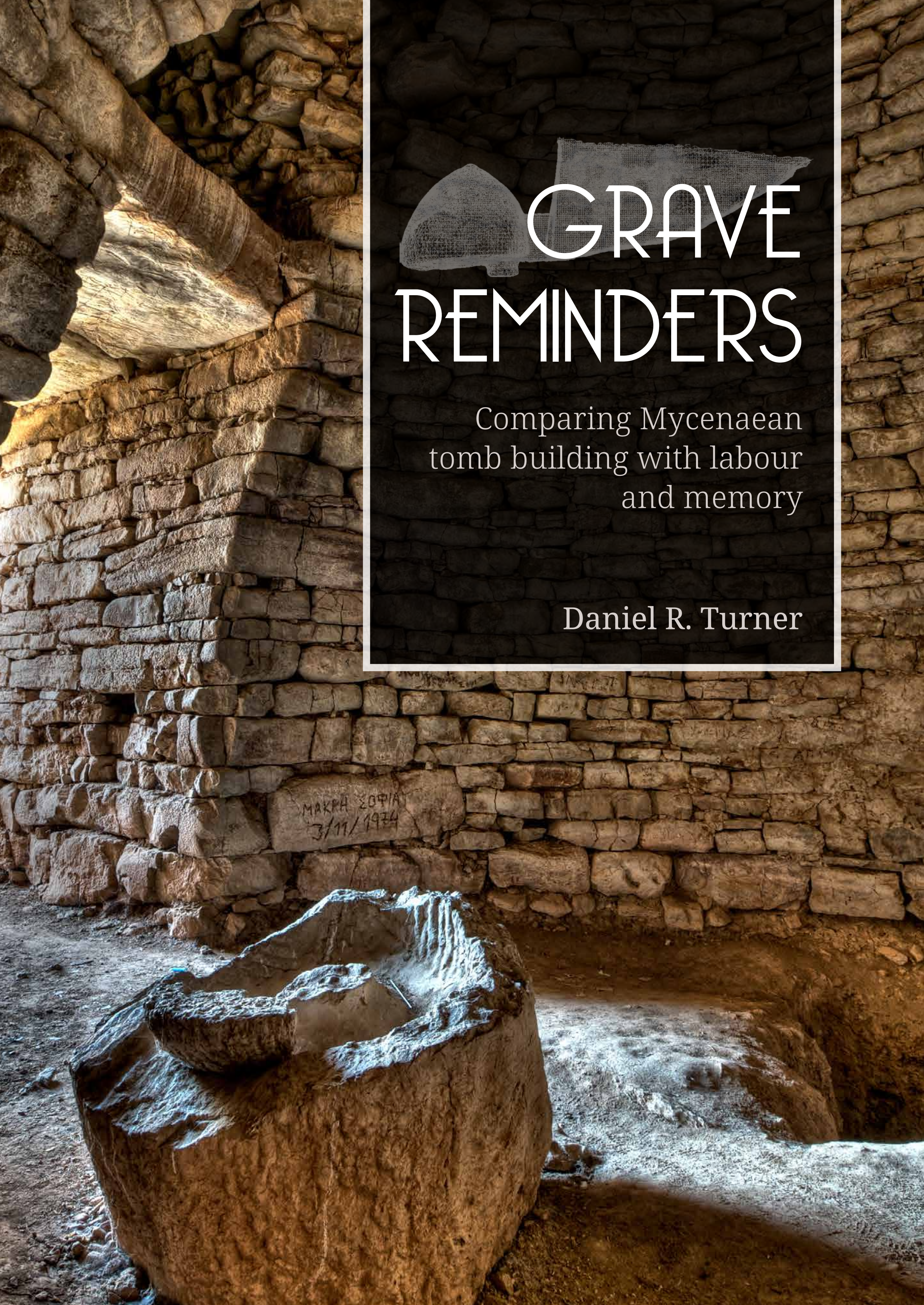
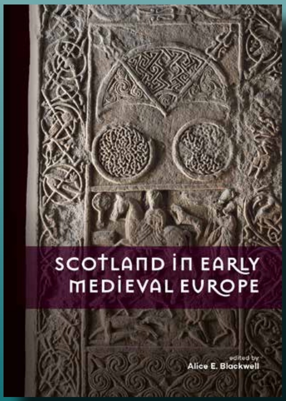


GRAVE REMINDERS

Comparing Mycenaean tomb building with labour and memory

Daniel R. Turner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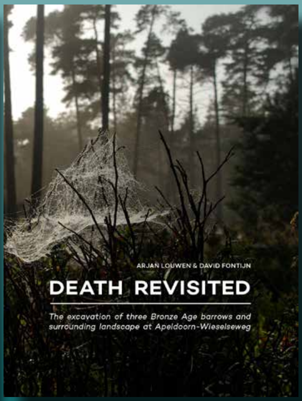
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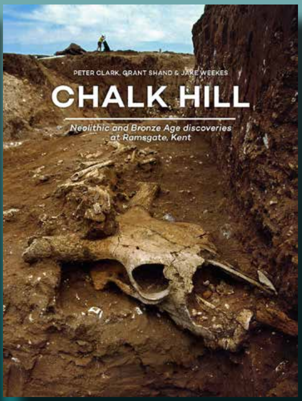
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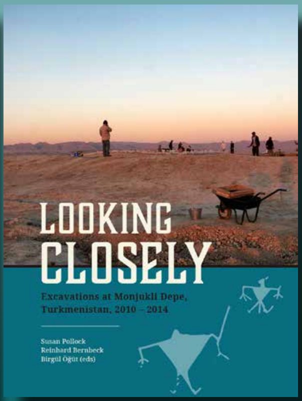
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GRAVE
REMINDERS

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For Bethany, still no earthworms

GRAVE REMINDERS

Comparing Mycenaean tomb building with labour and memory

Daniel R. Turner

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Preface

Earthmoving has followed me for some time in ways not so solemn and grand as the Mycenaean tombs I examine here. As a field archaeologist in the south-eastern US, I found myself on the wrong side of a reservoir backwater separating my clipboard and me from our crew in late October 2015. With barely a trickle of water in the channel ahead of me, I considered the crossing a simple matter of fording. There certainly was no other option nearby. Aggressive cut banks formed sheer cliffs several metres high upstream, and the dam reservoir blocked all but watercraft and fish downstream. The channel was only a few metres wide where I stood. Crossing could not be exceedingly difficult where my mind's eye offered reassurances of larger puddles jumped as a child. As it turned out, historically low water levels did not offset decades of reservoir-triggered, fine-grained mud deposition, the kind that hides beneath a paper-thin crust, strips knee-high boots in seconds and traps most of a 193 cm frame like a tar pit swallowing a mastodon. In a connectivity dead zone and kilometres out of earshot, my shovel spared local officials an unpleasant search. What felt like hours was in reality a 20-minute ordeal that concluded with a half-day of hiking in damp socks, but the steps I carved into the bank as an exit likely remain in slumped form to this day.

Even after digging myself out of an early grave and thousands of other test pits besides, the thought never occurred to me that I would spend more than a decade writing about earthmoving, nor that I would continually drift eastward and backward in time with case studies (Turner 2010, 2012, 2018). On its own, few could conjure a more lifeless subject. The term itself is deliberately broad to encompass moving all manner of ground underfoot. Soil, sediment, and rock type distinctions are the purview of others – a conciliatory aside only partially motivated by my frustrating inability to identify them. My concern is how fast humans can break ground and move it, a test for the limits of desire and engineering even where only scattered memories of construction remain. The path to the simplest answer can be alliterative: compaction (of the material being cut and moved), conditioning (of the labourer's physique and motivation), and cutting surface (of the digging tool). However, memories of construction, much like my channel crossing, can quickly turn into an impassable mire for the wrong steps. Fortunately for such a common global phenomenon, one can hardly walk alone.

Memories of construction where death is concerned are not worth chasing without addressing the elephant in the tomb. Death is immortally faceless and even the most extravagant memorial will succumb to anonymisation. Our daily lives are spent as if inexhaustible, and though oblivion lies in wait, we hardly think about it until confronted. As Flaherty and Throop (2018: 162) put it, “the intensities associated with [death’s] rupture into our world afford us only the most fleeting and imperfect glances at its essence”. *Grave reminders* give a name to those unsettling moments where mortality and memorial clash with an endless daily routine. These springboard from my own experiences, chiefly those as a contract archaeologist in the rural U.S. Southeast. How grave reminders apply to Mycenaean, or any, mortuary architecture, is a short leap. It began with the shock of wandering into centuries-old cemeteries shorn of caretakers. Surrounded by life resurgent after decades of human absence, stark reminders of mortality were unwelcome and provoking. This is a common experience for archaeological surveys in rural woodlands. Ghost towns dot old maps where rapid changes in the nineteenth and early twentieth centuries drove residents away. If not for crumbling stone markers and tell-tale rectilinear depressions visible even in dense leaf litter, the few dozen plots of a forgotten community might go unremarked. Memorials thought to have been made permanent through the act of carving stone rot in the rain, with their links to living memory broken. Stone is not the eternal material here that it might seem in the desert (Drennan and Kolb 2019: 59, citing Badawy 1966: 35 and Wright 2009: 56-57). Absent curated state and family records, few could recount the who and where of derelict cemeteries.

This led me to wonder how memorials maintain a place in the collective conscious when individual memories break down. As part of a project funded by the Alabama Army National Guard, I conducted interviews with former residents of communities converted into artillery ranges by War Department efforts in 1941 (Turner et al. 2014). Though they were children at the time, those I interviewed recounted striking details of their former homes. More relevant to the following chapters, they could retrace their steps in annual trips to clear the cemeteries despite the intervening decades and, in one case, complications from dementia. Conspicuously absent was any overt mention of religion or external pressure to perform the task; the obligation to return was inherited, not simply from family ties but through a personal connection to the story. Age and tighter access restrictions to military facilities following the terrorist events of 11 September 2001 prevented most from returning. Even so, they adopted me as an outsider into their memory, frankly acknowledging its rapid decline. They had internalised but had no interest in articulating that there were social mechanisms striving against forgetting through memorialisation and collective memory, which can be applied to the Aegean Bronze Age just as easily as modern rural Alabama.

Memory as an academic concept is a heterochthonous polylith for an autochthonous precept, a horrifying phrase that belies its ubiquity and simplicity. Doing it is simple – articulating it is not. Ask someone for a memory and a pause is as inevitable as the answer that follows. Memory is breathing. For most, it sits on the edge of consciousness unless called forward, sidestepping cumbersome discursive storage in favour of sensory anchors and embodied experience (Connerton 1989; Halbwachs 1992; Hamilakis 2013; Jones 2007; Lillios and Tsamis (eds) 2010; Nora 1989, 1997; Peterson 2013; Ricoeur 2004). I can trace the pattern of the vines on the wallpaper at my childhood home after a decade of not seeing them. I could walk around every trap at golf courses that no longer exist, erased by storms or disinterest. I know by heart the locations of my grandparents’ graves amid hundreds of others, despite brief goodbyes in dimly remembered funerals. All of these I can do without a visual aid. These memories are episodic and individual, teasing someone who was there with no hope for chronological order or verification (Connerton 1989: 37; Halbwachs 1992: 42). Assuming this manuscript dies as well, “all those moments will be lost in time”, to borrow from Rutger Hauer’s famous ‘tears in rain’ monologue in *Blade Runner* (Deeley and Scott 1982).

Whether through emotion or resonance, temporary events form durable memories that survive on transmission between generations. A shocking experience, next to writing, elevates memory through two of the “three uses of the indistinct idea of trace” adapted from Plato and historian Marc Bloch (1992 [1949]), with the other third situated in neuroscience (Ricoeur 2004: 13-15). Connerton (1989: 22-23) also preferred a tripartite classification of memory: personal (e.g., I was here on this date), cognitive (e.g., rote memorisation, such as song lyrics), and habit (e.g., riding a bike). Some philosophical disagreement collapses these categories into two: habit (including rote memorisation) and true (recollection of a precise event) (Connerton 1989: 23). Without writing or some other detailed and long-term conveyance, older generations are the primary custodians for collective memories of traditional process, primarily memories of ‘habit’ bolstered by anecdotes of ‘true’. Witnesses pass on their memories, perhaps generating a resonating message or sufficient interest to warrant performance in encore far removed from witnesses and the original event. The blind bard Demodocus recounts tales from the Trojan War to the hidden witness Odysseus, himself overcome with grief but curious for history’s testimonial to his actions (Homer *Od.* 8.89-103, 545-587; history as testimony *sensu* Ricoeur 2004: 21). Had the Phaeacians been indifferent to the Argives’ struggles against Troy, the bard may have kept to popular tales of the gods’ exploits such as Hephaestus ensnaring adulterous Aphrodite with Ares (Homer *Od.* 8.301-410). Instead, the bard impresses King Alcinous’s nameless guest, who declares his authentic perspective “as if you were there yourself or heard from one who was” (Homer *Od.* 8.551).

Relatability and interest sustain living memory so long as the chain does not detach through a generational gap, wilful (redaction/suppression) or involuntary (demographic crisis). Generational divide blocks complete sharing of memories and experiences, causing the social order to inevitably diverge with each passing generation (Connerton 1989: 3). Connerton illustrates this point with the exchange between Proust (1922) and a younger American socialite, wherein the name-dropping of both participants fails to resonate with their interlocutor due to a 25-year gap in their experience of French high society. Although involuntary memories sparked by Proust’s madeleine cakes are more familiar as personal epiphanies often launched by scent (Hamilakis 2010: 190, 2013: 84), generational leaps are more informative for collective instruction in commemoration. Here, Connerton (1989: 39) also invokes Bloch (1992 [1949]) on the tendency of preindustrial societies to have grandparents supervise children while parents work, resulting in the ancient trope of storytelling grandmothers and traditionalism that skips a generation.

Detachment, not indifference, accompanies our perception of Mycenaean tombs, and indeed most older architectural ruins, now protectively viewed as our non-renewable past. The past as a resource to be tapped implies value, one that originates by remembering minutely what is mostly forgotten (Forty 1999: 13; Heidegger 2010 [1927]). Riegl (1903) made the early distinction of ‘age value’ and ‘historical value’, or passing time versus a time in the past, in comments on the valuation of art. Antiques and ruins are old, their makers and context lost. Both take the romantic view that something once great has faded (Cooper 1999: 115), and ignite attempts to reclaim it. Resurrection is the operative metaphor for a contemporary gaze breaking into a time that has passed (aged and historical). In describing how Piranesi handled figures in famous eighteenth-century engravings of Rome, Cooper (1999: 117) captured the central tension in viewing ruins during which "bewilderment and fiery passion amount to a desire and an attempt to repossess the ancient, a commodity that through an act of fantasy, becomes the spectators' own world". Ruins deliver a powerful message with many meanings, but without a witness or translator, they whisper fantasy.

Collective memory in mimetic design constrains that fantasy. It endures, detached from the brevity and frailty of life, with the power of atavistic imagination, a gravitating reversion to something old that has no immutable connection to the present. Perceived connections perpetuate interest in antiques, ancestors, and ages immemorial. We can spare, harvest, and make them anew (Larsson 2010). Atavistic imagination is relentless in collective memory, yet both feel rudderless to Westerners in the absence of testimonial memory embedded in written records (Ricoeur 2004: 21) or *lieux de mémoire* linked to places (Nora 1989, 1997). For at least ten millennia we have invested reminders in each other, in commemorative objects and architecture. Only the specificity of commemoration is comparatively recent. Commemorative monuments became the fetish of early twentieth century Westerners who sought to protect the past, wishing to hold in stasis what they perceived was rapidly lost in mechanisation. The idea of memory in object had arrived via medieval European scholasticism, though all complex societies seek some form of memorialising the dead (Küchler 1999: 53). The chief difference for prehistory lies in where that memory originates. Events were immersive and remembered *en masse*, while monuments and individuals were forgotten. Emphasis falls on the momentary and collective rather than the intransient and individual. To us the built environment seems a poor substitute, itself shaped by memory during construction and continually shaping memories anew as both decay (e.g., Argenti 1999). Therein lies its pervasive power. If memory is truly inseparable from experience and archaeology (Hamilakis 2010: 188), then reminders are how we can measure it.

Grave reminders operate best within contested space – graves, war memorials, and ruins where commemorative expectations and atavistic imagination collide (Cummings 2003: 38; Holtorf 1996: 120-126; King 1999: 148, 152-155; Larsson 2010: 180; Rowlands 1993: 146; 1999: 139-140). Here, deviation is a risk not lightly taken. Reminders act as a weather vane for commemorative investment rather than a forecast. Accepting that tomb design is predictable at all, measurable parameters in shape and scale track the strength of architectural signals and their targeted audience. They do so within the well-tested theoretical frameworks of costly signalling, collective memory, and architectural energetics, which combine to reconstruct available resources that influence or constrain the choices people made when faced with the end.

Note for the trade edition

As a final note to the reader, it will become abundantly clear in the following pages that my contextual interests are peripatetic. My background and training railroad me toward methods first, theory second, and context a very distant third. Advancing methods for *how* we study labour and tomb construction demands cross-cultural and pan-temporal examples, leading to timeless generalisations that crumble under a too-close look. Mycenaean experts will understandably wonder how the tombs and people they study fit in grand labour narratives. The bibliography is better suited to their needs than any one of my chapters. Lacunae from data loss or access limitations hindered my own context-exclusive approach to comparative labour– intentionally designed, if imperfectly executed, on a global scale. We do not know the exact relationship between those who built the tombs and those interred within them. It is likely my own hyper-economic, reductionist bias that casts tomb builders as regional specialists for exceptional commissions and adept locals for more muted ones. As pointed out by Natacha Massar (personal communication, 2020), mortuary display by (sub)elites all but negates peers, related or not, as a potential source for the strenuous labour in building a multi-use tomb. Yet I wonder if the intimate spiritual and cosmological facets of tomb construction partly offset its dirty, exhausting reality – reinstating communal participation by well-connected families in the labour pool. Labour participation by proxy using dependents is at least well attested in Mycenaean crafting and herding schemes (Killen 2001, 2006; Nakassis 2015; Parkinson et al. 2013; Schon 2011; Shelmerdine 2001; see also Burford 1969; DeLaine 1997; Coulton 1977, 1983, for similar Greek and Roman aristocratic-sponsored building).

Provocative perhaps in its glancing treatment, I suggest a 'modest' (sub)elite family commissioning a chamber tomb at Portes and Voudeni could call upon multiple regional contacts, dispersing the burden while increasing the performative visibility of construction (*sensu* Boyd 2014a, 2016; Maran 2006b; Santillo Frizell 1997, 1997-1998). 'Modest' only fits here when compared with exceptional tombs that demanded a broader network of experienced builders. Just as the mega-*tholoi* outshine all others (e.g., Cavanagh and Mee 1999; Fitzsimons 2014, with earlier references; Harper 2016), standard chamber tombs in their turn far outclass mortuary investment in simpler pit and cist graves presumably dug by kin or close contacts (Lewartowski 1995, 2000; Voutsaki 1997; Voutsaki et al. 2018). On the basis of cost alone, conscription and professional training are not prerequisite for any but the most exceptional tombs. Being superfluous to fulfilling construction cost, however, does not rule out coercion or professionalism as a social choice better examined on a contextual basis.

My oft-repeated 10 labourers excavating a standard chamber tomb over the course of a week is admittedly a limited model for comparison – one in which I was perhaps too hasty in devaluing the investment given the potential number of families involved (Natacha Massar, personal communication 2020). My focus rather was in dismissing historical (and modern) exaggeration of the communal burden in preindustrial labour. Individually, the cost of mortuary display can indeed be prohibitive, but I contend that the primary mechanisms for exclusion relied more upon social rather than economic barriers. Following the labour models further into the lives of builders awaits further research. Comparative labour thrives in comparison *with* reservation and thought experiment *without* hesitation. If readers are left with more questions, or better targeted ones, then I have at least fulfilled part of my purpose.

Daniel R. Turner
June 2020, Oegstgeest

Acknowledgements

The process that led me here has been in some sense Dickensian, mostly absurd and mixed with the best and worst of times. I have many to thank for propelling me through it. My supervisors, Prof. Ann Brysbaert and Dr Quentin Bourgeois, admirably weathered my cycles of confidence and despair, wading with me through subjects that take several lifetimes to master. The bibliography would not be half so dense without them. Prof. Brysbaert obtained the fieldwork permits that allowed work at Menidi, Portes, and Voudeni. Training patiently provided by Prof. Jari Pakkanen and Esko Tikkala of the Finnish Institute at Athens facilitated most of the field methods herein, and the 2016 field school on Salamis – Anna-Maria, Tuna, and Tuuli, among others – left some indelible memories. Fieldwork permissions were kindly provided by Dr A. Koumousi from the Eforate of Antiquities of Achaea for the work carried out at Portes and Voudeni, and by Dr A. Lazaridou at the Eforate of East Attica for the work done at Menidi. My sincerest gratitude goes to Dr E. Andrikou (Menidi), Dr L. Kolonas (Voudeni and Portes), Mr I. Moschos (Portes), Mr M. Gazis (Voudeni), and the helpful staff at the sites of Menidi, Voudeni, and Portes. Permission from the authors to cite pre-published work included helpful contacts with Dr L. Kolonas, Dr I. Moutafi, and Dr Y. Galanakis, for which I am very grateful. Many of the theories presented here benefited greatly from my discussions with Prof. Raymond Corbey, and several improvements were made over previous drafts from helpful comments by Dr Yannis Galanakis, Dr Natacha Massar, Prof. Pieter ter Keurs, Prof. Sofia Voutsaki, and Prof. Annelou van Gijn. The responsibility for any mistakes that remain is mine alone.

My time at Leiden has been punctuated with a list of life-changing encounters that will regrettably go unremarked. A few will not go so quietly. My close colleagues, Dr Victor Klinkenberg, Riia Timonen, and Yannick Boswinkel, never failed in roasting and rebuilding me when I needed it most. Special thanks to Victor for the *Black Books* style of GIS training, to Riia for being an encyclopaedia of Greek sites and sources, and to Yannick for solidarity in summer fieldwork and summary translation into Dutch, likely improving it by miles. All would have been grim indeed without my graduate cohort at the Faculty of Archaeology. My friends from Alabama and Cambridge brought levity at all the right times and no small amount of inspiration from radically different perspectives. Andrea, Ben, Bittle, Brian, Bogdan, Cole, Corey, Griffin, Haobo, Jamie, Jordan, Kelley, Kevin, Mark, Paul, and Tobias, you need not read this to know your worth to me.

None had more cause to celebrate the death of this manuscript than my partner and editor-in-chief, Bethany Startin, who caught grammatical mistakes with surgical precision. Our four-legged family, Ginger, Cortana, and Mr Benedict Cumbercat Mittens, quite often attempted their own edits and will share authorship in our hearts. To Dad, Mom, Jamie, and Emery, who brightened my Sunday afternoons, and the rest of my family who supported me from afar, enjoy the confounding text to follow.

Since I did not set out to be an archaeologist, I follow a path cut by others. To my early field mentors who diverted me from aerospace, Prof. John Blitz, Dr Lauren Downs, Prof. Vernon 'Jim' Knight, and Mr Steven Meredith, I can never thank you enough. Graveline Bayou somehow spawned its own school of archaeology with at least eight PhDs awarded among its tiny 2010 crew, and I take pride in that membership. To my former colleagues and crew members at Panamerican Consultants, Inc., especially those who marched through 'impassable' briar and Osage orange with equanimity, you are all legends.

Much can change in years spent far from home, and losses among family, friends, and colleagues have been acutely felt in that time: Joe Hanner, Robin O'Connor, Paul Samuelson, Hanna Stöger, Justin Turner, Marcia Turner, Laura Turner, Charlie and Copper. To my classmates who are forever young: Ivelise, Mario, Mike, Ray, Anthony, and Bobby, you are not forgotten. My grandparents have all 'gone home', but their memory awakens every day. What merit may be found herein I hope will honour their memories.

List of figures & tables

1

Introduction

> *"Now the gods have reversed our fortunes with a vengeance – wiped that man from the earth like no one else before. I would never have grieved so much about his death if he'd gone down with comrades off in Troy, or died in the arms of loved ones, once he had wound down the long coil of war. Then all united Achaea would have raised his tomb and he'd have won his son great fame for years to come. But now the whirlwinds have ripped him away, no fame for him! He's lost and gone now-out of sight, out of mind-and I…he's left me tears and grief."* Telemachus mourns the absence of Odysseus, Homer *Od.* 1.234-244.

