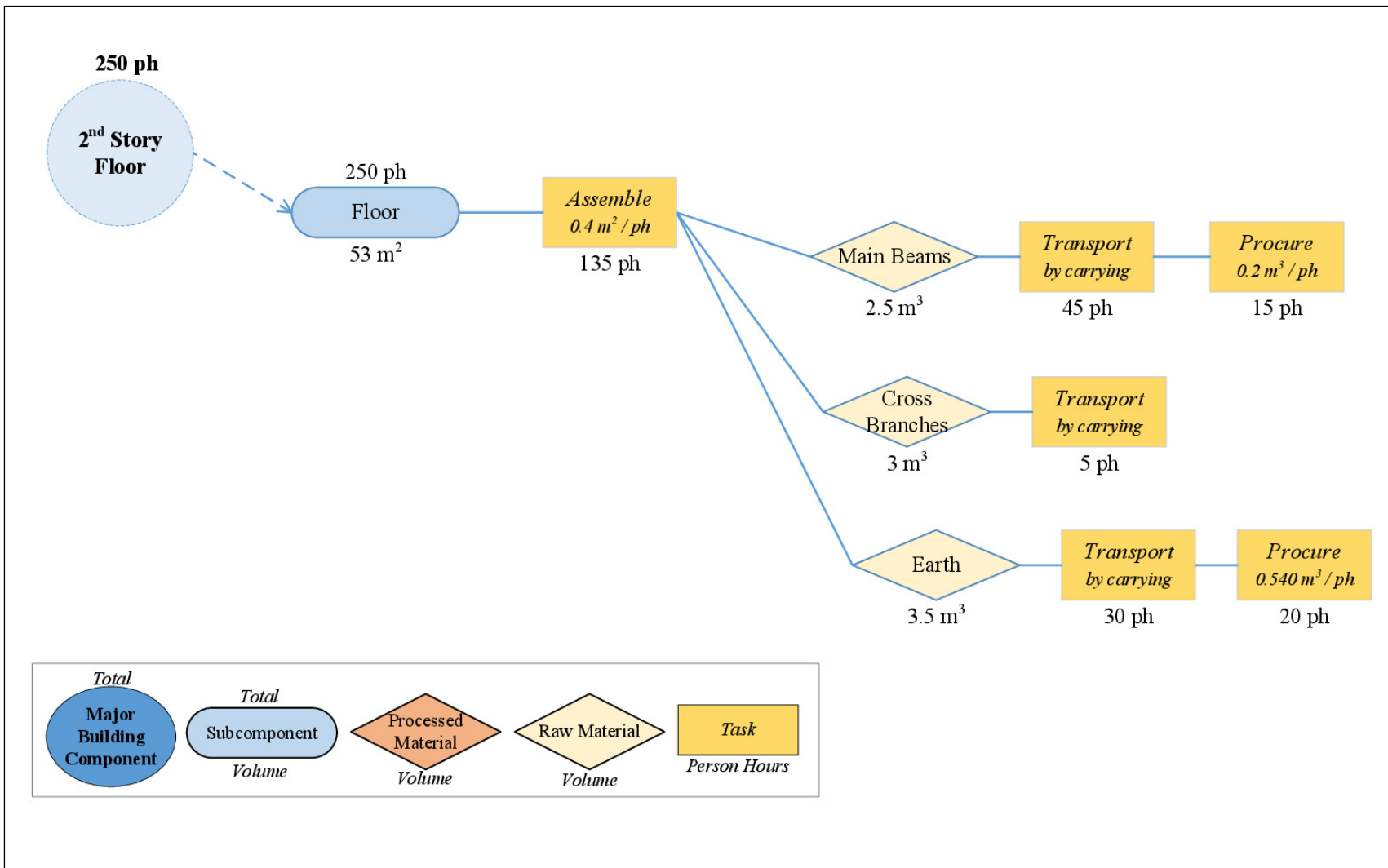
Figure A.115 Energetic flowchart for structure 7-X, 2nd story floor.
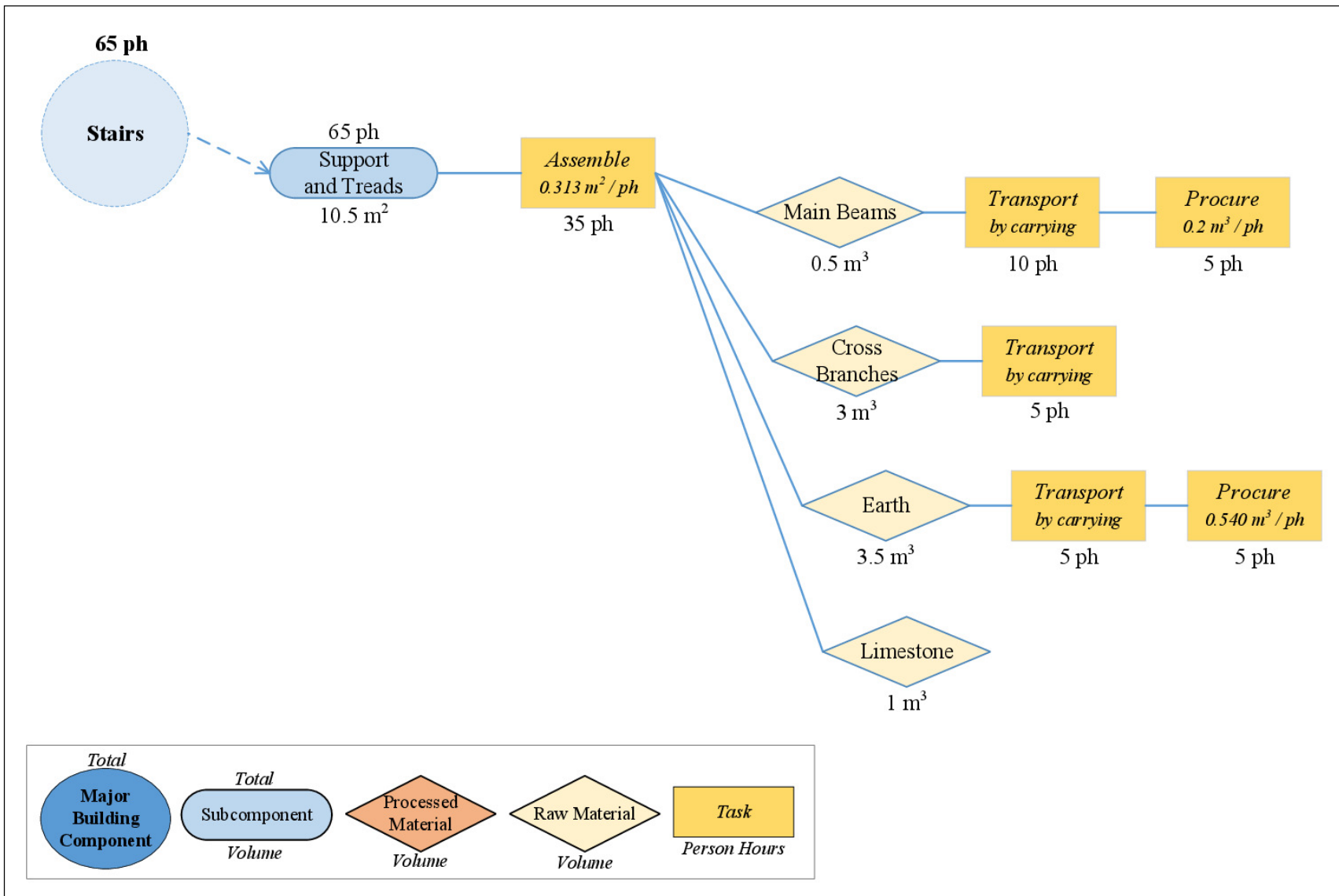
Figure A.116 Energetic flowchart for structure 7-X, stairs.
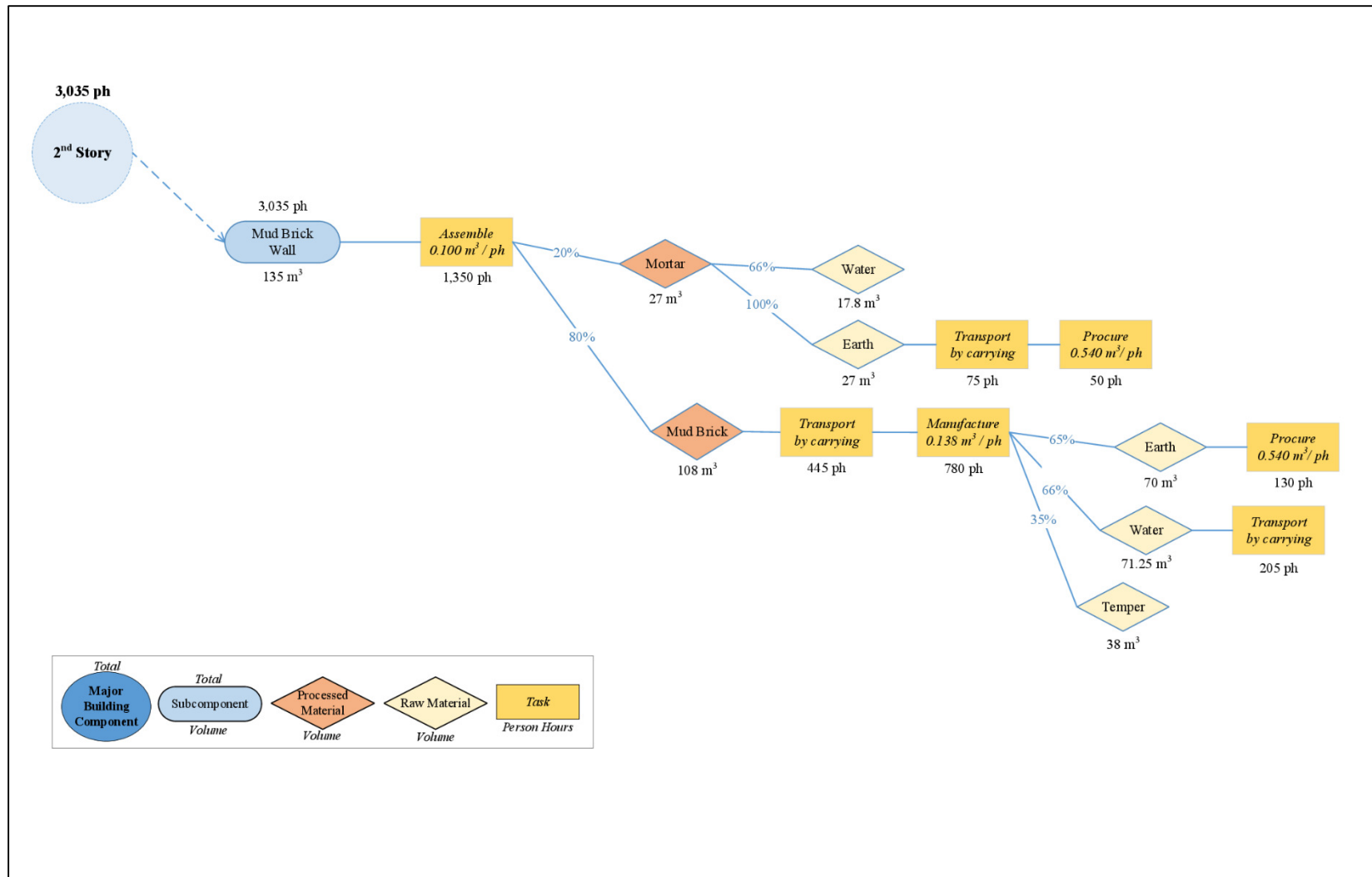
Figure A.117 Energetic flowchart for structure 7-X, 2nd story.
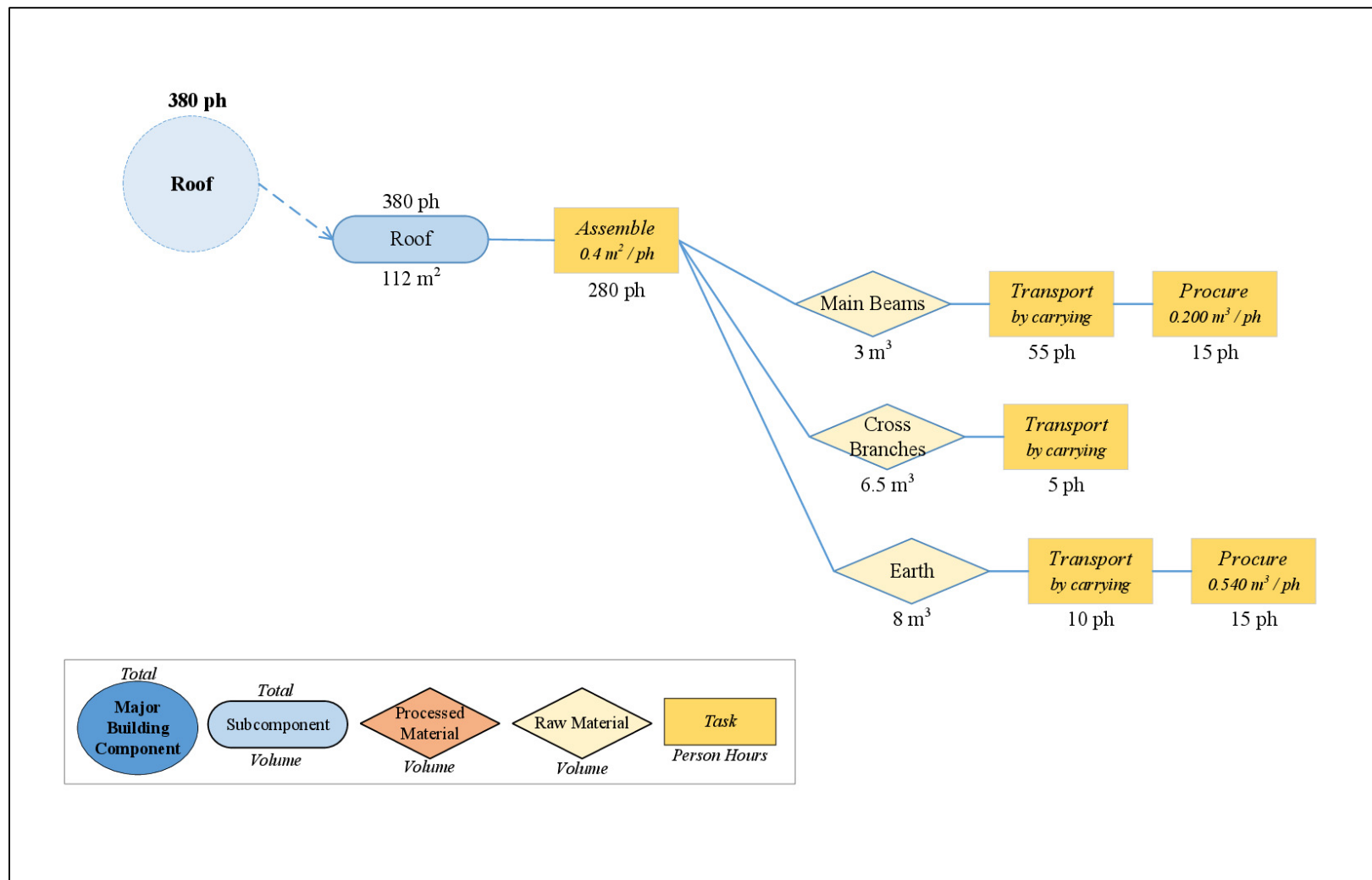
Figure A.118 Energetic flowchart for structure 7-X, roof.
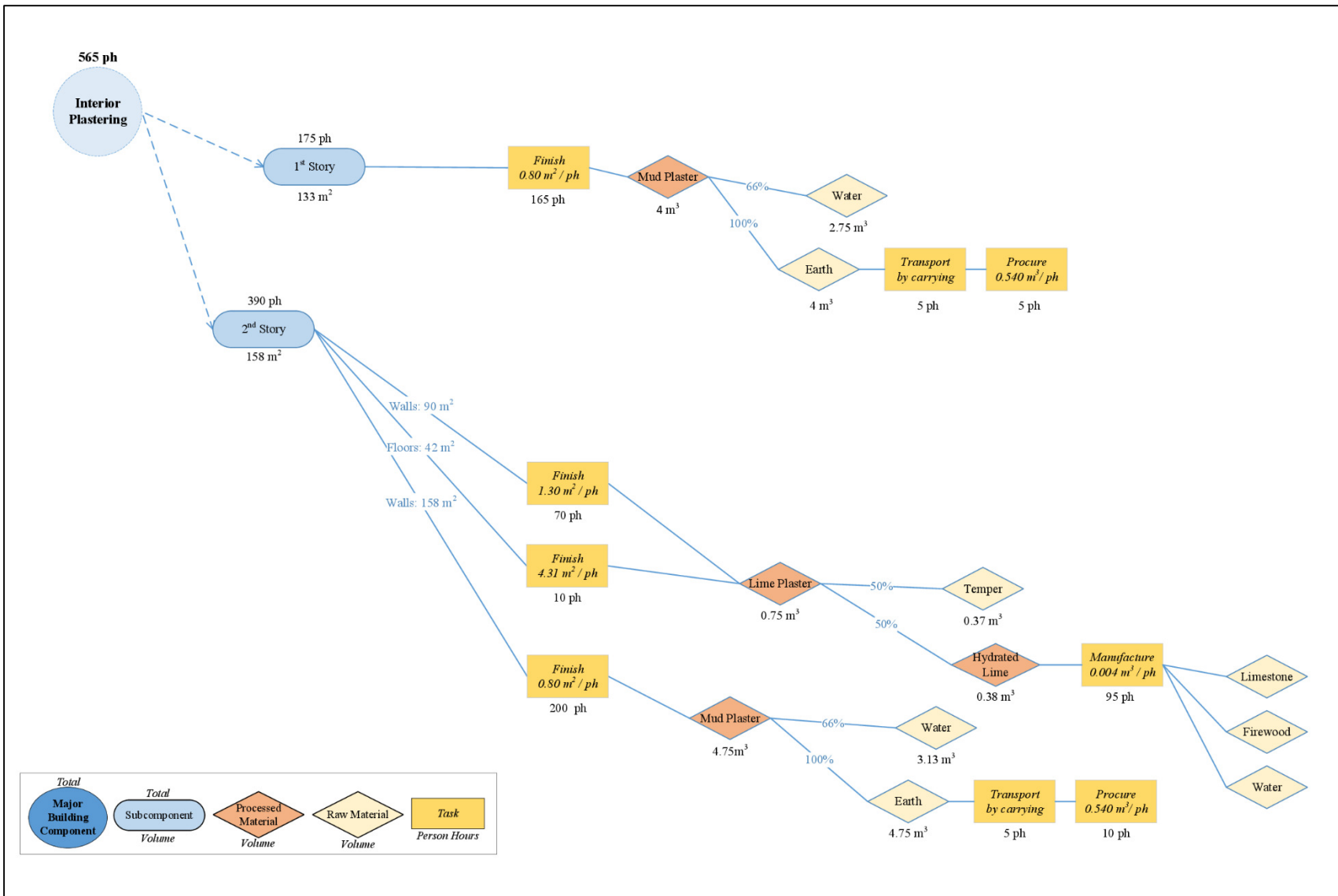
Figure A.119 Energetic flowchart for structure 7-X, interior plastering
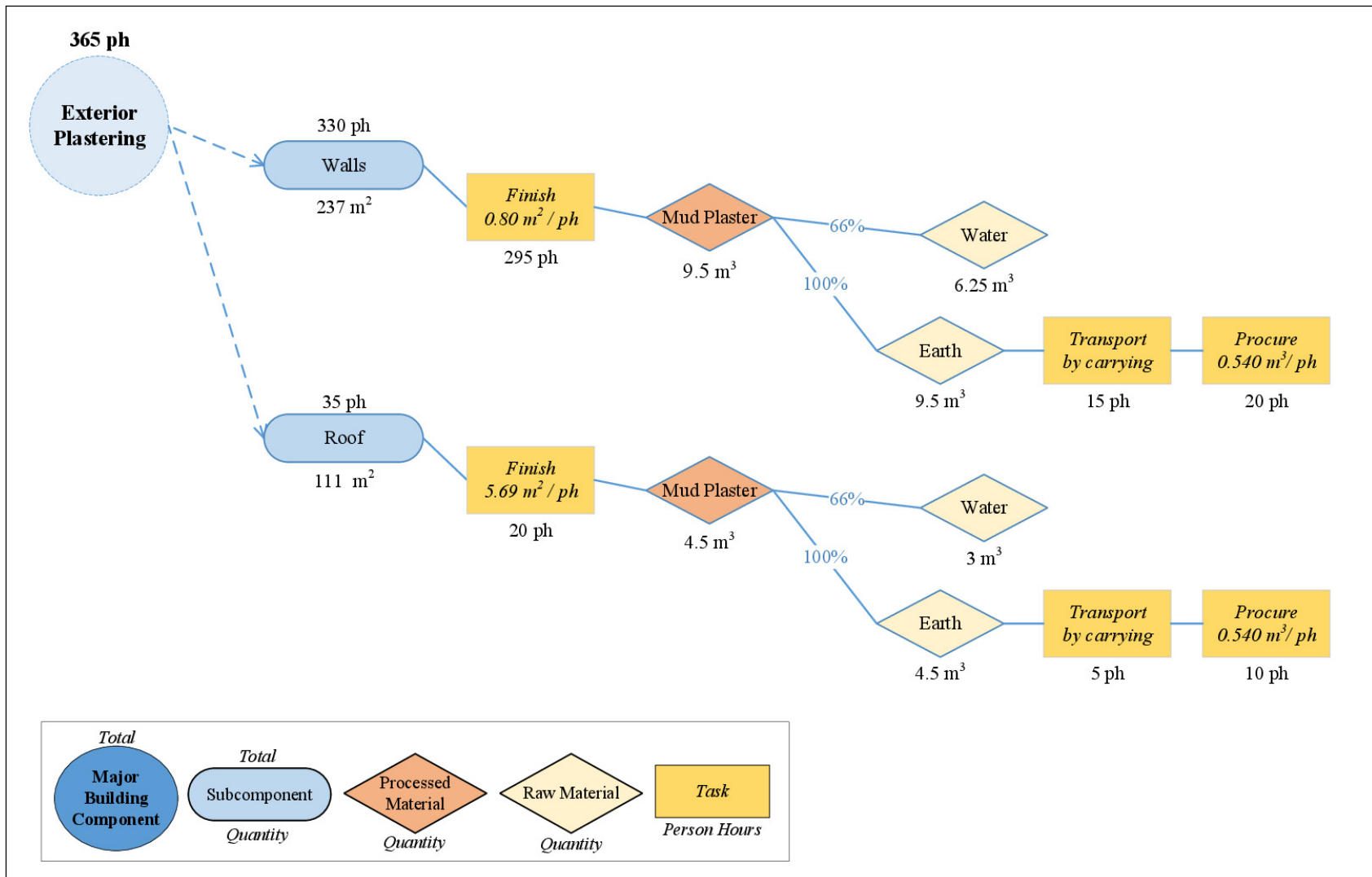
Figure A.120 Energetic flowchart for structure 7-X, exterior plastering.
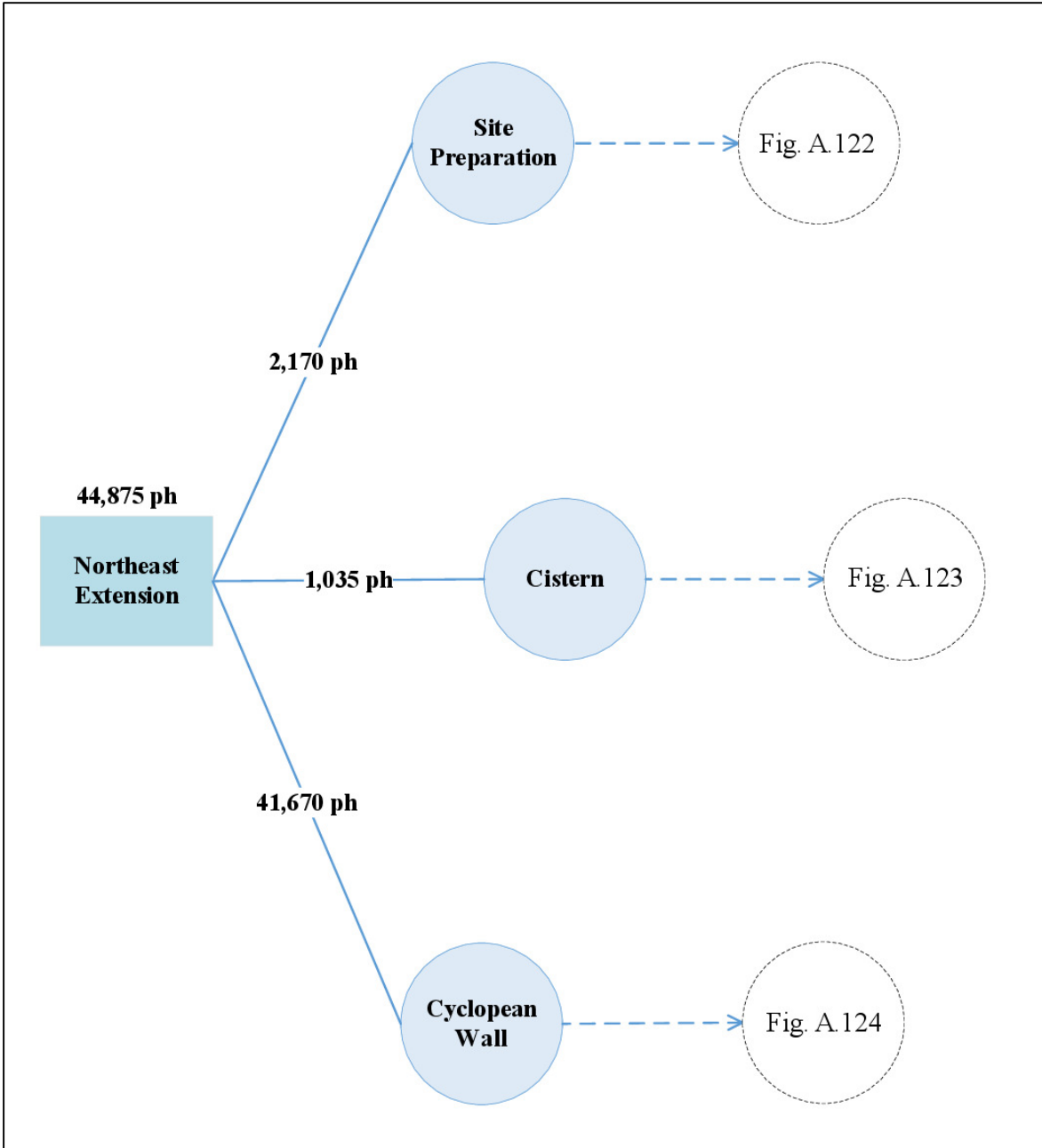
Figure A.121 Energetic flowchart for the Northeast Extension
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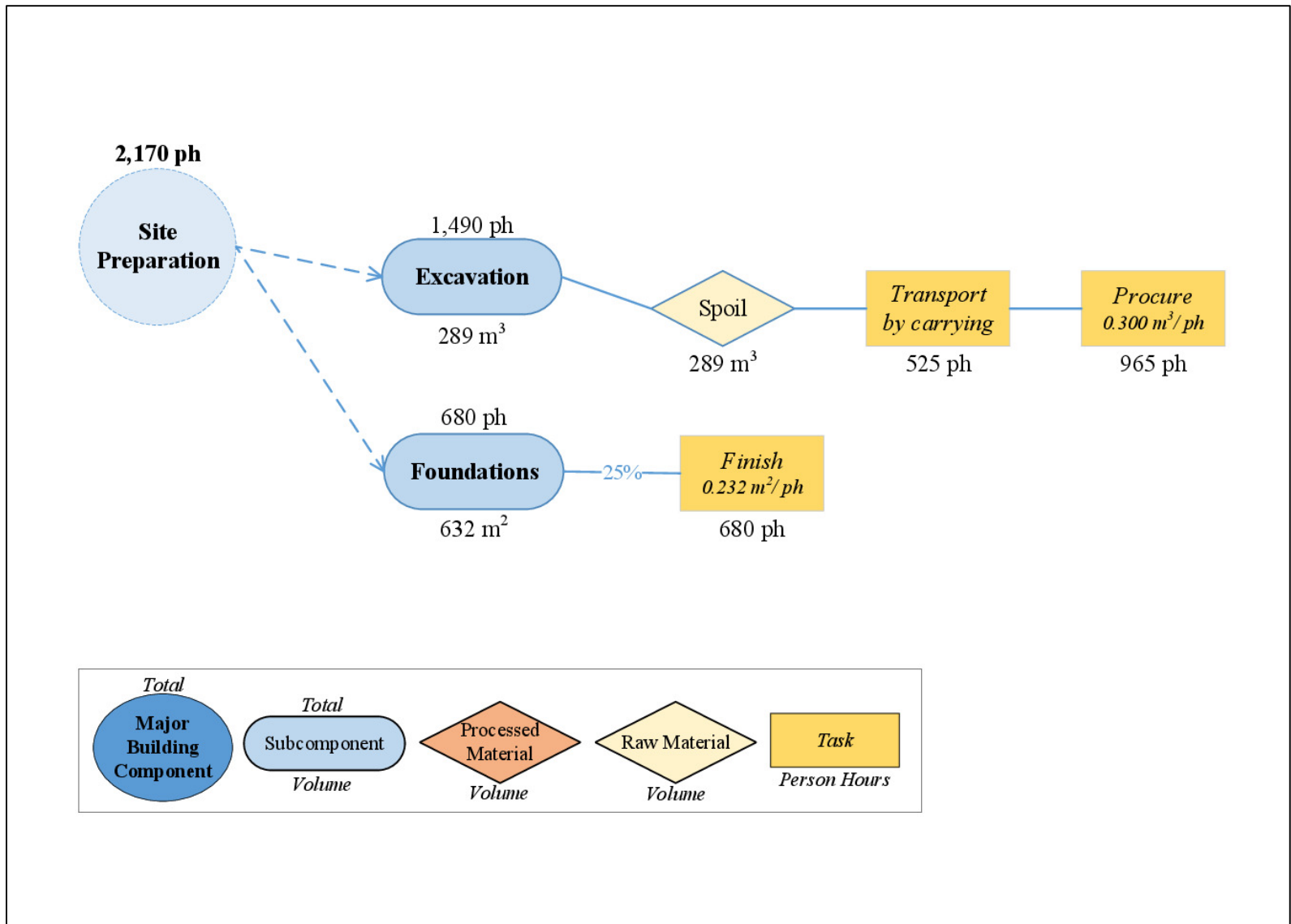
Figure A.122 Energetic flowchart for the Northeast Extension, site preparation.
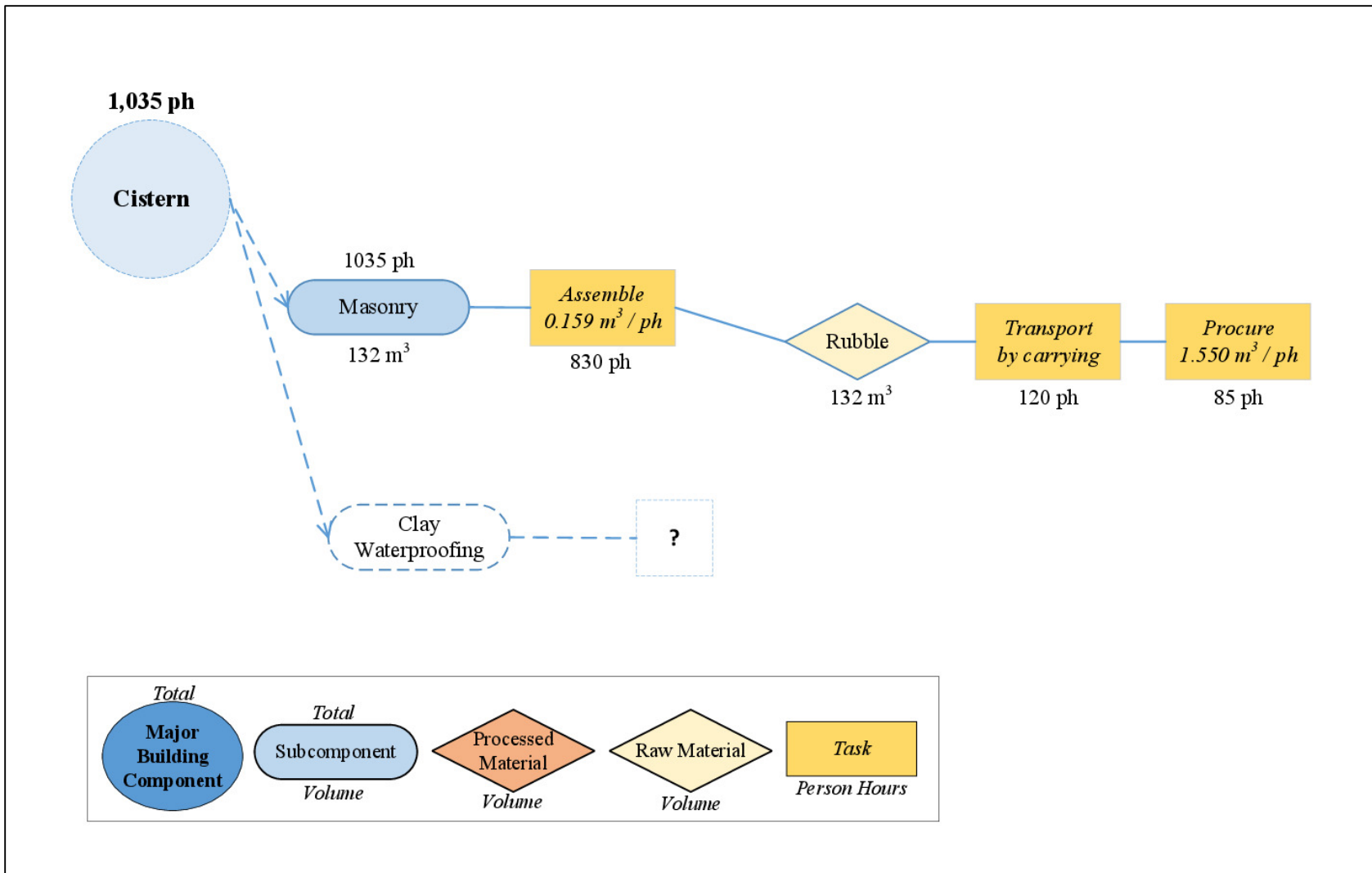
Figure A.123 Energetic flowchart for the Northeast Extension, cistern.
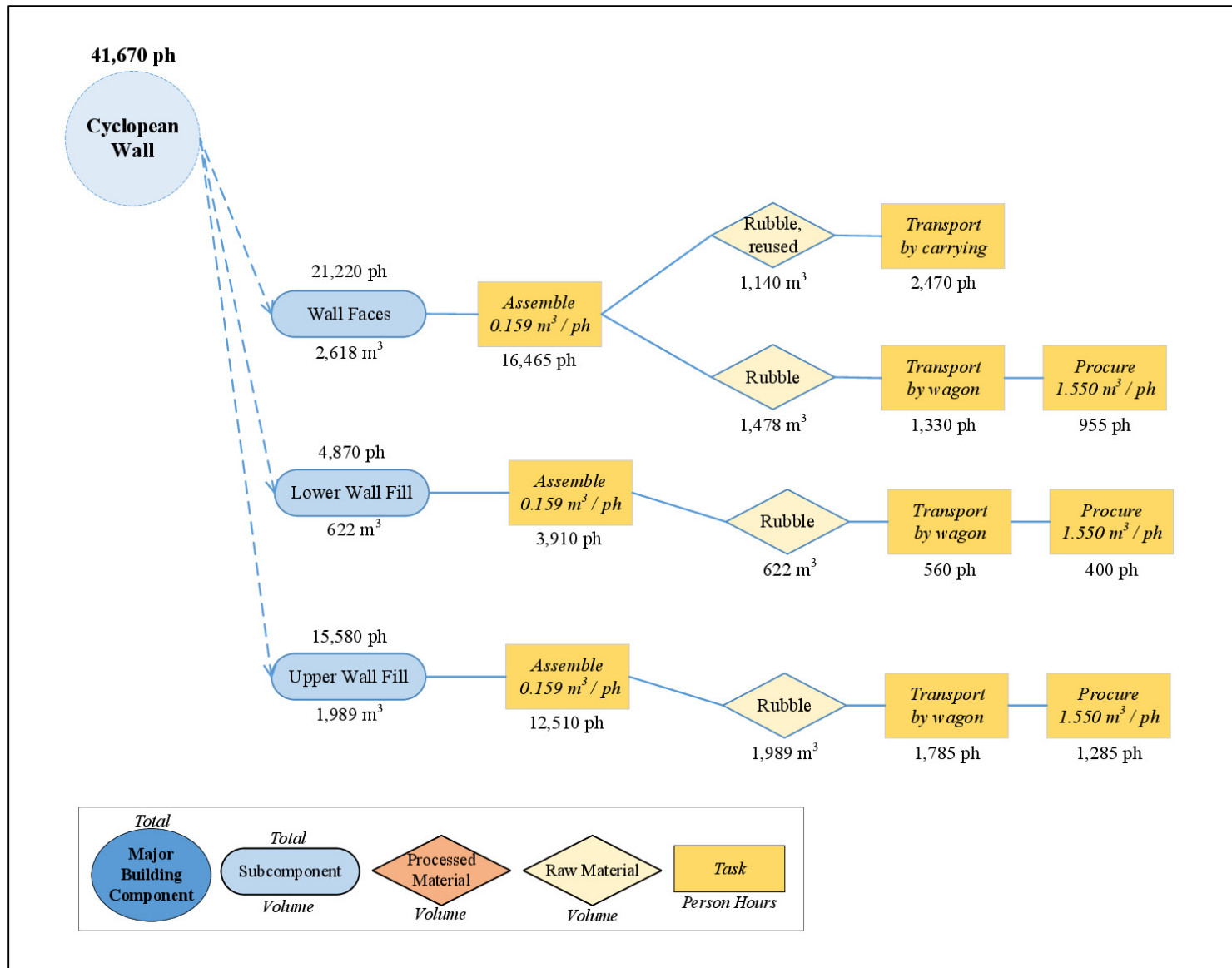
Figure A.124 Energetic flowchart for the Northeast Extension, cyclopean masonry.
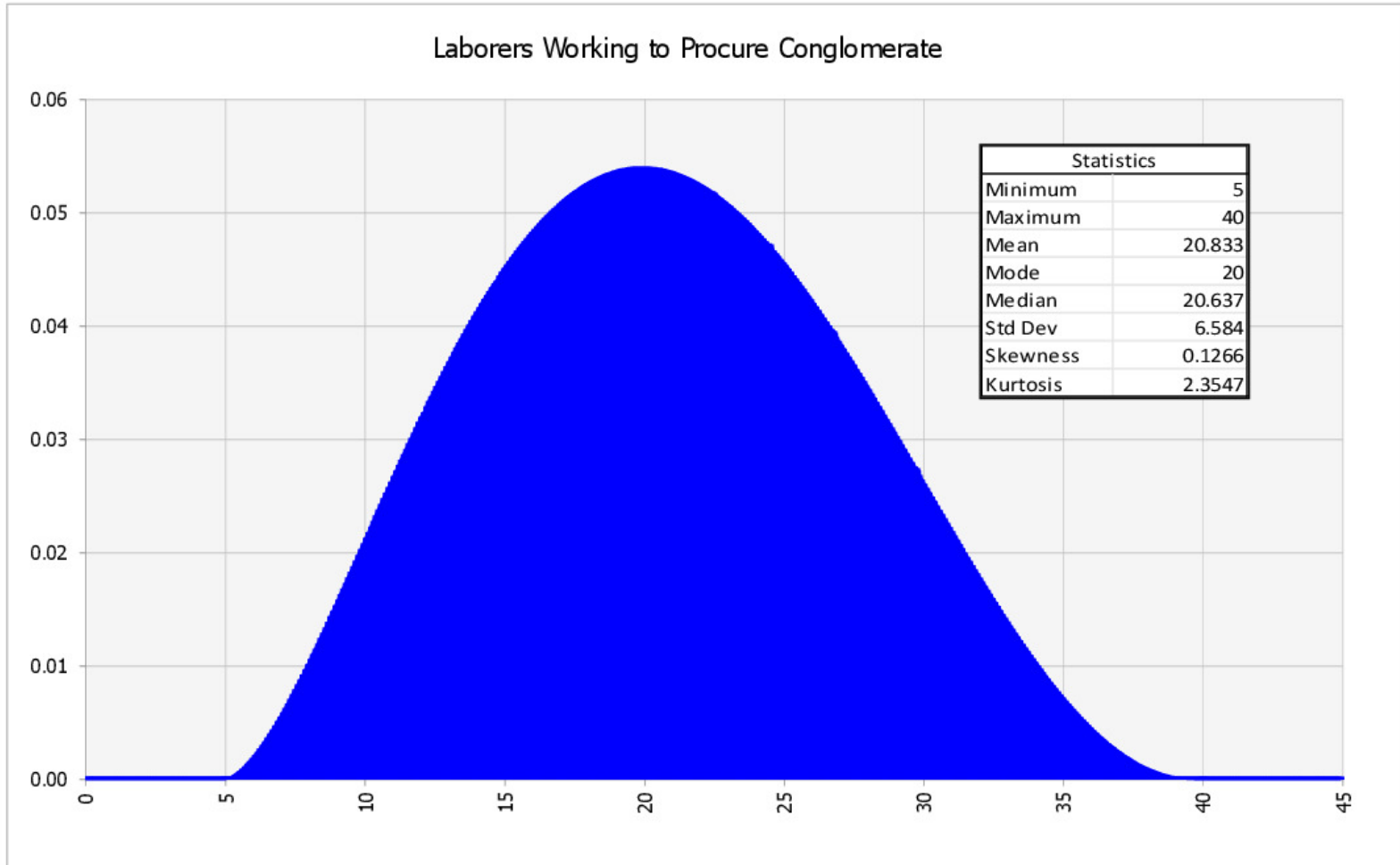
Figure A.125 An example statistical distribution for the laborers working to procure conglomerate for the Treasury of Atreus. The low, middle, and high are 5, 20, and 40 laborers, respectively. The vertical axis shows the probability density.