Fagles's beloved translation of *The Odyssey* moves the reader for the son whose father is lost and forgotten, seemingly robbed of a glorious death and memorable send-off. Rather than wish for his unlikely return, the son complains only for what might have been had his father died with witnesses willing to grant final rites of passage and erect a commemorative monument. This wish is as much for the renown of the family left behind as for the memory of the deceased. Whoever inspired the account would not have had the foreknowledge to be comforted by the ironic twist of texts musing over them millennia later. From poetic phrasing and the underlying reality of practice, the chosen method for commemoration was to move earth and stone for the body to be outlived by memorial, itself outlasted by the memory and rumour of construction. Thus, moving earth marked someone leaving it, and the scale on which it was moved weighed the life lost.

Here, I explore how people shaped earth and stone into funerary monuments ca. 1600-1000 BC in southern Greece, part of the inspiration behind the sentiments above. I test methodologies assessing the burden of construction and planning, where builders crafted near-perfect replicas of tombs separated by hundreds of kilometres and years with only murky light and memory as a guide. All of this I collapse under a single, versatile term: earthmoving. It captures part of the physical process of construction – breaking and transporting ground, rocky or not – as well as the metaphorical sense of changing worldviews and accomplishing the improbable: longevity through cooperative effort.

Earthmoving, in one form or another, has accompanied us since we were recognisably human. Millions of years of hominid tool use suggest a much earlier appearance, but earthmoving in its full maturity was certainly global by the second millennium BC. Since infrastructure has options to minimise earthmoving for all the perils it holds (e.g., Bowles 1984: 310-312, 356-359; Selby 1993: 377-379; Chapter 2, this volume), its most common *raison d'être* by volume was to memorialise the dead, sinking or elevating a space where life cedes to memory and oblivion. North-western Europe, for instance, hosted more than 120,000 barrows, mostly funerary monuments dating to the third and second millennium BC (Bourgeois 2013: 3-7). Thousands of built or rock-cut tombs also peppered the funerary landscape of southern Greece during the second millennium BC (Cavanagh 2008: 327-328), useful inspiration for hero cults and Homeric epics centuries later (Mylonas 1948: 56; Palaima 2008: 346-348; on Aegean tomb cults see, e.g., Alcock 1991; Antonaccio 1994; Coldstream 1976; Whitley 1988).

The methodologies I have chosen to combine – architectural energetics and collective memory – have their own fundamental suppositions. Energetics safely assumes that labour invested each act of construction with available resources, above all time. Memory is less rigidly defined and must be specified, such as 'habit' learned from social performance (Connerton 1989: 22-23) or the 'trace' of a shocking experience (Ricoeur 2004: 13-15). Collective memory in labour – as both 'habit' and 'trace'–aligns mortuary architecture against the threatening prospect of a forgotten death using our most enduring tools, shaping memories with materials that resist decay (e.g., Cummings 2003: 38; Holtorf 1996: 120-126; Rowlands 1993: 141). With these key suppositions in mind, I compare Mycenaean tombs in a new way, combining relative investment (energetics) with architectural experience (collective memories of construction). Thus, I update the methodologies of architectural energetics and collective memory – common topics uncommonly paired – to parse labour and mortuary behaviour into transferable terms, as readable to us as to those in the past.

1.1. Place and purpose

In brief, architectural energetics and collective memory track the cost of construction and the dominant recollections of groups. Neither pretend to re-enact reality stride for stride, but much like what we 'know' in our flawed conception of history, informed estimates are "better than nothing" (Putnam 1987: 69). Energetics and memory have long pedigrees, envisioned here as two trees. As far as I can tell, this will be the first time they are grafted together. Who planted the trees is debatable, but their modern definitions come from Abrams (1984; 1987: 489; 1989: 53; 1994; Abrams and Bolland 1999: 263-264) and Durkheim (summarised in Forty 1999: 2-6), respectively. Substantial branches of the older tree of memory, if not parts of the trunk itself, have grown under Aristotle, Freud, and, of most consequence here, Halbwachs (1992). The past few decades especially saw a resurgence for the topic in archaeology and related disciplines (e.g., Forty and Küchler (eds) 1999; Hallam and Hockey 2001; Hamilakis 2013; Holtorf 1996; Jones 2007; Lillios and Tsamis (eds) 2010; Ricoeur 2004; Rowlands 1993; Van Dyke and Alcock (eds) 2003; Williams (ed.) 2003; see also the critique by Herzfeld 2003). Energetics has experienced a similar revival. Conceptually understood since at least the early third millennium BC in Egypt and the Near East (Ristvet 2007: 198-199; Turner 2018: 195), energetics was commonly seen in physiology and physical geography (e.g., Durnin and Passmore 1967; Edholm 1967; Gregory (ed.) 1987) before its popularity in archaeology turned it almost exclusively toward human capabilities in preindustrial construction (e.g., Ashbee 1966; Ashbee and Jewell 1998; Atkinson 1961; Bernardini 2004; Brysbaert et al. (eds) 2018; DeLaine 1997; Devolder 2013; Erasmus 1965; Hammerstedt 2005; Jewell 1963; Lacquement 2009; McCurdy and Abrams (eds) 2019; Milner et al. 2010). Mycenaean tombs have also seen energetics modelling, limited at first (e.g., Wright 1987) and developing in different directions ever since (Cavanagh and Mee 1999; Cook 2014; Fitzsimons 2006, 2007, 2011, 2014; Harper 2016; Voutsaki et al. 2018).

What I have chosen to graft memory and energetics onto are Mycenaean multi-use tombs built and reused during the later second millennium BC in southern Greece. Differences from previous research – aside from the roles of memory and investment risk (Chapters 1 and 2)–lie in the number and choice of cases, the application of photogrammetric modelling and comparative labour (Chapters 3 and 4), and the new benchmark of an expected standard chamber tomb based on medians from 492 original measurements (12 variables across 41 reasonably well-preserved tombs) (Chapters 4 and 5). Most of the cases and activity under review fall within the Late Bronze Age (henceforth LBA), otherwise known here as the Late Helladic and further split into tell-tale ceramic periods favouring appended divisions of three (e.g., LH IIIA2 or LH IIIC Late) (Figure 1.1). The popular label, Mycenaean, is effective shorthand for the shared spatial, temporal, and cultural milieu here, named after the well-known citadel in the north-eastern Peloponnese. Once made prominent by Homeric epics driving the accounts of early excavators (Mylonas 1948: 56), Mycenaean fame has outpaced the historicity of the Trojan War. Here, it is only partially revived as a compass for sentiments applicable millennia before and after purported events (Palaima 2008: 346-348; cf. Finley 1982: 232). It is a testament to Mycenaean success as well as generations of archaeological efforts that this label applies to hundreds of sites scattered across the Aegean, to say nothing of the materials that travelled much further afield. My reference maps of tomb and cemetery locations necessarily fall short of full coverage but nonetheless hint at the scale and frequency for half a millennium of multi-use tomb construction (Figures 1.2-1.5).

My research objectives target the experience of Mycenaean tomb building. Tomb design and construction preceded the funeral and post-funeral activities exhaustively treated in the archaeological literature. Mycenaean chamber tombs, for instance, started as empty shells, filling with the remains and offerings of progressively forgotten funerals over generations of reuse. In rare cases, the tombs were used once or seemingly not at all, cleaned thoroughly or sealed and forgotten entirely. I hope to improve our understanding of architectural choices by applying the following questions:

1. What considerations governed tomb shape and scale, where to place them in relation to others, or which older tombs to reuse?
2. Was construction and reopening burdensome in terms of cost for the commissioner(s), and was it memorable as an experience for the builders and witnesses?
3. Does the architecture reflect the memory of the deceased, or is that question better posed of their remains and the assembled offerings of those remembering them?
4. In short, how did the builders perceive tomb construction, its costs and rewards?

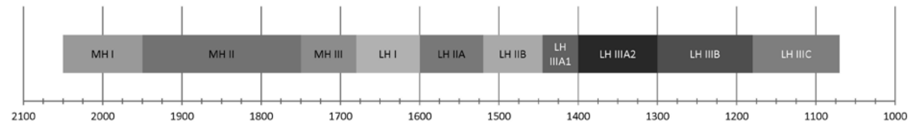


Figure 1.1. Simplified 'high chronology' calendar date range for the MH I to LH IIIC periods (2050-1070 BC) in southern Greece, adapted from Boyd (2015a: 200, Table 13.1).

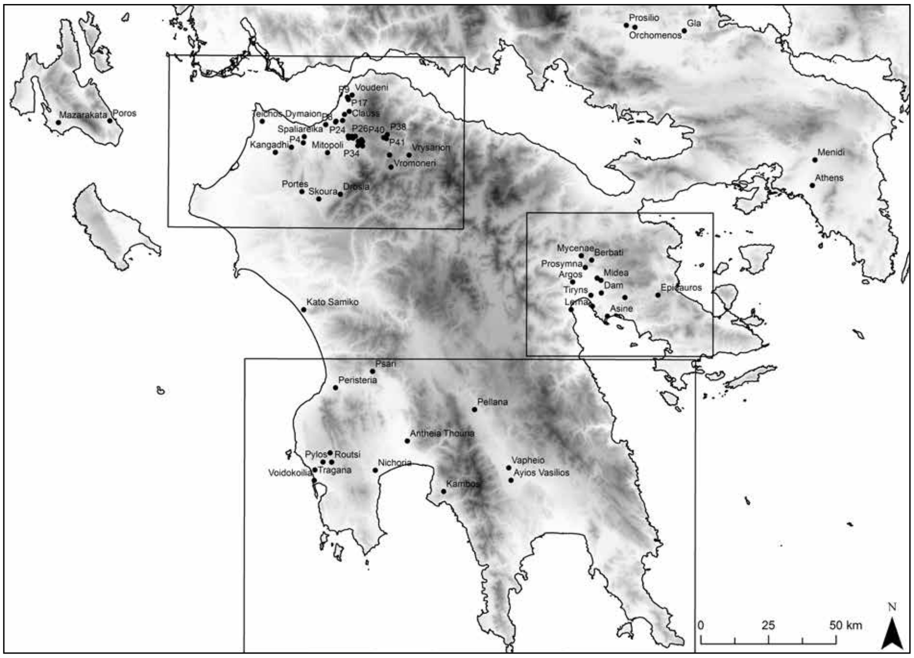


Figure 1.2. Map of southern Greece showing selected sites and tomb locations mentioned in the text. Locations derived from satellite reconnaissance, Papadopoulos (1979), Hope Simpson (2014), and Consoli (2017). See Figures 1.3-1.5 for inset details.

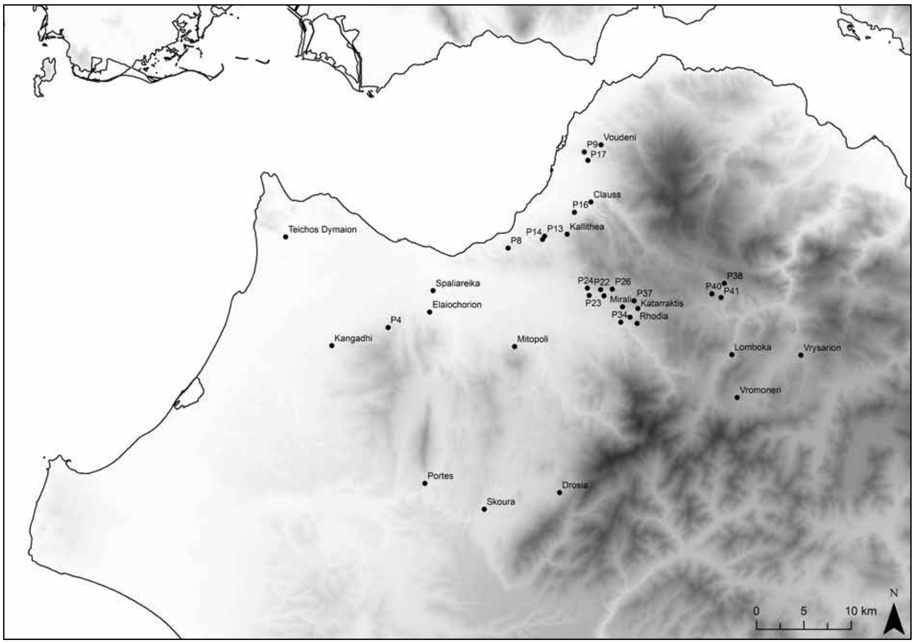


Figure 1.3. Map inset detail of western Achaea (see Figure 1.2). Sites with a P-numbered designation reference the summary Table 1.1.

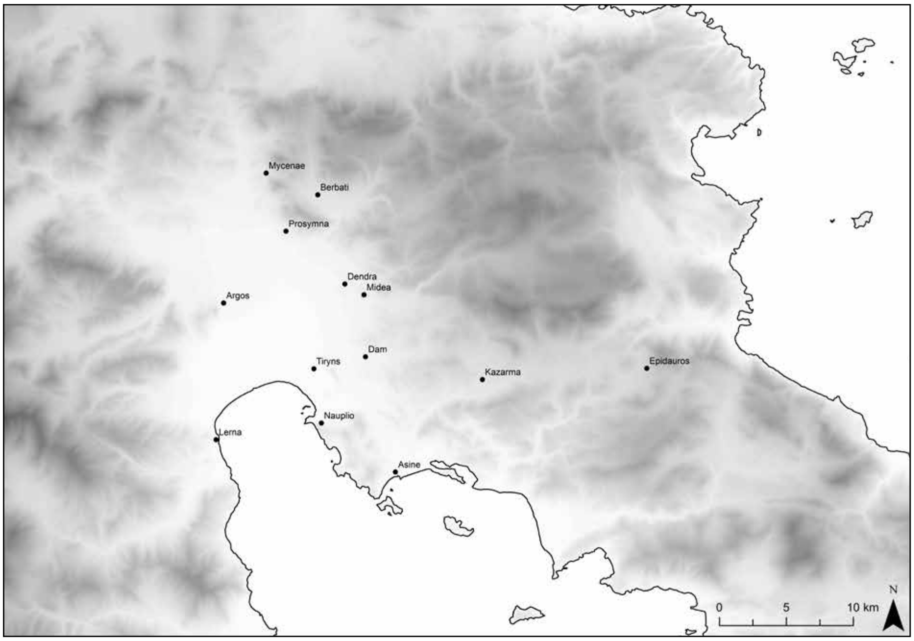


Figure 1.4. Map inset detail of the Argolid (see Figure 1.2).

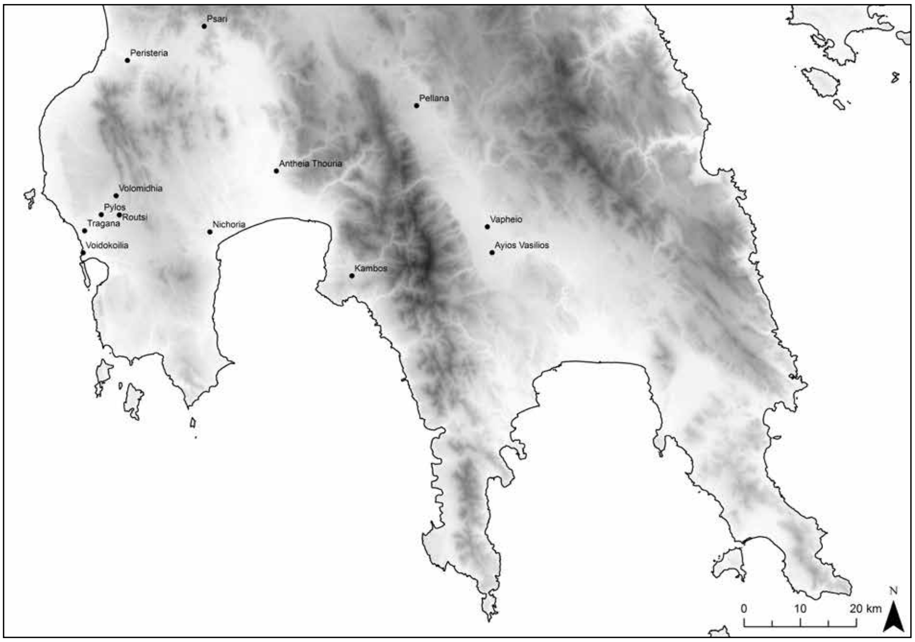


Figure 1.5. Map inset detail of the southern Peloponnese, including Messenia and Laconia (see Figure 1.2).

My scope is methodological and addresses two recurring issues, that of cost in architectural energetics and perception in Mycenaean tomb architecture. Architectural energetics continues to grapple with the question of cost (e.g., Brysbaert et al. (eds) 2018; McCurdy and Abrams (eds) 2019), whether our estimates reflect reality for timing and impact. Timing requires the expansion of labour rates, and impact needs above all context for the people at work. Suspicion over the "indeterminacy of the total cost" is no longer threatened so much as how that cost may be applied (Abrams and Bolland 1999: 266-267). Aegean mortuary archaeology likewise continues its struggle to revive Mycenaean life from its dead, pivoting away from catalogues of tombs and finds toward mortuary performance and practice (e.g., Dakouri-Hild and Boyd (eds) 2016; Gallou 2005). Both the methodology of architectural energetics and the research focus of Aegean mortuary behaviour can find common purpose in labour measured through a relative index and collective memory. Single calculations of labour do not inform on the social cost or reward of construction. Whether expressed in person-hours (Abrams and Bolland 1999: 264-265; Turner 2018), kilojoules (Lacquement 2009, 2019; Shimada 1978), or currency (Burford 1969; Pakkanen 2013), cost yields little in isolation of contemporary econometric perception – how labourers and patrons saw their work. I believe that metric for comparison lies within a relative index measured through a median standard – in this instance, tombs expressed in terms of correlative shape and simple labour investment of the earth and rock moved to create them. The analytical force of cost on its own cannot be improved by refining labour models (cf. Abrams and Bolland 1999; Harper 2016), but it can be improved in how and where we measure comparative value. Value is more often ascribed to prestigious offerings and monumental display (Dabney and Wright 1990; Santillo Frizell 1997, 1998-1999; Voutsaki 1995, 1997; Wright 1987). Seldom does it apply to our recollection of 'ordinary' things, those common objects and events that lie between the extremes of power and poverty. 'Ordinary' tombs fall far behind the richest and poorest graves in terms of past scrutiny (e.g., Cavanagh and Mee 1999; Lewartowski 2000). Defining them anew is the first step toward closing the gap.

1.2. Case studies and reasoning

Three sites totalling 137 tombs were selected for the core database of photogrammetric measurements that anchor comparative labour models (see Figure 1.2). Not all models functioned and not all tombs were accessible, so the usable core quickly contracted to 86 labour determinations for at least partial construction. In order of fieldwork, the first was the LH IIIA/B (ca. 1400-1200 BC) Menidi *tholos* north of Athens, followed by the long-serving LH cemeteries of Portes and Voudeni in Achaea. For roughly 600 years (ca. 1600-1000 BC), the cemeteries served local hilltop communities of regional importance. Similar to higher profile palatial centres, finds indicate that these sites were plugged into wider networks of eastern Mediterranean contact and trade (Bennet 2013: 242-244; Graziadio 1998; Kristiansen and Suchowska-Ducke 2015; van den Berg 2018; Voutsaki 2001: 195, 212), creating in some cases visible expressions of substantial wealth in the form of exceptionally large tombs and rare grave offerings (Kolonas 1998, 2009a, 2009b; Moschos 2000). At the same time, far more modest burials took place in smaller tombs. Thus, a significant – though by no means complete – cross-section of Mycenaean society is expected to have been buried here.

Being part of the multinational SETinSTONE project (Brysbaert et al. 2018), fieldwork permissions determined the selection of sites, serendipitously so given the diversity of architecture and scale available. My initial role was to document the tombs using high-accuracy, non-invasive techniques taught by Pakkanen (2009, 2018) and modified by Boswinkel and me in the field (Chapters 3 and 4). The tomb catalogue and analyses developed inductively from there. That my correlative models for sameness and scale focus on excavated and mostly empty chamber tombs is a factor of the dataset and timing of the work. Bioarchaeological and material cultural studies could only improve the models, and I have deliberately set them up to be modified and added to as needed. Expansion of the dataset to more tombs in other places would also strengthen the relative index, though the median correlative values are not expected to change drastically.

Although the majority of Mycenaean tomb types are represented at Portes and Voudeni (Figure 1.6), chamber tombs are by far the most common type in use. Much like their built, stacked-stone counterparts in *tholos* (pl. *tholoi*) tombs, so named for the 'beehive' shape of their corbelled vaults (e.g., Hood 1960: 166), chamber tombs are tripartite rock-cut tombs with an entrance passage (*dromos*, pl. *dromoi*), bottleneck threshold (*stomion*, pl. *stomia*) typically closed with a dry-stone or rubble-and-fill wall, and a burial chamber (*thalamos* or vault) (Figure 1.7). Practically, the tombs were built to be reopened and reused, hosting a variety of funerary treatments. By the time I arrived, the tombs had been excavated and almost entirely cleared of contents. From the observations of excavators, particularly Kolonas and Moschos, the dead associated with chamber tombs at Portes and Voudeni were variously left directly on the floor of the chamber, on raised benches, under or on deliberate clay layers, in sunken pits occasionally covered with slabs, swept to the side or carefully curated into secondary pits of commingled earlier remains, or removed from the main chamber into side chambers, entrance passages, or elsewhere (e.g., Kolonas 1998, 2009b: 25; Kontorli-Papadopoulou 1995: 114-118; Moschos 2000; Moutafi 2015; Chapter 4, this volume; focused discussion of secondary treatment in Gallou 2005: 112-114; Gallou and Georgiadis 2006: 128-129; for benches in tombs, including Menidi, see also Demakopoulou 1990: 122; Tsountas and Manatt 1897: 136). At Portes, 30 out of 56 labelled tombs were chamber tombs. Of the 68 tombs revisited at Voudeni, 63 were either chamber tombs or partially developed in that manner. A dozen additional labelled tombs were not relocated but were probably also chamber tombs given the excavator's observations (Kolonas 2009b: 8). Dividing this data into digestible pieces are comparative labour – through an index of relative cost based on catalogues of tombs and task rates – and grave reminders, which situate that cost in the context of transient experience and adapted recall. With the phrase *grave reminders*, I refer to tombs reminding living descendants of a shared past through a brief exchange (the *transient experience* of building, funeral and post-funeral activity) and how they invent an enduring narrative for the dead with *adapted recall*.

Figure 1.6. Other tomb types at Portes and Voudeni. In reading order, (1) cist (PTA6), (2) built chamber tomb (BCT) (PTA2), (3) large BCT (PTST1), (4) BCT with covering slabs (PTA1), (5) tumulus with reconstructed *peribolos* circuit wall (PTA), and (6) simple pits (VT33, VT37, VT41, VT35, VT38).

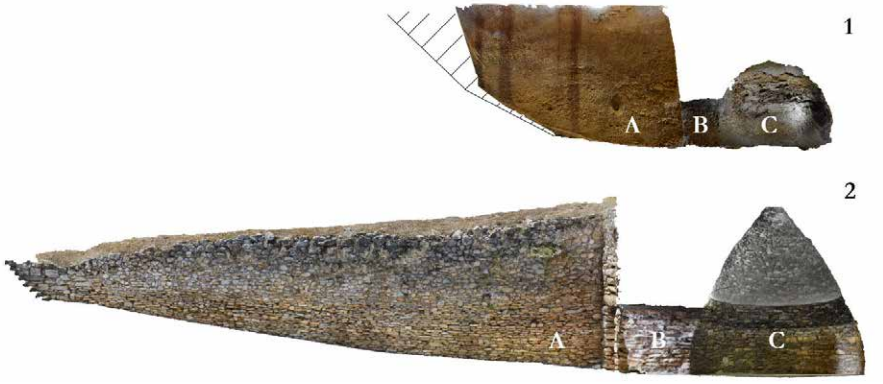


Figure 1.7. Schematic profile comparing chamber and *tholos* tombs, not to scale. Tripartite shape includes (a) entrance passage or dromos, (b) threshold or stomion, and (c) thalamos or burial chamber/vault. Based on textured photogrammetric models: (1) Portes chamber tomb 3 (PT3), and (2) Menidi *tholos* tomb (MT1).

1.3. Advancing objectives: comparative labour and grave reminders

Before stepping into case studies, labour costs demand task rates obtained through an interdisciplinary detour, something at which comparative labour excels and for which much of Chapter 3 has been reserved. Comparative labour links studies in architectural energetics through standardised reporting of labour rates, observations of effort scattered through historical, ethnographic, physiological, and experimental sources. Others (e.g., Abrams 1989: 76; Abrams and McCurdy 2019: 20; Lacquement 2009: 156; Remise 2019: 91) have called for rate compilations, and some have answered with context-specific task rates for Minoan Crete (Devolder 2013: 42-47), Mycenaean Greece (Harper 2016: 519-530), Early Iron Age Germany (Remise 2019: 80-85), prehistoric Malta (Clark 1998: 166, *passim*), China (Xie 2014: 284-286; Xie et al. 2015: 74-76), and North America (Milner et al. 2010: 109), as well as the later monetised economies of historical Greece and Rome (Burford 1969: 193-196, 246-250; DeLaine 1997: 111-129, *passim*) and the nineteenth-century West (Hurst 1865; Pegoretti 1865; Rankine 1889). Two of the most advanced compilations of labour rates have appeared recently with the explicit goal of refining and increasing the number of rates for diverse contextual applications (Abrams and McCurdy 2019: 6-13, Table 1.1; Remise 2019: 80-85). I incorporate these rates within a comparative format (Appendix 1), focusing foremost on rates for earthmoving and building upon a system I tested previously (Turner 2012: Tables 3-10, 2018: Tables 9.1-9.4). The objective is not so much to force these rates into a particular context, but rather to assemble them for the benefit of future energetics studies irrespective of time and place. Until each region and material type undergoes timed trials with analogous toolkits and techniques, labour-time estimates rely upon a multiregional compendium of rates. Thus, the assembly of rates in Appendix 1 aims to provide a foundation upon which future observations may be added as these become available. In its simplest form, a systematic checklist enables others to look critically at quantitative labour, especially where single-rate minimalism has been introduced without extensive discussion about what the ‘final cost’ actually represents.

Grave reminders rein in comparative labour’s tendency to target extremes where ‘final cost’ assessments commonly invoke power and complexity. Without underplaying or overstating the impressive numbers often reported for person-hour investment, grave reminders elevate memories of construction and use beyond relative cost and visual impact. Both are dampened by what I have referred to as transient experience – forgotten snapshots in process (e.g., during construction or funeral activity) that paradoxically forge strong collective memories (see below). In place of Mycenae’s bully pulpits for the power of elite clans (Dabney and Wright 1990: 49-52; Santillo Frizell 1997: 625, 1997-1998: 103; Wright 1987: 176)–nine monumental *tholoi* facades (e.g., Figure 1.8), not to mention other captivating spectacles like the Lion Gate (Figure 1.9)–I draw focus to ordinary Achaean hillsides littered with chamber tombs (see Figures 1.10-1.11). Systematic excavation made sites like Voudeni, Portes, Achaea Clauss, Aigion, and Chalandritsa-Agios Vasileios seem exceptional (Aktypi 2017; Kolonas 1998, 2009b; Moschos 2000, 2009; Papadopoulos and Papadopoulou-Chrysikopoulou 2017; Paschalidis 2018; Paschalidis and McGeorge 2009). However, the reality of nearby cemeteries shows the presence of chamber tombs here was more of a rule than an exception (Kolonas 2009a; Papadopoulos 1979). These tombs were not seen as anomalous or unusual. Multi-tomb localities – what remnant percentage we still see – are prevalent enough in the Patra and Pharai regions east and south of Patras that it is more surprising to find a slope untouched (see Figure 1.3; e.g., Smith et al. (eds) 2017 for another clustered chamber tomb cemetery in southern Greece).

Figure 1.8. Tomb of Clytemnestra entrance at Mycenae, facing north.

Figure 1.9. Lion Gate entrance at Mycenae, facing southeast.

Figure 1.10. Landscape surrounding the cemetery at Voudeni (centre of frame) as viewed from its settlement ca. 1 km northwest, facing southeast.

The difficulty lies not in finding tombs for study or modelling labour investment, but in dialling back claims that they physically dominated the landscape and local lives. Being present does not mean being visible, as any who have seen unexcavated chamber tombs can attest. Excavated and landscaped, Voudeni still effectively blends into the background (Figures 1.10-1.11). Unlike monumental *tholoi*, common chamber tombs were relatively low-cost, inconspicuous, and resolutely *not* independent sources of influence and display. Open (excavated) tombs are only visible at a distance from the air and along their line of orientation, often the least convenient angle for viewing due to the surrounding slope. Looking back from downslope the tombs vanish; it is easier to spot them from upslope *behind* the tombs. Even when open, narrow *dromoi* are not conducive to large audiences, limiting physical space, funnelling passage, and promoting tunnel vision, vertigo, and light sensitivity with unavoidable shadows cast by the sun and added lighting (Figure 1.12). Of course, this can change depending on the season and time of day, but the shape itself narrowing toward the surface is highly limiting if visibility was a concern. Moreover, in by far their dominant state of being (e.g., Karkanas et al. 2012: 2731; Mee 2010: 287), backfilled *dromoi* disappear easily into the background of the hillslope.

Two possibilities remain to keep the tombs present beyond construction and reuse (including post-funerary use): superimposed markers vulnerable to decay or prone to repurposed use elsewhere (to justify their absence from the archaeological record here) and tomb locations along communication routes facilitating processions or frequent passers-by (Boyd 2002: 92, 2015a: 204, 2016: 65; Mee and Cavanagh 1990: 228; Wilkie 1987: 128-129). No tomb markers were found associated with *dromoi* excavated early in Achaea (Papadopoulos 1979: 52), and I am not aware of any subsequent finds. In the case of processions, however, the slopes around the tomb could provide the grandstand to watch incoming waves of mourners, provided there was no taboo of standing over or near adjacent (buried) tombs. Speaking quietly and avoiding stepping directly upon graves evokes the Western sleep metaphor for death (Hallam and Hockey 2001: 28), a

Figure 1.11. Eastern half of the excavated cemetery at Voudeni, facing southeast. Roughly 35 open tombs are within the frame but are not visible due to restricted sightlines from slope and vegetation.

Figure 1.12. Voudeni tomb 25, facing southeast. One of the largest excavated tombs at Voudeni with its entrance left uncovered, VT25 illustrates the overpowering contrast of summer morning sunlight with the tunnel-shadowing of the dromos.

surprisingly persistent superstition I recall vividly as a child in Alabama but not one freely transplanted to Mycenaean Greece, where the natural/supernatural divide could blur as freely as it does in many non-Western cosmologies (e.g., Argenti 1999: 22-23; Descola 2013: 5-11). Personifications of the supernatural certainly seemed to play an active role in painted and engraved Mycenaean funerary iconography (e.g., Crowley 1995: 484; Evans

1901: 180), whether or not similar Homeric scenes were an effective commentary on remembered customs (cf. Mylonas 1948; Palaima 2008).

Even allowing for the grandstand scenario, the importance of tomb architecture is diminished next to the structured acts of funeral and post-funeral activities. For instance, fire use in the relative seclusion of the burial chamber sends its signals beyond the tomb's immediate vicinity through smoke, scent, and sound, creating for Galanakis (2016a: 194) a prime hook for memory and closure – allowing mourners to move on and forget. Processions likewise provide ample opportunity for display viewed from afar. Bright colours and simple shapes give commemorative events like processions or parades a visual stamp that witnesses can more easily retain (Jarman 1999: 173-174). Mycenaean dedication to processions may have been enough to exert influence even over the layout of their citadels (Maran 2006b: 85). The festive scenes depicted on the Tanagran *larnakes* (decorated clay sarcophagi) suggest that the same could be said for Mycenaean funerals (Gallou 2005: 17; Gallou and Georgiadis 2006: 139-140). Being one of the few direct sources for depictions of mourning and other funerary performance (Cavanagh and Mee 1995: 45), the Tanagra case is special and will bear repeating where a change in perspective is in order. All this leads to the summary point that it was the people and process being watched, not the tomb.

Grave reminders challenge the notion that ordinary tombs were more than a fleeting record of those who had left a world bustling with life. Something beyond the limited space and brief experience kept multi-use tombs in collective memory for a dozen or more generations. Being 'multi-use' in itself conveys a sense of "cross-generational planning and expectations of the future" (Dakouri-Hild 2016: 20). Transient events and anonymisation of the dead (e.g., commingling remains) signify a willingness to forget (individuals) in order to immortalise (traditions and offices) (Boyd 2015a: 212-213; Küchler 1999: 54-56). This is where grave reminders reorient previous frameworks of power and display away from architecture and closer to rumour and memory. Even acknowledging that monumental tombs promoted public spectacle, many more would hear about it than witness it. Ethnographic and cognitive precedent (see papers in Forty and Küchler (eds) 1999, especially Argenti 1999: 22; Forty 1999: 7-10; Küchler 1999: 55-57; see also Rowlands 1993: 148-149) grants hidden or remembered events more influence than visible common architecture or mundane construction processes, unremarkable as it is to dig what amounts to a large and elaborate hole. Mystery and intrigue captivate for longer, allowing superstition to outplay explanation. Underlying facts are immaterial compared with the interest generated by stories that resonate fear or pride. Unlike the spectacles of moving massive lintel blocks for the tombs of Atreus and Clytemnestra (Santillo 1997: 439; Santillo Frizell 1997: 626-627, 1997-1998: 107) or oversized conglomerate stone transport between Mycenae and Tiryns (Brysbaert 2013: 79, 86; 2015a: 78-81; 2015b: 102), the carving of all but the largest chamber tombs could be missed if not inflated by some rumour or ceremonial necessity.

Doubtless opening a new chamber tomb on any scale was momentous for close kin. Beyond that, even if opening a new, standard chamber tomb stirred more than the dozen or so labourers it required (Chapter 4), expectations to impress anyone else must have been muted. The intended audience was smaller, and the message more akin to closure and comfort than anything outlandish or ambitious. Perhaps it was a novelty in the early years of introducing the tomb form, but tumuli and especially *tholoi* are not radically different concepts from chamber tombs (Cavanagh 2008: 328-329; Galanakis 2011: 220; see Figure 1.7, this volume). New construction mostly happened in the LH II/IIIA periods at Portes and Voudeni, with later materials stemming from reuse as inheritors took advantage of the much reduced cost of reopening *dromoi* (Cavanagh and Mee 1978: 44; Chapter 4, this volume). Though Boyd (2016: 63) appeals to the limited pool of resources suggested by a smaller tomb in labelling the investment nontrivial, I would argue that the cost of construction is more manageable than it seems (Chapter 4), at least compared with other necessities like house construction (Boswinkel forthcoming; Harper 2016: 481). Cost alone sparks no memory, but designing the tomb and cemetery layout does.

If cheaper costs seem to promote runaway tomb construction, planning design prohibits it and encourages local reproductions of regional styles (see "archetypal memories" in Cummings 2003: 39). The difficulty lies in another "field of action" as Boyd (2016: 63) puts it: navigating the layout versus other tombs in a crowded cemetery. Granting the possibility for deliberate clustering (Boyd 2015a: 204, 2016: 63, 68; Wilkie 1987: 127; Chapter 5, this volume), siting a new tomb may have been a matter of consulting family memories on the position and extent of buried vaults. Access to older tomb vaults would ease the pressure of precise measurements, if such were a priority, but again would require reopening a *dromos*, making construction anew superfluous or at least more burdensome. Close approximations show deliberate choices in tombs that resemble one another in scale and form. However, few layout patterns are apparent beyond a site-wide tradition at Portes to integrate older tumuli and follow the hive type (*tholos*-like) chamber vaults and more ambiguous groupings of similarly scaled house vaults (four-sided) at Voudeni (Chapter 4). None match so closely as to betray an official system of measurements and records, but enough commonalities in proportions suggest an internalised blueprint for sites or intra-site clusters (Chapter 5). One can easily imagine specialised organisations of builders for exceptional and standard tombs, but the undersized variety demands little more than basic construction proficiency (Wright 1987: 174; Chapter 4, this volume).

Travelling skilled workers or not, Achaean repetition in formulaic funerary acts and portable materials certainly earned wide circulation (e.g., Kaskantiri 2016: 103; Kontorli-Papadopoulou 1995: 114; Papadopoulos 1995: 203). Materials recovered mostly in funerary contexts from across the western regions of Greece (Achaea, Aetolia, Elis-Olympia, Epirus, and Messenia) and nearby islands (Ithaca, Kephallenia, and Zakynthos) suggested a western Mycenaean koine (Papadopoulos 1995: 201, with earlier references). The shared material culture of western Greece makes a strong case for interaction in the LH IIIB/C periods – a time of serious troubles elsewhere in Greece and the eastern Mediterranean (Bennet 2013: 253-254; van den Berg 2018: 37-40)–but "political unity is another matter" (Papadopoulos 1995: 208). Trends were westward-looking and late following destructions and regressions of sites to the south and east (Fotiadis et al. (eds) 2017; van den Berg 2018). Achaea's own famous fortified citadel at Teichos Dymaion experienced two destructions with little noticeable effect on the region's temporary fluorescence (Moschos 2009: 375-376). Something happened in the century leading up to 1160-1070 BC that gave Achaea strong links to Italy and Central Europe, as signified by Naue II type swords and other diagnostic metal finds (knives and fibulae) from "warrior/official" graves (Dietz 2016: 88; Moschos 2009: 375-376; Paschalidis and McGeorge 2009: 89; van den Berg 2018: 62-63; see PT3 in Chapter 4, this volume). Adriatic materials and their associated links also filtered into the Argolid with finds at Tiryns (van den Berg 2018: 62-63, 101). The Ionian islands (especially Kephallenia and Ithaca) evidently experienced their wealthiest period in the LH IIIC Late period immediately following the apogee and decline of the Achaean sites (Dietz 2016: 84, Moschos 2009: 369). The chronologies after the destruction of the Mycenaean palaces, based largely on ceramic typologies from the LH IIIB onward, differ regionally according to Moschos (working in Achaea) and Mountjoy (working in the north-eastern Peloponnese) (Dietz 2016: 82; van den Berg 2018: 27-29), but the general trend is clear. The Mycenaean world had changed, and mortuary customs changed with it. Whatever the case for their political climate, Achaean cemeteries evolved with tomb layouts burned into local memories until those, too, had changed (Chapter 5).

Given the potential for in-depth architectural analyses for dozens of intact tombs, particularly those reused during unstable times, a method of comparison is needed to place the tombs on equal footing. This is done primarily with a catalogue approach to labour modelling, first outlining materials, motivations, and energetics in Chapters 2 and 3 before building a relative index of tombs in Chapters 4 and 5. The rest falls to hammering out as many tomb descriptions as possible for the sake of replicability, peppered with reminders as to how tombs were perceived: always in passing by lives lived elsewhere. A tomb is far more than a container, and its influence far exceeds its contents or the duration of its use (Dakouri-Hild 2016: 16; Küchler 1999: 64; Sherratt 1990: 164).

1.4. Forecast: from catalogue blueprints to transient experience

On its own, attempting photogrammetric-based labour models of 86 tombs has its drawbacks in failure rate and redundancy (Appendix 2). Three or four exceptional tombs had eclipsed the others in terms of labour and reporting, such that I spent far more time exploring ways to equalise coverage than it would have taken to build them. The catalogue of tombs lay dormant until I began the process of dimension reduction, trimming redundant or inconsequential data through correspondence analyses. Following Bourgeois and Kroon (2017: 10), dissimilarity matrices showed interrelationships among tombs and variables (see Figures 3.3-3.4), but only after finding a relative index through median measurements to trim the spread triggered by the largest outliers (Drennan 2009: 275). This relative index, presented as part of the catalogue in Chapter 4 and discussion in Chapter 5, clarified architectural choices and labour investment and did so in terms understandable to those who built the tombs.

The catalogue and relative index reinforce the idea that the tombs were shaped and sized with forethought. In other words, an expected standard governed design. Explored previously with Aegean Bronze Age conical cups (Berg 2004), standardisation refers to attempted craft reproduction that, while never reaching precise copies with pre-mechanical techniques, can vary up to the Weber fraction of 3% without being noticed by unaided observers (Eerkens 2000: 663-664; Eerkens and Bettinger 2001: 494-495; Rice 1991). Since errors escalate with increasing object size (Eerkens and Bettinger 2001: 494), no two tombs would match exactly. Expected standards in tomb design encouraged near-rote adherence at Portes, where all chamber tombs were shaped alike and limited in scale deviation. At Voudeni, mimetic innovation filtered free-form changes in shape and scale into two primary traditions: the hive-like smaller chambers and the four-sided, house-like chambers, usually of exceptional size. Change had its limits, and expression of individual preferences was suppressed by risk-averse investment in all but the two largest chamber tombs at Voudeni (VT4 and VT75). Following a contextual introduction to Mycenaean tomb development and earthmoving in Greece, this risk assessment is a central focus of Chapter 2.

Entry	Period	Tholos	Chamber	Other/Unsp.	Settlement
DYME AREA					
1. Paralimni (Teichos Dymaion)	N, EH, MH, LH I-IIIC, SM, PG (?)	U	U	EH	Fortified
2. Gerbesi (Araxos)	MH (?), LH	U	U	U	P
3. Kangadhi	LH IIIA (?), IIIB (?), IIIC, SM	U	Multi.	U	P
4. Pournari	LH IIIA (?), IIIB-C	Single	U	U	U
5. Fostaina [[Elaiochorion]]	LH III	U	U	Multi.	U
6. Kato Achaea (Bouchomata)	EH, LH	U	U	U	P
PATRAS REGION					
7. Tsoukaleika	LH (III?)	U	U	Multi.	U
8. Vrachneika (Ayios Pandeleimon)	LH IIIA-B	U	U	Multi.	P
9. Aroe-Samaika	LH IIIB-SM	U	U	Multi.	P
10-11. Ano Sychaina (Agrapidia)	LH IIIA-C	U	8+	Multi.	P
Addendum: Voudeni (Kolonas 2009b)	LH IIIA-SM	U	78+	Multi.	Fortified
12. Klauss (Koukoura, Antheia)	LH IIIA-C, SM	U	12+	Multi.	P
Addendum: Achaea Clauss (Paschalidis and McGeorge 2009)	LH IIIA-SM	U	28+	Multi.	Fortified
13. Thea (Tsaplaneika)	LH IIIA-C	U	4+	U	P
14. Pavlokastron	LH IIIA-C	U	Multi.	U	U
15. Kallithea	LH IIIA-C, SM (?)	U	2+	8+	U
16. Krini (Velizi)	LH IIIB-C	U	Multi.	U	P
17. Gerokomeion	LH IIIA-C	U	Single	U	U
18. Patras	LH IIIA-C	U	Multi.	Multi.	P
19. Akarnes	LH I	U	U	U	U
19a. Drepanon	PG (?), G	U	U	Pithos multi.	U
PHARAI REGION					
20-21. Platanovrisis (Medzena)	LH	U	U	Multi.	U
22. Ayios Antonios [Chalandritsa]	LH (?)	U	U	U	P
23. Ayios Vasilios [Chalandritsa]	LH IIIA (?), IIIB-C, SM	U	Multi.	Extensive	U
24. Troumbes [Chalandritsa]	LH (?), G	3+ (?)	U	U	U
25. Agriapidies [Chalandritsa]	LH I-II (?) (or PG?)	U	U	Cists	U
26. Pori [Chalandritsa]	LH (?)	U	Multi.	U	U
27. Mitopolis (Ayia Varvara)	LH	U	U	Multi.	C
28. Mitopolis (Profitis Elias)	LH IIIB-C	U	U	U	P
29. Starochorion (Lalousi)	LH IIIC	U	U	Multi.	U
30. Vasilikon (Brakoumadhi)	LH (?)	U	U	U	U
31. Pharai (Lalikosta)	LH (?), G	U	U	Multi.	U
32. Mirali	MH	U	U	2+	U
33. Drakotrypa [Katarraktis (Lopesi)]	EH (?), MH, LHI-II (?), LH IIIA, LH IIIB-C	U	U	Child tomb	C

Table 1.1. Summary of catalogue for Achaean tombs, based on Papadopoulos (1979).

Entry	Period	Tholos	Chamber	Other/Unsp.	Settlement
34. Ayios Athanasios [Katarraktis (Lopesi)]	MH, LH IIB, IIIA (-B?)	2+	U	Child tomb	C
35. Rhodia-Bouga [Katarraktis (Lopesi)]	LH IIIB-C, G	U	10+	Multi.	C
36. Ayios Yeorgios [Katarraktis (Lopesi)]	LH (?), G	U	U	U	P
37. Pyrgaki [Katarraktis (Lopesi)]	MH	U	U	Child tomb	P
38. Vrayianika [Leontion (Gourzoumisa)]	EH (?), LH IIIB-C	U	Multi.	U	U
39. Koutreika [Leontion (Gourzoumisa)]	LH	U	Multi.	U	U
40. Ayios Ioannis [Leontion (Gourzoumisa)]	LH IIIB-C	U	U	Multi.	U
41. Ayios Konstantinos [Leontion (Gourzoumisa)]	LH (?)	U	U	U	P
KALAVRYTA REGION					
42. Mikros Pondias (Lomboka)	LH IIIC	U	3+	U	U
43. Ayios Vlasios	LH	U	U	U	P
44-45. Manesi (Vromoneri)	LH IIIC-SM (?)	U	3+	U	P
46. Bartholomio (near Lomboka)	LH IIIC (?), PG (?)	1+ (?)	U	3+	U
47. Kastria	N, EH	U	U	U	P
48-49. Vrysarion (Kato Goumenitsa)	LH I, LH IIIA, (IIIB-C?)	U	28+	U	U
50. Kertezi	LH IIIC	U	Single	U	U
TRITAEA REGION					
51. Drosia (Prostovitsa)	LH IIIC, SM	U	100+	U	U
52. Skoura	LH IIIA-B	U	U	Cist	U
NORTHEAST AREA (AIGION AND DHERVENI)					
53-54. Kamarais (Xerikon, Paliomylos)	EH, MH, LH IIIA or B	U	Multi.	U	P
55. Mayeira (Paliometocho)	LH IIIA	U	U	Single	U
56. Aravonitsa	MH	U	U	Single	U
57. Aigion (Psila Alonia or Gymnasion)	LH IIB-IIIC, SM (?)	U	15+	16+	P
58. Kallithea (Aigion)	LH IIIA-SM (?)	U	1+	Multi.	U
59. Kouloura (Paliokamares)	LH IIIC (?)	U	U	U	U
60. Vovoda	LH IIIC (?)	U	U	Multi.	U
61. Chadzi (Trapeza)	LH IIIA-B, C (?), SM, EIA, G	U	Multi.	U	P
62-63. Achladies (Achouria, Vareliossa)	LH IIIA-B, SM	U	Multi.	U	U
64. Mamousia (Dherveni)	LH (?), PG	U	U	Multi.	U
65. Keryneia (Ayios Yeorgios)	LH (III?)	U	U	U	P
66. Helike	LH (?)	U	U	U	U
67-68. Akrata, Krathion-Silivaniotika	N, MH, LH (?)	U	U	Multi.	P
69. Aigeira	EH, LH II, IIIA-C, SM-PG (?)	U	U	Multi.	P
70. Dherveni (Psila Alonia)	LH IIIB-C	U	2+	U	P
Key: unknown (U); probable (P); multiple, no number specified (Multi.); isolated find (Single); reported number, more likely (n+)					

Replicating chamber tomb styles decades apart would require help. Aging builders would not be able to wield the tools or recall where to stop. They could instruct younger relatives and friends, but the result would be filtered in a vague imitation. Harder still would be a late copy when the original builders were already gone. That would rely on information obtained secondhand, replicating imperfect mental images into mimetic designs. Mimesis here gives little thought to its literary origins beyond the tragic chase, imitation after original and art after reality (Auerbach 1953: 44). In the case of similar tombs, mimetic design replicated older forms closely enough for a style or tradition recognisable 3,000 years later.

Part of what makes the Mycenaean 'blueprint' for chamber tombs impressive is the likelihood of it being internalised through transient experience. In a general sense, with no inherent natural blueprints of determining things made, we follow what inspiration comes, for better or worse (Putnam 1987: 78). Tangible visual aids are relatively unknown, as only the Menelaion and Cretan examples show LBA cognates for the Neolithic practice of making house models (Hitchcock 2010: 201). The tombs were closed spaces, opened at intervals for funerals and 'second funerals' when remains were consolidated and eschatological prescriptions fulfilled, for which explanations are forced to proceed piecemeal from the minimum of material evidence (Gallou 2005: 16). Although many tombs were popular venues used sporadically for several hundred years – some at Voudeni more than 20 times (Moutafi 2015: 537)–others were simply buried and forgotten. Perhaps those families died off or moved on, and the tombs were not notable enough to warrant reuse by others (Cavanagh and Mee 1978: 32). Their ephemeral roles, while powerfully emotive in the moment, lack the enduring presence of conspicuous architecture. Ephemerality may seem wrongly suited for a tomb like VT75, used over the course of 400 years and large enough to drive a wagon into. That is until one considers its transient experience, being only open and active (e.g., undergoing building, maintenance, or funerary/post-funerary activity) for less than 1 percent of that time. Ironically, this brevity may be equally or more effective at maintaining collective memory than an overlooked monument ever present and visible. Defence of that stance relies on a review of Mycenaean tombs and the decisions that constrained them, to which the following chapter turns.