The Treasury of Atreus, Mycenae
Relative Frequency of Days to Complete

Statistics	
Minimum	463
Maximum	938
Mean	643
Mode	613
Median	634
Std Dev	72.83
Skewness	0.6184
Kurtosis	3.4461
10%	559
50%	634
90%	742
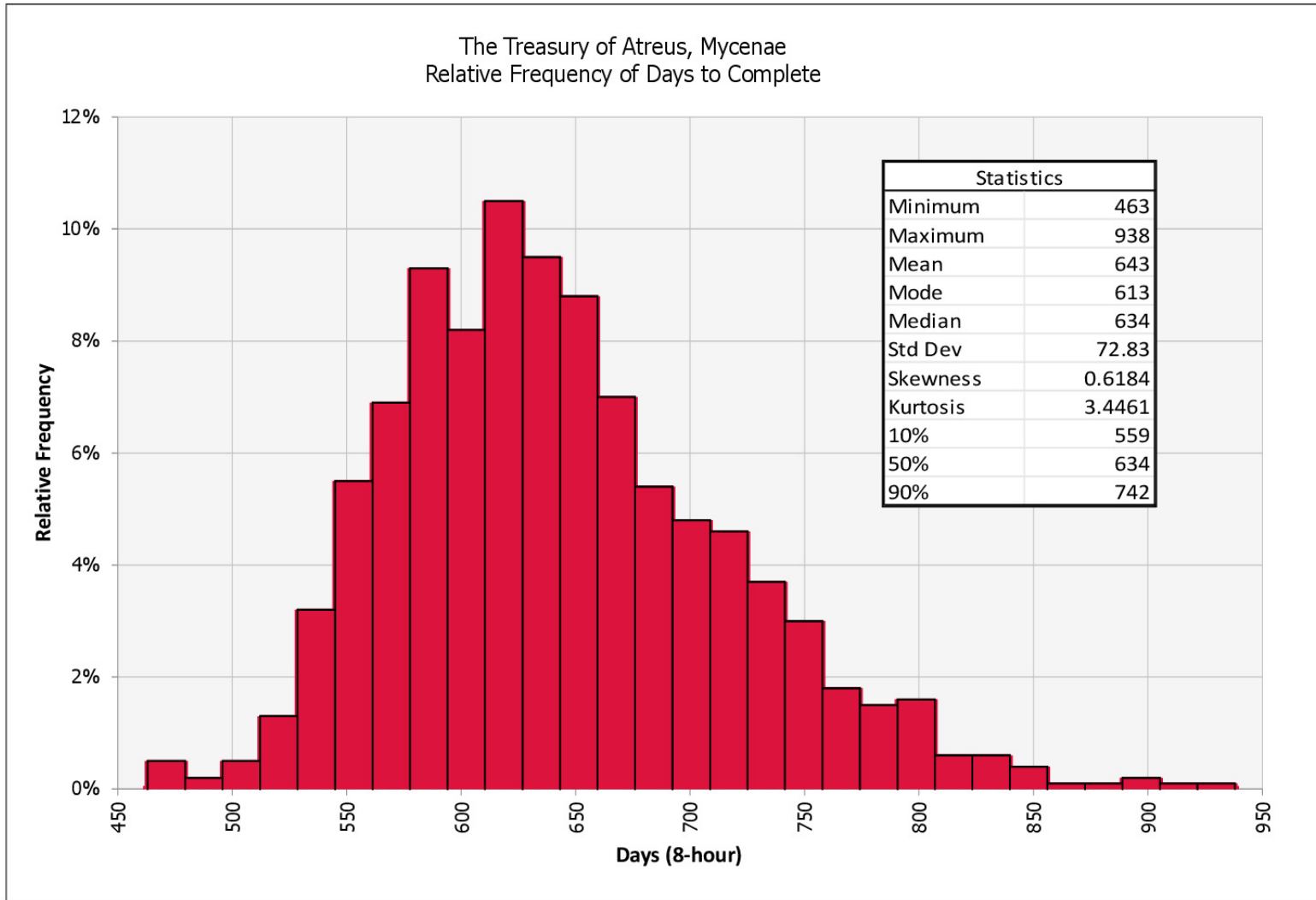
Figure A.126 The number of work days to complete the Treasury of Atreus based on simulated schedules of construction.