2

Setting

> *"I could not but look upon these Registers of Existence, whether of Brass or Marble, as a kind of Satire upon the departed Persons, who had left no other Memorial of them, but that they were born, and that they died."* Joseph Addison (1711)

Bleak as it is to confront oblivion, no shortage of artists have tried. Bindman (1999: 93) introduced his work on commemorative futility with its captivation of eighteenth-century English writers like Addison, who remarked on the inevitable oblivion that awaited both elaborate and common grave memorials. Tombs fall into disrepair and names come to mean nothing. That cold reasoning tends to fail, however, in discouraging the pursuit of fame with tomb investment. Tomb expense and design encode – rather than determine or confine – where remains and mourners parted ways. With this chapter I elaborate on Mycenaean multi-use tomb investment, from general architectural forms and funerary development (Section 2.1), to physiographic (Section 2.2) and social (Section 2.3) constraints. The goal here is to simulate the starting components of Mycenaean tomb construction, including the ground underfoot and ideas as to how and why to shape it.

2.1. Mycenaean tomb development

As far removed as we are from the Mycenaean funerary experience, some limited windows remain to that perspective. Each of the tombs, no matter how undersized, played a momentous role for multiple witnesses, before being broken open much later under different eyes for loot or knowledge. The experience was visceral for events near tombs during their primary phase of use. Hands raised near the head, torn garments, mouths open in lament, and possible facial scratches tag mourners on the painted Tanagran *larnakes*, and the more animated of these figures might be closely related to the deceased (Cavanagh and Mee 1995: 47). Female ceramic figurines recovered in LH IIIC tombs at Perati, Kamini, and Ialysos similarly show the tearing of hair and garments (Cavanagh and Mee 1995: 51), while mourners depicted on rings from Vapheio and Mycenae lie prostrate on shields in apparent grief for lost warriors (Evans 1901: 179-180). Re-inhabiting those feelings of fatigue and despair lies beyond the reach of the modern observer, though others have shown interest in reviving a multi-sensory experience of tombs (e.g., Barrie 2010: 228; Boyd 2014a: 200, 2016: 63; Watson and Keating 1999: 327-329).

For three years and more, Mycenaean tombs became part of my world. For others, lifetimes have been spent there and, since the mid-nineteenth century, roughly to the same end of piecing together lives from limited evidence of the dead. The assembled knowledge is immense. In his review for a wider audience, Cavanagh (2008: 327) correctly described Aegean archaeology as being "haunted by graves", with the number of excavated tombs climbing into the tens of thousands. Settlements, even palatial ones, were too few and muddled in the archaeological record to afford being selective with supporting mortuary evidence. That affordance has tightened in recent years with substantial surveys across southern Greece (e.g., Cavanagh et al. (eds) 2002; Davis et al. 1997; Wells and Runnels (eds) 1996). Forecasting of LH III palatial complexes using MH/LH elite burials no longer avoids critique (Boyd 2015a: 201). The time gap is daunting, and the consumption practices of early elites were indeed executed with their own parameters in mind. Voutsaki (1995: 62, 1997: 37-44, 2001: 205-207, 2010: 82) highlighted their flagrant practices with portable wealth, which continued even as architectural developments spent centuries making the jump from monumental tombs to monumental public spaces. The apparent tardiness of Cyclopean – rubble-style assembly of massive unworked stone – fortifications and other palatial building programmes, particularly on a crowded acropolis, may have more to do with obscuring or destroying predecessors, of which we know very little (Boyd 2015a: 201).

Mortuary architecture, on the other hand, is easier to read and has given rise to detailed sequences across southern Greece (e.g., Boyd 2002, 2014b, 2015b; Dickinson 1983, 2016; Fitzsimons 2006; Lewartowski 2000; Mee and Cavanagh 1990; Moutafi and Voutsaki 2016; Papadopoulou-Chrysikopoulou et al. (eds) 2016). One hallmark of early Mycenaean behaviour was a rapid transition from austere simple graves in MH tumuli to richly provisioned shaft graves and LH built and cut multi-use tombs, though cists and simple graves of variable wealth persisted throughout (Lewartowski 1995: 106-107; Voutsaki 1997: 44-45; Voutsaki et al. 2018: 170). Boyd (2015a: 201) mapped the changes in five core areas, paraphrased here as (1) tripartite architecture (chamber tombs and *tholoi*), (2) collective (or multi-use) practices, (3) secondary treatment of remains, (4) dedicated funerary spaces (extramural cemeteries), and (5) objects created and manipulated for mortuary ritual. My focus falls on the developed (LH IIIA) and end-stage (LH IIIC) variants for the first two categories (collective or multi-use funerary architecture), with some comments on the spatial layout of two large Mycenaean cemeteries in western Achaea.

Funerary architecture in southern Greece at the MH/LH transition suggested influence from similar Cretan forms via Kythera (Dickinson 1977: 61; Hood 1960: 168), evolution from MH tumuli spread across the mainland (Boyd 2002: 55-56, 218; 2015a: 202; Cavanagh and Mee 1998: 44-45; Voutsaki 1998: 43), or combined innovation with some elements of Kytheran, Cretan, and earlier mainland traditions (Gallou 2009: 89). LH I-II tumuli in western Greece appeared at Chalandritsa-Agriapidies in Achaea as well as several locations from Elis-Olympia, Messenia, Kephallenia, and northward along the coast to Albania (Aktypi 2017; Papadopoulos 1995: 203-205). To that list can be added the tumuli from Portes. Papadopoulos (1995: 205) saw the practice as a continuation of earlier ("pre-Mycenaean" or late MH) traditions. More recently, elements of *pithoi* (very large ceramic jar) burials in MH tumuli have been compared with *tholoi* in the sequence at Kaminia in Messenia (Boyd 2015a: 202-203; Korres 2011: 589; Papadimitriou 2011: 473-474). With borrowed ideas of form and practice from earlier tumuli and *pithoi*, *tholoi* resemble earlier tumuli from most outside perspectives when covered with an earthen mound or sunk into a hillside (Galanakis 2011: 220). The key difference is the shift in focus to activity within the chamber (Boyd 2015a: 203; Gallou 2009: 89). Whatever the case for their origins, *tholoi* appeared in Messenia during MH III, proliferated during LH I, and spread across southern Greece in LH II (Boyd 2015a: 202; Petrakis 2010). Chamber tombs appeared slightly later (LH I in the Argolid, Laconia, and Messenia) before co-occurring and becoming the dominant form outside Messenia after LH II (Boyd 2015a: 202; Gallou 2009: 87). Most large chamber tombs were built during early Mycenaean times (LH IIB-IIIA1) and followed closely the height of large *tholos* construction (LH I-IIA) in the same regions but rarely the same cemeteries (Galanakis 2016b: 162). Labelled by Pelon (1976: 340, 417-418) as Type III, *tholos* tombs in western Greece tended to be smaller and less well-constructed, omitting in many cases a clear transition between the *dromos* and *stomion* and occasionally having slabs over part of their entrance passages (Papadopoulos 1995: 203).

Chamber tombs in western Greece especially bore a strong resemblance to one another in construction and custom, including the widespread practice of multiple burials in pits, to which tombs on the Ionian island of Kephallenia seemed to adhere most (Papadopoulos 1979: 60-61, 1995: 203). General chronological trends for LBA Achaea highlighted chamber tomb construction during the LH IIIA period for coastal sites (Chadzi-Trapeza, Vrachneika), LH IIIB period for the Pharai sites (Chalandritsa, Katarraktis, Leontion) as well as Dherveni, and LH IIIC period for the Kalavryta and Tritaea sites (Drosia, Kertezi, Manesi) in the mountainous interior (Papadopoulos 1979: 57; Table 1.1, this volume). Forming a clearer picture from more recent excavations, chamber tombs at Achaea Clauss, Portes, and Voudeni cut across the LH III period in construction and reuse (Kolonas 2009a, 2009b; Moschos 2000; Paschalidis and McGeorge 2009; Chapters 4 and 5, this volume). The later appearance of construction in LH IIIC Kephallenia suggested to Papadopoulos (1979: 60-61) a migratory influence – one of many possibilities for the rippling westward trends mentioned earlier – but how those tomb forms initially arrived in Achaea must have followed upon their popularity elsewhere in southern Greece.

Increasing steadily during the LH II period, LH III construction of chamber tombs experienced a meteoric rise across southern Greece (Boyd 2015a: 205). Chamber tombs are by far the most common recorded funerary architecture for LH Achaea, with already 219 examples across 58 sites known by the 1970s (Papadopoulos 1979: 51, 60; see Table 1.1, this volume). From 1919 to 1940, Kyparisses investigated at least 150 of them, for which few and brief records survived (Papadopoulos 1979: 51). The large number of known examples repeated shapes and styles by preference, rarely diverging radically. Since *dromos* shape was largely beholden to scale (Chapter 4), chamber shape offered more freedom of choice, particularly in roof shape. Galanakis (2016b: 159) listed five common roof types, paraphrased here as (1) irregular, (2) horizontal or slightly arched, (3) saddled, (4) tholoid, and (5) pitched. Where preserved, the tholoid type often contained a *hypotholion* at its apex, which apart from mimicking a *tholos* roof could allude to "a 'hut's smoke hole' or a 'slot for a roof post'" (Galanakis 2016b: 159; Kolonas 2009b: 16; Chapter 4, this volume). Several other elaborations (e.g., grooved sidewall, also referenced as ledges, shoulders or eaves, and "ridge poles (imitations of central beams)") point to correlations between mortuary and domestic architecture (Galanakis 2016b: 162).

Galanakis (2016b: 159) focused on pitched roofs in chamber tombs, the earliest of which appeared during the LH IIA-IIIA2, mostly in the northern Peloponnese. Although not universal (cf. smaller counterparts at Kallithea-Spenzes in Achaea), chamber tombs with pitched roofs are larger on average than tombs otherwise roofed and include some exceptionally large examples, as at Antheia Ellinika in Messenia (Galanakis 2016b: 160-161) and Voudeni's largest excavated tombs (VT4 and VT75) (Kolonas 2009b: 15-17, 27-29; Chapter 4, this volume). LH II-IIIA2 chamber tombs with pitched roofs co-occurring alongside those with tholoid roofs, as at Mycenae and Voudeni, reinforces the idea of divergent traditions in early Mycenaean tomb building, where Galanakis (2016b: 162) has suggested competition with societal overtones. This mirrors the case put forward by Voutsaki (1995: 62; 1997: 44-45) for competition with portable wealth in grave offerings, though – perhaps through targeted reuse or looting – chamber size at Voudeni did not always correlate with the most used or best equipped (Moutafi 2015).

Exponential differences in Mycenaean tomb scale and relative locations (e.g., clustering of tombs within cemeteries) have informed positions on mortuary changes as much or more than the aforementioned variations in style. Boyd (2015a: 215-216; 2015b; 2016) framed tomb scale as elite manipulation of space and perspective using the 'mega-*tholoi*' of Mycenae. From situating the individual body in a standard space to allowing for "dozens in the chamber, hundreds in the *dromos* and on the slopes above", growth in mega-*tholoi* highlighted a larger audience (Boyd 2015a: 216). Even so, most of the action takes place on the way to the tomb, where positioning matters. Early *tholoi* were cut underground to support their superstructures, but many were sited within or around earlier tumuli. Techniques expanded to purpose-built tumuli as counterweights to *tholoi* vaults above ground (Boyd 2015a: 202-203; Cavanagh and Laxton 1981: 111-118; Hitchcock 2010: 205; Papadimitriou 2015: 100). Chamber tombs and multi-*tholoi* mound groupings opted for clustering rather than visibility (Kontorli-Papadopoulou 1995: 122), unlike the larger *tholoi* set apart in later examples (Boyd 2015a: 204). Early (MH III-LH I) elaborations on simple graves, including large cist and built chamber tomb types, as well as Mycenae's shaft graves, show another form of clustering and, occasionally, experimental *dromoi* (Boyd 2015a: 204-205; Papadimitriou 2001a: 93-94; 2001b: 43; 2015: 82, 101). The longer *dromoi* of later, larger *tholoi* facilitated mortuary innovation focusing on spectacle (Boyd 2015a: 205; Papadimitriou 2011: 477; 2015: 71-72, 101). Spectacle – for similarly large audiences at least – operates for the Achaean chamber tombs only under the condition of performance away from its cramped spaces.

Contextualised and interdisciplinary approaches have proliferated in recent years as our understanding of Aegean mortuary architecture pivots toward performative space (Boyd 2014a; Dakouri-Hild and Boyd (eds) 2016: 2; see Maran 2006a, 2006b for the same trend in citadel layout). Secondary practices, like fire use and the deliberate disarticulation and commingling of remains, have especially seen recent reassessments (e.g., Galanakis 2016a; Jones 2014; Moutafi 2015). Fire use in tomb chambers, for instance, has been interpreted variously since the late nineteenth century as evidence for cremation, lighting, purification (ritualised), and fumigation (a practical step to alleviate the stench) (Galanakis 2016a: 190 with references; Kontorli-Papadopoulou 1995: 118). Difficult to identify properly and often missed or misread in earlier research, confirmed fire use is neither universal nor perhaps as rare as low percentages suggest (Galanakis 2016a: 190). Multiple applications in different locations make it unlikely that there was any one rule governing fire use in post-funerary practices (Galanakis 2016a: 193-194), much as there seems to have been a certain freedom of choice in burial (Kontorli-Papadopoulou 1995: 114). Likewise, no one rule applied to tomb shape and scale, but a combination of mimetic design for shape and risk assessment for scale seems as likely as fire's multiple uses for lighting and fumigating dark chambers.

2.2. The rock canvas

With the above section having established general trends in Mycenaean tomb development, this section elaborates on physiographic constraints to tomb design, outlining the composition and physical properties of soils in Achaea and Attica. I comment mostly on geological and hydrological processes in southern Greece and how these affected human activity during the Bronze Age. Since concerns over water management weighed heavily on Mediterranean populations then as now, water is helpful as a signpost for general climatic trends and the first to constrain labour given the lethal consequences of its absence. Infiltration from intermittent rainfall also heavily affects tomb preservation, and the response of rocky soils to weathering and tool strikes partly explains the surviving tomb shapes. The following subsection reviews the dynamic rock canvas from which Mycenaean tombs were built and how they have resisted entropy.

2.2.1. Physiography of southern Greece

Stark contrast with temperate climates familiar to Western researchers, particularly during the summer fieldwork season, has earned Greece dire environmental descriptions, “a land of dry and barren mountains, poor in fertile, well-watered soil” (van Andel et al. 1986: 103). A fairer representation characterises Greece as a typical landscape of thermomediterranean valleys broken by meso- and supramediterranean mountain zones (Yassoglou et al. 2017: 11). Hot summers exacerbate dry and rocky soils that otherwise appear fertile in the rainy spring and late autumn. Tempering those hot summers at higher elevations, these bioclimatic regions foster sclerophyllous vegetation of dense evergreen scrub (Velitzelos et al. 2014: 56), with dominant species including smilax (*Smilax aspera*) and juniper (*Juniperus communis*). For the Mediterranean region in general, forests tend to occupy cooler highland areas beyond the premium space claimed for agriculture in the lowland plains (Meiggs 1982: 40). Thriving in the middle zone (500-1,200 m above mean sea level (amsl)) as described by Meiggs (1982: 42), deciduous trees such as oak, chestnut, maple, and hornbeam – evidently preferred for oxen yokes (Plommer 1973: 4)–lend themselves to coppicing, an economical way of sourcing firewood and high-demand building timbers by exploiting the ability of these trees to grow back from root systems after cutting. For much of antiquity, oak was likely the most widely distributed of trees below 800 m amsl in southern, western, and central Greece (Meiggs 1982: 109). The valley climate here continues to support a thriving vine, olive, and citrus agriculture (Kavvadias et al. 2013). The success of that industry has been dependent on water management, made precarious by infrequent, heavy rains that drain rapidly through rill flow and interrill infiltration.

Soils with abundant rock fragments represent more than 60% of Mediterranean soils, prompting much research on the properties of rocky soils and their hydrological responses (Poesen and Lavee 1994). Rock fragments ranging from pebbles to large cobbles are prevalent throughout the study area and have shaped how populations have managed it. Depending on rainfall amounts, rock fragment size and quantity can affect water conservation by either increasing (non-drought or large surface cobbles) or decreasing (drought) water retention beyond the capacity of soils with fewer stones (Danalatos et al. 1995). Runoff and sediment loss also increase where surface rock fragments and less vegetation fail to consolidate soils under rainfall of varying intensity (Moustakas et al. 1995: 115), though laboratory tests have shown more ambivalence linked to soil particle size, subsurface rocks, preceding moisture content, and the "umbrella effect" of surface rocks (Jomaa et al. 2012: 11; Smets et al. 2011). Removal of surface rock fragments, as might be the case in agricultural field and tomb site preparation, drastically increases erosion rates (Cerdà 2001: 59; McNeill 1992: 311). Overall, rocky soils have been beneficial to agricultural productivity in the Mediterranean by decreasing water loss through evaporation and limiting deflation by wind erosion, with runoff effects varying according to surface coverage (Cerdà 2001: 66). For soil use in construction, however, rock fragments have mostly negative impacts, greatly increasing labour and decreasing tool use-life (Milner et al. 2010: 103; Xie 2014: 297). Construction of new tombs in a growing cemetery would require at least partial clearance of vegetation and surface stones to avoid complications with work flow. Loose rocks sliding into an open *dromos* of more than a few metres depth could prove fatal for tomb builders or mourners, adding a practical element to keeping the immediate vicinity clear of debris.

The soils and parent rock materials of Achaea and Attica share several properties with those found in much of Greece and around the Mediterranean. Low organic content and abundant rock fragments typify the well-drained, calcareous slopes eroding from shallow flysch, conglomerate, and limestone bedrock (Yassoglou et al. 2017: 10-13). The most common parent material associated with Mycenaean rock-cut tombs, *kimilia*, can be described as foraminiferous (fossil-rich chalk) or argillaceous (containing clay, as in the lime-clay mixed marlstone)–both derive from calcium carbonates with ultra-small particle size ideal for chamber tombs, as noted at Mitopoli (Kolonas 2009a: 20). Others have focused on formation or age to label the rock, such as "Neogene marls" (Cavanagh and Mee 1999: 96), lacustrine or lake-deposited (Andreou et al. 1996: 540-542), karstic or cave-forming (Vika 2009: 2024), or simply "soft, impure limestones" (Mason 2007: 39). With the exact diagenesis of flysch, conglomerate, and limestone – each thrust upward from an ancient sea bed of variable depth (see below)–being unknown to tomb builders, it is generally enough to note that they preferred these sedimentary formations for holding shapes while being relatively easy to cut.

Soil profiles throughout the southern Greek mainland have been defined largely from movement, whether tectonic, aeolian, nivation, or alluviation. Sediment cores from the Messenian plain in the south-western Peloponnese show Plio-Pleistocene sediments at higher elevations and Holocene floodplain deposits with an average thickness of 90 metres (Katrantsiotis et al. 2016: 189). During the Early Bronze Age, land clearance began to have a significant effect on soil composition in densely populated areas of southern Greece, notably in the Argolid (van Andel et al. 1986) and Messenia (Katrantsiotis et al. 2016: 189-190). Locally, soil modifications in Achaea and Attica followed a similar pattern, with activity intensifying prior to the LBA if known tombs and settlements provide an accurate sample (Papadopoulos 1979; Table 1.1, this volume).

In addition to the relative antiquity of human environmental modifications in the region, comparatively recent natural processes in geological time (roughly the past 250 million years) have shaped topography and climate in the Aegean. Young mountains of "blinding limestone" once occupying the shallow bed of the Tethys Sea now girdle its Mediterranean successor, products of plate collisions that also power the region's active volcanoes (Shiel 2016: 67-70). Throughout the late Pleistocene and early Holocene, colluvial deposits accumulated in valleys from erosion driven primarily by runoff on steep slopes (Pope and van Andel 1984: 282; van Andel et al. 1990: 381). This sloping terrain ensures sufficient and occasionally excessive drainage affecting tomb preservation. Loss of mountainous glaciers and snowmelt after the most recent Ice Age around 20,000 years ago triggered rapid alluviation in Greek valleys (Woodward and Hughes 2011; Yassoglou et al. 1997: 264), and colluvium from the slopes increased again from Early Bronze Age land use (van Andel et al. 1986: 105). Colluvium (accumulation from hillslope erosion) and debris dominate soil profile descriptions, particularly where tombs trap the downward slide of destabilised materials (e.g., Rife and Morison 2017: 39). As discussed later in this chapter in relation to the somatic risks challenging LBA Aegean tomb builders, the loss of mature forests and depletion of soil minerals may also have contributed to the rise in infectious diseases like dysentery, hookworm, and malaria as early as the Neolithic (Angel 1972: 90; Arnott 1996: 265-266; for a similar situation in Roman Italy, see Sallares 2002). Although less of a problem in southern Greece where rivers often vanish into dry limestone beds (Shiel 2016: 70), slow rivers in southern Mesopotamia incubated malaria and schistosomiasis (McMahon 2015: 32).

Reactions to environmental change, whether accompanied by health risks or not, remain visible. For instance, erosion and flooding initiated significant countermeasures in the LBA Argolid, where the construction of the Tiryns dam rerouted a stream threatening the Lower Town with seasonal flooding (Balcer 1974; Bintliff 2019; Maran 2010: 728; Maran et al. 2019; Weiberg et al. 2016: 47; Zangger 1994). Roughly a century later, engineers in the Late Helladic IIIC period diverted the Alfeios River near ancient Olympia (Giannakos 2015: 73-75). Earthen dams initiate controlled seepage along the *phreatic* (saturation) line, not so much halting the flow of water as drastically reducing it (Bowles 1984: 277, 286). Unless it held back a reservoir following an especially wet winter, the Tiryns dam would have acted more as a diversion barrier, needing no impermeable core to address flow net theory (Bowles 1984: 286).

Apart from flood mitigation, generations of agricultural specialists on the southern Greek mainland sought to conserve water through tactical soil movements, mostly terracing (also deployed for construction, e.g., Nelson 2007: 150-151) and irrigation. Although effective in combating semiarid conditions, complications can arise that reverse the advantage of irrigation. Known as bypass flow, loss of water and soil nutrients through cracks in dry soil threatened land productivity from the outset of intensive agriculture in the region. This presents an even greater problem for modern irrigation, which exacerbates the same effect during the dry season (Kosmas et al. 1991: 140). Unlike the Tiryns dam in the Argolid and land reclamation from Lake Kopias in Boeotia (Giannakos 2015: 73), large irrigation efforts in the LBA have not been found in the immediate vicinities of Voudeni, Portes, and Menidi, but standard infrastructure projects like bridges and roads abounded (Hitchcock 2010: 206; Hope Simpson and Hagel 2006). Placement of the settlement and burial areas for these sites on high ground, with ready access to natural channels like the Meilichos (Voudeni) and Pinios (Portes) rivers, removed the need for significant artificial drainage works but raised the stakes for reliable sources of potable water. Springs provide the only steady source of water in most areas of Achaea, whose rivers tend to dry up without snowmelt and a reliable rainy season (Papadopoulos 1979: 21).