449
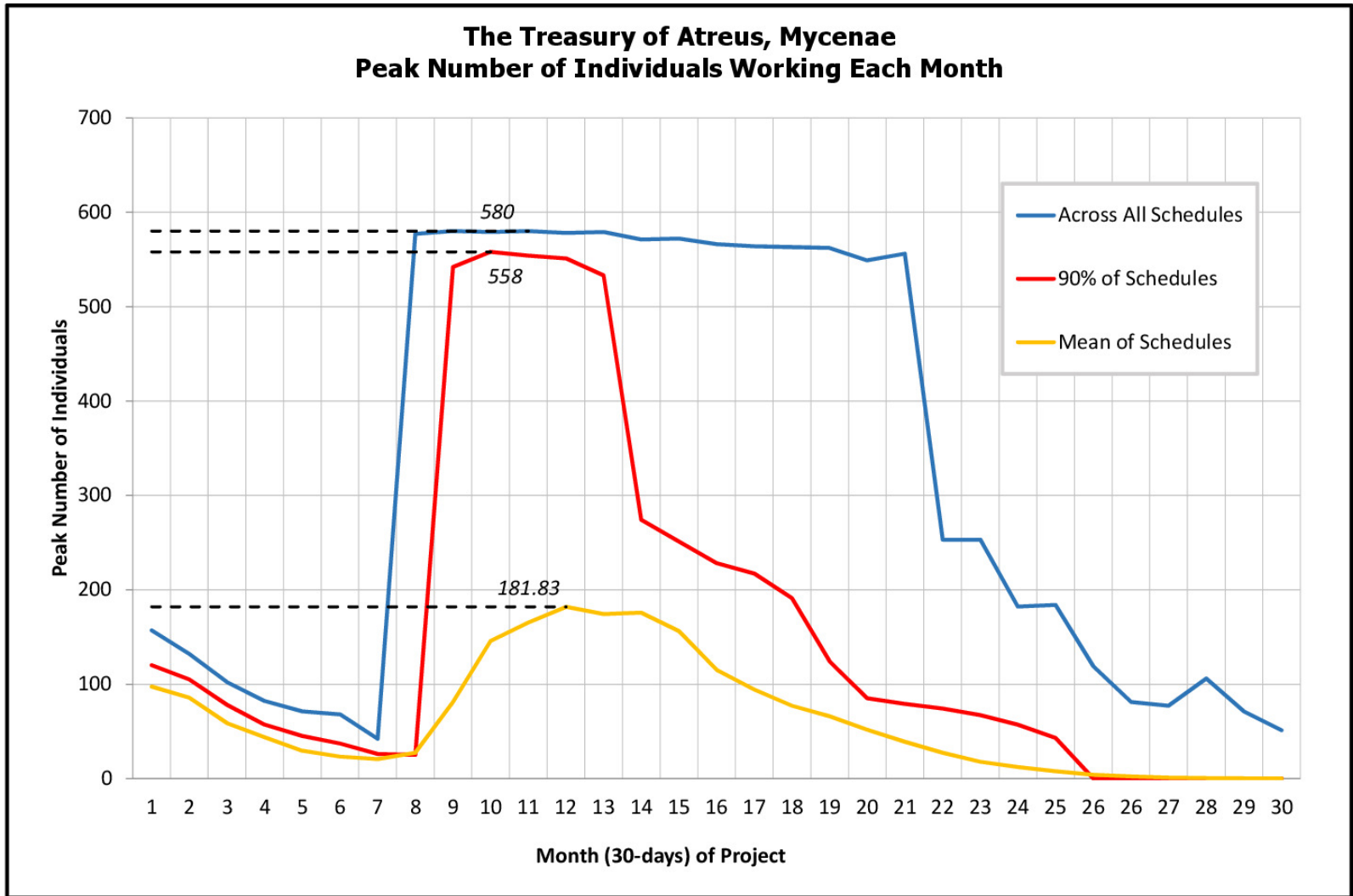
Figure A.127 Time-scaled data showing the peak number of individuals working on the Treasury of Atreus each month.
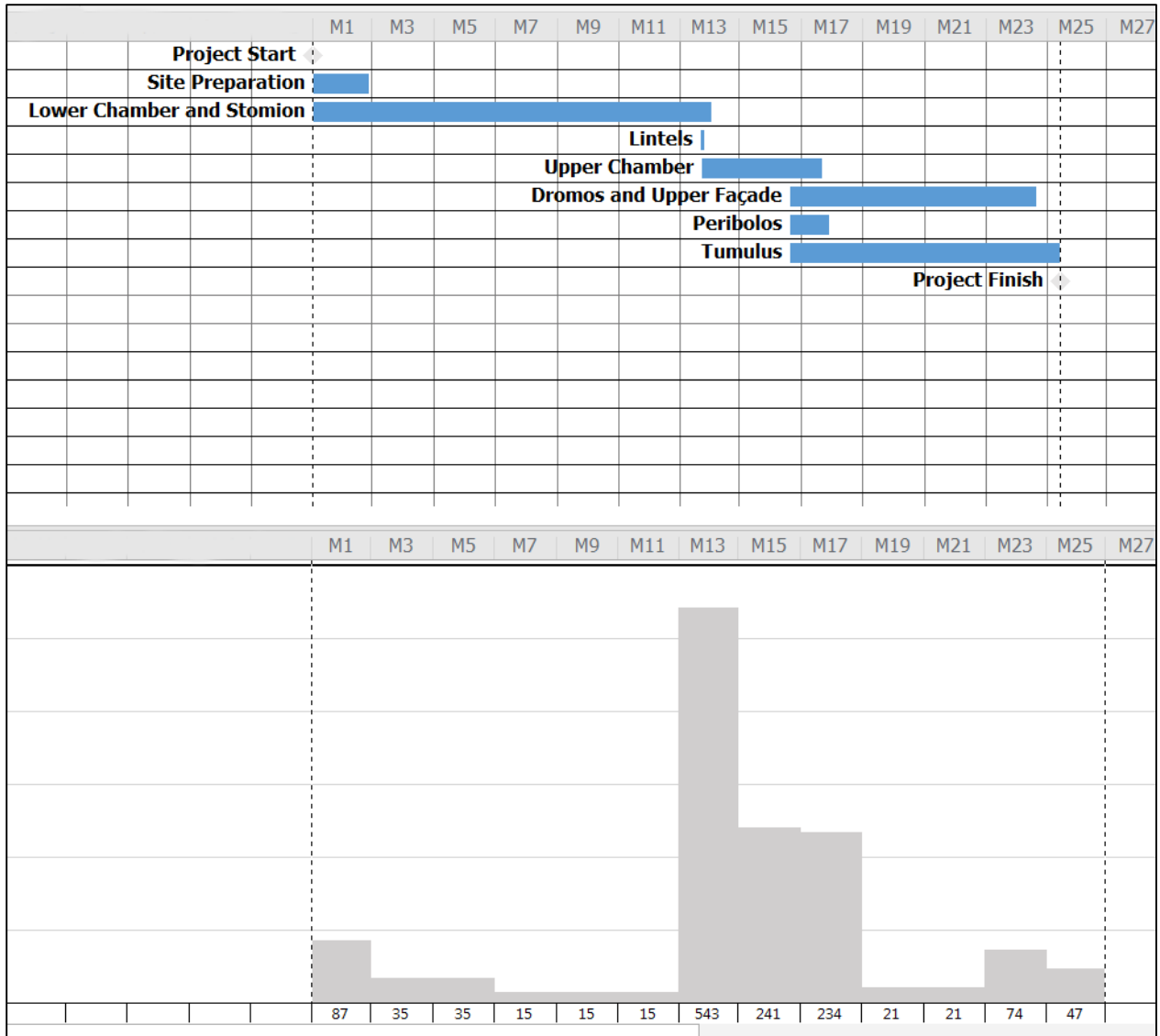
Figure A.128 A schedule for the Treasury of Atreus showing completion in 742 days, a little under 25 months, and peak labor in two month intervals.
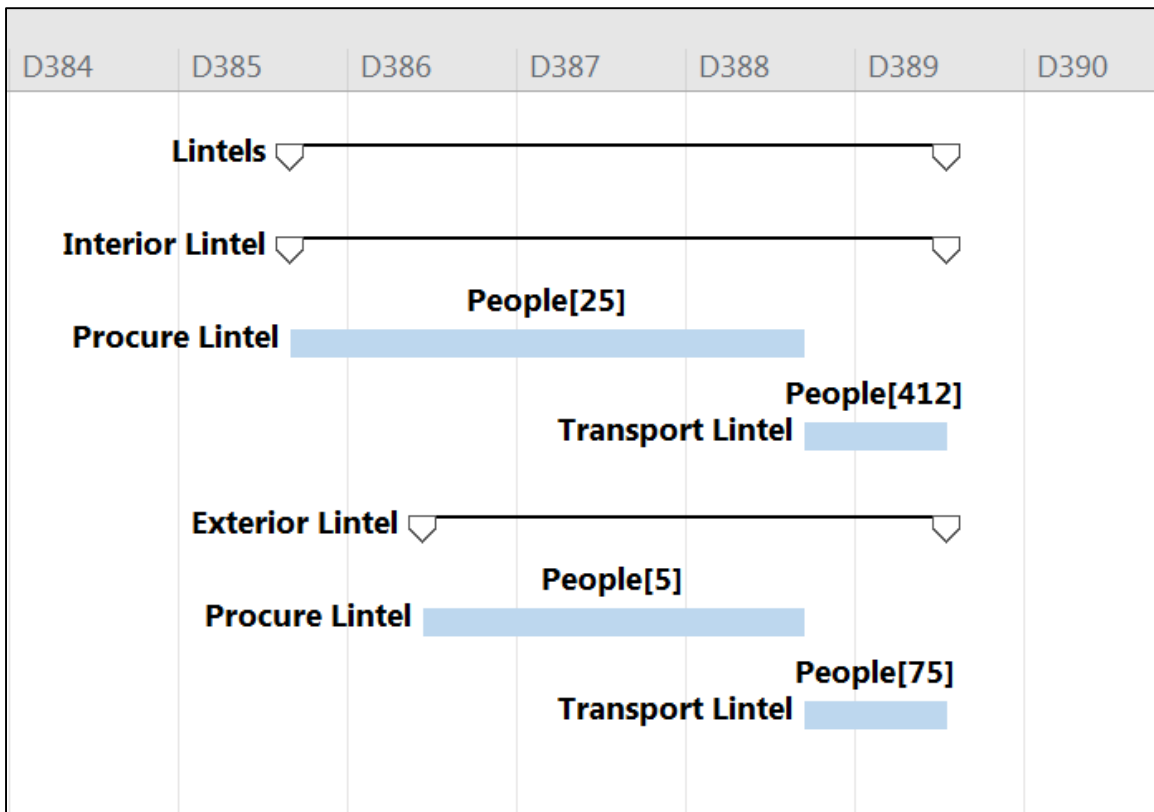
Figure A.129 The procurement and transportation of the lintels during the 742-day schedule showing the number of individuals working on each task.
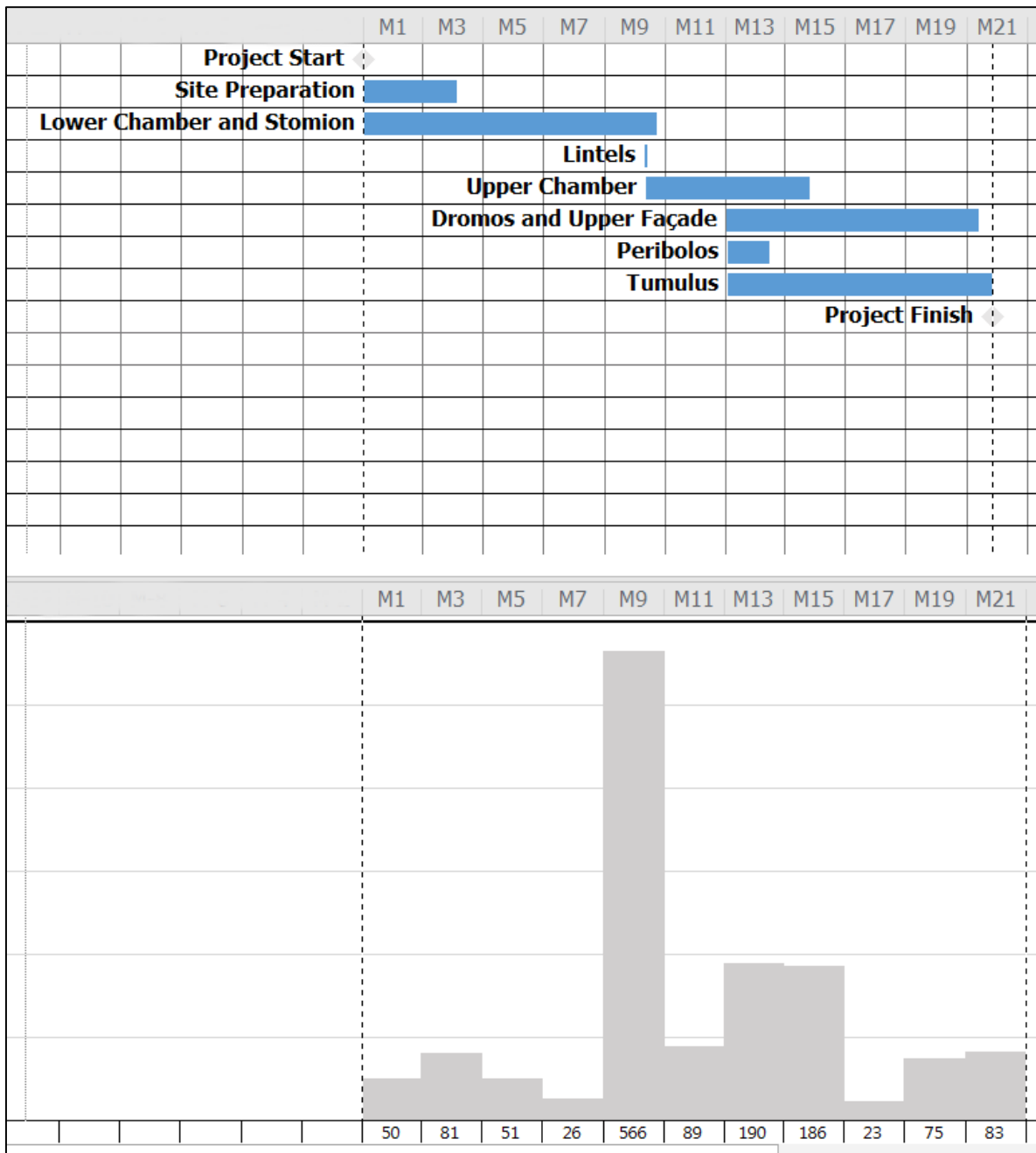
Figure A.130 A schedule for the Treasury of Atreus showing completion in 634 days, a little under 22 working months, and peak labor by month
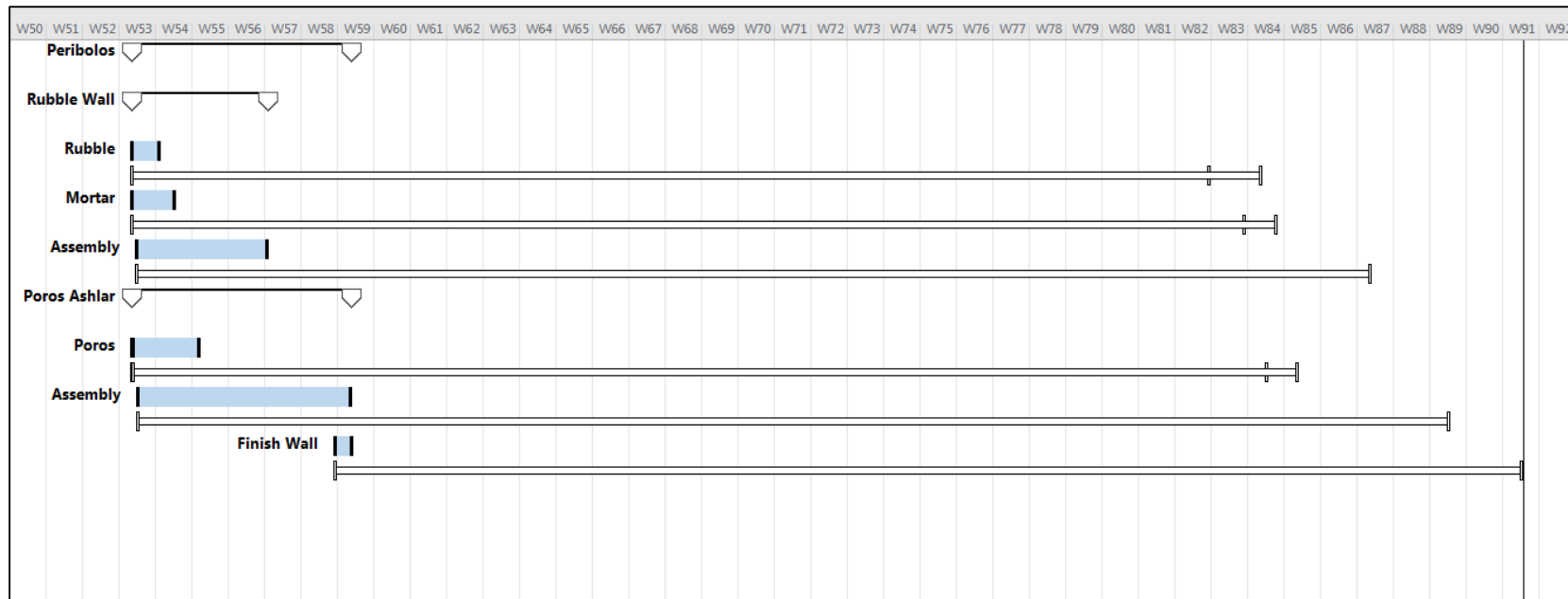
Figure A.131 The construction of the peribolos and the float time of tasks during the 634-day schedule.
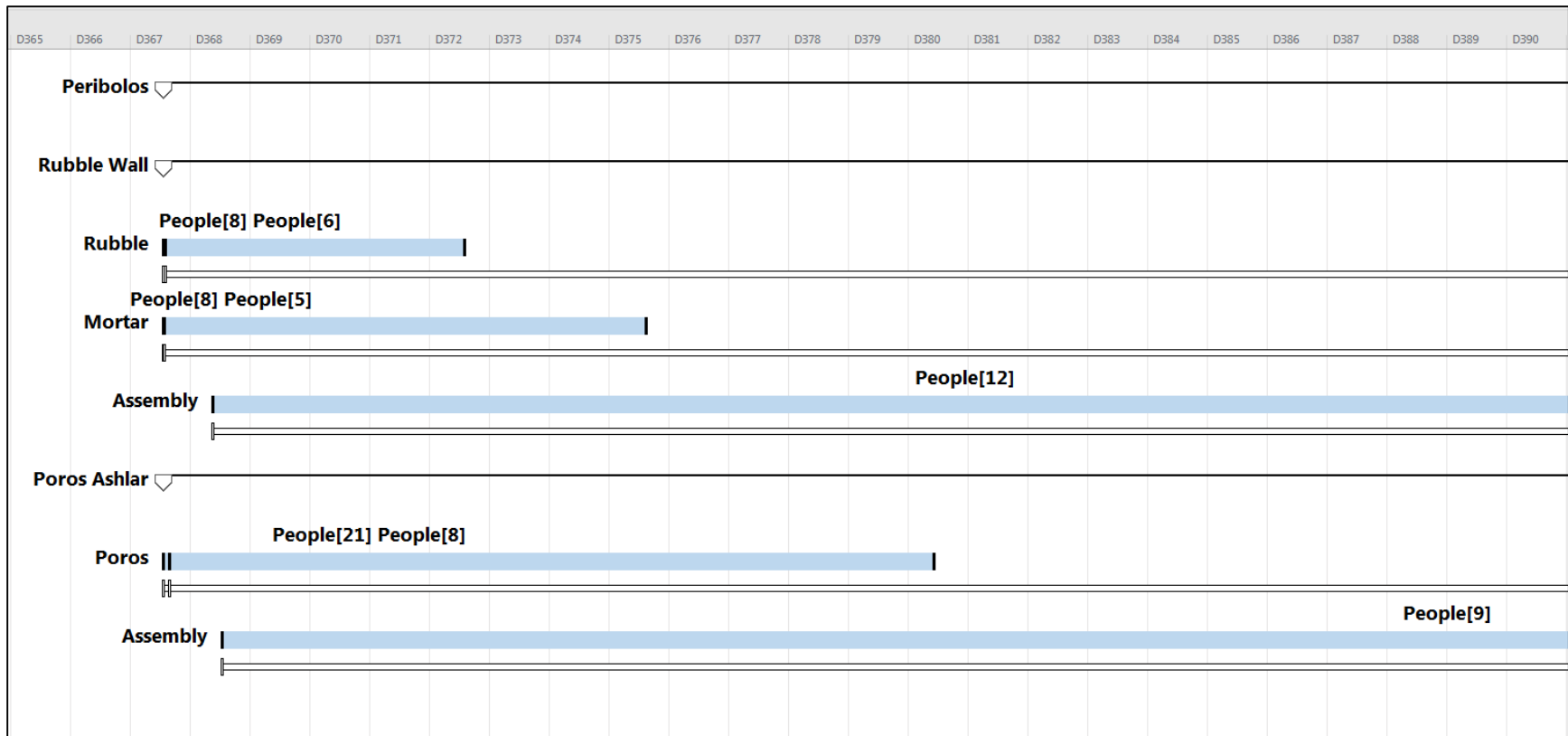
Figure A.132 The construction of the peribolos and the float time of tasks during the 634-day schedule, showing the number of laborers working at each task.
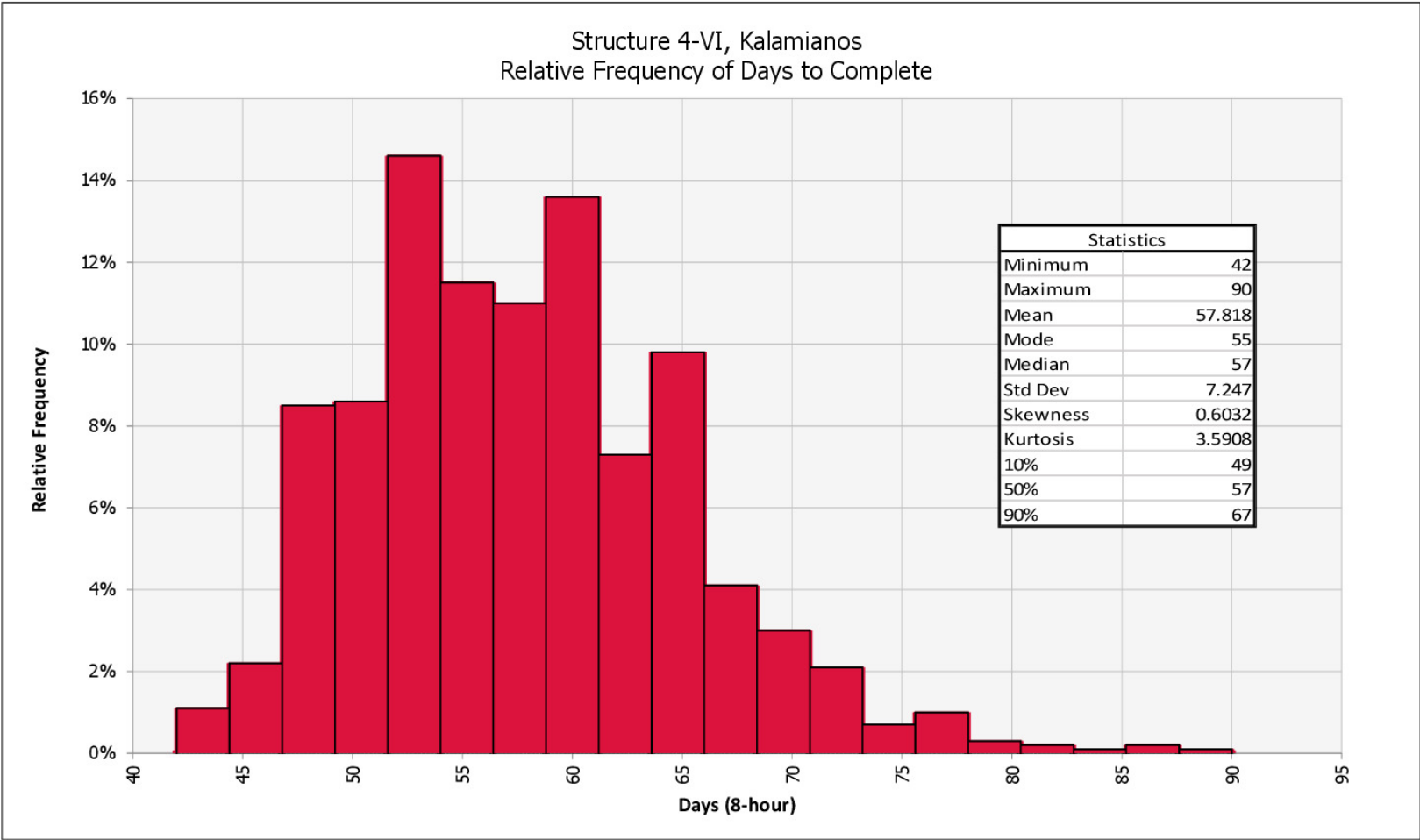
Figure A.133 The number of work days to complete structure 4-VI at Kalamianos based on simulated schedules of construction.
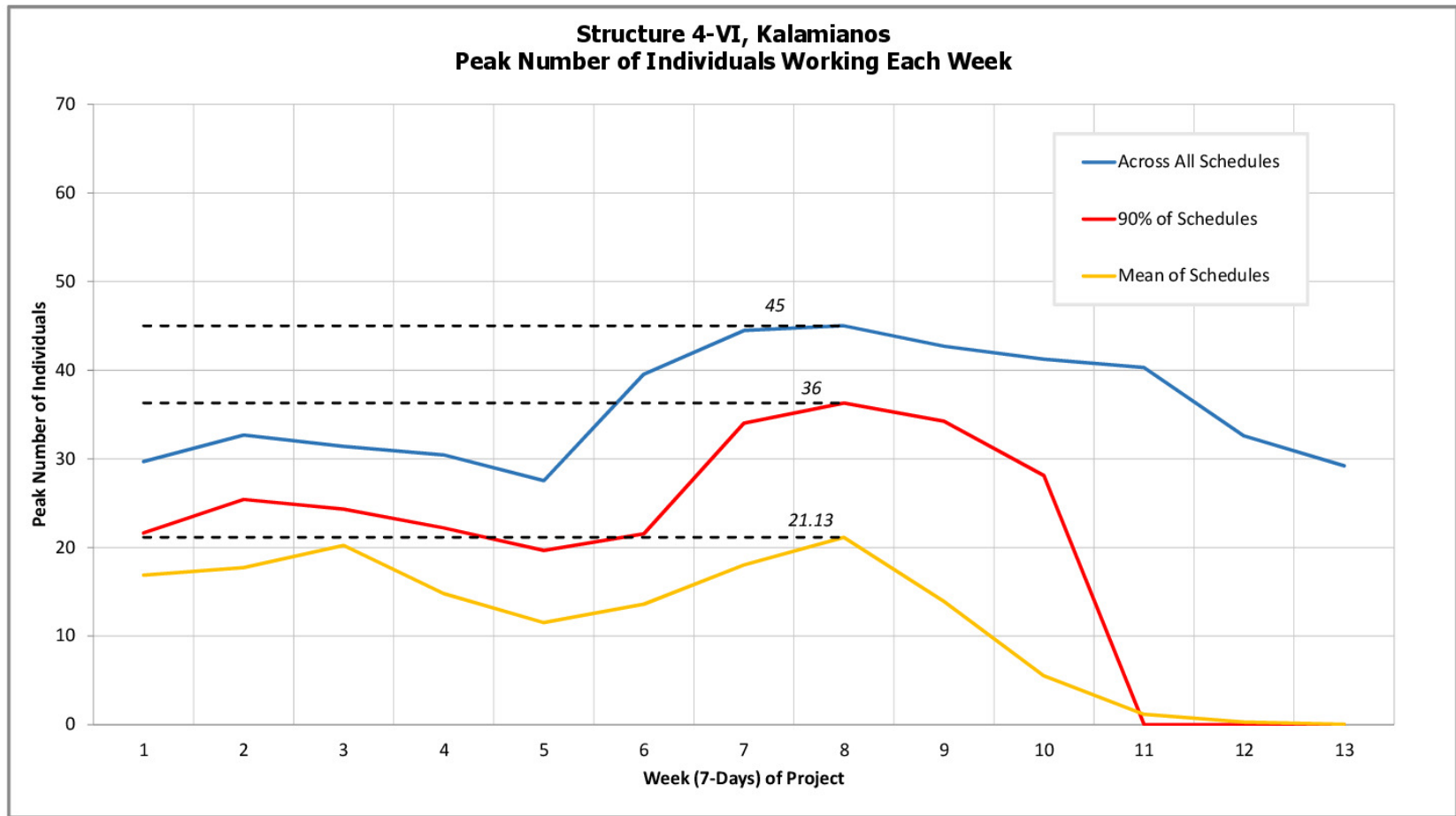
Figure A.134 Time-scaled data showing the peak number of individuals working on structure 4-VI each week.
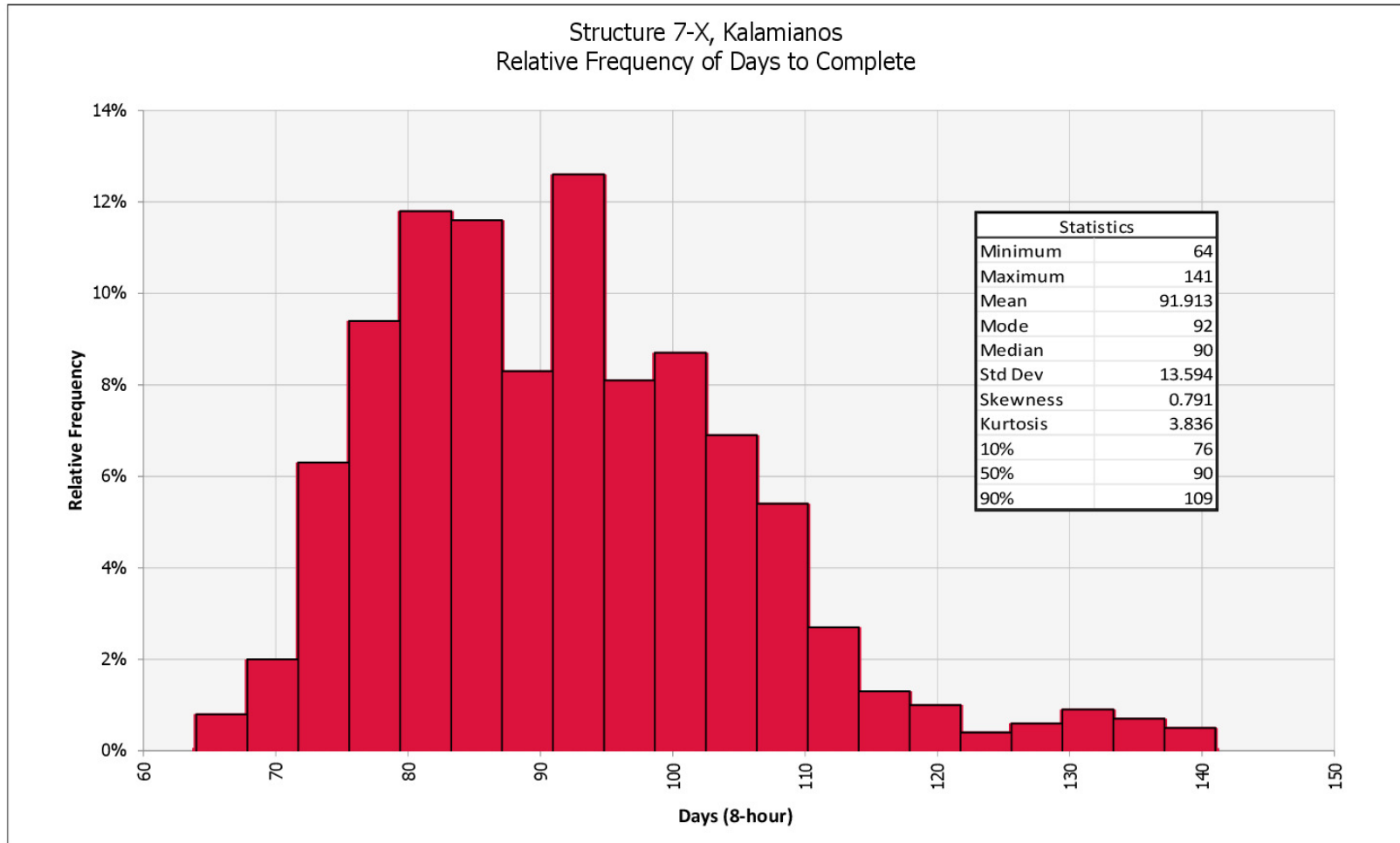
Figure A.135 The number of work days to complete structure 7-X at Kalamianos based on simulated schedules of construction.
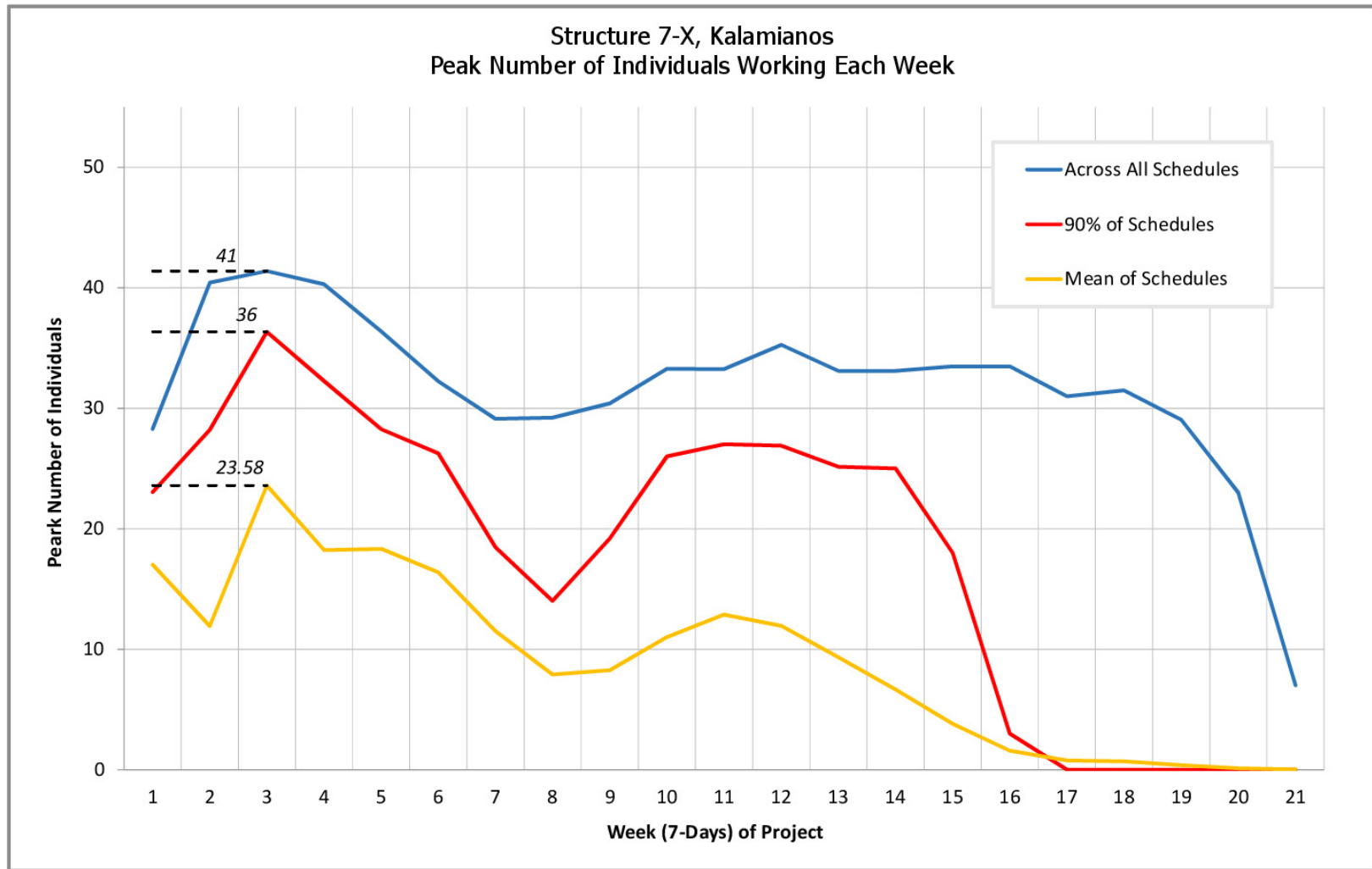
Figure A.136 Time-scaled data showing the peak number of individuals working on structure 7-X at Kalamianos each week.
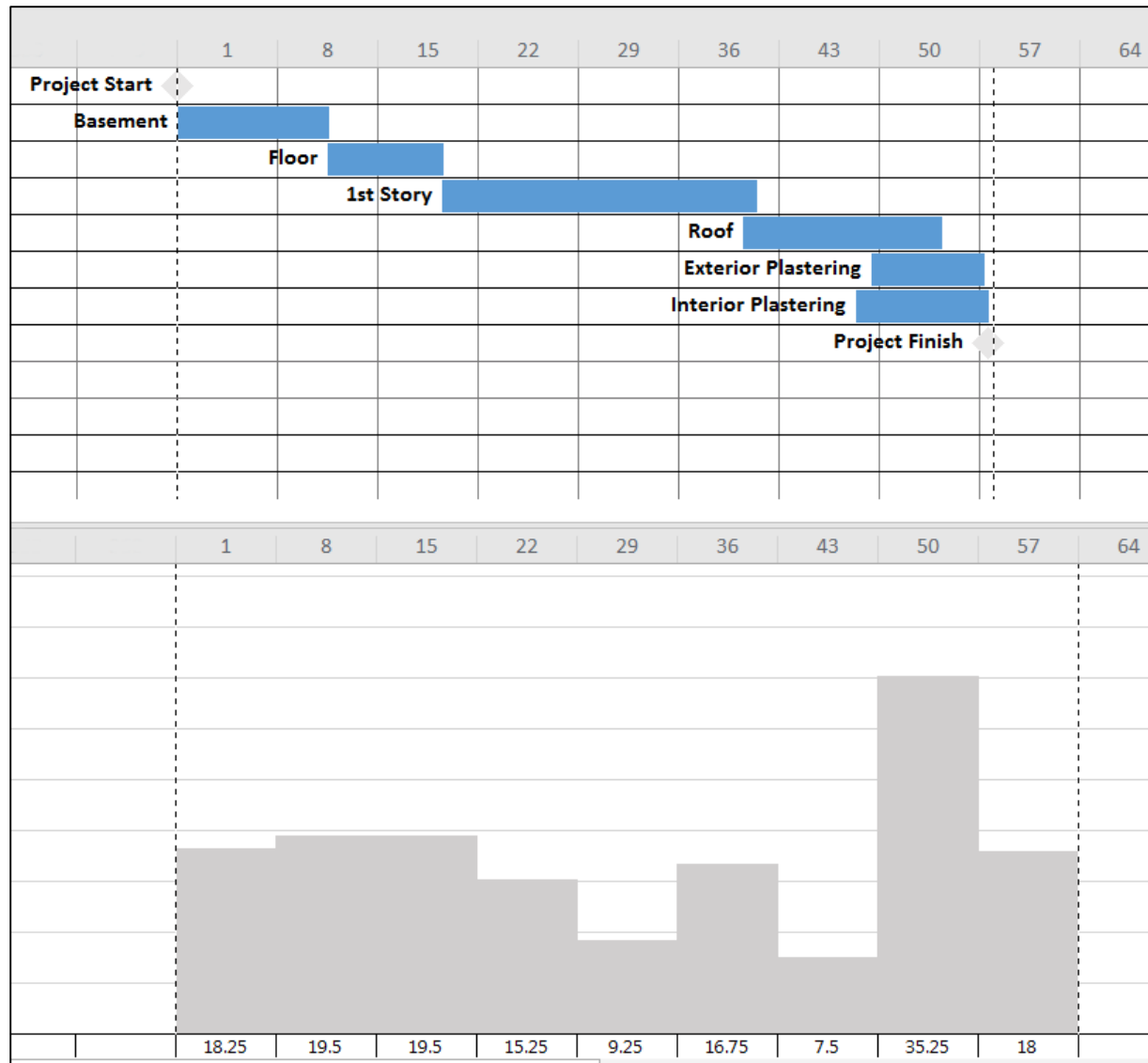
Figure A.137 A schedule for structure 4-VI at Kalamianos showing completion in 57 days and peak labor by weeks of 7 working days.
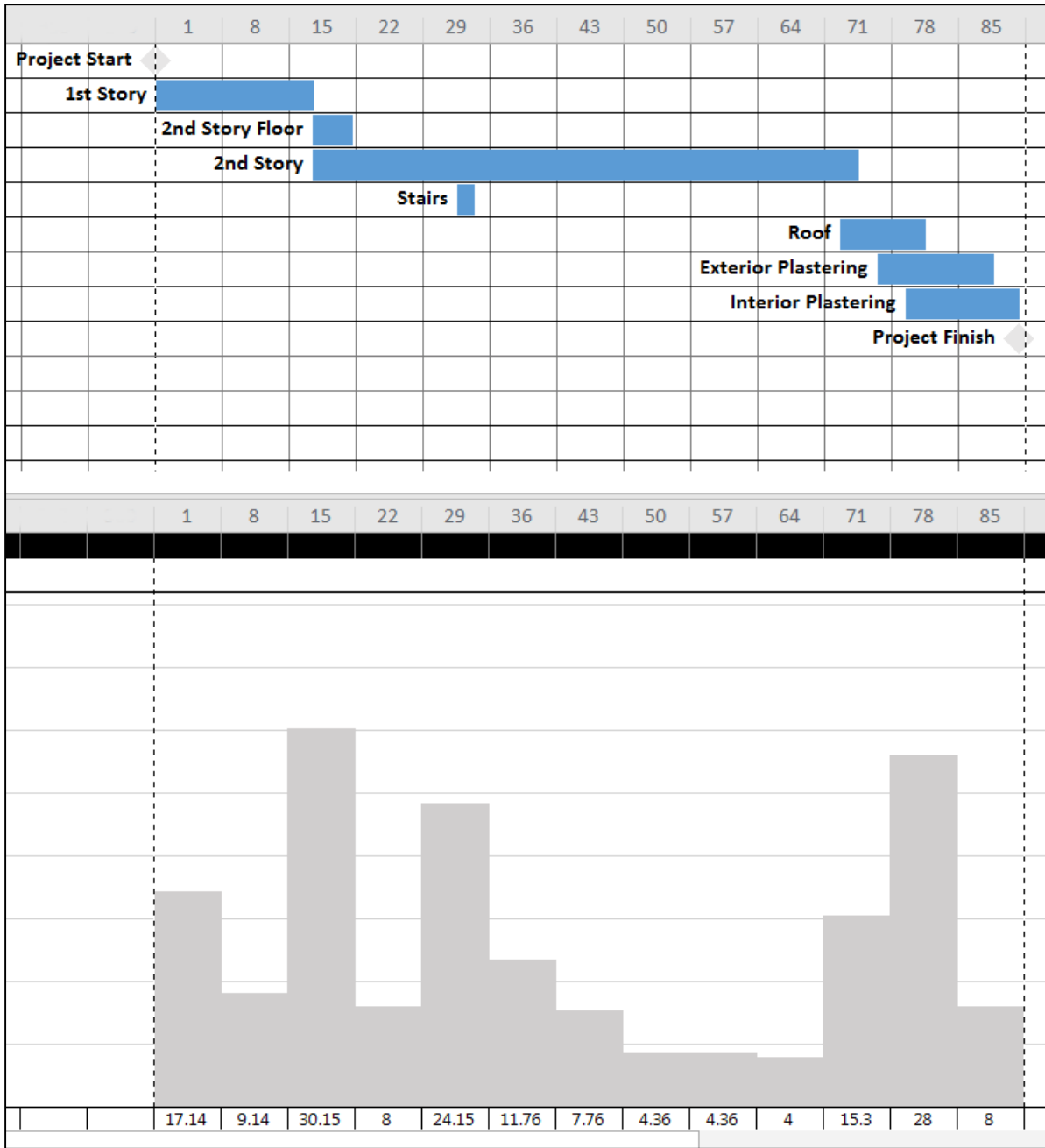
Figure A.138 A schedule for structure 7-X at Kalamianos showing completion in 90 days and peak labor by weeks of 7 working days.