2.2.2. Soil mechanics and risks

The case study sites that feature prominently in later chapters show no exceptions to the soil map of the wider regions (Figures 2.1-2.2). Light-coloured, friable luvisols appear at

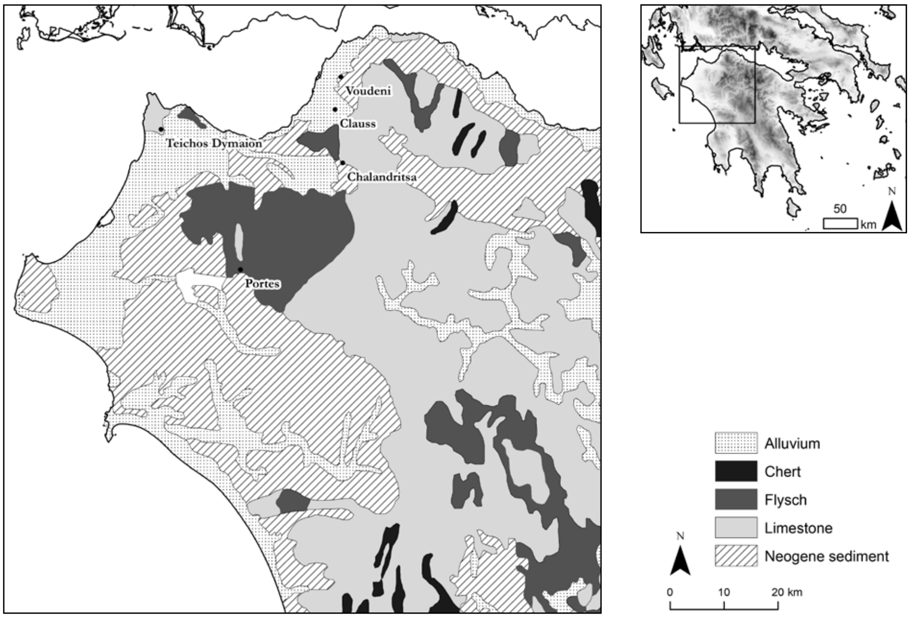


Figure 2.1. Geological map of the north-western Peloponnese, based on Higgins and Higgins (1996: 66).

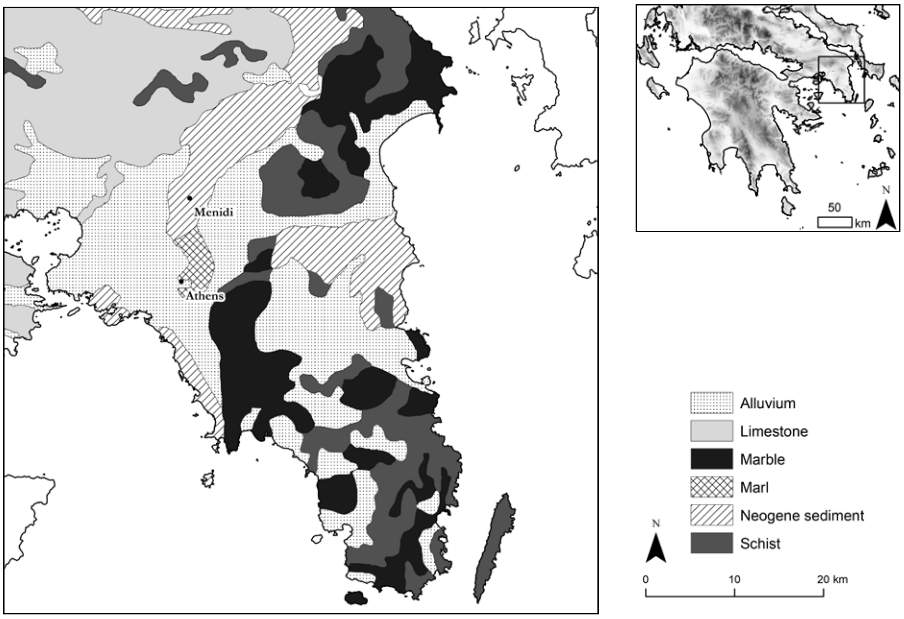


Figure 2.2. Geological map of Attica, based on Higgins and Higgins (1996: 27).

both cemeteries in Achaea, with a sandier tan from flysch at Portes and more homogeneous grey from Mesozoic limestones at Voudeni (Yassoglou et al. 2017: 12, 33). The soils around the Menidi *tholos* have been heavily modified by the urban expansion of modern Athens, but the mound above the tomb retains enough undisturbed material to reconstruct pre-modern conditions. Of natural processes that have affected tomb preservation at the sites, tectonic activity and water infiltration are the most visible. These are discussed alongside other risk factors for earthen architecture below. Damage to individual tombs perceived during fieldwork or indicated by site guards will be specified in Chapter 4.

As seen above, soil studies conducted in Greece and similar environments have focused on the primary concern of land management within the region (both recently and in prehistory): agriculture and water conservation in a climate susceptible to rainfall variability and drought. Recurring summer droughts followed by "strong katabatic winds and periods of intense, in autumn often thundery, rainfall" combine to speed soil loss, with up to 20 cm per thousand years dumped from steep coasts onto the sea floor (Shiel 2016: 70). Many of the properties affecting farming and water conservation efforts also apply to soil movement in tomb construction and preservation. Without adequate drainage and maintenance of soil compaction, shear stresses could result in lateral flow and collapse of voids opened by construction; failure is caused by soil particles sliding or rolling over one another (Bowles 1984: 310-312; Selby 1993: 27-34), rather than the tearing of tensile materials (wood, fibre) or the shattering of crystalline structures (rock, glass) (Cotterell and Kamminga 1990: 68-71). Subsidence and catastrophic ground loss also threaten underground excavations that disrupt the balance of nearby loads in weakly bonded soils (Bowles 1984: 356-359; Selby 1993: 111-121). Differential settlement affects most tombs, since imperfections in the friable paralithic bedrock leaves stability an open-ended question, causing cracks where the imbalance of loads has shifted the built feature and the surrounding soil matrix. From field observations, the most destructive natural forces acting upon the tombs have been infiltration by rainfall, nivation in colder winters, and tectonic activity.

Human threats to tomb preservation have taken a greater toll than natural processes. Cultural priorities shifted away from the monuments at the end of the Bronze Age, leading to neglect or reappropriation of the features and surrounding land for other uses, such as the early modern conversion of chamber tombs near Drosia into quarries and lime pits (Papadopoulos 1979: 33) or those used at Lysaria-Pori as sheepfolds (Aktypi 2017: 1). The mythos of larger and better-built burial mounds persisted (Alcock 2016), with their social advantages still plain to tomb cults and the Homeric epics recorded centuries later (e.g., Homer *Od.* 1.234-244, see Chapter 1, this volume). Here is where I depart from the physical constraints on tombs and travel onward to the cognitive decisions that shaped their material form.

2.3. Sponsor's gamble

Conceptualising tomb shape and scale seems intuitively simple at its extremes, from the minimal pragmatic pit for disposal of remains to a multi-story mausoleum's statement of memorial and solidarity. What lies between – the expected standard – bows to contextual circumstances with limits on individual innovation and acceptable space. The balance lies with creating a tomb that fits, investing in a memorial that elevates successors to the deceased. The truth of their position may be stretched with a bigger or better-built tomb, so long as the temptation to inflate does not lead to an outrageous lie. As seen with the opening quote to Chapter 1, Telemachus mourned his father's disappearance for the absence of a glorious tomb, which damaged his prospects as well as his father's memory. Leading small but strategically positioned Ithaca afforded Telemachus some room to dream without overstepping his people's willingness to forget a ruler in absentia. Recalling ancestors with funerary architecture would motivate more than the sons of leaders, just to a humbler scale as risk outweighed advantage for an overly grand tomb. Taboos tolerate only slight deviation from cultural blueprints that impose order to protect health and spiritual wellness in disposing of the dead (Oladepo and Sridhar 1985: 219). With this in mind, the cognitive picture of tomb shape originates in a dialogue between cultural conceptions and techno-environmental constraints.

First, looking backward from what remains, hindsight tracks value ascribed to tomb shape and scale. The central assumption is that tomb construction projected some advantage, now partly captured as inheritance (e.g., our glorious past). Of those not hidden and forgotten, tombs – temples, public spaces, etc.–survived partly due to the affordances made by later generations, who could link iconic architecture and imagined cultural ties with new political regimes. Maran (2016: 153, 161) highlighted construction sequences superimposing structures on places of aged significance at Olympia (Protogeometric sanctuary over an EH II tumulus), Lerna (Early Mycenaean shaft graves over EH II tumulus capping the remains of the House of the Tiles), and Tiryns (LH III *megara* over the EH III/ MH tumulus capping the remains of the *Rundbau*). With 700-1,000 years separating the structures, the strength of the relationship is unclear despite the telling placement and possibility for narrative persistence in oral traditions (Maran 2016: 153). Written examples of (re-)claiming monuments, however, dispel doubts over the durability of cultural memory, even if re-invented. Classical stone inscriptions commemorating those involved in financing and organising temple-building, for instance, created lasting reminders claiming the work, which in the absence of living memory and written records could be re-appropriated by any charlatan with something to gain (Burford 1969: 84-88). That relationship between the monumental built environment and people claiming it was in continual transition, flowing into contemporary imaginations or ebbing into the background (Osborne 2014: 3-4). Aspiring leaders, consciously or not, foregrounded monuments as "timemarks" or "links to the ancestral world" and legitimated through invented ties (Holtorf 1996: 127, with references). What they invoked is a form of adapted recall, bending cultural memory with the gravity of emotive scale and persona, seen *in extremis* with megalomaniacal or, in the modern sense, nationalistic pursuits. Incorporating anachronistic symbols from a multitude of eras in the Aegean past, the Tomb of the Unknown Soldier in Athens commemorates the anonymous dead from wars for territorial expansion in the nineteenth and early twentieth centuries (Davis 2007: 240-245). The message is one of unity in a collective past, wherein the sense of an unbroken inheritance is fabricated for the benefit of the modern state. As Davis (2007: 245) indicated, however, fragmented political allegiances have been glossed over and forgotten in the design. Several German examples of megalith reuse were also tailored to fit nationalistic revivals, but these rely on highly visible monuments that "are simultaneously relics of many ages" (Holtorf 1996: 141-142). Cut or dug tombs, virtually invisible when backfilled to the level of the surrounding slope, cannot generally be incorporated in such a way. One spectacular exception is the evolution of the Danish monument Julianehøf, where a French geometric garden surrounds a prehistoric passage grave (Holtorf 1996: 125). The radical aesthetic shift in purpose owes much to the time gap, with forgetting key in allowing a thoroughly remodelled past.

Recently the process of co-opting monuments has been targeted as part of a “new materialism” elevating objects on a level with human agents (as summarised in Ingold 2012: 429-432; Thomas 2015: 1288-1289). The Latin roots of the word “monument” invoke an active role of reminding observers about a collective past, memorialising an influential persona or a memorable event in an enduring medium (Holtorf 1996: 120; Osborne 2014: 3). To put it another way, existing monuments blend with the social practices and materials of new generations as “entrained action” shaping socio-political trajectories in a manner reminiscent of fluid-sediment interaction – with humans, objects, and environments suspended and colliding in the braided streams of divergent histories (Bauer and Kosiba 2016: 117-120). Simply stated, no single agent takes full control of material design.

Others have referred to the interconnectedness of humans and things as entanglement, but to what extent has not been decided (Harman 2014; Hodder 2012, 2014; Ingold 2008, 2012). For Ingold (2012: 435), interconnectedness is perpetual, and tracking the flow of concept, material, and process embodies a “meshwork”, for which the prime analytical tool is, as Miller (2005: 8) puts it, the “material mirror”. In that sense, the shape and scale of a tomb mirrors both physical constraints and cognitive decisions. Claiming the advantages of their entangled monumental past, later generations inherited the risks and rewards begun in the original investment and social calculations of the monument builders. Simply stated, the sponsor’s gamble was handed forward. Weighing risks and rewards shaped Mycenaean tombs and can be parsed further into semiotic, evolutionary concerns of costly signalling and altruism, to which the following sections turn.

2.3.1. Costly signalling with tombs

Before launching into costly signalling and altruism, I will place explicit limits on how I apply them to Mycenaean tomb shape and scale. I use them more as a pedigree of thought to link the risks and rewards of tomb architecture to a broader theoretical discussion. In this sense I imply only a socioeconomic gamble– commissioners risking resources and reputations – alongside limited altruism from the personal sacrifices made by workers, largely as a factor of time spent. Costly signalling with tombs weighs the advantage of a memorial worth claiming against backlash from, in order of increasing severity, a *faux pas*, reputational or economic ruin, and worker fatalities or uprisings. I disavow the survival game implied by costly signalling’s biological origins (e.g., Maynard Smith 1976, 1994; Maynard Smith and Harper 2004; Zahavi 1975), as entangling tombs with reproductive fitness is a bridge too far (see below, cf. Hildebrandt and McGuire 2002; Gat 2006; Lawler 2012). Without omitting where these ideas originated, I tone down the evolutionary implications of costly signalling by exploring its semiotic dimension, from a tomb’s intended message onward through its evolving meanings (*sensu* Corbey and Mol 2012; Glatz and Plourde 2011). First, some definitions are needed.

Costly signalling refers to investing resources in a feature that signals strength or vitality, such as a male white-tailed deer growing a large rack of antlers or a bank housing its corporate headquarters in a skyscraper (Carballo et al. 2014; Codding and Bird 2015; McGuire and Schiffer 1983: 281; Spence 1973; Trigger 1990). This is done despite the liabilities of the feature – the handicap principle (Zahavi 1975: 213)–which paradoxically can also threaten the health and safety of the owner (Conolly 2017: 435-436; Corbey and Mol 2012: 375-376). In the previous examples, this could be hunter preferences for deer with large racks or the bankruptcy risk of failing banks with excessive overhead expenses. Costly signalling thus tracks three principal components: 1) sender/gambler, 2) message/risk, and 3) receiver/judge. With each component the balance between roles is finely tuned, loading even slight variations with the potential for escalating fallout. The costly signal of a strongly deviant tomb would weigh 1) the advantage of political and social influence gained by association with an enduring symbol of wealth and authority against 2) the social and economic risks of expending resources and losing public opinion to a megalomaniacal or garish project. The latter interrogates the authenticity or reliability of the costly signal, assuming those less strategically positioned would not attempt it (Maynard Smith 1994: 1115). Summarised by Grose (2011: 677) under *honest signalling* and corroborated in human social competition as early as 30,000 BP with elaborate stone tools and cave art (Conolly 2017: 440, with references; alternately explained as emblemic group signalling by Gittins and Pettitt 2017: 482), rare or nonlocal items are accumulated and/or destroyed to boost prestige validated by observers aware of the cost. Using these terms, cemeteries – like Portes, see Chapters 4 and 5 – capable of building exceptional tombs could avoid the reliable signal challenge by restricting deviation and its attendant socio-economic and somatic risks (see below).

Costly signalling is often invoked when analysing religious architecture and expenses, since the social and economic benefits therein are not always directly clear (Sosis 2003). Questionable investment in landscape monuments from LBA Anatolia also raised the issue of costly signalling in terms of communication among political competitors, particularly in contested areas further away from political centres (Glatz and Plourde 2011: 35-37). As a political cohesion strategy, construction of monuments was considered less costly than military conquest and occupation (Glatz and Plourde 2011: 38). Examining costly signalling in tomb construction involves an analysis of the expected costs, risks, and rewards – in other words, the expected standard to uphold. Commissioning the monument preceded actual (both real and perceived) costs, risks, and rewards – the comparative cost and investment risk – and consequently relied upon a gamble against the expected standard, including materials (building and consumables), animal resources, and human capital. Each of the categories is quantifiable, intensely variable, and combines with intangible factors like reputation and altruism – for the labourers at least – to underwrite construction. As others have indicated (e.g., Conolly 2017: 440-441; Grose 2011: 677-678), costly signalling would be self-fulfilling and ubiquitous without empirical modelling, for which I introduce the relative labour index in the remaining chapters. A recurring problem with tomb visibility, cost, and timing for cemeteries lasting six centuries (Portes and Voudeni, see Chapter 4) prevents a broad reassessment here of costly signalling as a partial explanation for conspicuous consumption in monumentality, especially through the complex failure of smaller sponsors (Conolly 2017: 442; see below). By contrast to the complexity of sponsor failure, altruistic behaviour can be a straightforward fit to the motivations of tomb builders. However, it is far more difficult to model formally without participant observation (e.g., 'ultimatum' and 'dictator' gaming decisions, Fehr and Fischbacher 2003: 786-787; see below).

Altruism involves the sacrifice or weakening of self-interests for the benefit of others (Fehr and Fischbacher 2003; Trivers 1971). The action need not be entirely selfless, as deferred benefits could rebound on the weakened position, and the behaviour could be conducted with this in mind. Forethought for recompense or the maintenance of reputation by avoiding the opposite of altruistic behaviour, known as cheating or free-riding (Fehr and Fischbacher 2003: 788), could influence actions just as strongly as deeply held convictions (e.g., honour, valour) used by cultural materialists to explain similar behaviour in exchange (Corbey 2006). The highest reward potential comes not from avoiding cheating altogether, but avoiding being caught in deception (Grose 2011: 685) or altruistic punishment (Fehr and Fischbacher 2003: 786-787), a risk-reward scenario popularised in game theory. Statistically, equivalent retaliation ("tit-for-tat") is more beneficial than acting altruistically, even if this only means a partial or temporary loss in self-interests. Cooperation has been shown to decay as optimism in group participation declines – even with high proportions of "strong reciprocators" vs. "non-cooperators"–unless reputation and punishment influence behaviour (Fehr and Fischbacher 2003: 788-789).

In biology and evolutionary archaeology, altruism is a factor in increasing fitness through the preservation of genes, such as that which motivates kin selection, or allying with blood relatives. The semantics of these and closely related biological terms like mutualism has been a source of confusion when testing the fitness limits of cooperation among humans and non-humans (West et al. 2007: 415). For human behaviour, "costly prosocial behaviours" like feasting have been targeted to find where extended benefits arise from temporary shortfalls to individuals and groups (Conolly 2017: 437, with references). The impetus of altruistic kin selection decreases with distant relatives and strangers, shifting actions of communal labour among non-relatives into the weaker but still-present selection preference for community. Economically and socially, altruism underlies exchange, reciprocity, and cooperation (e.g., Ellen 2010; Granovetter 1992; West et al. 2007). For the built environment, altruism manifests as communal cooperation in architectural efforts that exceed the capabilities of a single nuclear family. In this sense, monumental tomb construction benefited community participants by increasing their monumental capital (with sponsors' reputations receiving an outsized share), reinforcing social advantages through physical presence and mythical tradition. Later fortifications and public works joined costlier tombs in staking claim to territory and cultural inheritances. Explanations for similar over-the-top investment can follow group reinforcement, as in the case of emblemic Palaeolithic Lascaux cave art (Gittins and Pettitt 2017: 470), or assertive displays from strong sponsors like the proliferation of island hillforts looming over the Bronze Age eastern Adriatic (Čučković 2017: 528). For Mycenaeans and their cultural heirs, perception of strong walls and elaborate tombs granted advantage (value/prestige/power/influence/memory) to noticeably costly affairs.

Each substantial building project required some form of cooperation or altruistic labour, as compensation for workers would inevitably leave a short-term deficit for those sacrificing time or resources. Mycenaean labourers may have undertaken that sacrifice to increase prestige or cement hereditary claims for elite groups, tying them to memorable tomb projects with oral legacies. Santillo Frizell (1997-1998: 103-107) emphasised this as a motivation for the construction of the Atreus, Clytemnestra, and Lion *tholos* tombs at Mycenae and compared their spectacle with the transport of the red porphyry sarcophagus of Swedish King Charles XIV in 1856. Participants dragging the 11-ton coffin and 5-ton lid were dubbed the "Royal Horses", and family legends continued to celebrate any ties to the event nearly a century and a half later (Santillo Frizell 1997-1998: 107). More recent examples of altruistic labour highlight the difficulties faced by political and economic asylum seekers with suppressed legal rights and wages (Garcia 2006: 28). Altruistic labourers tolerate the deficit with the hope for long-term economic stability and societal integration, advantages also weighed by unforced workers prior to the commodification of labour.

With the above constraints in mind, the impetus at the root of Mycenaean tomb construction is semiotic and evolutionary. In other words, tomb construction conveyed meaning to observers and aimed to advance the interests of investors – those associated with commissioning and organising building rather than the builders themselves (Santillo Frizell 1997-1998: 103). As summarised by Osborne (2014: 6), monumental tombs and monuments in general have been cast as expressions of territorial control and political power (DeMarrais et al. 1996: 18; Glatz and Plourde 2011; Schnapp-Gourbeillon 2016: 207), social complexity and identity (Renfrew 1983; Sherratt 1990), and benchmarks of scale for power and labour mobilisation (Abrams 1989, 1994; Trigger 1990). Each of these indicate advantage for the sponsors, with a less direct link to motivating labourers. Methods tracking labour mobilisation and the construction process feature prominently in Chapter 3, but the advantages conveyed by commissioning construction are the focus here. Commissioning monuments and funeral activity are exceptional events (Boyd 2014a: 194), elevating the impact of monumental tombs on social memory most prominently during the spectacle of construction. Why launch that spectacle?

For monumental tombs, exceeding any practical dimension of mortuary necessity as in Trigger's (1990: 119) thermodynamic definition of monumental building, construction is often translated as a performative message meant to have an audience, similar to the "performative space" provided by Mycenaean citadels (Maran 2006b: 76; Wright 1987: 176). The message of monumental tomb construction is less one of grief and remembrance for the dead than it is one of attention-grabbing and improvisation among living actors (Boyd 2014a: 194-197). From a Darwinian or evolutionary stance, costly signalling and altruism theories offer motives for monumental tomb construction, with definitions and examples above. The concepts will be familiar to researchers in the Aegean, but the terms are different. Cooperation, competition, and consumption, for instance, are proximal explanations addressing the same cultural phenomena as costly signalling theory (Conolly 2017: 435). Rather than power (e.g., Cavanagh and Mee 1999: 93; Maran 2006b: 76; Voutsaki 1995: 62, 1997: 44-45; Wright 1987: 176) or wealth (Shelmerdine 2006: 84; Voutsaki 2001: 204), tombs reflect advantage in the scale and quality of construction. More importantly, the contextual details of Mycenaean funerary performance, so difficult to reconstruct from partial evidence, are less critical than the comparative empirical benchmark set by tomb scale. Instead, analogies to relevant scenarios fill in the gaps throughout the long monumental past of human engineering, calling upon evolutionary and architectural theories as anchor points.

2.3.2. Risks of investment: the expected standard

The combination of costly signalling and altruism theories has been used before to explain motivations for warrior displays in literary texts, notably the Anglo-Saxon folk classic Beowulf (Corbey and Mol 2012: 375). Boastful and arrogant, the Geatish hero Beowulf reflects the concerns of the Anglo-Saxon aristocracy and its preoccupation with young retainers making bold (altruistic) gambles to increase their leaders' stocks as well as their own. Beyond being technically functional tools in the hands of proficient warriors, elaborate armaments signal to others that the bearer is formidable and their leader generous. Focus is easily shifted from those bodily ornaments in Anglo-Saxon folklore to over-the-top architecture in multiple burial contexts, as Beowulf's earthen tomb makes an enduring statement of its own (Milner et al. 2010: 110-111; Williams 1998: 91). The Treasury of Atreus at Mycenae loudly proclaims a similar message, one that no other tomb before or after could equal (Mason 2007; Wace 1940: 233).

The bold step of diminishing the visual impact of smaller previous tombs with larger and better-built ones risked criticism from economic and social conservatism, a famously restrictive mechanism in Egyptian engineering and medicine (e.g., Cotterell and Kamminga 1990: 60-61; Ritner 2000: 107). Bierbrier (1982: 14) blamed “religious conservatism” for delaying major alterations to traditional pyramidal tombs as late as the early Eighteenth Dynasty. Conservatism also manipulated Mycenaean funerary rites, particularly regarding the scope and material requirements of processions (Cavanagh 1998). Late Helladic I ceramics from Portes reflected a preference for conservative forms over contemporary wares from similar tumuli at Samiko and Makrysia in Elis (Moschos 2000: 16). That resistance to change stemmed from tradition, collective beliefs on acceptable architectural and artefactual forms and ritual prescriptions. In the case of chamber tombs at Voudeni, variation in vault shape was hidden from view by closed entrance passages that largely do not vary except in size. Differences of form and scale could go largely unnoticed by casual observers unable to access the interior of the *dromoi* and vaults. At Portes, vault shape was similar, but the chamber tombs were not the only grave types present, being joined by two *tholoi*, tumuli, and multiple built chamber tombs and cist graves. These changes are far more noticeable and reflect several centuries of use, with different generations focusing on their own preferred tomb types, though not to the exclusion of others (see Chapter 4).

Although an evolutionary perspective recasts Mycenaean funerary performance in this section, I reiterate here that reproductive motivations are not considered to affect mortuary behaviour, as has so often been the case in the famous debate over violence (e.g., Gat 2006; Lawler 2012). The advantage relies upon social (political and economic) advantage and the somatic – that is, bodily upkeep – rewards that it precipitates, driving the enterprise’s evolutionary success. These rewards arise from the asymmetric exchange of communal labour for monumental construction, not unlike the asymmetric gift exchange and conspicuous consumption that Voutsaki (1995, 1997) highlighted as critical in early Mycenaean elite competition.