461
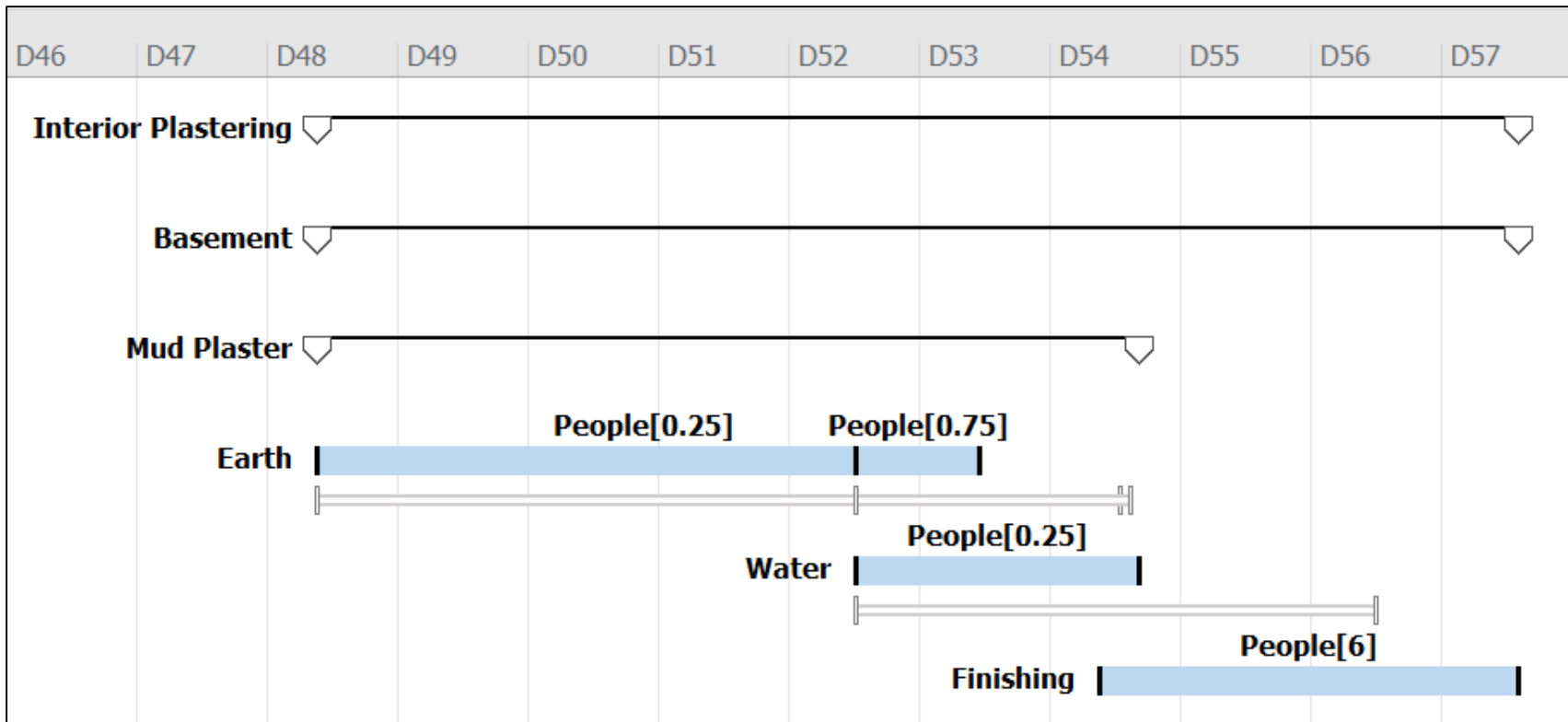
Figure A.139 The interior plastering of structure 4-VI's basement rooms in a median schedule finishing on work day 57.
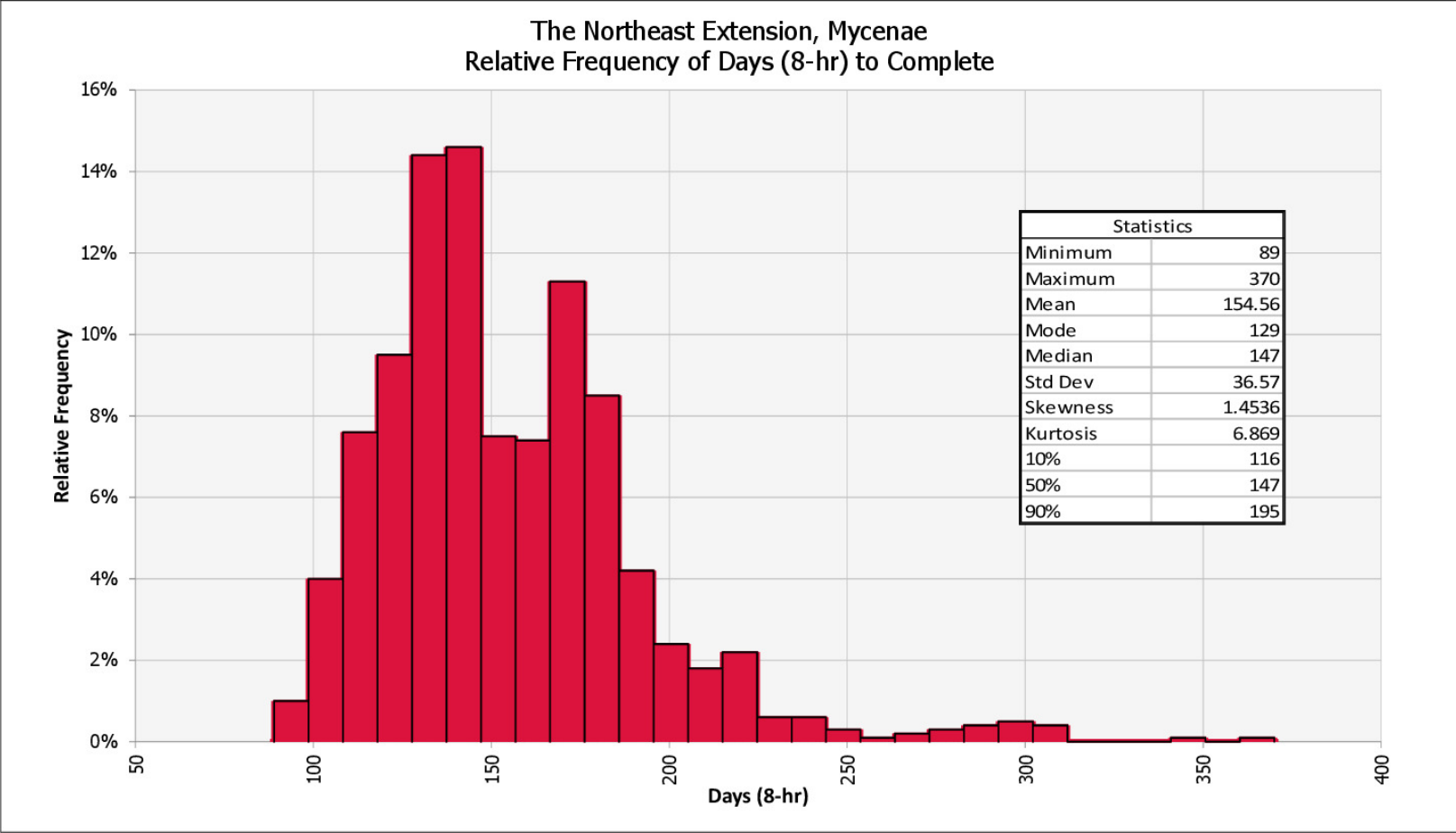
Figure A.140 The number of work days to complete Northeast Extension based on simulated schedules of construction.
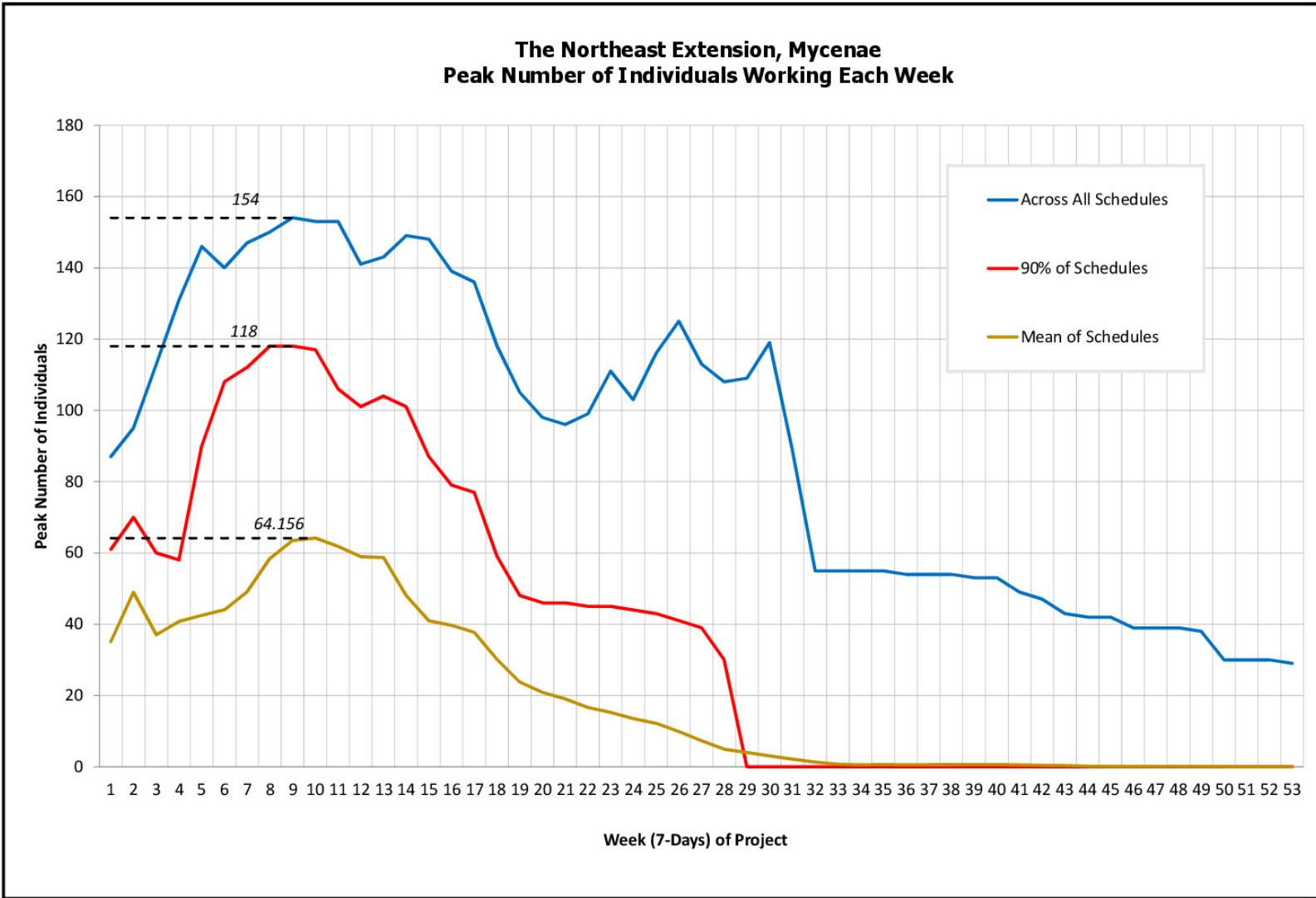
Figure A.141 Time-scaled data showing the peak number of individuals working on the Northeast Extension each week.
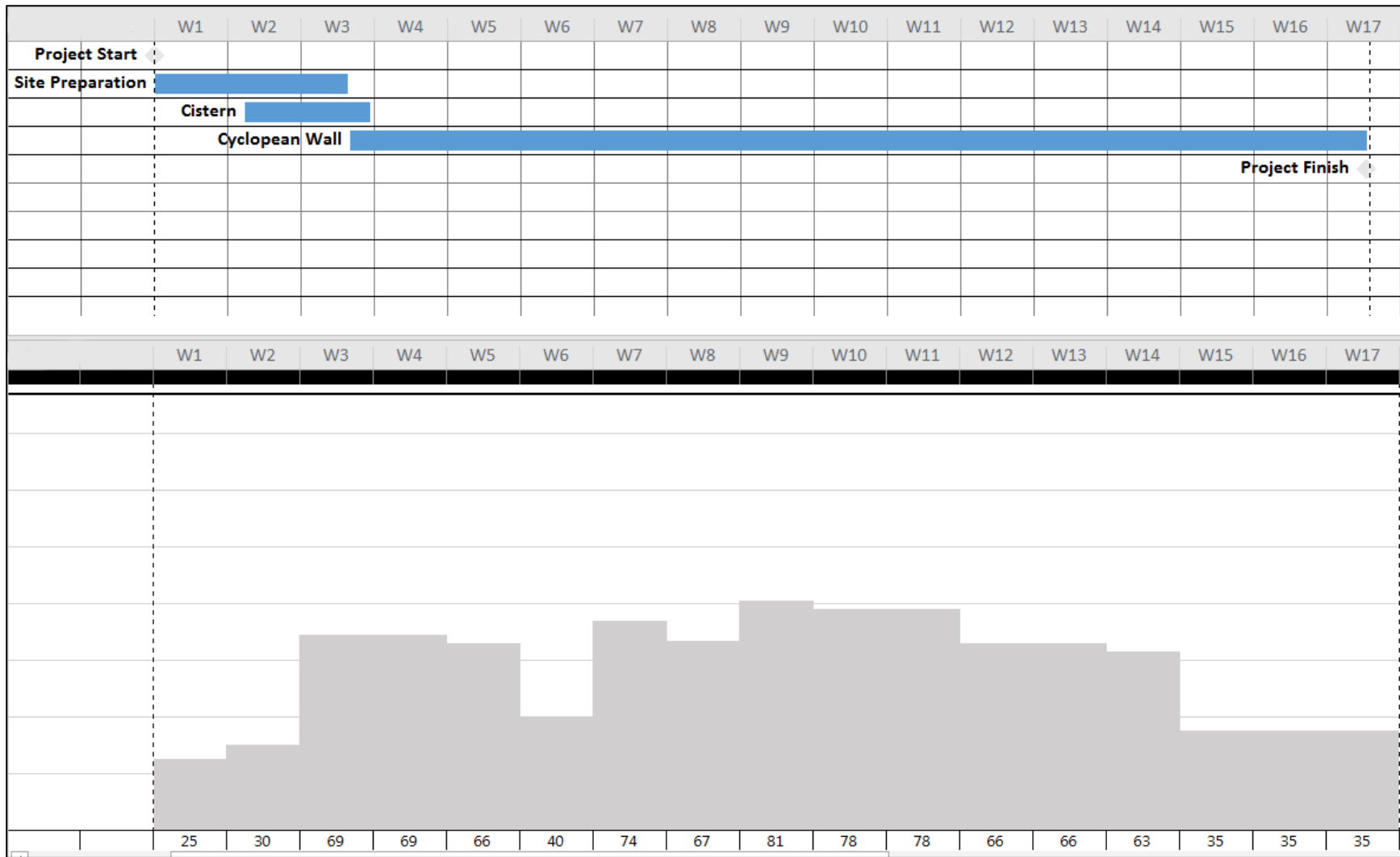
Figure A.142 A schedule for the Northeast Extension showing completion in 116 days and peak labor by week.
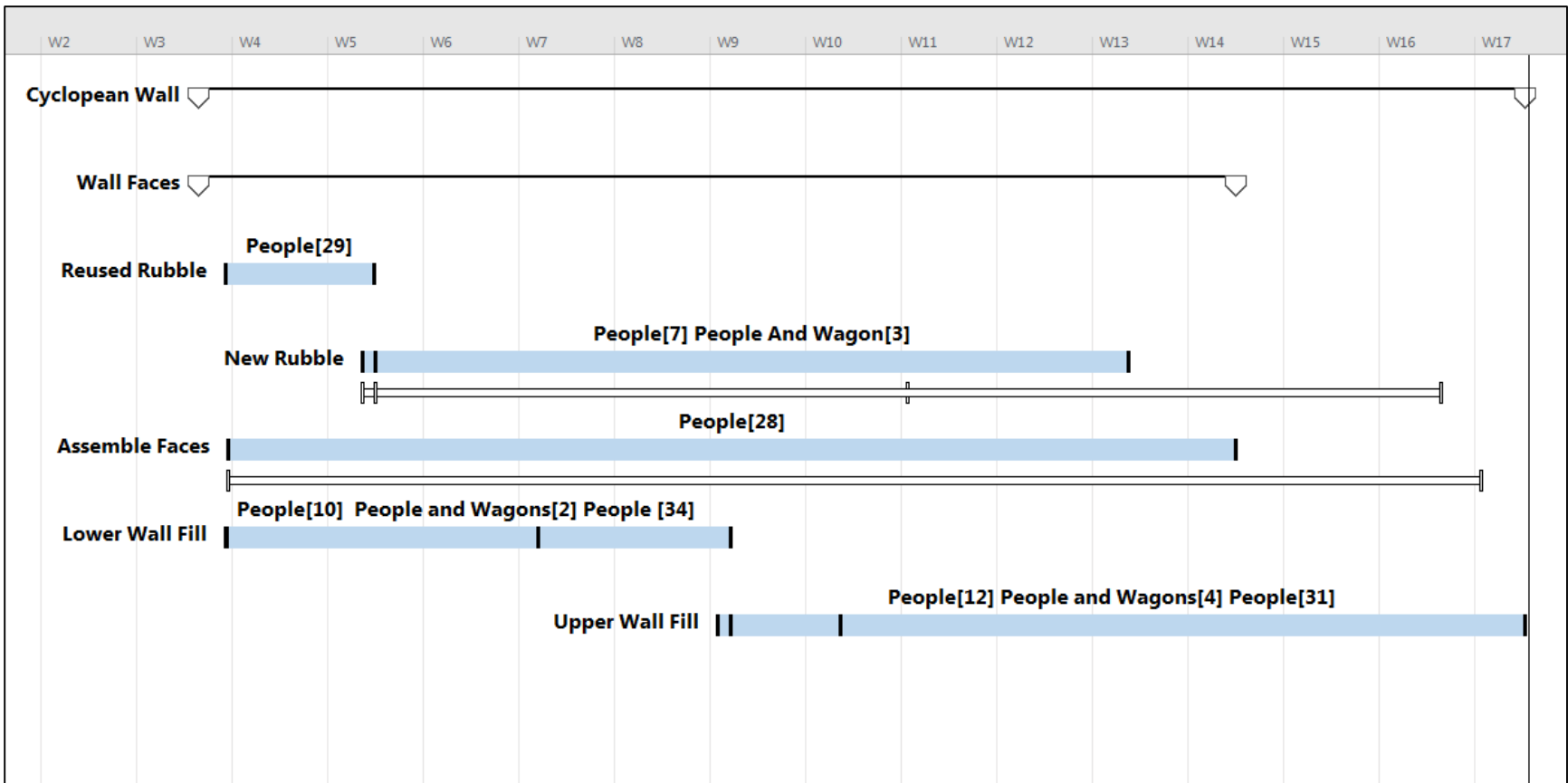
Figure A.143 The construction of the Northeast Extension's cyclopean wall in a median schedule finishing on work day 116.
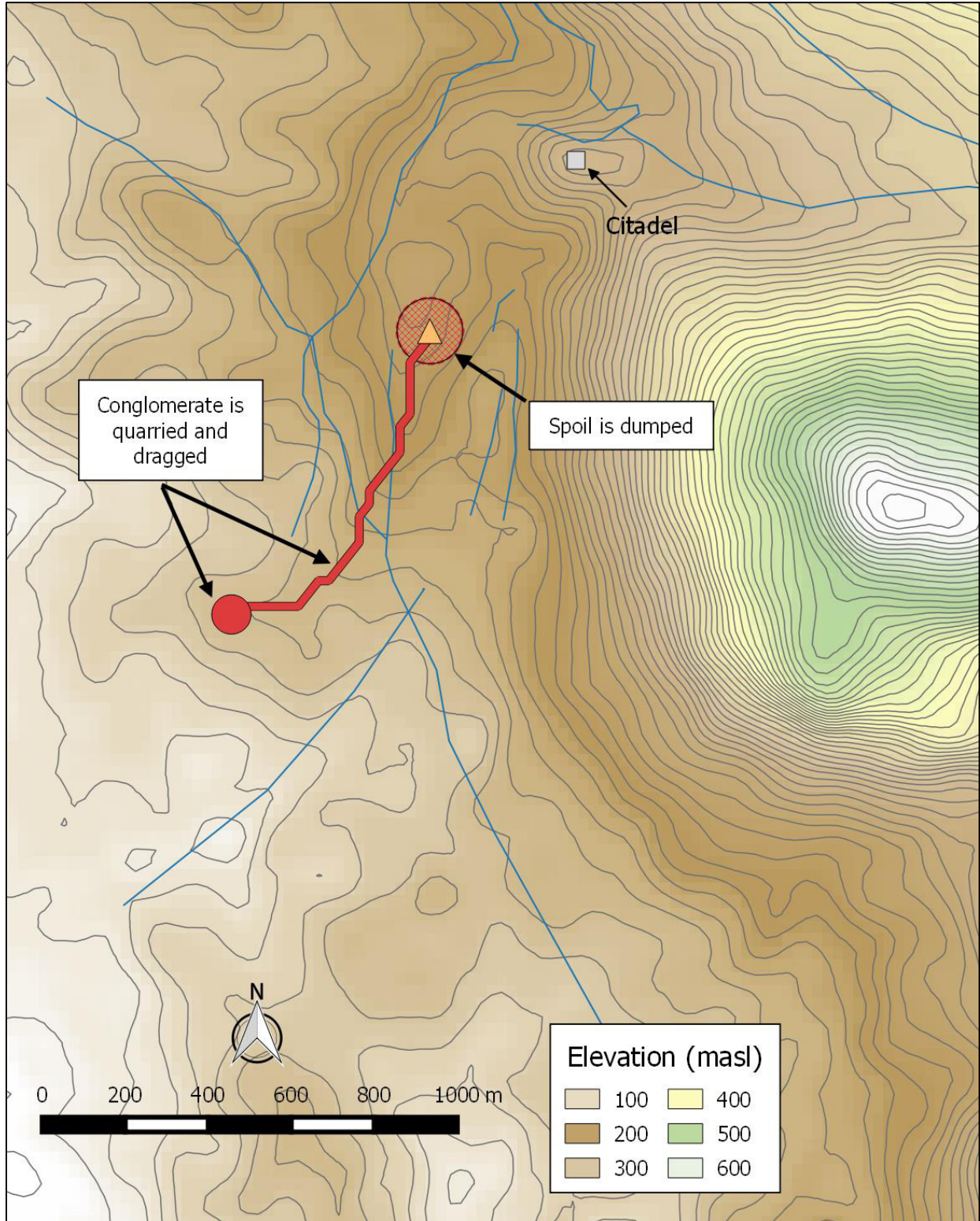
Figure A.144 Spatial configuration during production of the Treasury of Atreus, site preparation and lower chamber.
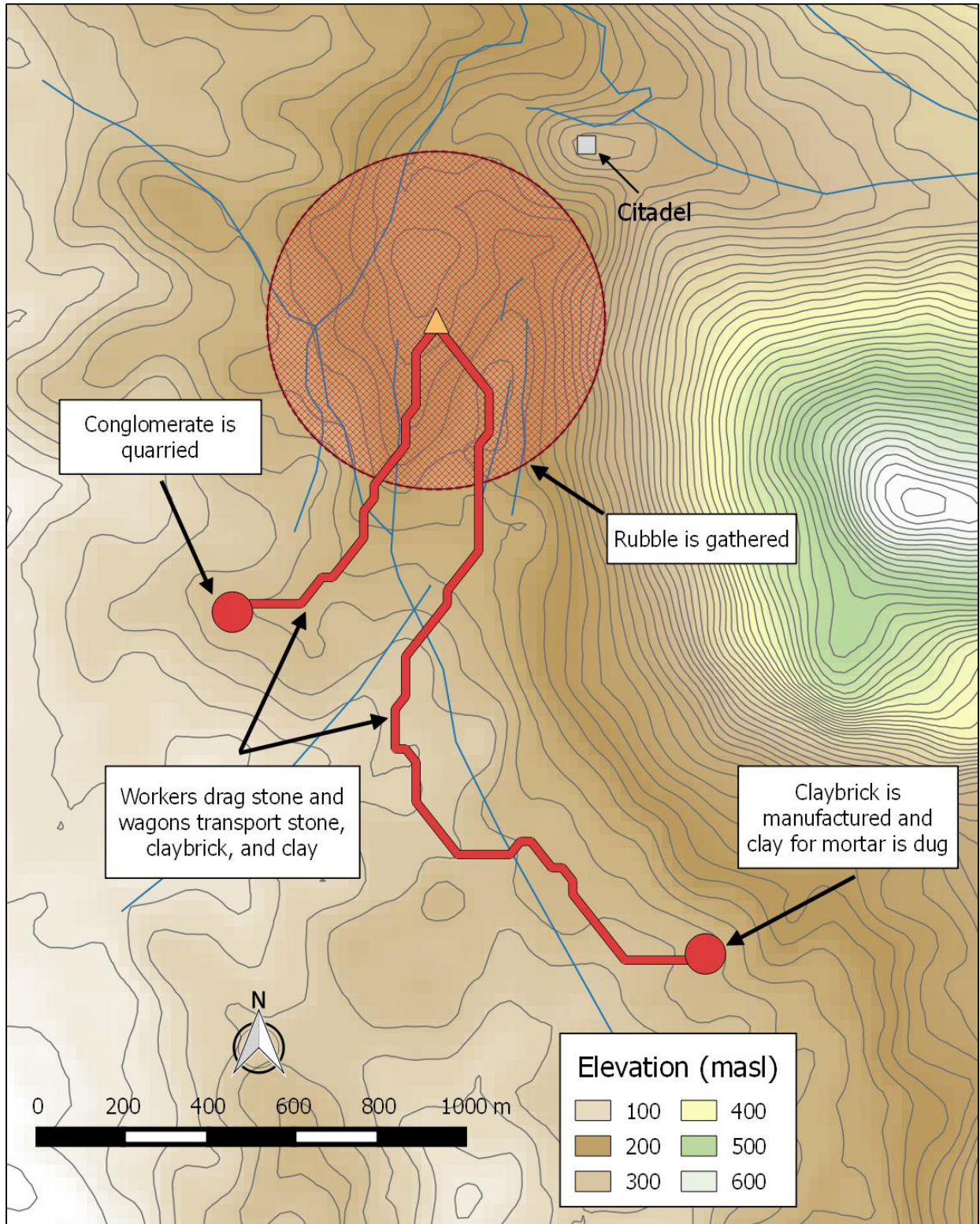
Figure A.145 Spatial configuration during production of the Treasury of Atreus, Upper Chamber, Dromos and Upper Stomion.
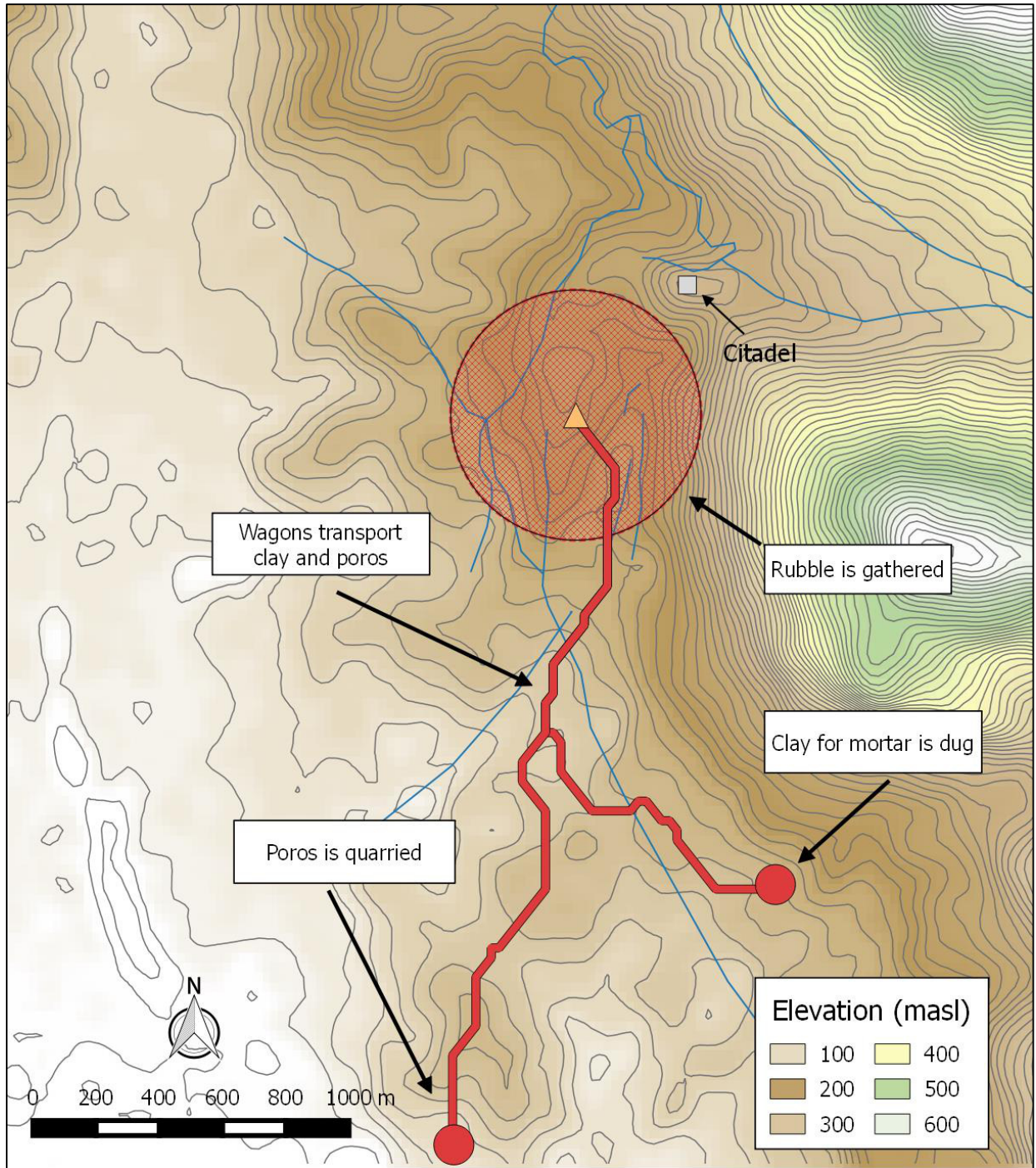
Figure A.146 Spatial configuration during production of the Treasury of Atreus, Peribolos.
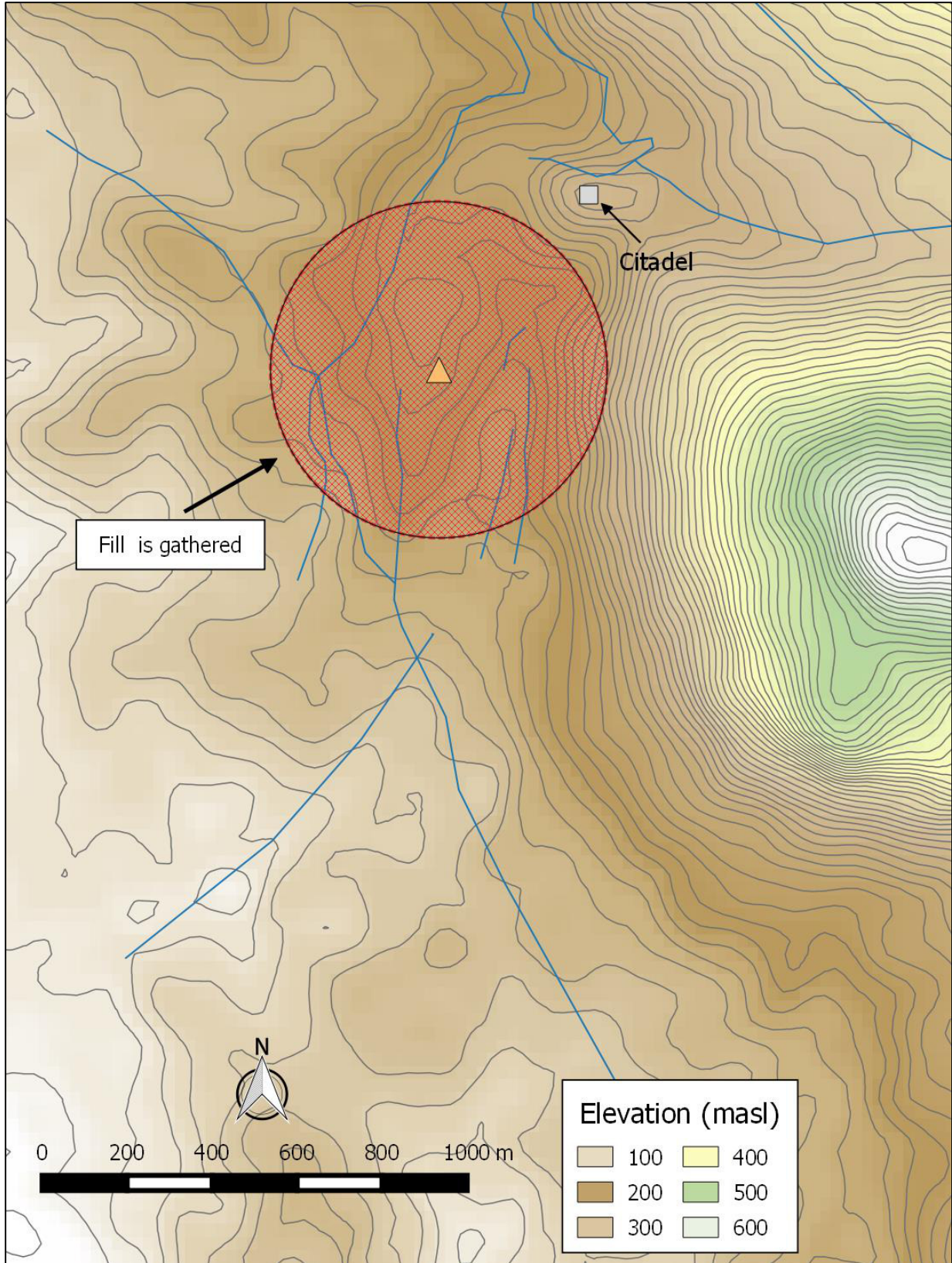
Figure A.147 Spatial configuration during production of the Treasury of Atreus, Tumulus.