Larger, better-built tombs benefit those closely associated with their commissioning and use more than those fulfilling basic construction roles, but the latter also see some returns for their inclusion (and sacrifice) over non-participants (e.g., Santillo Frizell 1997-1998: 103-107). In the Shaft Grave period, elites benefited from elaboration of burial ceremonies and increasing scale of architecture as proof of their control over resources (Dabney and Wright 1990: 50-51; Fitzsimons 2011: 78). In the proliferation of tomb forms to encompass monumental *tholoi* and chamber tombs, competition can be read into conspicuous displays from gift exchanges and labour mobilisation (Voutsaki 1995: 62, 1997: 44). Grave goods of rare and expensive items taken out of circulation in the closing of Mycenaean tombs depict an accumulation of wealth and the willingness to sacrifice it to gain influence, bolstered as family members and close associates maintained an indirect claim to the material (Voutsaki 1997: 38). For modern analogies with estimated net worth of nearly $300,000 each, multi-storey tombs of cartel leaders at Jardines del Humaya near Culiacán, Mexico, reflect both a massive accumulation of wealth and, with the inclusion of air conditioning, an unwillingness to forgo luxury even in death (Mendoza 2017).

With the potential to derail any advantage in the costly signalling competition of elite architecture and conspicuous consumption, excessive ostentation risks reputation. This is best captured by the term "folly", which so often accompanies spectacular failures or useless endeavours. Quoting Stuart Barton, Howley (1993: 2) highlights the dual definition of an architectural folly, either celebrated as pleasing for the sake of it or derided as "foolish monuments to greatness and great monuments to foolishness". Many examples survive from the British Isles and sustain a form of landscape tourism in Georgian, Victorian, and Edwardian gardens. One that has not survived, known as Beckford's Folly, enshrines the commissioner (William Thomas Beckford) rather than the architect (James Wyatt) as the guilty party behind a famously short-lived Gothic tower, despite the latter's experiments with "compo-cement" that ultimately doomed the structure (Wilton-Ely 1980: 45-46). Wilton-Ely (1980: 46) referred to it as a form of "poetic justice" when Wyatt later earned the epithet "the Destroyer" for his "vigorous restoration of ancient buildings". In the discussion of negative reactions on elite architecture to follow, commissioner and architect would share the blame. Unlike a tower's sudden disappearance from the local skyline, however, a tomb collapse even of a similar magnitude might not send reputations plummeting. The collapse, after all, would largely be hidden from view, and collapse layers overtopped by Mycenaean materials show it did not deter reuse (Cavanagh and Mee 1978: 42; Smith and Dabney 2014: 151-153). A tomb's costly signal is worth the risk so long as the spectacle veers toward the positive side of folly, invoking festive appreciation as a memorable venue for a feast or contemplative reverie in memory of the deceased (e.g., Hamilakis 1998: 117-120, with references).

Long-term advantages driving the costly signalling of Mycenaean tomb construction included boosts to local economies and personal reputations, whether from the spectacle of construction (Fitzsimmons 2006: 188; Santillo Frizell 1997-1998: 103), procession and orientation relative to potential spectators (Boyd 2014a: 194, 2016: 64-70), or the completed (and enduring) monument (Wright 1987: 181-182). That potential growth in economy and reputation encouraged increasing the size and quality of tombs, within the limits that convention or ability allowed. When compared with previous examples in Grave Circle B at Mycenae, groups of larger tombs like those in Grave Circle A reflected a successful faction's control over more resources (including labour) than their predecessors (Fitzsimons 2014: 91). Mycenaean palatial complexes functioned in a similar fashion with imposing Cyclopean stone fortifications and gateways geared towards impressing viewers through their contrast with the small stone and mud-brick architecture of contemporary housing (Maran 2006b: 79). Cost set them apart and attracted envy among peers and subordinates. The citadels also directed views or restricted access through closed courts and corridors (Cavanagh 2001: 124; Maran 2006b: 80), a task for which the entrance passages of Mycenaean chamber and *tholos* tombs excelled (Papadimitriou 2015: 72).

Negative associations can also rebound on monumental construction – unravelling the original intention of the costly signal – with the majority of ill-feeling falling on architects and dictators more than engineers and labourers (e.g., Bretschneider 2007: 4; Davis 2007: 251, citing Petropoulos 1996: 243-245). Iconoclastic vandalism has often answered public fervour against failed regimes, seen most recently in the targeted bombing of high-profile buildings and dramatic toppling of towers and statues to dictators in the past 75 years (Bretschneider 2007: 8; Davis 1991: 90). In a classical parallel, the vulnerability of Roman imperial memory compelled successors to destroy images and control mourning, as in the case of Domitian and the *damnatio memoriae* (Reitz 2013: 202-203). Many Egyptian regime changes also famously resulted in the effacement of names from existing monuments, whether to aid the claim of the new leader or erase memory of a previous one. Perhaps with multi-semiotic intent, the late construction of Building T atop the Tiryns citadel left partially visible the ruins of the Great Megaron (Ann Brysbaert, personal communication 2018; Maran 2016: 168). Enduring theories addressing the conflagrations at palatial centres near the end of the LBA suggested internal unrest, possibly related to a population overstretched by the demands of building, as one of many sources for collapse (summarised in Knapp and Manning 2016: 123-124). If that was the case, few clearer messages could be sent against the ruling elite than to attack the costly signals synonymous with their authority.

Apart from long-term advantages and enduring social memories, monumental construction spurs some immediate responses. Among the immediate somatic rewards conferred by Mycenaean tomb construction, a concentration of resources occurred that demanded rapid allocation. Some resources were redistributed to sustain construction. Others were consigned to the tombs and removed from circulation. Feasting and votive offerings fell within the latter category. Giving an idea of the resources involved, some records of grain allotments and substantial herds administered by palatial complexes were fortuitously preserved in catastrophic fires at Pylos, Knossos, and Thebes (Palaima 2015). Others have suggested the decentralised control of substantial resources among sanctuaries and districts (s. *damos*) with mayors (s. *ko-re-te*) and vice-mayors (s. *po-ro-ko-re-te*) (Lupack 2011: 212). After palatial administration and monumental architecture ceased before the LH IIIC period, market exchange assumed primacy in the crafting and movement of prestige items and commodities (Pullen 2013: 443). Who controlled the resources is not as imperative here as the timing of allocation during building programmes, which could face significant delays if the somatic needs of labourers were not met in a timely fashion. Consequences could range from work stoppages to violence. These are outlined further as part of the risks of costly signalling and altruistic labour exchange in tomb construction, borrowing examples primarily from mining prior to early industrial labour reforms.

2.3.3. Cost and altruism in cooperative labour

To reap the rewards of costly signalling in monumental tomb construction, commissioners would risk personal reputation and local resources, as outlined above. In extreme conditions, the lives of workers were also at stake. Since no account of conditions or labour rights in Mycenaean tomb construction survives, analogy is necessary to explore the upper limits of management concerns for physically demanding labour with underground installations. It must be stressed that the conditions are analogous and not identical. For instance, unlike for lengthy tunnels and mines, separate ventilation shafts would not be as imperative for comparatively shallow tombs. Shoring of walls to prevent collapse, however, would be a shared concern among all underground operations, as would somatic requirements to sustain the health and safety of participants. For instance, Roman building manuals highlighted the need during the digging of wells to protect workers and prevent collapse by shoring walls with vertical wooden planks reinforced by horizontal cross-ties (Plommer 1973: 51). Mycenaean builders deployed temporary wooden framing in “pier-wall construction” to set walls, as seen in the Palace of Nestor (Blackwell 2014: 477 citing Nelson 2001). Examples of failure in meeting the somatic requirements of workers are prevalent in Classical accounts of slave uprisings, as well as the labour reforms of the nineteenth and early twentieth centuries (see below). What led to these reforms are some of the worst conditions ever recorded for manual labour. Many incidents involved mining operations, already risky enterprises for their substantial physiological and logistical demands. Shifting materials in subterranean passages required coordinated efforts to keep bodies in motion and prevent collapse.

Off-site, the workers had to be paid, housed, hydrated, and fed. For wage economies, these costs are easily traced in epigraphic evidence. From the second millennium BC, Egyptian and Near Eastern texts reflected suppressed wages in silver or their equivalent in grain (namely barley or wheat) allotments (Scheidel 2010: 439-440). Wages among unskilled workers in the early Roman Empire varied according to location but were comparable when linked to the local cost of wheat (Temin 2004: 519). Miners were compensated according to production in AD 164, sharing risks through contracts with employers (Temin 2004: 520). Signalling the Roman economic pillar of slavery, Plommer (1973: 8) referred to simple machines, even the *torcularia* mechanical presses, as little more than "expensive toys," using as his example Palladius (I, 18) calling for a *calcatorium* (treading floor) over the press advocated by Vitruvius. Similarly, long-term contracts for hired labour in fifth-century BC Athens had to be weighed against the upkeep for slaves performing similar tasks (Loomis 1998; Silver 2006: 259). Assuming illiteracy was the norm in the LBA Aegean, any compensation for workers would rely on verbal understandings. If conscripted labour was used in constructing monumental tombs, workers would still require substantial upkeep to divert counterproductive losses in ability or morale.

If providing ample food and rest guarded labour readiness, entertainment also diverted unrest, the recurrent *panem et circenses*. From a costly signalling and altruism perspective, few other categories of expected costs, risks, and rewards better highlight the disparity between commissioner and labourer (e.g., Murphy 1997: 51). Amassing support for infrequent events, the question of downtime loomed large for communal building projects in antiquity. If part-time specialists and travelling architects were employed to construct more refined tombs, as suggested by Boyd (2002: 61-62) for the large chamber tombs at Volimídhia and the rapid proliferation of the *tholos* tomb form from Messenia, tomb construction would not preoccupy anyone for long. Idle tomb builders flooding labour markets were not a plausible concern, unless work coincided – and competed – with contemporary public works. Roman efficiency in diverting labour resources provides one possible solution through strategic scheduling. Peacetime armies provided frontier labour throughout the empire, building public works for diversion and avoiding disruption of civilian labour markets (Temin 2004: 522). During the Irish famines of the eighteenth and nineteenth centuries, starving sharecroppers were redirected by landowners and government officials to build follies – roads to nowhere and elaborate buildings without purpose – to avoid direct handouts (Howley 1993). Mycenaean leaders could deploy similar tactics with unused labour if the need arose. Unfortunately for those leaders, both action and inaction with large groups could invite one of many demographic crises, sanitation first among them.

Beyond payment, subsistence, and diversion, construction programmes required adequate sanitation to ward off disease, a threatening equaliser for preindustrial costly signalling. Early urban contexts struggled for sanitation solutions with densely populated areas. By the late third millennium BC in Mesopotamia, Akkadian texts linked toilets and rubbish heaps to demons and blamed disease as bad luck brought on by divine disfavour (McMahon 2015: 21). Even so, building projects related to public utilities were not prioritised by rulers, and the bulk of responsibility fell on individual households (McMahon 2015: 19). Plumbing in Minoan palaces prioritised clean water and adequate sanitation, but public systems, like that in the crowded streets of Late Minoan Gournia, were improvised (Arnott 1996: 266). Streets were common catchments for waste in Classical Athens, collected by cleaners and reused in part as fertiliser (Jameson 1990: 110). Millennia later, the debilitating power of poor sanitation remains prominent, especially where events conspire to concentrate labour resources (e.g., Friedgut 1987: 249-250). For the Aegean, the consequences are evident in several cases since the Early Bronze Age. The mass burial of 12 individuals capped by a tumulus at Thebes in the late Early Helladic II period (ca. 2200 BC) revealed no outward signs of "long-term pathologies or trauma", reflecting a rapid event (Vika 2009: 2024-2025). Likewise, the Late Helladic IIA/B mass burial of 11 individuals at comparatively rural Nichoria in south-western Peloponnese suggested the possibility of an unknown epidemic (Arnott 1996: 265-266; Boyd 2014b: 197-198). More than a millennium later, Athens withered under a multi-year outbreak (ca. 430-426 BC) that killed thousands, felling their leader Pericles and leaving a mass grave of at least 150 at Kerameikos with three apparent carriers of typhoid fever (Papagrigorakis et al. 2008: 162-166). Overall, causes for the sweeping scale of the epidemic are still contested (Littman 2009: 456-459, 465-466).

The spread of many infectious diseases is unconsciously self-inflicted. As mentioned above in early land modifications, deforestation starting in the Neolithic could have contributed to a rise in malaria (Angel 1972: 90). Research into ancient DNA could revise the malaria hypothesis and proposed genetic disorders like thalassaemia in favour of iron-deficient anaemia acquired through poor diet (Chilvers et al. 2008: 2707). Without soft tissues and written records, only pathogens that leave signatures on bones can be identified here. Typhoid, smallpox, and cholera are conjectured throughout the early urban eastern Mediterranean but cannot be proven (Arnott 1996: 265). Pathological evidence from skeletal remains, sparse as it is from the LBA, cannot be linked conclusively to labour requirements temporarily increasing local population densities. It is possible that specialists and traders travelling from overseas could have brought pathogens with them, as happened during the devastating early medieval pandemic of mid-fourteenth century Europe. Larger Mycenaean settlements were famously connected to sea routes and materials from abroad, including potential pathogens. An influx of labourers was likely not necessary for tomb construction, but concern over sanitation is no less valid for locals brought into close contact for longer-running projects. Paradoxically, outbreaks could also improve circumstances for surviving workers. When the Antonine plague (AD 165-175) thinned the available labour pool in Egypt, wages doubled (Temin 2004: 519).

Compounding the risks from rapidly spreading epidemics, diffuse assaults on the health of workers could originate in the air itself. As with all underground work, long-term health risks resulted from poor air quality in enclosed spaces. Records for at least two millennia showed the diversion of substantial resources to ensure breathable air during tunnelling and mining. For example, from AD 41 to AD 52 under Emperor Claudius, the 6 km tunnel draining Fucine Lake into the River Liris prompted the sinking of ventilation shafts for each of the 40 vertical tunnels facilitating the removal of water and rock for the main channel, increasing costs substantially (Reitz 2013: 68-72; Thornton and Thornton 1989: 61-63). Given the consequences of inaction, this was not excessive. For the beleaguered early twentieth century copper miners of Montana, for instance, federal investigators found that 42% of Butte miners examined in 1916 suffered lung scarring from exposure to silica dust (Murphy 1997: 18). Lighting and ventilation were especially problematic prior to electrical lights and fans. Classical regulations in the Laureion mines near Athens attempted to limit the smoke from oil lamps with the threat of severe penalties for contractors (Marmaras et al. 1999: 362). Complications from lighting using open flames likewise jeopardised excavators of the pier foundations for the Brooklyn Bridge, with Washington Roebling's solution of shorter, vinegar-soaked wicks and alum-mixed tallow failing to alleviate concerns for ventilation (Fitchen 1986: 190). Prevalent in each tomb modelled during this study, a damp musk signalled exposure, however slight, to mould and bat faeces. Both are later additions, products of post-excavation conditions ideal for the new residents, but stale air would still greet entrants to vaults closed for months or longer. Digging the tombs in warm and dry conditions would also ensure inhalation of airborne particulates. Apart from a temporary inconvenience or general anxiety for proximity to the dead (see below), tomb construction would be sufficiently staggered (brief in duration and separated from other tomb construction) to limit connections to direct health consequences. A more easily recognisable hazard would be sudden injury, particularly that threatened by collapse under construction.

Visible in the short term and evincing emotionally charged responses that can culminate in full-scale rioting, accidental injury reduced the available labour pool and strained relations between workers and organisers. Incident rates from rapidly industrialising economies near the turn of the twentieth century show worst-case scenarios that are unlikely to have occurred frequently in prehistoric regional projects. For example, accidents injured as many as one-third of miners in the Donbass region annually prior to 1896 (Friedgut 1987: 246). Between 1914 and 1920, 559 miners in Butte suffered fatal accidents with falling rocks and mine fires (Murphy 1997: 18). Of the limited skeletal material that remains from the LBA, sudden injury and its causes are difficult to identify with certainty. Relating more to disease susceptibility, as discussed above, some data is available on malnutrition and anaemia through porotic hyperostosis, but not on the levels seen in the New World (Angel 1978; Buikstra and Lagia 2009: 15). Not surprisingly, there is a noticeable drop in the incidence of dental and skeletal indicators of malnutrition among the better-fed Mycenaeans in Grave Circle B (Arnott 1996: 266). Wear and tear from vigorous activity, however, is more evident in arthritic joints and traumatic fractures (Arnott 1996: 266; Buikstra and Lagia 2009: 17). Setting and immobilising bone fractures for healing seems to have been a common practice by the LBA, as well as the successful application of trepanation, including the example from the Agia Triada cemetery in Ilia (Arnott 1996: 268; Mountrakis et al. 2011). So long as complications from infection did not arise, Mycenaean healers could restore injured labourers in a matter of months (using the 12-week average cited by Arnott [1996: 268] for healing fractures).

As a final aside to tomb commissioners' preoccupation with designing the most advantageous form within their means, steps had to be taken to alleviate necrophobia among locals living or working in the vicinity of the tomb. Blocking the *stomion* served a dual purpose of limiting access from living intruders as well as the escape of vengeful spirits (Tsaliki 2008). As Boyd (2002: 83) puts it, the blocked entrance served as a liminal space "where the dead are transformed from recognisable corpse to part of the ancestral mass…[and]…where the living might go to stand on the edge of the world, at the interface between the living and the dead, to confront through the remains their beliefs about death and, if any, the afterworld". Large chambers and lavish gifts would further appease the interred and ease the minds of survivors. The location and orientation of the tombs may have been planned with local eschatology in mind, avoiding malevolent spirits among the living by following a particular spatial format (Mee and Cavanagh 1990: 226-227). At the same time, close association with the tombs of celebrated ancestors could advance the aims of living descendants through proximity to the tombs and the grand memories they recalled (Fitzsimons 2007: 114).

2.4. Summary

If the above discussion serves as any indication, tracking the costly signalling of monumental tombs and the altruistic sacrifices of their builders is no simple task. Quantifying the labour and resources directly involved, however, represents a step in the right direction. Prominent Mycenaean multi-use tomb styles evolved with passing generations, roughly progressing from tumuli to *tholoi* and chamber tombs between the seventeenth and fifteenth centuries BC (Section 2.1). During the following two centuries, the largest known *tholoi* were built near major citadels while chamber tombs of all sizes proliferated across southern Greece. Local geology encouraged experimentation with rock-cut tombs that mimicked the designs of *tholoi* at a much cheaper cost, opening participation in derivative mortuary legacies to less influential families (see Section 2.2; Chapter 4). Choice in which tomb shape and scale to follow amounted to a sponsor's gamble in the theoretical language of costly signalling and altruism (Section 2.3).

An empirical framework for measuring costly signalling among commissioners and altruism among builders recasts the decision to invest in multi-use tomb construction as a risk. Commissioners risked resources and communal support, while tomb builders ran a deficit of time spent on the legacy of others. Witnesses would weigh the authenticity of a tomb's type and scale against the position of the deceased and their followers. While a well-received tomb at the edge of social tolerance could boost support, overstepping expectations with too large a tomb might tarnish the memory of the deceased and undermine the influence of survivors. Too rapid a change in style would also raise eyebrows, throwing group identity into question. The first to build a local *tholos* or chamber tomb where earlier types predominated must have wagered this choice with witness opinion in mind. Upstaging a more powerful lineage with a mismatched tomb could upset the local order, a step not lightly taken for those expecting or experiencing loss and shifting roles (see Chapter 5). Social limits – rather than physiographic (Section 2.2) or economic constraints (Chapters 3 and 4)–restricted the scale at which tombs could be built. This chapter provided the theoretical basis for that judgment, while the following chapter grounds it with comparative earthmoving, energetics, and a relative index for pragmatically tracking signalling with tombs.

3

Artists at work: logistics in cooperative earthmoving energetics

> *"So architects who without culture aim at manual skill cannot gain a prestige corresponding to their labours, while those who trust to theory and literature obviously follow a shadow and not a reality. But those who have mastered both, like men equipped in full armour, soon acquire influence and attain their purpose."*
> Vitruvius 1.1.2, [Granger 1962]

Having introduced commissioner and builder motivations from collective memory, costly signalling, and altruism, I turn now to logistics in establishing a practical comparative approach to preindustrial earthmoving energetics. Logistics estimates planning, procurement, transport, manufacture, and assembly of materials through building mechanics, operational sequences, and architectural energetics, using rates of work derived from timed observations (hereafter labour rates). I hesitate to overcomplicate the process with anachronisms of a global supply chain and operations management, though eastern Mediterranean trade had advanced toward prototypical mass markets and standardisation before my period of interest (1600-1000 BC) (e.g., Berg 2004: 74; Broodbank 2013: 415). Keeping my frame of reference locked onto construction sites sharpens focus on the main logistical concerns of cooperative building. Few if any preindustrial planners would micromanage tools when coordinating construction, nor would component origins noticeably affect investment with common and multi-purpose tools. Optimised scheduling would also negate time-intensive techniques where excessive care sought precision (e.g., Blackwell 2014: 458), or when non-commoditised labour opted for inefficient methods discordant with industrialised markets (Baudrillard's (1975: 22-23) critique, see also Appadurai 1986: 31; Voutsaki 1997: 36; Voutsaki et al. 2018: 172). I propose instead to look at what has remained consistent: the average human's physical limits and the mutually intelligible sacrifice of pushing them. Whatever the case for value perception, shared technical and physiological constraints reinforce manual labour, logistically deconstructed, as a worthy comparative for past effort.

I use this chapter to explore the cross-cultural examples of earthmoving from which most labour rates derive, particularly what flies as an acceptable workload. Seldom do I mention logistics specific to Mycenaean multi-use tombs, preferring instead to contextualise these in the chapters to follow. In general terms, cooperative tomb building can be simply deduced from related tasks, though not so easily proven without written records. Local labourers likely built standard tombs with available handheld tools, at an exhausting pace surpassing daily routine but falling well short of the urgency inspired by a natural or military emergency. Available handheld tools might refer to digging sticks, chisels, and baskets sourced from nearby households and workshops, or in the case of expert stone-carving for large *tholoi*, quarrying saws wielded by specialists (Fitzsimons 2007: 104, 2011: 98). For Cyclopean fortifications Loader (1998: 46-49) split LH masonry toolkits into picks and wooden wedges for quarrying, hammers and chisels for shaping, and saws for detailed work, with reservations about copper and bronze saws being too soft to handle hard limestone and dolomite. Blackwell (2011, 2014) elaborated on LH masonry tools through tool marks, from the common kit to the pendulum saw (for this machine see Blackwell 2014: 454, 470). Examining the LH IIIB Lion Gate relief at Mycenae from a ladder, Blackwell (2014: 453) noted that the sculptors' kit contained "drills, saws, chisels, punches, hammers/mallets, scoring implements, and polishing devices", including rasps and whetstones. The technical demands of LH III stonework partly spurred this lengthy catalogue from competent yet modest beginnings. Tool scarcity at MH sites contrasted sharply with contemporary Crete and subsequent LH sites, where metal tools – particularly "bronze chisels and double axes" for stone- and woodworking – proliferated alongside Minoan and possible Hittite influences (Blackwell 2014: 452-453). From bowstring-powered tubular drills to simple hammerstones, manufacturing variety made use of sand, emery (rock type containing abrasive mineral oxides of aluminium and iron), water, oil, reed, bamboo, wood, bronze, and stone to abrade, polish, split, lever, cut, penetrate, and pound materials into shape (Blackwell 2014: 453-456). Unlike the toolkits accommodating ashlar elaborations in *tholoi* (Fitzsimons 2007: 104), most chamber tombs likely only required a fraction of these skills and materials.

With a credible workforce, economised daily-use tools could favour multi-purpose types and expedient local sources to cut waste and transport expense. Forged tools demanded a longer chain of nonlocal manufacture already embedded within regional trade, with evidence largely derived from catastrophic change (LH IIIB-C) or shipwrecks (e.g., Deger-Jalkotzy 2008: 401-402; Kristiansen and Suchowska-Ducke 2015: 363; Mee 2008: 363-365). Tracking the supply chain of tool components – distant ores in alloys for forged tools, for instance – would be superfluous in one-to-one comparisons for tomb building, as more such steps misrepresent worker readiness. Some careful analogies offset the gap where my shortcuts to tomb construction may seem unimaginative or flat, particularly where I omit speculative transport costs. The numbers that I ultimately call upon in the catalogue of tomb labour (Chapter 4) avoid becoming a spectacle themselves through simplicity. Their value is in comparing rather than retelling construction, dispensing with minutiae by cancelling out shared tasks. In other words, modelling tomb construction alongside a median standard needs no long strain of proof equations.

I arrive at the catalogue (Chapter 4) through two digital surveying methods – reflectorless total station drawing and photogrammetry – modified from Pakkanen (2009, 2018). Both were meant to undercut the cost of other three-dimensional digitisation of architectural remains while still providing accurate measurements. With that cost falling, however, most other forms of digital survey may soon be rendered obsolete. Given its explosion in popularity in recent years, photogrammetry is still comparatively inexpensive, and my trial-and-error anecdotes may prove useful for similar work. From this accounting of building materials – mostly rocky earth removed to shape the tombs – I infer the original dimensions and transient tasks that are less visible after construction. Transient tasks included temporary works such as shoring or scaffolding – otherwise termed “falsework” and deployed especially in the case of masonry vaults that were “virtually impossible” to construct without it (Fitchen 1986: 21, 85-87)–as well as supervisory and supporting roles that left no direct record while potentially doubling the associated workforce (de Haan 2009: 13). Quantification of tasks then requires estimates of the effort involved, usually measured in labour-time, energy, or wages in later monetised economies. Variability in these labour rates and their limited reporting stands out as one of the primary concerns of this chapter and the supplementary tables in Appendix 1 (see also Aaberg and Bonsignore 1975: 61; Abrams 1989: 76; Abrams and McCurdy 2019: 20; Lacquement 2009: 156; Remise 2019: 91; Turner 2018; Chapter 1, this volume).

After establishing my preferences for modelling earthmoving logistics, the final methodological step defines completed architectural forms and the taphonomic cycle that obscures them (Gifford 1981: 365; Schiffer 1972: 158). Since no preindustrial construction remains pristine, digital models must account for post-depositional modifications – most often denudation and ploughing for earth, decay for wood, and robbing, reuse, or collapse for stone. The method described at the end of this chapter shows the capabilities and limitations of digital surveying tools in measuring architecture for labour costs. Common problems here were inflated volumes caused by ceiling collapse of burial chambers and the failed rendering of models in tight, dark spaces. These spawned the supplementary short descriptions of other tombs in Appendix 2 with protocols for restoring the models from existing data (photos and georeferenced photomarkers). Like the tombs themselves, the only hindrance to a larger catalogue of labour models is time.

3.1. Construction planning and alignment: pragmatic signalling

Adding to those constraints from Chapter 2, here I review practical considerations in launching cooperative construction, with function (pragmatic signalling) helping to track socially cohesive (group signalling) and assertively deviant (costly signalling) architectural choices (see also Čučković 2017: 528; Gittins and Pettitt 2017: 470). As will be shown in Chapters 4 and 5 with greater nuance, Mycenaean tomb builders could opt for cohesive group signalling (Portes chamber tombs: same shape, similar scale), assertive costly signalling (Menidi *tholos*: isolated and expensive, with an innovative relieving system), or pragmatic signalling deploying both (or neither if the burden goes unnoticed) in a small space (Voudeni chamber tombs: freedom in shape and scale). In this way, the labour indexing to follow in the remaining chapters can shed loaded signalling terminology in favour of a tripartite cohesive-pragmatic-assertive scale for investment. More generally for earthmoving, a simple ditch can functionally reflect control over the immediate environment, water or waste management, and defence or delineation of territory, inspiring proportionate responses from labourers. Few have ever gleefully dug a latrine, but erecting a sacred place abounded with material and spiritual incentives. In each instance, function influenced scale (to a degree) and, by extension, labour investment. Those projects that overshot an expected standard retained pragmatic roles but exceeded the bounds of practicality, capturing labels of *monument* or *folly* (see Chapter 2). Rather than search for the pragmatic/monumental threshold through volumetrics or energetics, this chapter deconstructs logistical constraints as a companion to the grave reminders that guide tomb shape and scale through collective memory and signalling, costly or otherwise (see Chapters 2 and 5). Cross-cultural examples illustrate logistics for earthmoving as the most widespread and analogous task in human environmental modification.

Practical functions for earthmoving included navigational and calendrical aids, additions and modifications to infrastructure, and socioeconomic manipulations, such as diverting excess labour in times of crisis. As to the latter, researchers have highlighted power behind elite-sponsored, aggressive increases in cooperative construction (Fitzsimons 2007: 112-114; Trigger 1990: 127; Squatriti 2002: 16), though others have challenged the timing of increasing monumentality and power (e.g., Aaberg and Bonsignore 1975: 62; Abrams 1989: 62; Erasmus 1965: 278-280). In one common narrative, elites mobilised labour for aggrandisement or legitimation, tracking monumentality through a top-down flow of power (DeMarrais et al. 1996; Renfrew 1983; Price 1984; Sidrys 1978; Trigger 1990). In this sense, elite sponsors of construction acted as prime movers to exploit labour for diverse but predictable reasons. One such manipulation by ruling lineages called for the calculated redirection of surplus labour to invigorate redistributive economies and divert internal tensions (e.g., Abrams 1994: 92; Broodbank 2013: 420; Polanyi et al. 1957; Saitta 1997: 21). Leaders may have perceived a threat from the accumulation of idle time during resource-rich years, whether deriving from technological advances, successful conquests, or perhaps just a string of fortunate seasons triggering expansion (e.g., Clark 1998: 67; Webster 1990: 339-340). Repurposing part of that surplus away from survival tasks reset the balance and gave leaders a shield against restlessness among followers who might rebel. It also backfired where projects distracted from more immediate issues, like the European obsession with ditch-digging in the martial eighth century AD (Squatriti 2002: 14-15).

Visually influencing potential rivals and supporters, conspicuous displays in construction boosted the emergent elite as well as craft specialists, expanding economies to incorporate new roles. This has been articulated for the Mycenaean polities through administrative records and mortuary behaviour (e.g., Cavanagh and Mee 1999; Fitzsimons 2006, 2007, 2011; Parkinson et al. 2013; Pullen 2013; Voutsaki 1997, 2001; Wright 1987). Craft specialisation in tomb architecture cycled through several modes of elaboration: surface treatments like painted or plastered surfaces (Demakopoulou 1990: 113-115; Galanakis 2011: 223; Gallou 2005: 68-69; Karkanas et al. 2012: 2731; Kontorli-Papadopoulou 1987: 153; Sgouritsa 2011: 737-739; Smith and Dabney 2014: 148), sculpted scenes on stelae (Mylonas 1951), and non-structural decorative flourishes like the marble half-columns at Atreus (Mason 2007: 38) or the experimental relieving slabs at Menidi (Laffineur 2007: 122; see below and Chapter 4). Other specialisations included engineering and management, onsite roles that are less visible in the archaeological record than separate crafting workshops leaving structural and portable material remains. For instance, attached workshops generated palatial ceramics at Mycenae and catered more specifically to *kylikes* at Pylos, filtering to secondary centres like Tsoungiza (in Mycenae's case) as recognisable assemblages (Pullen 2013: 437). Ceramics like these frequently ended their use-lives in tombs alongside other items that flaunted a flourishing production network, for which the literature is vast. Mycenaean specialised crafts that can be tied to grave offerings and funeral/post-funeral activities included elaborate textiles, perfumes, glass, and metalwork known primarily from Linear B references to production and intermediary roles (Killen 2006: 87; Nakassis 2015: 584-588; Parkinson et al. 2013: 413).

Socioeconomic systems that channelled this specialised creative energy through elite patronage redirected unskilled as well as adept manual labour – the kind presumed to be directly responsible for multi-use tomb construction. Such labour was stimulated by bulk payment or raw material loans in exchange for their products (see *ta-ra-si-ja* in Killen 2001; Nakassis 2015: 584-585 with references; Shelmerdine 2001: 360). DeLaine (1997: 11) framed a similar scheme in the Roman tradition as liberality and munificence in aristocratic-led building during peacetime. Mycenaean economies spawned certain crafts and construction within administrative networks built around elite nodes of wealth, partly redistributed using established systems: households, communities (*damos*), and sanctuaries (Lupack 2011: 207; Pullen 2013: 441). Although their dependence on palatial centres is debatable (e.g., Killen 2006; Lupack 2011; Palaima 2015: 638; Parkinson et al. 2013: 414; Shelmerdine 2006: 84), elites named on tablets orchestrated a substantial flow of goods and services, from chariots and perfumes to smithing and shepherding (Nakassis 2015: 584-585; Schon 2011: 221-222; Shelmerdine 2001: 360-361). No great interpretive leap barred those elites and advancing sub-elites from commissioning larger, better-built tombs to strengthen and preserve their families' position. Perhaps the sizeable middle class suggested by Broodbank (2013: 415) as supporting eastern Mediterranean trade during the second millennium BC can partly account for the scale and spread of standard chamber tombs across southern Greece. Whether these tombs measurably boosted an otherwise vibrant economy is less critical than their place in an existing system capable of efficient construction. Locals drove exchange of portable crafts and were more than capable of building and filling multi-use tombs with metalwork, jars of perfumed oils, and other materials from near and far (see tomb descriptions in Chapter 4).

That aptitude for earthmoving was likely honed outside mortuary construction, with infrastructure stimulating interconnected economies in a feedback loop. Earthmoving enhanced infrastructure and connected regional partners. Roads and dykes generally claimed priority – both in order of construction and research – but more elaborate transportation also demanded labour-intensive earthmoving. Bronze Age planners circumvented the Aegean's broken terrain with bridges and water transport by dredging harbours and canals (Fitzsimons 2007: 112-113, 2011: 109-110; Hope Simpson and Hagel 2006; Mason 2007: 39-40; Shelmerdine 2001: 339). Through networks of canals and terraces, irrigation and erosion control also bolstered agrarian economies susceptible to variations in annual rainfall (Aaberg and Bonsignore 1975: 44; Arco and Abrams 2006; Hard et al. 1999), a noteworthy problem in southern Greece (see Chapter 2). Terraces were incorporated into the extensive road network connecting major sites in the Argolid, as well as during new construction at Pylos, Tiryns, and the extensive LH IIIA2 remodelling of Mycenae's acropolis (e.g., Mason 2007: 40, 44-45; Nelson 2007: 150-151).

Perhaps the most visible pragmatic role for earthmoving lay in defence. Unmodified, earthen ramparts offered very little as a practical obstacle apart from hinting at a larger defensive force, inspiring confidence in communal wherewithal, and deterring expedient raids (Tracy 2000; Turner 2018: 207-210, with references; Tyler 2011: 157). Early medieval chroniclers Gildas and Bede openly disparaged earthen defences, which they cast as a long fall from Roman engineering (Squatriti 2002: 27; Tyler 2011: 159). Ironically, engineers in Roman Britain had built substantial turf forts like the first century AD Lunt near Coventry, partially reconstructed by prison labour in 1966 (Coles 1973: 79-82). Real or imagined, major linear earthworks served practical needs for martial posturing, and smaller earthen enclosures had merits in communal defence and food security (Turner 2012, 2018). Rather than earthen ramparts, stone rubble and earthen fill sheathed in stone masonry constituted the bulk of Mycenaean circuit walls (Boswinkel forthcoming; Loader 1998), but it is the stones that have attracted the most attention. Accumulating earthen fill for a wall required ramps, mass coordination, and brute strength, parallels only the largest known *tholoi* would share from mortuary construction. Cutting a smaller tomb into soft rock or building it from stones less than 50 kg each demanded small teams and far less planning (see below, *Transport* under Section 3.3.2 for human portage limits). For my case studies, only the Menidi *tholos* and the largest chamber tombs at Voudeni would benefit significantly from intensive planning, particularly in the organisation of wheeled transport to move materials to and from their entrances.

Scheduled earthmoving could be recurring or executed on demand depending on task-related timekeeping. Earthmoving itself marked time, tying into food security and socioeconomic incentives with calendar and repetitive acts that reinforced collective memory and group signalling (see Chapters 1 and 2). I treat scheduling here as another influence to the planning and scale of tomb construction, since most of my case studies were presumably purpose-built (unscheduled, rarely pre-emptively built or seemingly never used, e.g., Boyd 2002: 59; Papademetriou 2001: 67) and angled with the surrounding slope without apparent regard for celestial alignment (see below and Chapter 4). Elsewhere, timekeeping with earthmoving did rely on line-of-sight spatial relationships, notably with celestial bodies as reconstructed through archaeoastronomy (Baity 1973; Ruggles 2005). Most attempts at incorporating cultural astronomies – historical and contemporary social conceptions of celestial phenomena – have focused on the orientations of earthworks and megaliths, particularly entryways marking sunrises or sunsets at certain times of the year (Aveni 2003; Hively and Horn 2013; Kelley and Milone 2005; Ruggles and Barclay 2000). Connecting timekeeping and food security, star and planet alignments that signal a solstice or equinox provided a benchmark for important seasonal events, such as the migration of game or optimal planting windows (Malinowski 1927; Leach 1950; Rice 2007; Varisco 1993). Applications of archaeoastronomy in Greece have typically focused on traditions from the fifth and fourth centuries BC (Boutsikas 2007; Boutsikas and Ruggles 2011), but precedents have been found centuries earlier for alignments of tombs at Mycenae (Maravelia 2002) and palatial architecture at Knossos (Goodison 2001, 2004).

Timekeeping through construction also manifested as regular social reinforcement, building in part on collective memory. Occurring at set intervals, activities like mound-building highlighted episodes of social cohesion that strengthened group identity for scattered populations. For instance, Neolithic pastoralists in southern India erected ash mounds of burned cattle dung as a means of maintaining an annual ceremonial rhythm (Johansen 2004). Similar recurrent mound-building strategies have been inferred from geoarchaeological analyses of mound sites in the south-eastern U.S. (e.g., Sherwood and Kidder 2011), notably shell middens in coastal areas and iconic earthen complexes in the interior. Multi-period mound construction proliferated in the later prehistory of eastern North America, where conical burial mounds and low, rectangular platform mounds marked areas for recurrent gatherings and feasts (Lindauer and Blitz 1997: 186), some of which were linked to observed traditions like the "green corn dance" of the Muskogee (Knight 1986: 683 with references). Micro- and mesoscale approaches to mound stratigraphy here have identified patterns where collective labour and feasting created a seasonal cycle of intensive resource exploitation (Sherwood and Kidder 2011: 72; Sherwood et al. 2013: 345). Similarly, feasting supported Mycenaean construction activity in the sense of redistribution and camaraderie (Brysbaert 2013: 84), as well as accompanying funeral/post-funeral activities honouring the dead (Borgna 2004: 263-264; Cavanagh and Mee 1998: 111; Gallou 2005: 112; Gallou and Georgiadis 2006: 128; Hamilakis 1998: 119-120).

Even with ambiguous calendrical importance, all visible earthworks could serve as geographical markers, complementing natural landmarks in the mental maps of pre-literate trackers and the physical recordings of early cartographers. In this sense, navigation prolonged the influence of cooperative construction as long as the feature remained noticeable. Mycenaean case studies for navigation via earthworks have focused on routes through broken terrain. For Mycenae, the mound over the LH III Treasury of Atreus occupied a prominent position that confronted observers travelling along roads outside the citadel (Mason 2007: 47-48). The mound temporarily blocked views and forced a circuitous route to the citadel for visitors approaching from the south. The proliferation of earlier LH II *tholoi* likely stemmed from local elite, but they have also been cast as territorial signs of Mycenae's expanding influence in the Argolid and Corinthia (Fitzsimons 2011: 99-100). For Pelon (1976: 99), however, Aegean tumuli did not occupy prominent places deliberately, with the many existing examples on summits being products of erosion or survey bias (Cavanagh and Mee 1998: 25; see also Alcock 2016: 4). Homeric tumuli were variously lookout points, territorial markers, and testaments to heroism (Schnapp-Gourbeillon 2016: 207). Whether occupying a topographic highpoint or not, tumuli tended to hold commanding views along the axis of adjacent ravines and in many if not all cardinal directions (Angeletopoulos 2016: 2). Galanakis (2011: 223-224, 227) limited claims on visibility to close-quarters viewing for Messenian *tholoi*, many of which were built above ground and subsequently covered, occasionally with a protruding vault coated in plaster as a visual draw. For the case studies presented in Chapter 4, the tombs were indeed carved into hills with commanding views (absent the current tree canopy shielding much of Portes). Despite closed and hidden entrances, clustered hilltop tombs would be recognisable to contemporaries as territorial markers, orienteering aids, and memorials of social and spiritual significance. If closed and relatively inconspicuous, they achieved this from privilege or deference in collective memory, primarily from post-funeral repetitive acts (Boyd 2014a, 2015a; Galanakis 2011; Gallou 2005). This could change if evidence surfaces of above-ground markers like the grave stelae at Mycenae, set above Shaft Graves and vulnerable to collapse (Mylonas 1951; for the reset stele of Grave Gamma see Button 2007: 85; for tomb visibility see also Chapter 1, this volume).

Navigating space relative to visible structures is straightforward, but the orientation of the structures themselves poses interpretive problems. Some Messenian *tholoi* have been enriched by unambiguous connections to nearby settlements. The LH I Tholos IV at Ano Englianos, otherwise known as the Palace of Nestor in Pylos, opened directly in line with the north-eastern gate of the early LBA fortification wall encircling the summit (subsequently to house palatial buildings) opposite the tomb (Galanakis 2011: 224-225). Together with the Vagenas Tomb 400 m to the south on the opposite side of the ridgetop, Tholos IV has been cast as a territorial marker (Galanakis 2011: 225, citing Bennet 1998, 2007; Wright 1984). For the expanding Pylian polity, the construction of Tholos III 1 km southwest of Englianos also played into this idea of spreading monumental markers for travellers to encounter (Galanakis 2011: 226), similar to the MME *tholos* at Nichoria (Wilkie 1987: 128-129). For the hilltop tombs at Voudeni and Portes, however, most entrances simply followed contours in a radial pattern, cutting into the slope toward the summit (Chapter 4). The Menidi *tholos* similarly faced away from higher ground. This was logical for keeping more ballast above the burial chambers, thereby mitigating risk of collapse through better distribution of forces in overlying soils and perhaps economising by supporting vaults directly on bedrock (Boyd 2015a: 202; Cavanagh and Laxton 1981: 115-119; Galanakis 2011: 223; Giannakos 2015: 71). It was also easier to remove materials nearer the surface by funnelling them downslope, an advantage that evaporated with depth from the countering slope of the *dromos* itself. Since people were economically and technologically capable of building bigger, the final logistical constraint to moving many tonnes of earth and rock lay with socially appropriate timing.

3.2. Further projections on time constraints

The timing of increasing construction scale challenges social acceptability rather than capability, as emergent leaders risked leveraging personal gains against communal obligations (Bourdieu 1990: 153). For Late Archaic builders in the Central Andes, large-scale public building originated with corporate authorities that avoided displays of personal interest (Sara-Lafosse 2007: 154-155). Early farmers in the Tehuacán Valley of Central Mexico likewise began work on the earthen Purrón Dam before differential wealth for leading factions fully materialised, allowing wealth accumulation to begin in earnest over the control of water for vital irrigation in an arid region (Spencer 1993: 49-51). The latter case especially illustrates the capabilities of communal construction to overcome environmental limitations, even without strong central leadership. Similar irrigation works directed under comparatively limited political authority have been attested in East Africa (Goldsmith and Hildyard 1984; Gray 1963; Moore and Puritt 1977), the American Southwest (Gilman 1987: 545; Trafzer 2015), Polynesia (Kirch 1990, 1994), and Bronze Age Turkmenistan (Arciero forthcoming). Scaled up under complex labour organisation, water manipulation with earthworks was writ large, for instance, by Mycenaean engineers who emptied the Kopias basin (Giannakos 2015: 73) and Roman engineers who redirected flows in water-rich Britain (Rogers 2013: 130) or along the Tiber itself (Purcell 1996).

A long view of behavioural parallels in building starts with a simple diachronic look at nomadic versus sedentary habits. Nomadic constructions generally paired lower initial efforts with anticipation of shorter use-life as populations continually relocated (Abrams 1989: 54; McGuire and Schiffer 1983: 284). Seasonal cycles of semi-sedentary groups encouraged cooperation with multiple local groups, allowing larger communal efforts to coalesce around important nodes of recurrent activity. Social importance of locales snowballed along a compounding accretion mechanism, easily imagined for earthen mounds built in stages of construction over generations as well as the repeated use of mortuary spaces. For domestic architecture and other environmental modifications, initial investment increased to offset greater long-term costs in upkeep for recurring settlements (Abrams 1989: 55; McGuire and Schiffer 1983: 286). Although no longer couched in these terms, White (1943) and Cottrell (1955) simplified similar construction evolutions by pairing increasing energy reserves from technological advancement with the expansion of labour potential and pursuits beyond subsistence. Labour studies advanced along these lines to track the culprit behind increased scale and elaboration in construction. Focus shifted away from social hierarchies (e.g., Childe 1950; Morgan 1881; Squier and Davis 1848) toward labour indexes for relative demography (Cheek 1986), complexity (Erasmus 1965), and specialisation (Abrams 1987).

Lack of chronological resolution and contextual clarity discourages converting labour into demography and socioeconomic impact from individual construction sequences. Where no clear sequence of construction survives, labour studies approximate a reasonable series of events but rarely synchronise activity with calendar years. Abrams (1987: 488) argued from practicality for sequential rather than simultaneous construction for the Main Centre at Copan, citing calendar inscriptions and stylistic dates that packed events within a decade (AD 763-771). LBA Aegean contexts typically lack chronological resolution with short-term changes due to subsequent activity on crowded sites like Mycenae (e.g., Boyd 2015a: 201). Although my case studies stretch into centuries of use, their initial construction and episodic reuse were likely limited to a fraction of that time. In that sense, tomb labour should be detached from the sense of rolling costs that total labour typically conveys. A similar reversal toward episodic tomb construction rather than cumulative costs has been applied in Laconia, albeit with a strong critique of other energetics approaches (Voutsaki et al. 2018: 172).

One way of comparing earthmoving without conflating or compressing multi-period construction comes from the well-studied moundbuilding phenomenon in North America. When facing multi-stage mound construction spanning more than a century, Lacquement (2009: 143) rightly pointed out the benefit of applying energetics to discrete episodes of construction, rather than the abstract pursuit of total labour costs. He used roughly a month-long window for construction and capped available labour to total population at 1:5 – a conventional ratio for estimating population from households (e.g., Aaberg and Bonsignore 1975: 45; Moore and Puritt 1977: 2). Lacquement (2009) also split labour along hypothetical requirements for three stages of mound construction at Moundville (ca. 1200 AD) in western Alabama. These ranged from smaller episodes capable of completion by kin-based groups (minimal lineages) to large endeavours requiring communal participation organised by the centralised elite. Such occurred at several mound complexes along major rivers east of the Great Plains during the early second millennium AD (e.g., Barrier 2011; Holley et al. 1993; Knight 2004; Peebles 1971; Reed et al. 1968; Trubitt 2000; Welch and Scarry 1995). Since isolated, lump sum labour costs for multi-stage construction can be decried as oversimplified or flat, more is needed about the progression of work from daily routine to communal effort.

3.3. Tracking progress from household to cooperative labour

Study of past labour typically separates the built environment and portable material remains when reconstructing daily routine. Both fall into the objects and work categories of Monica Smith's (2012: 45) tripartite division of human quotidian activity, with the third being food. Disassociating labour from elite exploitation with a broader definition of work, Smith (2012: 46) added to simple physical costs with "intangible activities such as storytelling, memory-work, adjudication, and other forms of communication". Examining labour in terms of earthmoving requires a breakdown of physical costs as well as these integrative mechanisms of communication that encouraged cooperative behaviour among non-related individuals. Allowing for altruistic labourers and gambling sponsors in shaping tombs (see Chapters 2 and 5), there should be a pragmatic way to track progress and consequences. In other words, what happened when logistical constraints challenged the resolve of participants in changing daily routine? If, for instance, surplus labour required the maintenance of cooperative effort over fragmentation from self-interest, what strategies did leaders deploy for cohesion and how did the strength and frequency of these strategies change closer to the fracture threshold that halted work? This has been a marked concern in the evaluation of pre-modern states and the tracking of inequality in the global market economy (e.g., Collins 1988; Levi 1988; Lichbach 1995, 1996; Rothstein 2000). More relevant for my focus, I contend that low-cost, low-skill labour requirements had an outsized, compounding effect on communal tolerance for lineage extravagance, and that this could hide behind deceptively low labour costs. Thus a comparative labour index (Section 3.4.2) can frame tolerance and extravagance as factors of signalling (cohesive/group-pragmatic-assertive/costly) or scaled investment (undersized-standard-exceptional). For instance, taking 9 days with 70 labourers to build the exceptionally large chamber tomb 75 at Voudeni sounds much less extravagant than when phrased as a tomb 9 times the standard cost and 51 times the cheapest completed chamber tomb (VT3) (see Chapter 4). The problem of how to express labour in meaningful terms can be traced back to where labour studies diverged along qualitative and quantitative inquiry.