Timber is harvested
from hills to the
north or further
inland?

0 250 500 750 1000 m

Mudbrick is
manufactured in the
open area to the
north

Rubble, earth, and
water are collected
near the building site

N

0   25   50   75   100 m
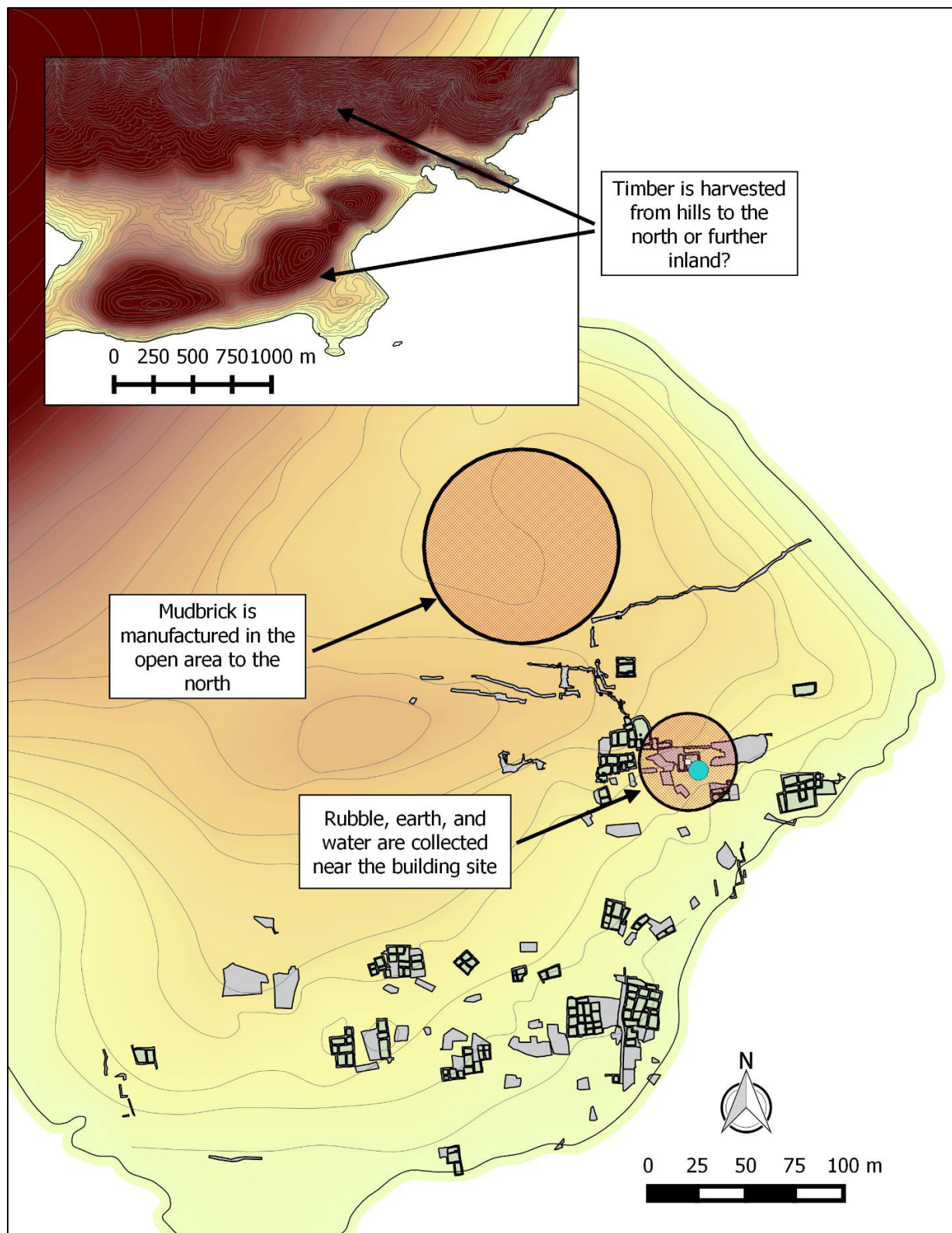
Figure A.148 Spatial configuration during production of structure 7-X at Kalamianos, all phases
of construction.

471
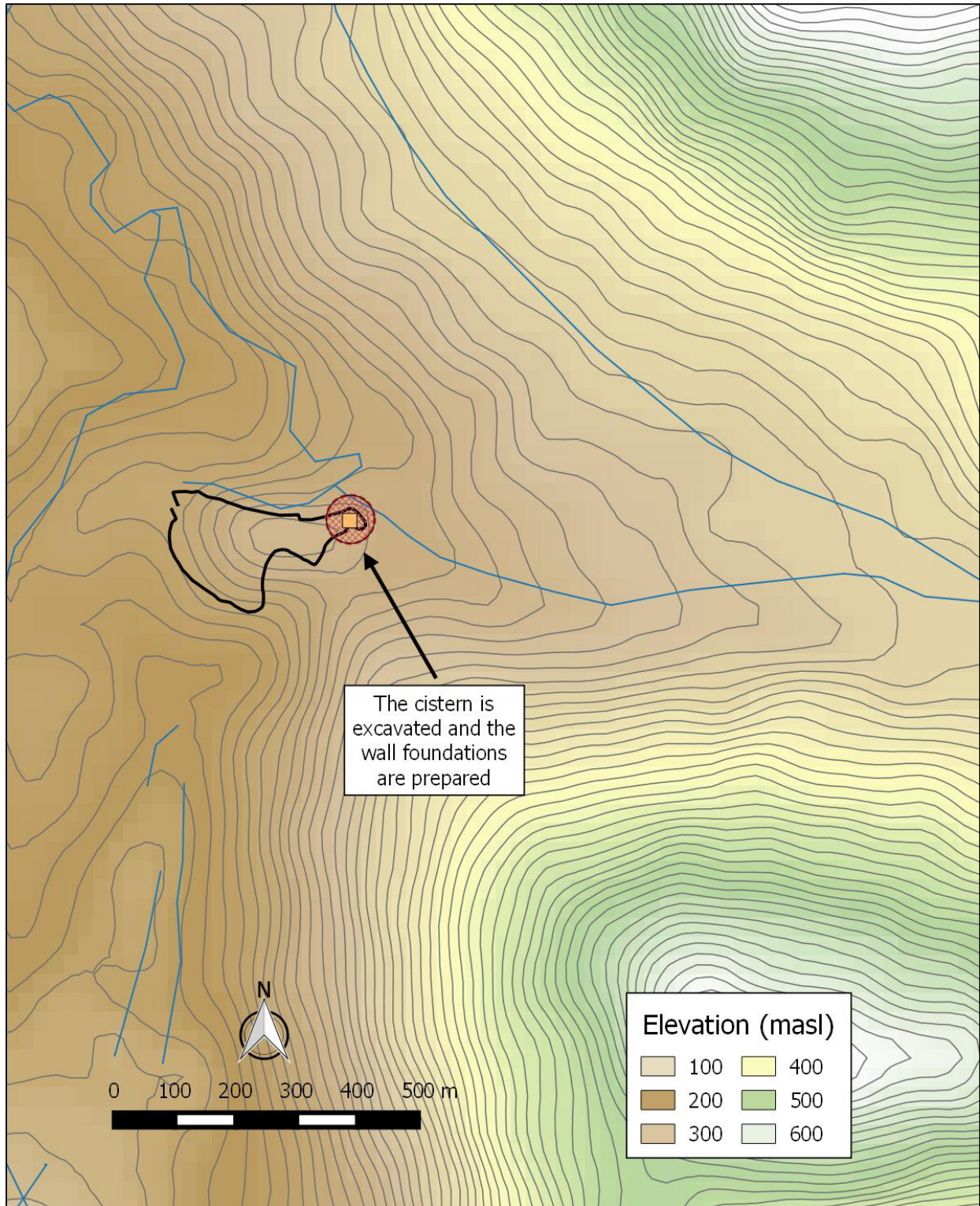
Figure A.149 Spatial configuration during production of the Northeast Extension, site preparation and cistern excavation.
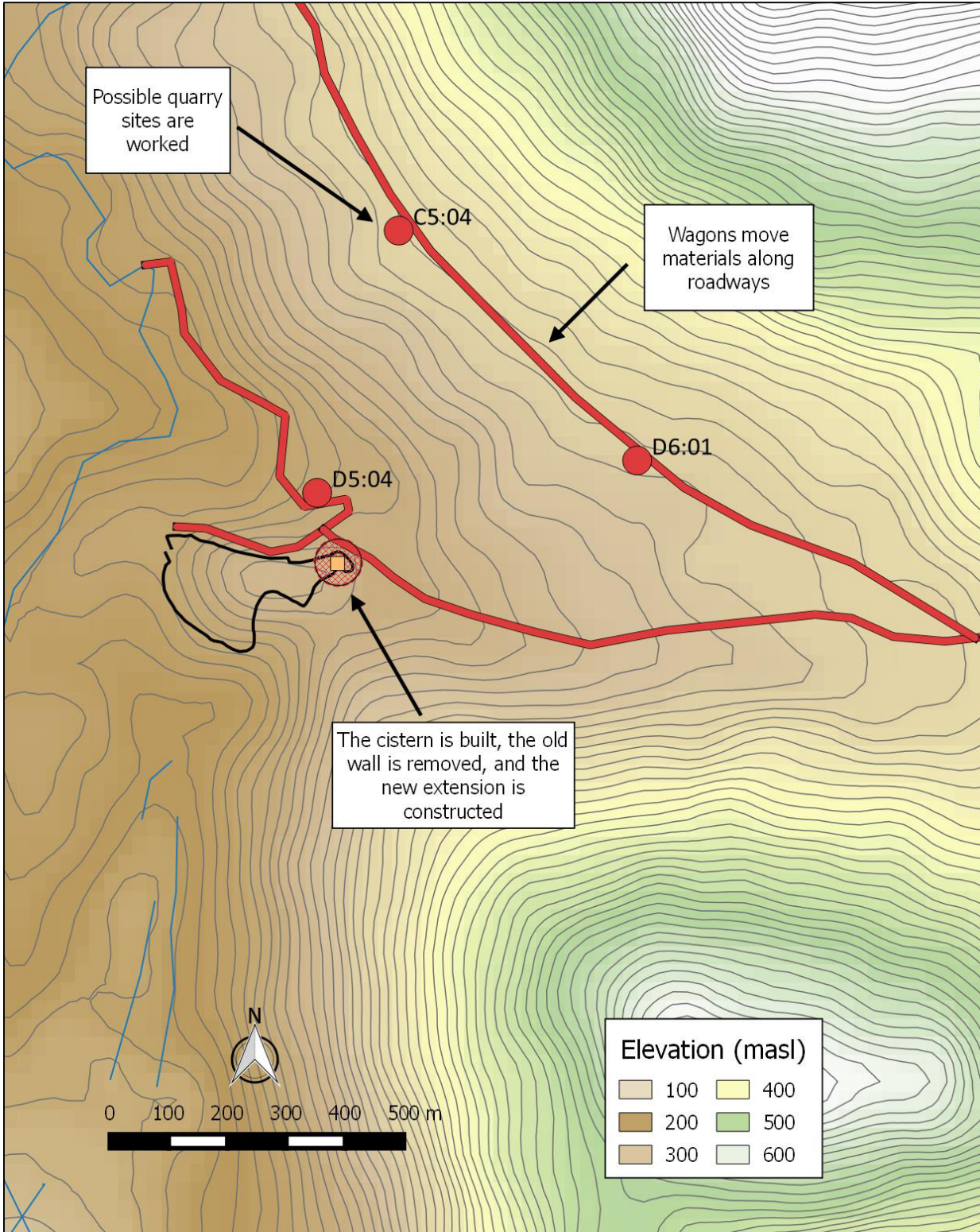
Figure A.150 Spatial configuration during production of the Northeast Extension, cistern and wall construction.

APPENDIX B

TABLES

Table B.1 The data used in CPM for construction of a hypothetical mudbrick wall. The absolute duration of each task is presented here in days.

Name	Volume	Task Rate	Person Hours	Laborers	Days
Dig Trenches	18	0.25	72	2	3
Gather Stones	20	0.1	200	4	4
Lay Foundations	20	0.2	100	4	2
Make Mudbrick	45	0.25	180	5	3
Lay Mudbrick	45	0.1	450	8	5

Table B.2 Dimensions of the Treasury of Minyas and the equivalent measures in Mycenaean feet.

Element	Actual Measurement	Feet of 0.3 m	Discrepancy	Recalculated Foot
Dromos, Width	5.11 m	**17F** = 5.1m	0.01 m	0.301
Stomion, Height x Width x Depth	5.44 m x 2.43 m x 5.3 m	**18F x 8F x 17.5F** = 5.4m x 2.4m x 5.25 m	0.04 m x 0.03 m x 0.05 m	0.303
Chamber, Diameter	14 m	**46F?** = 13.8 m	0.20 m	0.304
Side Door, Height x Width	2.12 m x 1.21 m	**7F x 4F** = 2.1 m x 1.2 m	0.02 m x 0.01 m	0.303
Side Chamber, Length x Width x Height	3.79 m x 2.75 m x 2.4 m	**12.5F x 9F x 8F** = 3.75 m x 2.7 m x 2.4 m	0.04 m x 0.05 m x 0.00 m	0.304
				Average = 0.303 m

Table B.3 The quantities of materials in Treasury of Atreus, rounded to the nearest 1 m³ or 1 m². Surface areas are presented only where task-rates rely on them.

Material and Component	Volume (m³)	Surface Area (m²)
Conglomerate Ashlar	1,960	882
Lower Chamber, Stomion, Lower Facade	760	305
Interior Lintel	55	
Exterior Lintel	10	
Upper Chamber	295	146
Upper Façade	245	36
Dromos	595	395
Claybrick	1,510	
Upper Chamber	955	
Dromos	555	
Mortared Rubble	1,235	
Upper Chamber	740	
Dromos	495	
Peribolos	335	
Fill or Spoil	10,310	
Excavated	2,885	
Tumulus	7,425	
Poros Ashlar	100	198
Peribolos	100	198

Table B.4 The distance and average slope from resource locations to the Treasury of Atreus following the least cost path.

Resource Location	Distance (m)	Average Slope
Kharvati Quarry	944	4°
Plesia Area	2,162	4°
Monastiraki Area	2,564	4.5°

Table B.5 The transportation rates rounded to the nearest $0.001 \, m^3$ / ph for the Treasury of Atreus based on distance and method as found in Appendix C.

Resource	Distance	Rate	Notes
Conglomerate	944 m	a. $0.031 \, m^3$ / ph b. $0.331 \, m^3$ / ph	By dragging (a) and by wagon (b), Moderate Terrain, Lubricated Road
Plesia Clay	2,162 m	$0.200 \, m^3$ / ph	By wagon, Moderate Terrain
Claybrick	2,162 m	$0.250 \, m^3$ / ph	By wagon, Moderate Terrain
Poros	2,564 m	$0.127 \, m^3$ / ph	By wagon, Moderate Terrain
Rubble	500 m	$1.113 \, m^3$ / ph	By wagon, Moderate Terrain
Fill	500 m	$0.820 \, m^3$ / ph	By wagon, Moderate Terrain
Spoil	100 m	$0.395 \, m^3$ / ph	By carrying with a basket

Table B.6 Traditional energetics for the Treasury of Atreus expressed in person-hours and as a percentage of the total person-hours.

Component	Procure	Manufacture	Transport	Assemble	Finish	Total	
Conglomerate	21,295		48,850	87,290	3,800	161,235	60%
Rubble Wall	1,390		2,690	11,460		15,540	6%
Claybrick	2,020	8,760	6,340	15,050		32,170	12%
Poros Ashlar	1,125		790	2,940	215	5,070	2%
Lintels	730		2,100			2,830	1%
Tumulus	24,750		9,055			33,805	13%
Excavation	9,615		7,305			16,920	6%
Total	60,925	8,760	77,130	116,740	4,015	267,570	
	23%	3%	29%	43%	2%		

Table B.7 The quantities of materials in structure 4-VI at Kalamianos, rounded to the nearest 0.25 m^3 and nearest 1 m^2. Surface areas are presented only where task-rates rely on them.

Component	Volume (m³)	Surface (m²)
Rubble Walls, Foundation	**231.5**	
Basement	84.5	
1st story	147	
Earth and Mud	**51.5**	
Flooring, earth fill	11	124
Roof, earth fill	13.5	
Basement, mud plaster	4	138
1st story, mud plaster	6.25	207
Exterior walls, mud plaster	9	226
Roof, mud plaster	7.75	193
Timber	**10**	
Flooring, main beams	5	
Roof, main beams	5	
Branches and Vegetation	**19**	
Flooring	7.5	
Roof	11.5	

Table B.8 The quantities of materials in structure 7-X at Kalamianos, rounded to the nearest 0.25 m^3 and nearest 1 m^2. Surface areas are presented only where task-rates rely on them.

Component	Volume (m^3)	Surface (m^2)
Rubble and Mortar	125.75	
1st story	124.75	
Stairway, treads	1	
Mudbrick and Mortar	135	
2nd story	135	
Earth and Mud	35.5	
1st story, mud plaster	4.5	150
Flooring, earth fill	3.5	53
Roof, earth fill	8	
2nd story, mud plaster	4.75	158
Stairway, earth fill	0.75	10.5
Roof, mud plaster	4.5	112
Exterior Walls, mud plaster	9.5	237
Timber	6	
Flooring, main beams	2.5	
Roof, main beams	3	
Stairway, main beams	0.5	
Branches and Vegetation	10	
Flooring	3	
Roof	6.5	
Stairway	0.5	
Lime Plaster	0.75	
2nd story, floors	0.25	42
2nd story, walls	0.5	90

Table B.9 The transportation rates rounded to the nearest 0.001 m^3 / ph for structure 4-VI at Kalamianos based on distance and method as found in Appendix C.

Resource	Distance	Rate	Notes
Earth	50 m	0.750 m^3 / ph	By carrying individually
Water	50 m	1.050 m^3 / ph	By carrying individually
Limestone	50 m	0.462 m^3 / ph	By carrying as a group
Timber	750 m	0.054 m^3 / ph	By carrying as a group
Branches and Vegetation	250 m	1.400 m^3 / ph	By carrying individually

Table B.10 The transportation rates rounded to the nearest 0.001 m^3 / ph for structure 7-X at Kalamianos based on distance and method as found in Appendix C.

Resource	Distance	Rate	Notes
Earth	50 m	0.750 m^3 / ph	By carrying individually
Water	0 m	n/a	Readily available
Limestone	50 m	0.462 m^3 / ph	By carrying as a group
Brickyard	150 m	0.243 m^3 / ph	By carrying individually. This applies to carrying dried mudbricks to structure 7-X from the brickyard.
Timber	750 m	0.054 m^3 / ph	By carrying as a group
Branches and Vegetation	250 m	1.400 m^3 / ph	By carrying individually
Water for Brickyard	150 m	0.350 m^3 / ph	By carrying individually. This assumes the closest water used in the brickyard is by 7-X.

Table B.11 Traditional energetics for structure 4-VI at Kalamianos expressed in person-hours and as a percentage of the total person-hours.

Component	Procure	Manufacture	Transport	Assemble	Finish	Total	
Rubble Wall	205		495	1,690		2,390	54%
Floor	45		115	310		470	11%
Roof	50		125	485		660	15%
Interior Plastering	20		25		435	480	11%
Exterior Plastering	30		30		320	380	9%
Total	350	0	790	2,485	755	4,380	
	8%	0%	18%	57%	17%		

Table B.12 Traditional energetics for structure 7-X at Kalamianos expressed in person-hours and as a percentage of the total person-hours.

Component	Procure	Manufacture	Transport	Assemble	Finish	Total	
Rubble Wall	110		250	910		1,270	21%
Mudbrick Wall	180	780	725	1,350		3,035	51%
Floor	35		80	135		250	4%
Stairs	10		20	35		65	1%
Roof	30		70	280		380	7%
Interior Plastering	15		10		365	390	7%
Lime Plaster		95			80	175	3%
Exterior Plastering	30		20		315	365	6%
Total	410	1,125	925	2,710	760	5,930	
	7%	19%	15%	46%	13%		

Table B.13 The estimated person-hours expended on the major structures at Kalamianos based on their footprint, using the person-hours per square meter expended on structures 4-VI and 7-X.

Structure	Area in m²	PH If Built Like 4-VI	PH If Built Like 7-X	Average PH
3-III	92	2,066	5,196	3,631
4-III	91	2,044	5,140	3,592
4-IX	231	5,188	13,047	9,118
4-VI	195	*4,380*	(11,014)	(7,697)
4-XIV	106	2,381	5,987	4,184
4-XIX	371	8,333	20,954	14,644
4-XVI	315	7,075	17,791	12,433
5-II	412	9,254	23,270	16,262
5-III	81	1,819	4,575	3,197
5-V	21	472	1,186	829
5-VIII	487	10,938	27,506	19,222
5-XIV	63	1,415	3,558	2,487
5-XV	187	4,200	10,562	7,381
5-XVI	98	2,201	5,535	3,868
5-XXVIII	38	853	2,146	1,500
7-I	318	7,142	17,961	12,552
7-II	95	2,134	5,366	3,750
7-III	191	4,290	10,788	7,539
7-V	63	1,415	3,558	2,487
7-X	105	(2,358)	*5,930*	(4,144)
9-IV	372	8,355	21,011	14,683
9-VIII	73	1,640	4,123	2,882
9-XI	63	1,415	3,558	2,487
Total	4,068	89,953	226,204	158,079

Table B.14 The estimated person-hours expended on plastering the major structures at Kalamianos based on the average cost per square meter of the building footprint in structures 4-VI and 7-X.

Structure	PH If Built Like 4-VI			PH If Built Like 7-X			Average of Totals
	Interior Plaster	Exterior Plaster	Total	Interior Plaster	Exterior Plaster	Total	
3-III	227	186	413	520	312	831	622
4-III	225	184	409	514	308	822	616
4-IX	571	467	1,038	1,305	783	2,088	1,563
4-VI	*480*	*380*	*860*	(1,101)	(661)	(1,762)	(1,311)
4-XIV	262	214	476	599	359	958	717
4-XIX	917	750	1,667	2,095	1,257	3,353	2,510
4-XVI	778	637	1,415	1,779	1,067	2,847	2,131
5-II	1,018	833	1,851	2,327	1,396	3,723	2,787
5-III	200	164	364	458	275	732	548
5-V	52	42	94	119	71	190	142
5-VIII	1,203	984	2,187	2,751	1,650	4,401	3,294
5-XIV	156	127	283	356	213	569	426
5-XV	462	378	840	1,056	634	1,690	1,265
5-XVI	242	198	440	554	332	886	663
5-XXVIII	94	77	171	215	129	343	257
7-I	786	643	1,429	1,796	1,078	2,874	2,151
7-II	235	192	427	537	322	859	643
7-III	472	386	858	1,079	647	1,726	1,292
7-V	156	127	283	356	213	569	426
7-X	(259)	(212)	(471)	*565*	*365*	*930*	(701)
9-IV	919	752	1,671	2,101	1,261	3,362	2,516
9-VIII	180	148	328	412	247	660	494
9-XI	156	127	283	356	213	569	426
Total	10,050	8,208	18,258	22,951	13,793	36,744	27,502

Table B.15 The quantities of materials in the Northeast Extension of Mycenae's fortification wall, rounded to the nearest 1 m^3 and nearest 1 m^2.

Material and Component	Volume (m³)	Surface Area (m²)
Limestone Masonry	3,318	
Northeast Extension	2,618	
Old Eastern Wall	568	
Cistern	132	
Rubble Fill	3,179	
Northeast Extension, Lower Fill	622	
Northeast Extension, Upper Fill	1,989	
Old Eastern Wall	568	
Foundations		632
Prepared Area		632
Spoil	289	
Cistern Excavation	289	

Table B.16 The transportation rates rounded to the nearest 0.001 m^3 / ph for the Northeast Extension based on distance and method as found in Appendix C.

Resource	Distance	Rate	Notes
Limestone Blocks and Rubble, new	500 m	1.113 m³ / ph	By wagon and oxen, moderate terrain
Limestone Blocks and Rubble, reused	50 m	0.462 m³ / ph	By carrying as a group
Spoil	50 m	0.553 m³ / ph	By carrying individually

Table B.17 Traditional energetics for the Northeast Extension expressed in person-hours and as a percentage of the total person-hours.

Component	Procure	Manufacture	Transport	Assemble	Finish	Total	
Cyclopean Wall	2,640		6,145	32,885		41,670	93%
Cistern	85		120	830		1,035	2%
Foundations					680	680	2%
Excavation	965		525			1,490	3%
Total	3,690	0	6,790	33,715	680	44,875	
	8%	0%	15%	75%	2%		

Table B.18 The task and precedence table for the Treasury of Atreus. The breakdown and groupings follow the energetic flowcharts. Outline numbers are referenced in the precedence diagram and table of labor ranges.

ID	Outline	Group / Task	Predecessors
1	**1**	**Project Start**	
2	**2**	**Site Preparation**	
3	**2.1**	**Excavation**	
4	**2.1.1**	**Spoil**	
5	2.1.1.1	Procure Spoil	1
6	2.1.1.2	*FF*	5FF+1%
7	2.1.1.3	Transport Spoil	5SS+1%,6FF
8	**3**	**Lower Chamber and Stomion**	
9	**3.1**	**Conglomerate Ashlar**	
10	**3.1.1**	**Conglomerate**	
11	3.1.1.1	Procure Conglomerate	5SS
12	3.1.1.2	*FF*	11FF+1%
13	3.1.1.3	Transport Conglomerate	11SS+1%,12FF
14	3.1.2	*FF*	13FF+1%
15	3.1.3	Assemble Walls	13SS+1%,14FF,7
16	3.1.4	Finish Walls	15
17	**4**	**Lintels**	
18	**4.1**	**Interior Lintel**	
19	4.1.1	Procure Lintel	11SS
20	4.1.2	Transport Lintel	19,15FF
21	**4.2**	**Exterior Lintel**	
22	4.2.1	Procure Lintel	11SS
23	4.2.2	Transport Lintel	22,20FF
24	**5**	**Upper Chamber**	
25	**5.1**	**Conglomerate Ashlar**	
26	**5.1.1**	**Conglomerate**	
27	5.1.1.1	Procure Conglomerate	15FS-1%
28	5.1.1.2	*FF*	27FF+1%
29	5.1.1.3	Transport Conglomerate	27SS+1%,28FF
30	5.1.2	*FF*	29FF+1%
31	5.1.3	Assemble Walls	29SS+1%,30FF,23
32	5.1.4	*FF*	31FF+5%
33	5.1.5	Finish Walls	31
34	**5.2**	**Rubble Wall**	
35	**5.2.1**	**Rubble**	
36	5.2.1.1	Procure Rubble	31SS+5%
37	5.2.1.2	*FF*	36FF+5%

ID	Outline	Group / Task	Predecessors
38	5.2.1.3	Transport Rubble	36SS+5%,37FF
39	**5.2.2**	**Mortar**	
40	5.2.2.1	Procure Clay	36SS
41	5.2.2.2	FF	40FF+5%
42	5.2.2.3	Transport Clay	40SS+5%,41FF
43	5.2.3	FF	38FF+5%,42FF+5%
44	5.2.4	Assemble Rubble Wall	38SS+5%,42SS+5%,43FF,31SS+5%, 32FF
45	5.2.5	FF	44FF+5%
46	**5.3**	**Claybrick Wall**	
47	**5.3.1**	**Claybrick**	
48	5.3.1.1	Procure Clay	31SS+5%
49	5.3.1.2	FF	48FF+1%
50	5.3.1.3	Manufacture Brick	48SS+1%,49FF
51	5.3.1.4	FF	50FF+7 days
52	5.3.1.5	Transport Brick	50SS+7 days,51FF
53	**5.3.2**	**Mortar**	
54	5.3.2.1	Procure Clay	52SS
55	5.3.2.2	FF	54FF+5%
56	5.3.2.3	Transport Clay	54SS+5%,55FF
57	5.3.3	FF	52FF+1%,56FF+5%
58	5.3.4	Assemble Claybrick Wall	52SS+1%,56SS+5%,57FF,44SS+5%, 45FF
59	**6**	**Dromos and Upper Façade**	
60	**6.1**	**Conglomerate Ashlar**	
61	**6.1.1**	**Conglomerate**	
62	6.1.1.1	Procure Conglomerate	31FS-1%
63	6.1.1.2	FF	62FF+1%
64	6.1.1.3	Transport Conglomerate	62SS+1%,63FF
65	6.1.2	FF	64FF+1%
66	6.1.3	Assemble Wall	64SS+1%,65FF,31
67	6.1.4	FF	66FF+5%
68	6.1.5	Finish Wall	66
69	**6.2**	**Rubble Wall**	
70	**6.2.1**	**Rubble**	
71	6.2.1.1	Procure Rubble	66SS+5%
72	6.2.1.2	FF	71FF+5%
73	6.2.1.3	Transport Rubble	71SS+5%,72FF
74	**6.2.2**	**Mortar**	

ID	Outline	Group / Task	Predecessors
75	6.2.2.1	Procure Clay	71SS
76	6.2.2.2	*FF*	75FF+5%
77	6.2.2.3	Transport Clay	75SS+5%,76FF
78	6.2.3	*FF*	73FF+5%,77FF+5%
79	6.2.4	Assemble Rubble Wall	73SS+5%,77FF+5%,78FF,66SS+5%, 67FF
80	6.2.5	*FF*	79FF+5%
81	**6.3**	**Claybrick Wall**	
82	**6.3.1**	**Claybrick**	
83	6.3.1.1	Procure Clay	66SS+5%
84	6.3.1.2	*FF*	83FF+5%
85	6.3.1.3	Manufacture Brick	83SS+5%,84FF
86	6.3.1.4	*FF*	85FF+7 days
87	6.3.1.5	Transport Brick	85SS+7 days,86FF
88	**6.3.2**	**Mortar**	
89	6.3.2.1	Procure Clay	87SS
90	6.3.2.2	*FF*	89FF+5%
91	6.3.2.3	Transport Clay	89SS+5%,90FF
92	6.3.3	*FF*	87FF+1%,91FF+5%
93	6.3.4	Assemble Claybrick Wall	87SS+1%,91SS+5%,92FF,79SS+5%, 80FF
94	**7**	**Peribolos**	
95	**7.1**	**Rubble Wall**	
96	**7.1.1**	**Rubble**	
97	7.1.1.1	Procure Rubble	31
98	7.1.1.2	*FF*	97FF+5%
99	7.1.1.3	Transport Rubble	97SS+5%,98FF
100	**7.1.2**	**Mortar**	
101	7.1.2.1	Procure Clay	97SS
102	7.1.2.2	*FF*	101FF+5%
103	7.1.2.3	Transport Clay	101SS+5%,102FF
104	7.1.3	*FF*	99FF+5%,103FF+5%
105	7.1.4	Assemble Rubble Wall	99SS+5%,103SS+5%,104FF
106	7.1.5	*FF*	105FF+1%
107	**7.2**	**Poros Ashlar**	
108	**7.2.1**	**Poros**	
109	7.2.1.1	Procure Poros	31
110	7.2.1.2	*FF*	109FF+5%

Table B.18 - continued

ID	Outline	Group / Task	Predecessors
111	7.2.1.3	Transport Poros	109SS+5%,110FF
112	7.2.2	*FF*	111FF+5%
113	7.2.3	Assemble Wall	111SS+5%,112FF,105SS+1%,106FF
114	7.2.4	*FF*	113FF+1%
115	7.2.5	Finish Wall	113SS+1%,114FF
116	**8**	**Tumulus**	
117	**8.1**	**Fill**	
118	8.1.1	Procure Fill	97SS
119	8.1.2	*FF*	118FF+1%
120	8.1.3	Transport Fill	118SS+1%,119FF,93,58,113
121	**9**	**Project Finish**	16,33,68,115,120

Table B.19 The task and precedence table for structure 4-VI, Kalamianos. The breakdown and groupings follow the energetic flowcharts. Outline numbers are referenced in the precedence diagram and table of labor ranges.

ID	Outline	Group / Task	Predecessors
1	**1**	**Project Start**	
2	**2**	**Basement**	
3	**2.1**	**Rubble Wall**	
4	**2.1.1**	**Rubble**	
5	2.1.1.1	Procure Rubble	1SS
6	2.1.1.2	*FF*	5FF+5%
7	2.1.1.3	Transport Rubble	5SS+5%,6FF
8	**2.1.2**	**Mortar**	
9	**2.1.2.1**	**Earth**	
10	2.1.2.1.1	Procure Earth	7SS
11	2.1.2.1.2	*FF*	10FF+5%
12	2.1.2.1.3	Transport Earth	10SS+5%,11FF
13	**2.1.2.2**	**Water**	
14	2.1.2.2.1	Transport Water	12SS+5%
15	**2.1.3**	**Assemble**	
16	2.1.3.1	*FF*	14FF+5%
17	2.1.3.2	Assemble Basement	14SS+5%,16FF
18	**3**	**Floor**	
19	**3.1**	**Main Beams**	
20	3.1.1	Procure Beams	17FS-5%
21	3.1.2	*FF*	20FF+5%
22	3.1.3	Transport Beams	20SS+5%,21FF
23	**3.2**	**Cross Branches**	
24	3.2.1	Transport Branches	22SS+10%
25	**3.3**	**Earth**	
26	3.3.1	Procure Earth	24SS
27	3.3.2	*FF*	26FF+5%
28	3.3.3	Transport Earth	26SS+5%,27FF
29	**3.4**	**Assemble**	
30	3.4.1	*FF*	22FF+5%,24FF+5%,28FF+5%
31	3.4.2	Assemble Floor	28SS+5%,30FF
32	**4**	**1st Story**	
33	**4.1**	**Rubble Wall**	
34	**4.1.1**	**Rubble**	
35	4.1.1.1	Procure Rubble	31FS-5%
36	4.1.1.2	*FF*	35FF+5%
37	4.1.1.3	Transport Rubble	35SS+5%,36FF

ID	Outline	Group / Task	Predecessors
38	**4.1.2**	**Mortar**	
39	**4.1.2.1**	**Earth**	
40	4.1.2.1.1	Procure Earth	37SS
41	4.1.2.1.2	*FF*	40FF+5%
42	4.1.2.1.3	Transport Earth	40SS+5%,41FF
43	**4.1.2.2**	**Water**	
44	4.1.2.2.1	Transport Water	42SS
45	**4.1.3**	**Assemble**	
46	4.1.3.1	*FF*	37FF+5%,41FF+5%,44FF+5%
47	4.1.3.2	Assemble 1st Story	44SS+5%,46FF
48	**5**	**Roof**	
49	**5.1**	**Main Beams**	
50	5.1.1	Procure Beams	47FS-5%
51	5.1.2	*FF*	50FF+5%
52	5.1.3	Transport Beams	50SS+5%,51FF
53	**5.2**	**Cross Branches**	
54	5.2.1	Transport Branches	52SS+10%
55	**5.3**	**Earth**	
56	5.3.1	Procure Earth	54SS
57	5.3.2	*FF*	56FF+5%
58	5.3.3	Transport Earth	56SS+5%,57FF
59	**5.4**	**Assemble**	
60	5.4.1	*FF*	52FF+5%,54FF+5%,58FF+5%
61	5.4.2	Assemble Roof	58SS+5%,60FF
62	**6**	**Exterior Plastering**	
63	**6.1**	**Walls**	
64	**6.1.1**	**Mud Plaster**	
65	**6.1.1.1**	**Earth**	
66	6.1.1.1.1	Procure Earth	61FF-10%
67	6.1.1.1.2	*FF*	66FF+5%
68	6.1.1.1.3	Transport Earth	66SS+5%,67FF
69	**6.1.1.2**	**Water**	
70	6.1.1.2.1	Transport Water	68SS
71	**6.1.2**	**Finish**	
72	6.1.2.1	*FF*	68FF+5%,70FF+5%
73	6.1.2.2	Finish Exterior Walls	70SS+5%,72FF,61
74	**6.2**	**Roof**	
75	**6.2.1**	**Mud Plaster**	
76	**6.2.1.1**	**Earth**	

ID	Outline	Group / Task	Predecessors
77	6.2.1.1.1	Procure Earth	61FF-10%
78	6.2.1.1.2	*FF*	77FF+5%
79	6.2.1.1.3	Transport Earth	77SS+5%,78FF
80	**6.2.1.2**	**Water**	
81	6.2.1.2.1	Transport Water	79SS
82	6.2.2	*FF*	79FF+5%,81FF+5%
83	6.2.3	Finish Roof	81SS+5%,82FF,61
84	**7**	**Interior Plastering**	
85	**7.1**	**Basement**	
86	**7.1.1**	**Mud Plaster**	
87	**7.1.1.1**	**Earth**	
88	7.1.1.1.1	Procure Earth	61FF-10%
89	7.1.1.1.2	*FF*	88FF+5%
90	7.1.1.1.3	Transport Earth	88SS+5%,89FF
91	**7.1.1.2**	**Water**	
92	7.1.1.2.1	Transport Water	90SS
93	**7.1.2**	**Finish**	
94	7.1.2.1	*FF*	90FF+5%,92FF+5%
95	7.1.2.2	Finish Basement Walls	92SS+5%,94FF,61
96	**7.2**	**1st Story**	
97	**7.2.1**	**Mud Plaster**	
98	**7.2.1.1**	**Earth**	
99	7.2.1.1.1	Procure Earth	61FF-10%
100	7.2.1.1.2	*FF*	99FF+5%
101	7.2.1.1.3	Transport Earth	99SS+5%,100FF
102	**7.2.1.2**	**Water**	
103	7.2.1.2.1	Transport Water	101SS
104	**7.2.2**	**Finish**	
105	7.2.2.1	*FF*	101FF+5%,103FF+5%
106	7.2.2.2	Finish 1st Story Walls	105FF,103SS+5%,61
107	**8**	**Project Finish**	73,83,95,106

Table B.20 The task and precedence table for structure 7-X, Kalamianos. The breakdown and groupings follow the energetic flowcharts. Outline numbers are referenced in the precedence diagram and table of labor ranges.

ID	Outline	Group / Task	Predecessors
1	1	Project Start	
2	**2**	**1st Story**	
3	**2.1**	**Rubble Wall**	
4	**2.1.1**	**Rubble**	
5	2.1.1.1	Procure Rubble	1
6	2.1.1.2	*FF*	5FF+5%
7	2.1.1.3	Transport Rubble	5SS+5%,6FF
8	**2.1.2**	**Mortar**	
9	**2.1.2.1**	**Earth**	
10	2.1.2.1.1	Procure Earth	7SS
11	2.1.2.1.2	*FF*	10FF+5%
12	2.1.2.1.3	Transport Earth	10SS+5%,11FF
13	**2.2**	**Assemble**	
14	2.2.1	*FF*	7FF+5%,12FF+5%
15	2.2.2	Assemble 1st Story	12SS+5%,14FF
16	**3**	**2nd Story Floor**	
17	**3.1**	**Floor**	
18	**3.1.1**	**Main Beams**	
19	3.1.1.1	Procure Beams	15FS-5%
20	3.1.1.2	*FF*	19FF+5%
21	3.1.1.3	Transport Beams	19SS+5%,20FF
22	**3.1.2**	**Cross Branches**	
23	3.1.2.1	Transport Branches	21SS+10%
24	**3.1.3**	**Earth**	
25	3.1.3.1	Procure Earth	23SS
26	3.1.3.2	*FF*	25FF+5%
27	3.1.3.3	Transport Earth	25SS+5%,26FF
28	**3.2**	**Assemble**	
29	3.2.1	*FF*	21FF+5%,23FF+5%,27FF+5%
30	3.2.2	Assemble Floor	27SS+5%,29FF
31	**4**	**2nd Story**	
32	**4.1**	**Mudbrick Wall**	
33	**4.1.1**	**Mudbrick**	
34	**4.1.1.1**	**Earth**	
35	4.1.1.1.1	Procure Earth	19SS
36	**4.1.1.2**	**Water**	
37	4.1.1.2.1	*FF*	35FF+5%

ID	Outline	Group / Task	Predecessors
38	4.1.1.2.2	Transport Water	35SS+5%,37FF
39	4.1.1.3	*FF*	38FF
40	4.1.1.4	Manufacture Mudbrick	38SS,39FF
41	4.1.1.5	*FF*	40FF+7 days
42	4.1.1.6	Transport Mudbrick	40SS+7 days,41FF
43	**4.1.2**	**Mortar**	
44	**4.1.2.1**	**Earth**	
45	4.1.2.1.1	Procure Earth	42SS
46	4.1.2.1.2	*FF*	45FF+5%
47	4.1.2.1.3	Transport Earth	45SS+5%,46FF
48	**4.1.3**	**Assemble**	
49	4.1.3.1	*FF*	42FF+5%,47FF+5%
50	4.1.3.2	Assemble 2nd Story	42SS+5%,47SS+5%,49FF,30
51	**5**	**Stairs**	
52	**5.1**	**Support and Treads**	
53	**5.1.1**	**Main Beams**	
54	5.1.1.1	Procure Beams	50SS
55	5.1.1.2	*FF*	54FF+5%
56	5.1.1.3	Transport Beams	54SS+5%,55FF
57	**5.1.2**	**Cross Branches**	
58	5.1.2.1	Transport Branches	56SS+10%
59	**5.1.3**	**Earth**	
60	5.1.3.1	Procure Earth	58SS
61	5.1.3.2	*FF*	60FF+5%
62	5.1.3.3	Transport Earth	60SS+5%,61FF
63	**5.2**	**Assemble**	
64	5.2.1	*FF*	56FF+5%,58FF+5%,62FF+5%
65	5.2.2	Assemble Stairs	62SS+5%,64FF
66	**6**	**Roof**	
67	**6.1**	**Main Beams**	
68	6.1.1	Procure Beams	50FS-5%,65FS-5%
69	6.1.2	*FF*	68FF+5%
70	6.1.3	Transport Beams	68SS+5%,69FF
71	**6.2**	**Cross Branches**	
72	6.2.1	Transport Branches	70SS+10%
73	**6.3**	**Earth**	
74	6.3.1	Procure Earth	72SS
75	6.3.2	*FF*	74FF+5%
76	6.3.3	Transport Earth	74SS+5%,75FF

ID	Outline	Group / Task	Predecessors
77	**6.4**	**Assemble**	
78	6.4.1	*FF*	70FF+5%,72FF+5%,76FF+5%
79	6.4.2	Assemble Roof	76SS+5%,78FF,50,65
80	**7**	**Exterior Plastering**	
81	**7.1**	**Walls**	
82	**7.1.1**	**Mud Plaster**	
83	**7.1.1.1**	**Earth**	
84	7.1.1.1.1	Procure Earth	79FF-10%
85	7.1.1.1.2	*FF*	84FF+5%
86	7.1.1.1.3	Transport Earth	84SS+5%,85FF
87	**7.1.2**	**Finish**	
88	7.1.2.1	*FF*	86FF+5%
89	7.1.2.2	Finish Exterior Walls	88FF,86SS+5%,79
90	**7.2**	**Roof**	
91	**7.2.1**	**Mud Plaster**	
92	**7.2.1.1**	**Earth**	
93	7.2.1.1.1	Procure Earth	79FF-10%
94	7.2.1.1.2	*FF*	93FF+5%
95	7.2.1.1.3	Transport Earth	93SS+5%,94FF
96	**7.2.2**	**Finish**	
97	7.2.2.1	*FF*	95FF+5%
98	7.2.2.2	Finish Roof	97FF,95SS+5%,79
99	**8**	**Interior Plastering**	
100	**8.1**	**1st Story**	
101	**8.1.1**	**Mud Plaster**	
102	**8.1.1.1**	**Earth**	
103	8.1.1.1.1	Procure Earth	79FF-10%
104	8.1.1.1.2	*FF*	103FF+5%
105	8.1.1.1.3	Transport Earth	103SS+5%,104FF
106	**8.1.2**	**Finish**	
107	8.1.2.1	*FF*	105FF+5%
108	8.1.2.2	Finish Interior, 1st Story	105SS+5%,107FF,79
109	**8.2**	**2nd Story**	
110	**8.2.1**	**Mud Plaster**	
111	**8.2.1.1**	**Earth**	
112	8.2.1.1.1	Procure Earth	103SS
113	8.2.1.1.2	*FF*	112FF+5%
114	8.2.1.1.3	Transport Earth	112SS+5%,113FF
115	**8.2.1.2**	**Finish**	

ID	Outline	Group / Task	Predecessors
116	8.2.1.2.1	*FF*	114FF+5%
117	8.2.1.2.2	Finish Interior, 2nd Story	114SS,116FF,79
118	**8.2.2**	**Lime Plaster**	
119	**8.2.2.1**	**Hydrated Lime**	
120	8.2.2.1.1	Manufacture Lime	112SS
121	8.2.3	Finish Lime Plaster	120FS+3 days,79,117FS+3 days
122	**9**	**Project Finish**	89,98,121,117,108

Table B.21 The task and precedence table for the Northeast Extension. The breakdown and groupings follow the energetic flowcharts. Outline numbers are referenced in the precedence diagram and table of labor ranges.

ID	Outline	Group / Task	Predecessors
1	**1**	**Project Start**	
2	**2**	**Site Preparation**	
3	**2.1**	**Excavation**	
4	2.1.1	Procure Spoil	1
5	2.1.2	*FF*	4FF+5%
6	2.1.3	Transport Spoil	4SS+5%,5FF
7	**2.2**	**Foundations**	
8	2.2.1	Finish Foundations	6
9	**3**	**Cistern**	
10	**3.1**	**Masonry**	
11	**3.1.1**	**Rubble**	
12	3.1.1.1	Procure Rubble	6
13	3.1.1.2	*FF*	12FF+5%
14	3.1.1.3	Transport Rubble	12SS+5%,13FF
15	3.1.2	*FF*	14FF+5%
16	3.1.3	Assemble Cistern	14SS+5%,15FF
17	**4**	**Cyclopean Wall**	
18	**4.1**	**Wall Faces**	
19	**4.1.1**	**Rubble, Reused**	
20	4.1.1.1	*FF*	8FF+5%
21	4.1.1.2	Transport Rubble	16,8SS+50%,20FF
22	**4.1.2**	**Rubble**	
23	4.1.2.1	Procure Rubble	21FS-5%
24	4.1.2.2	*FF*	23FF+5%
25	4.1.2.3	Transport Rubble	23SS+5%,24FF
26	4.1.3	Assemble Wall Faces	21SS+5%,25FF+5%
27	**4.2**	**Lower Wall Fill**	
28	**4.2.1**	**Rubble**	
29	4.2.1.1	Procure Rubble	21SS
30	4.2.1.2	*FF*	29FF+5%
31	4.2.1.3	Transport Rubble	29SS+5%,30FF
32	4.2.2	*FF*	31FF+5%
33	4.2.3	Assemble Lower Fill	26SS+5%,31SS+5%,32FF
34	**4.3**	**Upper Wall Fill**	
35	**4.3.1**	**Rubble**	
36	4.3.1.1	Procure Rubble	33FS-5%
37	4.3.1.2	*FF*	36FF+5%

Table B.21 - continued

ID	Outline	Group / Task	Predecessors
38	4.3.1.3	Transport Rubble	36SS+5%,37FF
39	4.3.2	*FF*	38FF+5%
40	4.3.3	Assemble Upper Fill	38SS+5%,26FF+5%,39FF
41	**5**	**Project Finish**	40

Table B.22 Labor Ranges for the Treasury of Atreus. Outline numbers correspond to the structure's precedence table and precedence diagram. The low, middle, and high are the hypothesized number of workers completing the task.

Outline	Group / Task	Low	Middle	High	Explanation
1	**Project Start**				
2	**Site Preparation**				
2.1	**Excavation**				
2.1.1	**Spoil**				
2.1.1.1	Procure Spoil	5	20	40	Based on how many workers can excavate along a face. The low is closely spaced at one face of excavation. The median is spaced along dromos' faces at 3.5 m. The high is along all faces at 3.5 m spacing.
2.1.1.3	Transport Spoil	5	20	40	This allows for variation in the number of carriers to diggers, ranging between a 1:8 and 1:1 ratio.
3	**Lower Chamber and Stomion**				
3.1	**Conglomerate Ashlar**				
3.1.1	**Conglomerate**				
3.1.1.1	Procure Conglomerate	5	20	40	Because block sizes vary, this is difficult. The low number is a conservative estimate of how many might work to channel around a single block. The median and high suggest that up to eight teams of five might work on blocks at once.
3.1.1.3	Transport Conglomerate	9	27	45	Lehner's experiments suggest a generous estimate that one person may drag up to 1/3rd of a ton over a lubricated surface (Lehner 1997, 224). In this case, a minimum of nine men would be needed for larger stones. The median and high suggest that this number can be scaled for larger blocks or to set multiple teams to work moving blocks.

Table B.22 - continued

Outline	Group / Task	Low	Middle	High	Explanation
3.1.3	Assemble Walls	9	20	28	Again, nine is a minimum suggested to move blocks and position them. The high number is the suggested maximum number of people who might work in the chamber at once. The middle allows for a number of skilled masons and shared block movers to work comfortably in the chamber.
3.1.4	Finish Walls	4	14	28	The high derives from the suggested maximum that might work in the chamber. The low and middle are reductions of the numbers during assembly and assume fewer can actually dress down the walls, especially if working on scaffolding at heights.
4	**Lintels**				
4.1	**Interior Lintel**				
4.1.1	Procure Lintel	4	17	35	The high derives from spacing workers at 1.75 m around the block. The medium is a more comfortable spacing of 3.5 m. The low is the suggested minimum of one worker per side.
4.1.2	Transport Lintel	412	412	412	The number to drag is fixed based on 1/3rd of a ton per person and a total weight of c. 137.5 tons.
4.2	**Exterior Lintel**				
4.2.1	Procure Lintel	4	5	6	The low is the suggested minimum of one worker per side. The exterior lintel's dimensions are much smaller than the interior's. Therefore, one or two additional workers may be added.
4.2.2	Transport Lintel	75	75	75	The number to drag is fixed based on 1/3rd of a ton per person and a total weight of c. 25 tons.
5	**Upper Chamber**				
5.1	**Conglomerate Ashlar**				
5.1.1	**Conglomerate**				
5.1.1.1	Procure Conglomerate	5	20	40	Same as above.

498

Outline	Group / Task	Low	Middle	High	Explanation
5.1.1.3	Transport Conglomerate	9	27	45	Same as above.
5.1.3	Assemble Walls	9	20	28	Same as above.
5.1.5	Finish Walls	4	14	28	Same as above.
5.2	**Rubble Wall**				
5.2.1	**Rubble**				
5.2.1.1	Procure Rubble	3	6	10	This is a reasonable suggested range that allows for exploration of behavior. This is not a driving task in construction.
5.2.1.3	Transport Rubble	3	6	10	This is a reasonable suggested range that allows for exploration of behavior. This is not a driving task in construction.
5.2.2	**Mortar**				
5.2.2.1	Procure Clay	3	6	10	This is a reasonable suggested range that allows for exploration of behavior. This is not a driving task in construction.
5.2.2.3	Transport Clay	3	6	10	This is a reasonable suggested range that allows for exploration of behavior. This is not a driving task in construction.
5.2.4	Assemble Rubble Wall	7	14	28	Around 28 people could work along the face of the wall. Half of this number give a more comfortable spacing for a mason and helpers. Half of the middle number is suggested as the low estimate.
5.3	**Claybrick Wall**				
5.3.1	**Claybrick**				
5.3.1.1	Procure Clay	3	6	10	Same as above.
5.3.1.3	Manufacture Brick	10	20	30	The Tomb of Rehkmira shows 10 individuals engaged in the process of making brick (Newberry 1900). The middle and high rates allow for multiple teams of 10 at work in different brick yards.

Outline	Group / Task	Low	Middle	High	Explanation
5.3.1.5	Transport Brick	3	6	10	This allows for a variable number of wagons to move back and forth transporting bricks.
5.3.2	**Mortar**				
5.3.2.1	Procure Clay	3	6	10	Same as above.
5.3.2.3	Transport Clay	3	6	10	Same as above.
5.3.4	Assemble Claybrick Wall	7	14	28	Same as above for 5.2.4 "Assemble Rubble Wall"
6	**Dromos and Upper Façade**				
6.1	**Conglomerate Ashlar**				
6.1.1	**Conglomerate**				
6.1.1.1	Procure Conglomerate	5	20	40	Same as above.
6.1.1.3	Transport Conglomerate	9	27	45	Same as above.
6.1.3	Assemble Wall	17	25	42	The high suggests that 21 people can work on each wall of the dromos at a 1.75 m spacing. The middle and low are based on evidence for two teams working on each wall. If nine men move each block and four teams of one skilled mason and three helpers set the blocks (Richardson 2004), the middle number is 25. The low is based on two teams of masons and nine block movers.
6.1.5	Finish Wall	4	21	42	The high derives from the maximum number that would fit at 1.75m spacing. The low suggests one finisher per team. The middle is half of the high and allows for a more comfortable spacing of 3.5 m.
6.2	**Rubble Wall**				
6.2.1	**Rubble**				
6.2.1.1	Procure Rubble	3	6	10	Same as above.
6.2.1.3	Transport Rubble	3	6	10	Same as above.
6.2.2	**Mortar**				
6.2.2.1	Procure Clay	3	6	10	Same as above.

Outline	Group / Task	Low	Middle	High	Explanation
6.2.2.3	Transport Clay	3	6	10	Same as above.
6.2.4	Assemble Rubble Wall	8	21	42	The high derives from the maximum number that would fit at 1.75m spacing. The low suggests a mason and helper for each team working at the dromos' façade. The middle is half of the high and allows for a more comfortable spacing of 3.5 m.
6.3	**Claybrick Wall**				
6.3.1	**Claybrick**				
6.3.1.1	Procure Clay	3	6	10	Same as above.
6.3.1.3	Manufacture Brick	10	20	30	Same as above.
6.3.1.5	Transport Brick	3	6	10	Same as above.
6.3.2	**Mortar**				
6.3.2.1	Procure Clay	3	6	10	Same as above.
6.3.2.3	Transport Clay	3	6	10	Same as above.
6.3.4	Assemble Claybrick Wall	8	21	42	Same as 6.2.4 "Assemble Rubble Wall"
7	**Peribolos**				
7.1	**Rubble Wall**				
7.1.1	**Rubble**				
7.1.1.1	Procure Rubble	3	6	10	Same as above.
7.1.1.3	Transport Rubble	3	6	10	Same as above.
7.1.2	**Mortar**				
7.1.2.1	Procure Clay	3	6	10	Same as above.
7.1.2.3	Transport Clay	3	6	10	Same as above.

Outline	Group / Task	Low	Middle	High	Explanation
7.1.4	Assemble Rubble Wall	4	12	24	This must progress in line with the assembly of the ashlar poros. Up to 94 could in theory work on the wall, but this is impossibly high to progress in tandem with ashlar assembly. The range of 4, 12, and 24 are hypothetical based on syncing up with the clamped poros ashlar.
7.2	**Poros Ashlar**				
7.2.1	**Poros**				
7.2.1.1	Procure Poros	6	15	30	Three people might work on one ashlar block at once, given the approximate size. The extraction of poros is similar to the quarry at Ta Skaria where five teams worked, which has been used to set the middle number. The low and high suggests a range of 2 to 10 teams of 3 extracting blocks.
7.2.1.3	Transport Poros	3	6	10	This allows for a variable number of wagons to move back and forth transporting blocks.
7.2.3	Assemble Wall	4	12	24	Same as 7.1.4 "Assemble Rubble Wall" since the two must work together.
7.2.5	Finish Wall	4	8	12	This hypothesizes that only a small range of people needed to final dress the wall.
8	**Tumulus**				
8.1	**Fill**				
8.1.1	Procure Fill	25	50	100	This is a driving task in construction so a large range has been chosen to explore variability. There is no good physical evidence for suggesting the exact spot where the fill came from or how many individuals may have procured and transported it.
8.1.3	Transport Fill	25	50	100	Same as above.
9	**Project Finish**				

Table B.23 Labor ranges for structure 4-VI, Kalamianos. Outline numbers correspond to the structure's precedence diagram and precedence table. The low, middle, and high are the hypothesized number of workers completing the task.

Outline	Group / Task	Low	Middle	High	Explanation
1	**Project Start**				
2	**Basement**				
2.1	**Rubble Wall**				
2.1.1	**Rubble**				
2.1.1.1	Procure Rubble	3	6	12	The quarry area to the northwest of structure 4-VI has under 12 m of workable face. You could fit up to six men working in this area. If the region to the east of 4-VI was also worked, as seems likely, another six might be added. As few as three men could extract the size of blocks needed.
2.1.1.3	Transport Rubble	5	7	10	For the upper range of average blocks, five people would be needed to carry them. The high range reflects two groups of five, alternating between quarry areas.
2.1.2	**Mortar**				
2.1.2.1	**Earth**				
2.1.2.1.1	Procure Earth	0.25	0.5	1	This is a non-driving task in the schedule. The range reflects a single person working from 1/4th of the time to full-time.
2.1.2.1.3	Transport Earth	0.25	0.5	1	This is a non-driving task in the schedule. The range reflects a single person working from 1/4th of the time to full-time.
2.1.2.2	**Water**				
2.1.2.2.1	Transport Water	0.1	0.25	0.5	This is a non-driving task in the schedule. The range reflects a single person working from 1/4th of the time to full-time.
2.1.3	**Assemble**				
2.1.3.2	Assemble Basement	4	8	16	The low reflects one skilled mason and three helpers working as a team. Up to four of these teams might work along different walls. The middle rate suggests two teams.

Outline	Group / Task	Low	Middle	High	Explanation
3	**Floor**				
3.1	**Main Beams**				
3.1.1	Procure Beams	1	2	4	This is a non-driving task. A range of one to four individuals with an axe is hypothesized.
3.1.3	Transport Beams	4	6	8	A team of four is needed to carry each beam. Two of these teams might work in tandem to move timber faster. The middle rate represents the median of the low and high rate.
3.2	**Cross Branches**				
3.2.1	Transport Branches	0.1	0.25	0.5	Same as above
3.3	**Earth**				
3.3.1	Procure Earth	1	2	4	A few individuals scattered on the site can quickly procure and transport earth. One to four individuals working on these tasks are hypothesized.
3.3.3	Transport Earth	1	2	4	Same as above
3.4	**Assemble**				
3.4.2	Assemble Floor	4	6	8	At least four individuals are needed to maneuver and set the beams. The high reflects two teams working on this. The middle rate is the median of low and high.
4	**1st Story**				
4.1	**Rubble Wall**				
4.1.1	**Rubble**				
4.1.1.1	Procure Rubble	3	6	12	Same as above
4.1.1.3	Transport Rubble	5	7	10	Same as above
4.1.2	**Mortar**				
4.1.2.1	**Earth**				
4.1.2.1.1	Procure Earth	0.25	0.5	1	Same as above
4.1.2.1.3	Transport Earth	0.25	0.5	1	Same as above

Outline	Group / Task	Low	Middle	High	Explanation
4.1.2.2	**Water**				
4.1.2.2.1	Transport Water	0.1	0.25	0.5	Same as above
4.1.3	**Assemble**				
4.1.3.2	Assemble 1st Story	4	8	16	Same as above
5	**Roof**				
5.1	**Main Beams**				
5.1.1	Procure Beams	1	2	4	Same as above
5.1.3	Transport Beams	4	6	8	Same as above
5.2	**Cross Branches**				
5.2.1	Transport Branches	0.1	0.25	0.5	Same as above
5.3	**Earth**				
5.3.1	Procure Earth	0.25	0.5	1	Same as above
5.3.3	Transport Earth	0.25	0.5	1	Same as above
5.4	**Assemble**				
5.4.2	Assemble Roof	4	6	8	Same as above
6	**Exterior Plastering**				
6.1	**Walls**				
6.1.1	**Mud Plaster**				
6.1.1.1	**Earth**				
6.1.1.1.1	Procure Earth	0.25	0.5	1	Same as above
6.1.1.1.3	Transport Earth	0.25	0.5	1	Same as above
6.1.1.2	**Water**				
6.1.1.2.1	Transport Water	0.1	0.25	0.5	Same as above
6.1.2	**Finish**				

Outline	Group / Task	Low	Middle	High	Explanation
6.1.2.2	Finish Exterior Walls	3	10	18	The low number reflect two plasterers and a helper. Along the perimeter six of these teams, at most, might work. The middle rate reflects a reasonable arrangement.
6.2	**Roof**				
6.2.1	**Mud Plaster**				
6.2.1.1	**Earth**				
6.2.1.1.1	Procure Earth	0.25	0.5	1	Same as above
6.2.1.1.3	Transport Earth	0.25	0.5	1	Same as above
6.2.1.2	**Water**				
6.2.1.2.1	Transport Water	0.1	0.25	0.5	Same as above
6.2.3	Finish Roof	3	6	9	The low number reflects two plasterers and a helper. Up to three such teams might work along the roof. More than this will potentially place too much stress on the roof beams.
7	**Interior Plastering**				
7.1	**Basement**				
7.1.1	**Mud Plaster**				
7.1.1.1	**Earth**				
7.1.1.1.1	Procure Earth	0.25	0.5	1	Same as above
7.1.1.1.3	Transport Earth	0.25	0.5	1	Same as above
7.1.1.2	**Water**				
7.1.1.2.1	Transport Water	0.1	0.25	0.5	Same as above
7.1.2	**Finish**				
7.1.2.2	Finish Basement Walls	3	6	9	The lower number reflects two plasterers and a helper. The smaller hypothesized height of the basement rooms means perhaps up to three such teams might work in the space.
7.2	**1st Story**				
7.2.1	**Mud Plaster**				

Outline	Group / Task	Low	Middle	High	Explanation
7.2.1.1	**Earth**				
7.2.1.1.1	Procure Earth	0.25	0.5	1	Same as above
7.2.1.1.3	Transport Earth	0.25	0.5	1	Same as above
7.2.1.2	**Water**				
7.2.1.2.1	Transport Water	0.1	0.25	0.5	Same as above
7.2.2	**Finish**				
7.2.2.2	Finish 1st Story Walls	3	10	18	The low number reflect two plasterers and a helper. With one team per room, up to six of these teams might work. The middle rate reflects a reasonable arrangement.
8	**Project Finish**				

Table B.24 Labor Ranges for structure 7-X, Kalamianos. Outline numbers correspond to the structure's precedence diagram and precedence table. The low, middle, and high are the hypothesized number of workers completing the task.

Outline	Group / Task	Low	Middle	High	Explanation
1	**Project Start**				
2	**1st Story**				
2.1	**Rubble Wall**				
2.1.1	**Rubble**				
2.1.1.1	Procure Rubble	3	6	12	Based on quarrying knowledge from structure 4-VI.
2.1.1.3	Transport Rubble	5	7	10	Based on quarrying knowledge from structure 4-VI.
2.1.2	**Mortar**				
2.1.2.1	**Earth**				
2.1.2.1.1	Procure Earth	0.25	0.5	1	This is a non-driving task in the schedule. The range reflects a single person working from 1/4th of the time to full-time.
2.1.2.1.3	Transport Earth	0.25	0.5	1	This is a non-driving task in the schedule. The range reflects a single person working from 1/4th of the time to full-time.
2.2	**Assemble**				
2.2.2	Assemble 1st Story	4	8	12	The low reflects a skilled mason and three helpers. The middle and high reflect two or three of such teams.
3	**2nd Story Floor**				
3.1	**Floor**				
3.1.1	**Main Beams**				
3.1.1.1	Procure Beams	1	2	4	This is a non-driving task. A range of one to four individuals with an axe is hypothesized.
3.1.1.3	Transport Beams	4	6	8	A team of four is needed to carry each beam. Two of these teams might work in tandem to move timber faster. The middle rate represents the median of the low and high rate.
3.1.2	**Cross Branches**				

Outline	Group / Task	Low	Middle	High	Explanation
3.1.2.1	Transport Branches	0.1	0.25	0.5	This is a non-driving task in the schedule. The range reflects a single person working from 1/10th of the time to half-time.
3.1.3	**Earth**				
3.1.3.1	Procure Earth	1	2	4	A few individuals scattered on the site can quickly procure and transport earth. One to four individuals working on this task are hypothesized.
3.1.3.3	Transport Earth	1	2	4	Same as above.
3.2	**Assemble**				
3.2.2	Assemble Floor	4	6	8	At least four individuals are needed to maneuver and set the beams. The high reflects two teams working on this. The middle rate is the median of the low and high.
4	**2nd Story**				
4.1	**Mudbrick Wall**				
4.1.1	**Mudbrick**				
4.1.1.1	**Earth**				
4.1.1.1.1	Procure Earth	1	2	3	A few individuals in the polje are can quickly procure earth. The amount of labor here is less important than coordinating with brick manufacture.
4.1.1.2	**Water**				
4.1.1.2.2	Transport Water	1	2	3	A few individuals can carry sufficient water from the area of 7-X to the polje. The amount of labor here is less important than coordinating with brick manufacture.
4.1.1.4	Manufacture Mudbrick	3	4	6	The low rate reflects a crew of three mixing, molding, and turning bricks. The high rate reflects two teams working independently. The middle rate suggests a team of three with an added helper.

Outline	Group / Task	Low	Middle	High	Explanation
4.1.1.6	Transport Mudbrick	2	3	4	A range of two to four individuals is sufficient to supply masons assembling the mudbrick wall.
4.1.2	**Mortar**				
4.1.2.1	**Earth**				
4.1.2.1.1	Procure Earth	0.25	0.5	1	Same as above.
4.1.2.1.3	Transport Earth	0.25	0.5	1	Same as above.
4.1.3	**Assemble**				
4.1.3.2	Assemble 2nd Story	2	4	8	The low rate reflects a mason and helper (McHenry 1989, 95-6). Up to four such teams might work on different areas of the building at once.
5	**Stairs**				
5.1	**Support and Treads**				
5.1.1	**Main Beams**				
5.1.1.1	Procure Beams	1	2	4	Same as above.
5.1.1.3	Transport Beams	4	6	8	Same as above.
5.1.2	**Cross Branches**				
5.1.2.1	Transport Branches	0.1	0.25	0.5	This is a non-driving task in the schedule. The range reflects a single person working from 1/10th of the time to half-time.
5.1.3	**Earth**				
5.1.3.1	Procure Earth	1	2	4	Same as above.
5.1.3.3	Transport Earth	1	2	4	Same as above.
5.2	**Assemble**				
5.2.2	Assemble Stairs	4	4	6	At least four individuals are needed to maneuver and set the support beams. Up to an additional two might assist, but there is very limited space to work.
6	**Roof**				

Outline	Group / Task	Low	Middle	High	Explanation
6.1	**Main Beams**				
6.1.1	Procure Beams	1	2	4	Same as above.
6.1.3	Transport Beams	4	6	8	Same as above.
6.2	**Cross Branches**				
6.2.1	Transport Branches	0.1	0.25	0.5	Same as above.
6.3	**Earth**				
6.3.1	Procure Earth	1	2	4	Same as above.
6.3.3	Transport Earth	1	2	4	Same as above.
6.4	**Assemble**				
6.4.2	Assemble Roof	4	6	8	Same as assembly of the floor.
7	**Exterior Plastering**				
7.1	**Walls**				
7.1.1	**Mud Plaster**				
7.1.1.1	**Earth**				
7.1.1.1.1	Procure Earth	0.25	0.5	1	Same as above.
7.1.1.1.3	Transport Earth	0.25	0.5	1	Same as above.
7.1.2	**Finish**				
7.1.2.2	Finish Exterior Walls	3	6	12	The low rate is based on two plasterers and a helper. Four such teams might work along the perimeter.
7.2	**Roof**				
7.2.1	**Mud Plaster**				
7.2.1.1	**Earth**				
7.2.1.1.1	Procure Earth	0.25	0.5	1	Same as above.
7.2.1.1.3	Transport Earth	0.25	0.5	1	Same as above.
7.2.2	**Finish**				

Outline	Group / Task	Low	Middle	High	Explanation
7.2.2.2	Finish Roof	3	3	6	The low and middle rate is based on two plasterers and a helper. A team might be added, but weight is a concern.
8	**Interior Plastering**				
8.1	**1st Story**				
8.1.1	**Mud Plaster**				
8.1.1.1	**Earth**				
8.1.1.1.1	Procure Earth	0.25	0.5	1	Same as above.
8.1.1.1.3	Transport Earth	0.25	0.5	1	Same as above.
8.1.2	**Finish**				
8.1.2.2	Finish Interior, 1st Story	3	6	9	The low rate is based on two plasterers and a helper. Up to three teams might work inside with one assigned to each room.
8.2	**2nd Story**				
8.2.1	**Mud Plaster**				
8.2.1.1	**Earth**				
8.2.1.1.1	Procure Earth	0.25	0.5	1	Same as above.
8.2.1.1.3	Transport Earth	0.25	0.5	1	Same as above.
8.2.1.2	**Finish**				
8.2.1.2.2	Finish Interior, 2nd Story	3	6	9	The low is based on two plasterers and a helper. Three teams might work inside each assigned to one room.
8.2.2	**Lime Plaster**				
8.2.2.1	**Hydrated Lime**				
8.2.2.1.1	Manufacture Lime	3	4	6	The range is hypothetical since only a small number are needed to acquire and heap the necessary limestone for a burn (see Russell and Dahlin 2007).
8.2.3	Finish Lime Plaster	2	3	4	The range is hypothetical.
9	**Project Finish**				

Table B.25 Labor Ranges for the Northeast Extension of Mycenae's fortification wall. Outline numbers correspond to the structure's precedence diagram and precedence table. The low, middle, and high are the hypothesized number of workers completing the task.

Outline	Group / Task	Low	Middle	High	Explanation
1	**Project Start**				
2	**Site Preparation**				
2.1	**Excavation**				
2.1.1	Procure Spoil	2	20	40	The high rate reflects a maximum that would fit in the area of the cistern based on its surface area. The low reflects a very pessimistic view of how many might work. The middle rate is a reasonable number to remove overburden and bedrock.
2.1.3	Transport Spoil	1	10	20	This allows for variation in the number of carriers to diggers.
2.2	**Foundations**				
2.2.1	Finish Foundations	5	31	67	The high rate reflects workers spaced at 1.75 m. The middle rate reflects a comfortable spacing of c. 3.75 m. Considering that not all area had to be worked, this is reasonable.
3	**Cistern**				
3.1	**Masonry**				
3.1.1	**Rubble**				
3.1.1.1	Procure Rubble	3	9	15	At least three individuals would need to work around a normal cyclopean block. The high number suggest five such teams might operate along the roads east of Mycenae.
3.1.1.3	Transport Rubble	1	3	5	This reflects a minimum ratio of one individual and a wagon for each team procuring rubble.
3.1.3	Assemble Cistern	4	12	20	The low rate is a skilled mason and three helpers. There is very limited space to work in the cistern, but three such groups can fit if staggered. The high rate reflects five such groups.
4	**Cyclopean Wall**				
4.1	**Wall Faces**				

Outline	Group / Task	Low	Middle	High	Explanation
4.1.1	**Rubble, Reused**				
4.1.1.2	Transport Rubble	15	25	35	Carrying the stones is intensive but only required for a short distance. The high number is taken from monolithic carrying experiments at La Venta (Heizer 1966, 825). Since space is limited the middle and low rate are reduced by 10 and 20, respectively.
4.1.2	**Rubble**				
4.1.2.1	Procure Rubble	3	9	15	Same as above.
4.1.2.3	Transport Rubble	1	3	5	Same as above.
4.1.3	Assemble Wall Faces	20	52	84	The high rate reflects the number of workers that could be spaced out along the wall's perimeter, but it would be quite crowded. The low rate suggests at least five teams of one mason and three helpers to maneuver and set the stones. The middle rate is the median of the two.
4.2	**Lower Wall Fill**				
4.2.1	**Rubble**				
4.2.1.1	Procure Rubble	3	9	15	Same as above.
4.2.1.3	Transport Rubble	1	3	5	Same as above.
4.2.3	Assemble Lower Fill	20	44	79	This reflects the ratio of lower fill to face. It is meant to reflect a range that will keep pace with assembling wall faces.
4.3	**Upper Wall Fill**				
4.3.1	**Rubble**				
4.3.1.1	Procure Rubble	3	9	15	Same as above.
4.3.1.3	Transport Rubble	1	3	5	Same as above.
4.3.3	Assemble Upper Fill	20	38	56	This reflects the ratio of upper fill to face. It is meant to reflect a range that will keep pace with assembling wall faces.
5	**Project Finish**				

Table B.26 Summary of a 742-day simulated schedule for the Treasury of Atreus broken down by major component. This corresponds with the Gantt chart in Figure A.128

Outline	Group / Task	Start Day	Finish Day
1	**Project Start**	0	0
2	**Site Preparation**	0	55
3	**Lower Chamber and Stomion**	0	395
4	**Lintels**	384	388
5	**Upper Chamber**	385	505
6	**Dromos and Upper Façade**	473	718
7	**Peribolos**	473	512
8	**Tumulus**	473	742
9	**Project Finish**	742	742

Table B.27 Summary of a 634-day simulated schedule for the Treasury of Atreus broken down by major component. This corresponds with the Gantt chart in Figure A.130.

Outline	Group / Task	Start Day	Finish Day
1	**Project Start**	0	0
2	**Site Preparation**	0	93
3	**Lower Chamber and Stomion**	0	295
4	**Lintels**	282	285
5	**Upper Chamber**	283	449
6	**Dromos and Upper Façade**	365	619
7	**Peribolos**	366	408
8	**Tumulus**	366	634
9	**Project Finish**	634	634

Table B.28 Summary of a 56-day simulated schedule for structure 4-VI at Kalamianos broken down by major component. This corresponds with the Gantt chart in Figure A.137.

Outline	Group / Task	Start Day	Finish Day
1	Project Start	0	0
2	Basement	0	10
3	Floor	10	18
4	1st Story	18	40
5	Roof	39	53
6	Exterior Plastering	48	56
7	Interior Plastering	47	56
8	Project Finish	56	56

Table B.29 Summary of a 90-day simulated schedule for structure 7-X at Kalamianos broken down by major component. This corresponds with the Gantt chart in Figure A.138.

Outline	Group / Task	Start Day	Finish Day
1	Project Start	0	0
2	1st Story	0	16
3	2nd Story Floor	16	20
4	2nd Story	16	73
5	Stairs	31	33
6	Roof	71	80
7	Exterior Plastering	75	87
8	Interior Plastering	78	90
9	Project Finish	90	90

Table B.30 Summary of a 116-day simulated schedule for the Northeast Extension broken down by major component. This corresponds with the Gantt chart in Figure A.142.

Outline	Group / Task	Start Day	Finish Day
1	Project Start	0	0
2	Site Preparation	0	18
3	Cistern	8	20
4	Cyclopean Wall	18	116
5	Project Finish	116	116

Table B.31 Tasks in the Treasury of Atreus' model showing correlation with the timeframe for project completion.

Rank	Outline	Component	Task	Regression Coefficient
#1	3.1.3	Lower Chamber	Assemble Walls	-0.738
#2	6.1.3	Dromos and Upper Façade	Assemble Walls	-0.427
#3	2.1.1.1	Site Preparation	Procure Spoil	-0.279
#4	5.1.3	Upper Chamber	Assemble Walls	-0.198
#5	6.1.1.1	Dromos and Upper Façade	Procure Conglomerate	-0.161
#6	6.3.4	Dromos and Upper Façade	Assemble Claybrick Wall	-0.112
#7	2.1.1.3	Site Preparation	Transport Spoil	-0.086
#8	8.1.3	Tumulus	Transport Fill	-0.07
#9	6.2.4	Dromos and Upper Façade	Assemble Rubble Wall	0.067
#10	6.1.1.3	Dromos and Upper Façade	Transport Conglomerate	0.067
#11	4.1.1	Lintels	Procure Interior Lintel	0.03

Table B.32 Tasks in structure 4-VI's model showing correlation with the timeframe for project completion.

Rank	Outline	Component	Task	Regression Coefficient
#1	4.1.3.2	1st Story	Assemble 1st Story	-0.538
#2	4.1.2.1.1	1st Story	Procure Earth	-0.454
#3	2.1.3.2	Basement	Assemble Basement	-0.28
#4	4.1.2.1.3	1st Story	Transport Earth	0.234
#5	5.4.2	Roof	Assemble Roof	-0.209
#6	5.3.1	Roof	Procure Earth	-0.201
#7	2.1.2.1.1	Basement	Procure Earth	-0.189
#8	2.1.2.1.3	Basement	Transport Earth	0.134
#9	5.3.3	Roof	Transport Earth	0.117
#10	3.4.2	Floor	Assemble Floor	-0.111
#11	6.1.2.2	Exterior Plastering	Finish Exterior Walls	-0.09
#12	3.3.1	Floor	Procure Earth	-0.079
#13	7.1.2.2	Interior Plastering	Finish Basement Walls	-0.067
#14	4.1.2.2.1	1st Story	Transport Water	-0.062
#15	6.2.1.1.1	Exterior Plastering	Procure Earth	-0.048
#16	2.1.2.2.1	1st Story	Transport Water	-0.043
#17	7.2.2.2	Interior Plastering	Finish 1st Story Walls	-0.042
#18	5.1.1	Roof	Procure Beams	-0.033

Table B.33 Tasks in structure 7-X's model showing correlation with the timeframe for project completion.

Rank	Outline	Component	Task	Regression Coefficient
#1	4.1.3.2	2nd Story	Assemble 2nd Story	-0.798
#2	4.1.1.4	2nd Story	Manufacture Mudbrick	-0.205
#3	2.1.2.1.1	1st Story	Procure Earth	-0.186
#4	2.2.2	1st Story	Assemble 1st Story	-0.162
#5	4.1.1.6	2nd Story	Transport Mudbrick	0.093
#6	2.1.2.1.3	1st Story	Transport Earth	0.091
#7	8.2.3	Interior Plastering	Finish Lime Plaster	-0.062
#8	8.2.1.2.2	Interior Plastering	Finish Interior, 2nd Story	-0.061
#9	5.1.2.1	Stairs	Transport Branches	-0.051
#10	4.1.2.1.1	2nd Story	Procure Earth	-0.05
#11	6.4.2	Roof	Assemble Roof	-0.046
#12	7.2.2.2	Exterior Plastering	Finish Roof	-0.046
#13	4.1.1.1.1	2nd Story	Procure Earth	-0.04
#14	4.1.1.2.2	2nd Story	Transport Water	-0.029
#15	8.2.1.1.1	Interior Plastering	Procure Earth	-0.029
#16	5.1.3.1	Stairs	Procure Earth	0.029

Table B.34 Tasks in the Northeast Extension's model showing correlation with the timeframe for project completion.

Rank	Outline	Component	Task	Regression Coefficient
#1	4.3.1.3	Cyclopean Wall	Transport Rubble, Upper Fill	-0.649
#2	4.1.2.3	Cyclopean Wall	Transport Rubble, Wall Faces	-0.43
#3	4.1.3	Cyclopean Wall	Assemble Wall Faces	0.215
#4	3.1.3	Cistern	Assemble Cistern	-0.09
#5	4.2.3	Cyclopean Wall	Assemble Lower Fill	-0.087
#6	4.2.1.3	Cyclopean Wall	Transport Rubble, Lower Fill	-0.068
#7	2.1.1	Site Preparation	Procure Spoil	-0.058
#8	2.1.3	Site Preparation	Transport Spoil	-0.054
#9	4.1.1.2	Cyclopean Wall	Transport Rubble, Wall Faces	-0.052
#10	4.3.3	Cyclopean Wall	Assemble Upper Fill	-0.038

APPENDIX C

MATERIALS AND TASK RATES

Material Constants

Table C.1 Building material densities.

Material	kg / m^3	Source
Brick, Dried	1,440	Homsher 2012, 18
Conglomerate	2,500	Como 2005, 128
Clay	1,800	Hurst 1865, 106
Earth	1,400	Gillette 1920, 113
Fill / Spoil	1,900	Como 2005, 128
Limestone, Rubble	1,400	Hurst 1899, 338
Limestone, Solid	2,400	Hornbostel 1991, 83
Poros Limestone	2,400	Arthur 1913, 407
Water	1,000	
Timber, Pine	800	
Lime, Hydrated	1540	
Branches / Vegetation	150	

Table C.2 Ratios of raw to manufactured materials.

Manufactured Material	Raw Materials	Source
Brick, Dried	Clay/Earth: 65% Temper: 35%	Homsher 2012, 19
Brick Wall	Brick, Dried: 80% Mortar: 20%	Burke 2004, 299
Rubble Wall, Mortared	Rubble: 80% Mortar: 20%	Rea 1902, 92–3
Clay or Mud Mortar	Clay/Earth/Additives: 100% Water: 66% (Percentage based on final wall volume)	Murakami 2010, 472
Lime Plaster	Lime, hydrated: 50% Sand: 50%	Murakami 2010, 205

Standardized Task Rates and Sources

Rates to Procure Materials

Table C.3 Quarry Rubble.

Standardized Rate	1.550 m³ / ph
Application	
Extracting limestone rubble from exposed outcroppings. Limestone rubble has a density of 1,400 kg / m³ (Hurst 1899, 338).	
Source	Devolder 2013, 24, 43 table 7
Rate as Published	(Volume x Density / 900) / ph
Source Notes	
The rate derives from experiments conducted by Abrams (1994, 46–7) in Mesoamerica. The rate was modified by Devolder to account for the densities of different rocks.	

Table C.4 Quarry Conglomerate.

Standardized Rate	0.089 m³ / ph
Application	
Extracting regular conglomerate blocks using channeling. The process of quarrying conglomerate remains vague so the appropriateness of this rate is uncertain.	
Source	Lehner 1997, 206–7
Rate as Published	12 quarrymen extracted 186 limestone blocks (1 m³ each) in 22 days.
Source Notes	
Lehner notes that the quarrymen were barefoot and used only hand tools. They did, however, have access to a hand winch. Lehner suggests up to 20 more men may have been required under stricter ancient conditions.	

Table C.5 Quarry Limestone.

Standardized Rate	0.089 m³ / ph
Application	
Extracting regular limestone blocks using channeling.	
Source	Lehner 1997, 206–7
Rate as Published	12 quarrymen extracted 186 limestone blocks (1 m3 each) in 22 days.
Source Notes	
Lehner notes that the quarrymen were barefoot and used only hand tools. They did, however, have access to a hand winch. Lehner suggests up to 20 more men may have been required under stricter ancient conditions.	

Table C.6 Excavate Hard Earth and Marls.

Standardized Rate	0.300 m^3/ ph
Application Excavating rocky, hard packed soils and marls.	
Source	Rea 1902, 48
Rate as Published	3–5 yd^3 / 10 ph
Source Notes Based on digging and throwing out hard ground when picking is required.	

Table C.7 Excavate Earth or Clay.

Standardized Rate	0.540 m^3/ ph
Application Excavating lighter packed materials for brick, mortar, or plaster.	
Source	Rea 1902, 48
Rate as Published	6–7 yd^3 / 10 ph
Source Notes Based on digging and throwing out clay or gravel.	

Table C.8 Fell Timber.

Standardized Rate	0.200 m^3 / ph
Application Felling trees whose diameter is c. 0.15 m and whose usable height is c. 5.5 m. This includes preparing the tree by removing bark, top, and limbs.	
Source	See source notes
Rate as Published	See source notes

Source Notes
    Hammerstedt (2005, 51–62) derived a rate of t = exp(-0.487535) * d $^{1.17247}$ for cutting timber of diameter (d) in time (t). Felling trees of dense wood whose diameter is c. 0.15 m and whose usable height is c. 5.5 m results in a rate of 0.4 m^3 / ph.
 	
    According to Kunkels' work, it takes c. 80 minutes to top, trim, and debark a tree of 22 cm diameter to form a primary roof beam and about 15 minutes for a tree of 12 cm (Windes and McKenna 2001, table 3). Based on these two rates, I approximate 40 minutes to prepare a tree with a diameter of 15 cm. With a usable height of 5.5 m, this works out to finishing about 0.4 m^3 / ph.
 	
    The combination of the two rates gives the result of 0.2 m^3 / ph to fell and prepare a tree.	

Rates to Transport Materials

Table C.9 Transport by Wagon and Oxen.

Standardized Rate	$(kg_{weight} / 2100) * (2 * km_{distance} / 1.67) = x$ ph

Application	Transporting loads under 2100 kg. This rate includes the return trip of wagon and oxen but does not account for loading and unloading time.
	
	kg_{weight} = the total weight of the materials being transported.
	$km_{distance}$ = the distance, one-way, that the material is carried.
	
	To provide some account of different terrains, the formula can be multiplied by the following constants if conditions warrant:
	
	   1) *Very steep terrain* = 4.5; slopes of 9° increase labor by 450% (Atkinson 1961, 297).
	   2) *Moderately steep terrain* = 2.25; half of the above rate for finer control.

Source	Devolder 2013, 24–7, 43
Rate as Published	"*Le poids total de matériau transporté divisé par 2100 (kg) donne le nombre de trajets effectués. On multipliera ceux-ci par la duree (en h-p) de chaque trajet, en considérant la distance parcourue à une vitesse de 1,67 km/h.*" (Devolder 2013, 43)
Source Notes	The formula relies on a walking speed of 1.67 km/h and dragging power of 2100 kg for a single ox over a flat surface. It assumes 2100 kg is an upper limit for wagons.

Table C.10 Transport by Carrying Individually.

Standardized Rate	$kg_{maxload}$ * 1 / ($km_{distance}$ / 3 + $km_{distance}$ / 5) = x kg / ph
Application	

Application

An individual carrying materials. It is assumed that an average human speed is 3 km / hr loaded and 5 km / hr unloaded.

$kg_{maxload}$ = the maximum load that the individual can sustain for the given distance per trip.
$km_{distance}$ = the distance, one-way, that the material is carried.

Source	Aaberg and Bonsignore 1975, 46
Rate as Published	Output = Q x 1 / (L / V + L / V') x H

Source Notes

The formula derives from a UN study on earthmoving.

Q = quantity of material carried in one trip
L = the distance, one-way, that the material is carried
V = velocity, loaded
V' = velocity, unloaded

Table C.11 Transport by Carrying as a Group.

Standardized Rate	$kg_{maxload}$ * 1 / ($km_{distance}$ / 1.5 + $km_{distance}$ / 5) = x kg / ph

Application

A coordinated group carrying materials. It is assumed that an average human speed working as a group is slowed to 1.5 km / hr loaded but remains 5 km / hr unloaded.

$kg_{maxload}$ = the maximum load that each individual in the group can sustain for the given distance per trip.
$km_{distance}$ = the distance, one-way, that the material is carried.

Source	Aaberg and Bonsignore 1975, 46
Rate as Published	Output = Q x 1 / (L / V + L / V') x H

Source Notes

The formula derives from a UN study on earthmoving.

Q = quantity of material carried in one trip
L = the distance, one-way, that the material is carried
V = velocity, loaded
V' = velocity, unloaded

Table C.12 Transport by Dragging

Standardized Rate	$(\text{kg}_{weight} / 41) * \text{km}_{distance} = x$ ph
Application	

Dragging larger loads on a sledge or directly on the ground. The basic formula assumes the load is dragged over flat ground with laborers supplying the traction.
 	
kg_{weight} = the total weight of the load being dragged
$\text{km}_{distance}$ = the distance, one-way, that the load is dragged
 	
To provide some account of different techniques and terrains, the formula can be multiplied by the following constants in combination or individually if conditions warrant:
 	
    1) *Lubricated surface* = 0.25; friction is reduced by 75% (Cotterell and Kamminga 1990, 222; Edwards 2003, 344).
    2) *Very steep terrain* = 4.5; slopes of 9° increase labor by 450% (Atkinson 1961, 297).
    3) *Moderately steep terrain* = 2.25; half of the above rate for finer control.	

Source	Loader 1998, 68
Rate as Published	4 workers drag 1.845 tons a distance of 1 km in 11.19 hours
Source Notes	
The formula derives from Loader's application of Atkinson's (1979, 114–5) Stonehenge experiments to Mycenaean cyclopean blocks.	

Rate to Manufacture Materials

Table C.13 Make Clay- or Mudbricks.

Standardized Rate	0.138 m^3 / ph
Application	
Mixing and drying clay or mudbrick including the minimal cost of turning them while curing. The cost of gathering water and temper can be added if the situation warrants. Otherwise, the rate assumes both are readily accessible and acquired at negligible cost.	
Source	Murakami 2010, 203
Rate as Published	1.1 m^3 / pd (8-hour)
Source Notes	
Presumably Murakami's rate is based on an eight-hour person-day. This rate agrees with Smailes' (2011, 44) rate of 1 m^3 / 7 ph.	

Table C.14 Make Hydrated Lime.

Standardized Rate	0.004 m^3 / ph
Application	
Producing lime, including collecting and transporting all materials (firewood and limestone), and slaking of the lime. Materials are assumed to be relatively close to the site of production.	
Source	Russell and Dahlin 2007, 417
Rate as Published	0.5 m^3 / 144 ph
Source Notes	
This rate derives from an experiment conducted in Mexico by local, skilled workers. The firing was completed using an open-air burn. I was not able to find any experimental labor times for kiln firing of lime, but some may exist in the ethnographic literature. This rate is supported by other lime production experiments (Abrams 1984, 173–5).	

Table C.15 Make Lime Plaster

Standardized Rate	0.220 m^3 / ph
Application	
Mixing hydrated lime with sand tempering (and possibly a small amount of water) before applying. For small quantities of plaster, this rate is negligible.	
Source	Murakami 2010, 205
Rate as Published	0.22 m^3 / 1 pd (8-hour)
Source Notes	
This is based on mixing experiments conducted by Murakami.	

Rates to Assemble Materials

Table C.16 Build Clay- or Mudbrick Wall.

Standardized Rate	0.100 m^3 / ph
Application	
Building a brick wall including mixing the mortar as needed. The cost of gathering water for the mortar can be added if the situation warrants. Otherwise, the rate assumes water is readily accessible and acquired at a negligible cost.	
Source	Smailes 2000, 43
Rate as Published	1 m^3 / 10 ph
Source Notes	
This rate agrees with Devolder's (2013, 43) rate of 0.105 m^3 / ph.	

Table C.17 Build Dry Rubble Wall

Standardized Rate	0.159 m^3 / ph
Application Building a dry stone wall.	
Source	Hurst 1865, 217
Rate as Published	1 yd^3 by 2 workers in 0.240 days (10-hour)
Source Notes Based on a mason and laborer building a rubble stone wall in courses without mortar to the foundations.	

Table C.18 Build Mortared Rubble Wall.

Standardized Rate	0.137 m^3 / ph
Application Building a mortared stone wall. This includes mixing the mortar. The cost of gathering water for the mortar can be added if the situation warrants. Otherwise, the rate assumes water is readily accessible and acquired at a negligible cost.	
Source	Hurst 1865, 217
Rate as Published	1 yd^3 by 2 workers in 0.280 days (10-hour)
Source Notes Based on a mason and laborer building a rubble stone wall in courses with mortar to the foundations	

Table C.19 Build Ashlar Courses with Small Blocks

Standardized Rate	0.034 m^3 / ph
Application Building ashlar walls with blocks approximately 0.1–0.2 m^3. This does not include final dressing of the exposed face.	
Source	Mayes 1862, 24
Rate as Published	1 ft^3 for 2 workers in 5/12th of 1 hour
Source Notes Based on a mason and laborer setting sandstone, bluestone, granite, or marble blocks of 2–6 ft^3.	

Table C.20 Build Ashlar Courses with Medium Blocks

Standardized Rate	0.024 m³ / ph
Application	
Building ashlar walls with blocks approximately 0.2–0.5 m³. This does not include final dressing of the exposed face.	
Source	Mayes 1862, 24
Rate as Published	1 ft³ by 2 workers in 7/12th of an hour
Source Notes	
Based on a mason and laborer setting sandstone, bluestone, granite, or marble blocks of 6+ ft³.	

Table C.21 Build Ashlar Courses with Large Blocks

Standardized Rate	0.019 m³ / ph
Application	
Building ashlar walls with blocks approximately 0.5+ m³. This does not include final dressing of the exposed face.	
Source	Mayes 1862, 24
Rate as Published	The rate for medium blocks decreases by 1/5th
Source Notes	
Based on a mason and laborer setting sandstone, bluestone, granite, or marble blocks of 20+ ft³.	

Table C.22 Build Traditional Floor or Flat Roof

Standardized Rate	0.400 m² / ph
Application	
The construction of a traditional flat roof or floor made of beams, branches/vegetation, and earth. This does not include any costs for acquiring or transporting the materials.	
Source	Lekson 1984, 280–1
Rate as Published	5 m² / 12.5 ph
Source Notes	
This represents Lekson's estimate for Anasazi roof construction, which is roughly similar to that found in the Aegean. It simplifies the complexities of roof construction by using the square meters of each roof, rather than the details of beams and fill, etc. This rate requires refinement in the future.	

Table C.23 Build Simple Staircase

Standardized Rate	0.313 m^2 / ph
Application	
The construction of a reasonably sloped (c. 27°) stairwell of wooden beams, branches/vegetation, and earth, topped with treads of mortared rubble. m^2 is a measure of the surface area of the supporting earth layer below the treads.	
Source	See source notes
Rate as Published	See source notes
Source Notes	
Since construction of the staircase is like a roof or floor at an angle, with added treads, this uses the rate for building a floor or roof (0.4 m^2 / ph) with the additional cost of the treads. The tread rate is based on my own staircase models which estimate that 1 m^3 of rubble is used per 10 m^2 of inclined surface area. Using the mortared rubble rate of 0.137 m^3 / ph, this gives a rough tread rate of 10 m^2 / 7 ph. With the roof rate (0.4 m^2 / ph = 10 m^2 / 25 ph) this gives a total rate of 10 m^2 / 32 ph or 0.313 m^2/ph.	

Rates to Finish Materials

Table C.24 Dress Stone with a Chisel

Standardized Rate	0.929 m^2 / ph
Application	
Dressing softer stones with a mallet and chisel.	
Source	Hurst 1865, 217
Rate as Published	1 ft^2 / .01 days (10-hour)
Source Notes	
Based on a mason or stonecutter dressing a stone to fair face with a chisel.	

Table C.25 Dress Stone with a Hammer

Standardized Rate	0.232 m^2 / ph
Application	
Dressing harder stones with a hammer.	
Source	Hurst 1865, 217
Rate as Published	1 ft^2 / .04 days (10-hour)
Source Notes	
Based on a mason or stonecutter dressing a stone to fair face with a hammer.	

Table C.26 Apply Mud or Clay Plaster to a Wall

Standardized Rate	0.800 m^2 / ph
Application Applying clay or earth plaster of moderate thickness (c. 5 cm) to walls, including mixing and smoothing the plaster.	
Source	Murakami 2015, 273
Rate as Published	6.37 m^2 / pd (8-hour)
Source Notes Derived from experiments applying a 5 cm thick clay amalgam to stone walls using a trowel.	

Table C.27 Apply Mud or Clay to a Floor or Roof

Standardized Rate	5.690 m^2 / ph
Application Applying clay or earth plaster of moderate thickness (c. 5 cm) to floors, including mixing and smoothing the plaster.	
Source	Murakami 2015, 273
Rate as Published	45.5 m^2 / pd (8-hour)
Source Notes Derived from experiments applying a 5 m thick clay amalgam to floors by dumping and leveling it.	

Table C.28 Apply Lime Plaster to a Wall

Standardized Rate	1.300 m^2 / ph
Application Applying a thin layer (a few millimeters) of lime plaster to a wall and smoothing it.	
Source	Murakami 2015, 273
Rate as Published	10.42 m^2 / pd (8-hour)
Source Notes Derived from experiments applying a c. 2 mm thick lime plaster to walls and smoothing it.	

Table C.29 Apply Lime Plaster to a Floor or Roof

Standardized Rate	4.310 m^2 / ph
Application Applying a thin layer (a few millimeters) of lime plaster to a floor and smoothing it. For multiple coats the rate should be multiplied appropriately.	
Source	Murakami 2015, 273
Rate as Published	34.5 m^2 / pd (8-hour)
Source Notes Derived from experiments applying a c. 2 mm thick coat of lime plaster to floors and smoothing it.	

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BIOGRAPHICAL SKETCH

I was born in Sleepy Hollow, New York and grew up in the nearby town of Ossining. I graduated from Ossining High School in 2001 and, after a year's hiatus, decided to attend the University of Puget Sound in Tacoma, WA. Having entered as a computer science major, I there became in engaged in Latin and archaeology and eventually transferred to the University at Buffalo, where I graduated in 2006 with a B.A. in Classics and a specialization in Mediterranean Archaeology. It was during my time at Buffalo that I came to appreciate the diverse field of classical studies in which I was encouraged to study languages, literature, art, and archaeology. It was also there that I first became interested in the many problems of Greek prehistory. After leaving the University at Buffalo, I entered the Ph.D. program in the Florida State University Department of Classics to further explore my interests in Greek prehistoric archaeology. At Florida State University, I have had the opportunity to act as both an advanced student of prehistoric archaeology and a teacher of Latin and mythology while also performing fieldwork in Greece and the southeastern United States.