Where comparative labour developed from earlier descriptions of architecture, one contentious divide separated qualitative and quantitative comparisons. The advantage of quantitative studies, no matter how measured, offered a comparable medium directly linked to the structures and artefacts into which people invested their time (Abrams 1989; Price 1982). This empirical shift in thought did not immediately translate to higher accuracy, as conclusions still funnelled toward problematic categorisation of social complexity (e.g., Cottrell 1955; Erasmus 1965). Early estimates for labour costs often misfired from fatuous historical accounts. Cottrell (1955: 33), for instance, inflated the severity of Egyptian construction: “The population was held constant or even diminished, since men were worked to death about as fast as they could be brought to maturity”. Under this prelude, he repeated historical hearsay from Herodotus that 100,000 slaves, or 4% of the population, built the Great Pyramid at Giza in 20 years. Dunham (1956: 165) quickly revised Herodotus’s “gross exaggeration” down to a more manageable 2,500, not counting those involved in supporting tasks beyond the main construction site.

Quantitative approaches to the built environment split further regarding what to measure: the final product or the invested process tracked through volumetrics and energetics. In many multi-stage constructions, energetics maintains analytical advantage over volumetrics’s tendency to repeat abstract cumulative costs, whereas energetics can be split into episodes of construction more relevant to labour’s impact on populations (Abrams 1989, 1994; Lacquement 2009, 2019). This has not deterred effective comparisons with volumetrics as the preferred baseline for the macro-scale view of moundbuilding (e.g., Blitz and Livingood 2004), despite limitations on available dimensions leaving these studies more exposed to revision.

Volumetrics and derivative energetics must tread carefully with their chosen measurements, particularly when relying on reported figures. Updating the volume estimates for the 32 earthen mounds at Moundville, Lacquement (2009: 25) discovered that previous volume estimations had exaggerated the size of some mounds by more than half, revising the total from 275,000 to 192,000 m^3. As shown elsewhere (Turner 2018), even a 30% reduction in size does not affect the corresponding energetic cost as much as a seemingly small tweak in the labour rate used. Sorant and Shenkel (1984) observed that planimetry using contour maps yielded greater accuracy than solid geometry, with Shenkel (1986: 213) later indicating differences ranging from -60 to +130% over previous measurements for monumental earthworks across the eastern U.S. Milner (1998: 145) showed much the same phenomenon for eleven mounds at Cahokia, with differences of 2-27% and a 6% average.

In correcting these volumetric issues, Lacquement (2009: 32) recognised that outdated technology and time obviated the use of planimetry over modern techniques. His gridding method also relied on contour lines, but using the SURFER (v. 8.0) and DIDGER (v. 4.0) programs to digitise contour maps and aerial photographs, he broke the three-dimensional model of the mound into thousands of rectangular prisms. These he likened to the virtual stacking of dice as opposed to the "frustum-shaped pancakes" limited to the few contour lines encompassing a mound in the previous technique (Lacquement 2009: 32-34). This accounted for many more variations in mound shape that undermined previous geometric methods of measurement, including irregular mound shape and sloping pre-mound surfaces. Digital modelling with measurements from total station survey and photogrammetry largely skirted these considerations for my purposes, but it is important to mark this step away from simple volume equations.

With a handle in place for measuring physical dimensions, comparisons should account for past perspectives with a recognisable standard, such as house construction (e.g., Devolder 2013; Harper 2016; McEnroe 2010; Walsh 1980; see also Boswinkel forthcoming). For instance, reconstructions of wattle-and-daub Neolithic houses yielded estimates of 150 person-days for total construction, with the 9 tonnes of clay used in the walls requiring 5 person-days (10-hour workday) to dig (Coles 1973: 55-57, citing Hansen 1961, 1962). This compares favourably with estimates from Abrams (1994: Table 8) for the lowest-tier of domestic architecture around Copan, requiring roughly 100 person-days for a wattle-and-daub structure set on a low earth-and-rubble platform. In contrast, observations of log cabin construction in northern Canada during the late eighteenth and nineteenth centuries showed that 4 person-days were sufficient for a 6-x-4 m rectangular structure, since this type required only a fraction of the materials used in wattle-and-daub construction and no wall-trench (Coles 1973: 55, citing Guillet 1963). In any case, reporting a larger house or tomb with a standard cost means more than the cost itself, such that one with a house worth 1,000 person-days fails to convey the message of excess that one worth 10 houses would. Social tolerances fluctuated to accommodate bolder choices in domestic and mortuary architecture since the communal benefits therein were unclear. In relative comparisons of house size, ethnographic surveys have shown size disparity for leaders in formative ranked societies, going so far as a direct index of political standing in the case of Polynesian sanctuaries (*maraes*) on Tahiti (Goldman 1970: 177). Redirection of surplus labour for personal use in stratified societies amplified residential inequalities, whereas restrictions formerly would have appeared to curb domestic extravagance where egalitarian values still predominated (Fried 1967).

Labour studies have commented previously on the ramifications of communal overreach, wherein a population surpasses its limits and readjusts. This logic has often appeared under discussions of systems collapse (e.g., Tainter 1988). Problematically, most empirical approaches to labour have used minimalistic costs that undermine the effects of communal effort, reducing it in some cases to a diminutive fraction of preindustrial potential. Reporting house construction costs at Nichoria as 1.1 million person-hours over 750 years, Walsh (1980: 80-85, 100) trimmed the annual cost to under 2,000 person-hours (40 days for a 5-person crew working 10-hour days), reducing skilled workers to part-time for having so little to do. Abrams (1987: 493-494) likewise rejected the potential for socioeconomic stress from labour demands for monumental construction in the case of Late Classic Copan. He cited estimates for labour involvement in elite projects as low as 1.5% of the annual available labour. Abrams contended that the degenerative effects, if any, of unreasonable construction demands could only form a small part of a much larger problem. This view rightly corrected qualitative overestimation, but it omits the multiple, compounding issues implicit in systems collapse and household overreach.

Demography and territoriality have played a larger role in comparative labour studies in European contexts. Case studies have ranged from the proliferation of small fortified sites with stone towers in late prehistoric Scotland (e.g., Armit 1990; Gilmour and Cook 1998; Hedges and Bell 1980; Parker Pearson et al. 1996) and Sardinia (Webster 1991) to medieval earthen constructions demarcating territory or rudimentary defence in northern Europe (Biddle and Kjølbye-Biddle 1992; Graham 1988; Hill 2000; Redknap 2004; Squatriti 2002). Problems arose when drawing these studies into the comparative frame, since labour rates that appeared here also privileged timed observations from the Americas. For example, preliminary assessments of labour deflated qualitative assumptions of significant effort in the building of *nuraghi* (stone towers incorporating corbelled vaults) on Sardinia, but these conclusions relied upon labour rates from Abrams (1984) and Erasmus (1965) using volcanic tuff half the density of the target material of basalt (Webster 1991: 852). Investing labour rates with more robust comparative value requires an intensive reassessment of preindustrial logistics.

3.3.1. Preindustrial construction logistics

Retracing preindustrial logistics rewinds work from architectural remains, accounting for post-depositional effects and breaking apart construction into its myriad components. Although threatened by minutiae and speculation, restructuring labour costs with logistics faithfully models the construction process *and* contemporary perception. The following sections attempt to run diagnostics on direct aspects of preindustrial construction: planning, performance, and product.

Planning and guidance

Before breaking ground on a project, sponsors wishing to mobilise workers called upon a management framework, either an existing one, such as a lineage, guild, or military group, or one purposefully designed. Such frameworks could change throughout a project but must have lent stability under duress. Stability derived from many sources: charismatic leaders, visible progress, and completion incentives being the first to mind (see below). Circumstances aside, an effective management network could bridge the narrow gap between success and failure. Concerning management relationships in Classical Greece (Burford 1969: 128-144), the building commissioners and prominent financial supporters of public works left most technical decisions to the architect and contract holders. Sponsors exercised duties of oversight as problems arose or completed work stages demanded the next payment instalment. However, by virtue of status and personal wealth, many in this position developed some technical expertise as a matter of interest and spectacle (Burford 1969: 128).

In addition to the individual or group commissioning projects, primary designers fulfilling the role of architect, engineer, or master builder translated ideas into reality. Whereas heads of households initiated construction for domestic needs, community councils or respected voices encouraged mid-level communal projects that called upon familiar skills already deployed by households. The novelty in higher-level demands was more an issue of scale and vision than one of technical advancement (Smith 2012: 57-58). Setting aside delegation to specialists and supervisors, few concurrent persons operated at the top of larger-scale projects. Vigorously studied, such commanding personalities in construction emerged as iconic Classical Greek architects. From inscriptional evidence and Plato's perspective, the role of the Greek *architekton* was that of a master builder (or master carpenter in the original sense) and overseer of construction, directing work on-site rather than designing from afar (Burford 1969: 138-140; Coulton 1977: 15). In practice, the role covered a far-ranging spectrum of duties from administrative clerk to engineer, inspector, and designer, all without a formal system of mechanical theory until the late fourth century BC (Coulton 1977: 16). Working primarily from inscriptions, Burford (1969: 144) highlighted the temporary, reputation-dependent status of two architects for the fourth-century temple complex of Asklepios at Epidauros, characterising Polykleitos as an experimental artist and Theodotus as more of a robotic follower of training. Abrams (1987: 492-493) also made a convincing case for a lone royal architect at Copan by stripping the role of its modern implications (e.g., compliance with governmental regulations, coordination with specialists, mediation of land disputes) and suggesting simplicity in its preindustrial manifestation.

Although heavy with modern comparisons, when placed into context the preindustrial architect did contend with extraneous issues, just under different circumstances and labels. Coulton (1983: 453) mused that the Pergamene kings Eumenes and Attalos may have conceived of projects and hired workforces led by a master architect, but it was the architect who controlled details like palm capitals. Architects in Classical Greece navigated the restrictions of tradition, pre-existing sacred spaces, and cult prescriptions in religious architecture, such that the demands of designing new constructions could not benefit from the freedom of a blank slate (Burford 1969: 41-42). Meeting demands of patrons while still erecting a viable structure involved more than aesthetic decisions, and coordinating with specialists could haunt the mediator with logistical nightmares. In place of the plumbers and electricians Abrams (1987: 492) mentioned as examples of dropped interactions, plasterers and sculptors required oversight from the master architect. Autonomous skilled positions could prove advantageous – or threatening if mishandled – to patrons and architects. Burford (1969: 206) asserted the relative independence of skilled workers from city patrons, who courted them to strengthen the labour capabilities of their respective communities. Reducing the role of architects and skilled workers gives the false impression of shells only responsible for repeating architectural designs that were already established. What appears now as flat in the *longue durée* may not have resulted in a generational copy-and-paste when these structures were in use. Such complications rang true for the Roman context, wherein DeLaine (1997: 45-68) tracked the architect's design hurdles for the Baths of Caracalla through reconstructed blueprints and lessons from Vitruvius.

Recruitment and supervision followed the project conception or design in the steps toward material realisation. Grain allotments mentioned in the Linear B tablets from Pylos have been linked with preparations for unskilled labour recruitment (Nakassis 2010). On labour recruitment at Copan, Abrams (1989: 73) suggested available sources along a three-tier system of need: family volunteers for basic domestic work, cooperative recruits from a larger corporate kin subset for upscale structures, and corvée labour for monumental public works or private investments by leaders. In a more popularly known example, there were strong indications for the importance of kin groups in organising labour for the movement of the Easter Island *moai* stone statues (Cotterell and Kamminga 1990: 225). Supervision proportional to the size of the workforce and the complexity of the task factored somewhat less than the average labour pool, with DeLaine (1997: 107) citing

3-20% as an appropriate portion and 10% as the most often employed (see also Brysbaert 2015: 101-103; Pakkanen 2013).

Although less so than other building materials, earthmoving required coordinated efforts to shift from the first load. Subsequent loads claimed less thought as they followed the first, so long as the basic tasks (e.g., digging, carrying, depositing, tamping) found their rhythm. Where and how an earthen construction took shape needed foresight on sourcing and placement to minimise interference and waste, but the real obstacle to navigate remained worker motivation. Since a single labourer saw no immediate benefits when performing repetitive tasks for a much larger purpose, management networks triggered one or more powerful cooperative emotions, such as pride or fear (see below). Fear ranked foremost in previous models of coercive labour (e.g., Cottrell 1955: 33), but societies where power remained diffuse earned alternative explanations. Symbolic importance, not coercion, was responsible for the sustainment of Chaco Canyon with maize from up to 90 km away (Benson et al. 2003; Saitta 1997; Windes and McKenna 2001). Enthusiasm and confidence in vested parties completing work contracts sustained the building of the first stone temple at the sanctuary of Asklepios at Epidauros, although threatening fines for failing contracts also encouraged compliance (Burford 1969: 59, 88-118). Communality, pride, and ritual influence have been suggested for platform mounds and pyramidal monuments in Central and North America (e.g., Aaberg and Bonsignore 1975: 49; Blitz 1993; Erasmus 1965). Late Archaic building at Poverty Point in Louisiana especially has defied previous assumptions with its nonlocal labour in the absence of coercion (Aaberg and Bonsignore 1975: 62). This ties into the discussion above on the social dimensions of earthmoving (see also Chapter 2), where reasons for building multiplied with socioeconomic complexity, despite inherent difficulties in disentangling motivational cause-and-effect.

With a management framework guiding a motivated workforce, cultural memories and personal skills from instruction and experience shaped labour into material reality. Initiated toward a communal objective, received instruction and heuristic experience informed individual tasks. Instruction sparked learned skills much as coming-of-age ideals revolved around shared myths and their recurring quest-for-value components (Greimas 1987; Propp 1968) Skills filtered through recipients (relatives, students, acolytes, apprentices), who augmented or devolved them depending on their own aptitude and interest. Subsequent generations either passed the torch or saw the flame extinguish from resource exhaustion, falling demand, or abrupt catastrophe. For the Aegean Bronze Age, pedigrees emerged from the founders to their offshoots where techniques and materials – like tomb shapes (Kontorli-Papadopoulou 1987: 145-147), pottery (Maran 2007: 174), and cylinder seals (Broodbank 2013: 415, citing Sherratt 2010), were openly imitated, improved, or ignored.

Instruction began early through familial ties. This allowed for a chain of inherited memories that relayed resource locations, optimal workflow, and tool use. The complement to this, heuristic experience, rewarded exploration and innovation rather than repetition of received instruction. Prevailing wisdom appealed to conservatives but eventually ran afoul of finite resources or waning interests, prompting chain reactions that withered support from supply or demand. If unchecked, conservatism led to errors in contemporary designs, such as that seen in Egyptian calendar ceilings and water clocks (Cotterell and Kamminga 1990: 60-61; Neugebauer 1983). It also led to bitterness over perceived changes in life's pacing. Although simplifying instructions from Vitruvius on the making of timekeepers, Faventinus hinted at the importance of the sixth and twelfth hours in functional design and accuracy, while dismissing the notion of accuracy less than an hour with the quip that men are in such a hurry that they will only ask what hour it is (Plommer 1973: 81-83).

Generational disruptions weakened instruction among households and small communities, but larger populations absorbed losses through innovation. Innovation could also backfire when mechanical theory lagged. In the case of parachutes, for instance, Cocking's inverted parachute and Reichelt's parachute jacket both resulted in the deaths of their inventors (Cotterell and Kamminga 1990: 45). Harder to trace without immediate consequences, structural failures in prehistory would have been no less dramatic. Blame may not have landed on the right culprit every time, but patterns would stand out where collapse occurred repeatedly. Adaptive changes to designs addressed structural issues without necessarily requiring understanding of the underlying mechanical theory (Coulton 1977: 16), much of which did not develop until the last half-millennium. Expected knowledge and responsibility were relative. Romans divided architecture into eight constituents, an elaboration on five inherited from Greek tradition, as "order, disposition, beauty, measurement, distribution, building, siting and mechanical engineering" (Plommer 1973: 41). Much of this had to do with managing water. Plommer (1973: 20-31) covered anecdotal instructions for cistern and well-making, baths, and hydraulics, originally in the refined prose of Vitruvius directed at public architecture and later modified for the private scene by Faventinus and Palladius. Competency could still ignore wilful mistakes, as the widely known deleterious properties of lead-piping failed to force the switch to earthenware (Plommer 1973: 53).

While not as susceptible to conservative or innovative misfires as other building methods, earthworks acquired sods or clay caps, layers of sand or shell for renewal, colour-coded sources for alternating visual contrasts, or ritual sweepings from adjacent plazas in annual festivals (e.g., Bourgeois 2013: 174; Kidder 2004: 529; Knight 1986: 683; Sassaman 2008: 14-15; Sherwood and Kidder 2011: 72). For Mycenaean cemeteries, clay was occasionally used to cap pits or underlie biers within burial chambers (see Portes Chamber Tombs 3, 9 and 18, Chapter 4, this volume). Manipulation of colour with stone types has also been noted in the context of the Upper Citadel at Tiryns (Maran 2006b: 82-83, Figure 12), but rock-cut tombs are limited to applied colour-contrasts like the aforementioned clay and painted plaster (e.g., Demakopoulou 1990: 115; Gallou 2005: 68-69; Karkanas et al. 2012: 2731; Sgouritsa 2011: 737-739; Smith and Dabney 2014: 148). Each of these elaborations relied on instruction and experience. Labourers and planners who recalled previous sources collected the same material for a desired effect without unreasonable delays in scouting sources anew. Far more difficult has been the identification of these sources, especially stone, for appropriate transportation costs (Brysbaert in progress-2020; Brysbaert et al. in progress-2019; Devolder 2013: 134-136). Compacting alternating layers as they were added likewise had mechanical advantages, limiting the risk of slumping, or in the case of dams and dykes for flood control, the risk of catastrophic failure (Bowles 1984: 277, 286; see Chapter 2, this volume).

Where instruction and experience combined, early labour exchange systems exploited developing specialists first. Abrams (1987: 494-496) addressed the issues of labour organisation and instruction among both specialists and nonspecialists at Copan. From his energetics assessment of the monumental masonry palace Structure 10L-22, the number of specialists plastering and sculpting represented a surprisingly low portion of the total labour force (40 persons from a total of 411). Given that this involved only 0.3% of the approximate total population around Copan, Abrams concluded that specialists passed knowledge along familial ties, such as parent to child, and low demand simply never sparked an expansion of this class. Abrams applied similar principles to nonspecialist labour where lineages organised household labour, and subsequent elite recruitment operated most efficiently through such an existing system. The implication here is such that a nonspecialist with aptitude demonstrated at the household level for masonry, for instance, applied these skills when called upon by the elite for communal construction. Where the cost of material procurement rose, the number of nonspecialists with access fell, and ability once considered nonspecialist became specialised. In an example from Classical Greece, the defeat of Athens at the end of the Peloponnesian war disrupted skilled labour exchange, which took roughly a generation to rebound (Burford 1969: 204-205).

As seen above under household instruction and master-apprentice relationships, knowledge transfer seems straightforward. That illusion shatters under Foucault (1972: 153-154), where the “history of ideas”–of thought at its broadest and most reflexive – rests on a crumbling mess of innumerable, vanishing “exchanges and intermediaries”, like endless forgotten book passages or conversations with teachers. One outlet from there leads to indirect transfer among observers, tracking where innovation started rather than how it arrived (Granovetter 1973: 1366, 1372). Contact exposed others to sights and ideas, and these spread into the network equivalent of inkblots connecting strangers from otherwise separate pools of collaborators (Granovetter 1973: 1366; 1983: 202). Kindled interest drove others to recreate the descriptions of an eyewitness or messenger, those who may have had no further motive beyond repeating the story. Rumours undoubtedly played a significant role in fanning the competitive spirit of outdoing peers, much like the “mythology of rumor” continues to drive market speculation with “the quasi-magical search for the formula” to incomprehensible wealth (Appadurai 1986: 51). Existing earthworks goaded leaders into eclipsing predecessors – for an early medieval Mercian example, see Offa’s Dyke doubling the length of Wat’s (though obscurely named and without a definitive patron, see Tyler 2011: 159). As architecture grew more complex, however, mimicry faltered, and successful copies disseminated through more direct and official channels (e.g., the exchange of experts), leading back to a pedigree of instruction. For a portable instance, faience *kylikes* and *rhyta* at Mycenae expressed in local form a technology demanding Egyptian (or Syro-Palestinian) skills-exchange (Tournavitou 1995: 237-244; van den Berg 2018: 60).

For exceptionally large earthworks, indirect observation and rumour may have been sufficient to provoke responses among neighbours and rivals to attempt construction of larger tombs (Fitzsimons 2006: 90), longer canals (Squatriti 2002: 14-16), and more expansive ramparts and terraces (Tyler 2011: 159). Unlike stone- and woodworking, where concentration on size in wilful ignorance to practical considerations of building mechanics invited disaster, earthworks were generally not susceptible to catastrophic structural failure (cf. the discussion of earthen structural failures in Chapter 2). Cautionary measures against slumping, slides, and sinks included effective drainage, care with soil textures, and perhaps some considerable luck with the underlying geology (Bowles 1984: 213-215, 418-419; Brandt and Thornes 1987). With enough willing hands, elites bent on erecting larger earthworks needed only to heed communal tolerance by safeguarding the health of the project’s supporters (see Chapter 2).

Support

Although procurement, movement, and placement of materials dominated the total labour cost of a project, less visible (and less considered) secondary tasks escalated the cost and reach of a project beyond the construction site, perhaps overshadowing primary tasks over a wider scale (de Haan 2009: 13; Homsher 2012: 22). Secondary or supporting tasks included anything not directly involved in construction but without which building would cease. Through nearly limitless degrees of separation, an arbitrary line cordons a manageable model (Abrams and Bolland 1999: 267). The supporting roles I refer to here may take many forms, but the most important revolve around the health of the workforce (see also Chapter 2). To remain viable, workers must hydrate, eat, and sleep with some regularity, and the same applies to any draft animals. As with building materials, proximity dictated much of the labour involved in procuring food, fodder, water, and housing. Above all else, daily access to drinking water determined whether a project succeeded or what constituted a habitable position (e.g., Harper 2016: 216-217; McMahon 2015: 32; Maghsoudi et al. 2014: 81; Runnels and van Andel 1987: 323, 329). Under the wrong conditions, often unavoidable when performing intense labour on a dry summer day, the human body hits its limits surprisingly quickly, with the undersold threats of dehydration and heat exhaustion rearing under little more than an intense walk (Ainslie et al. 2002: 185-186). From manufacturing drinking vessels to maintaining a steady supply of potable water, the need for water demanded continuous investment throughout the construction process, necessitating transport personnel or portable containers for each worker and time enough for trips to the source.

Labour involved in food and fodder procurement varied according to primary subsistence strategies (see also Timonen forthcoming). Mixed strategies for food and fuel from cultivation and foraging prevailed over the eastern Mediterranean, at least where forests were not depleted (Klinge and Fall 2010: 2623). Halstead (1998: 212) noted montane foraging for livestock in north-western Greece, where “in the limestone area of the western Zagri, in villages up to ca. 1,000m altitude, evergreen bushes of prickly oak (*Quercus coccifera*) could be cut fresh for stall-feeding or browsed by sheep and especially goats even in quite deep snow”. When combined with foraging, intensive agriculture allowed surpluses but remained susceptible to shortages from poor yields or livestock mismanagement. Only a few dry years separated much of the Bronze Age Mediterranean from catastrophe (Wilkinson 1997: 67-69). Regardless of yield, two high-intensity seasonal work episodes, planting and harvesting, amplified the burden of other concurrent activities. Caretaking between planting and harvesting depended upon the crop, but none could go entirely unattended without substantial risk to yield. Multi-purpose use in early Cycladic olive domestication, for instance, demanded continual labour-intensive pruning (Margaritis 2013: 752). Animal husbandry involved a similar annual cycle, with seasonal relocation of herds and culling of non-breeding stock to reduce the burden on winter stores, once a dire concern in northern latitudes (e.g., O’Connor 2010: 12). The influence of weather upon agriculture and its timing constrained other major activity calendars in warfare and construction, and from its unpredictability, sowed investment in divine intervention. For factors beyond mortal control, like a punishing season, personnel may have diverted more time to intercede with divinities (for the archetype of the Minoan procession leader see, e.g., Soles 2016: 250 with references), reasserting ritual or symbolic investment in construction enterprises or, at worst, basic survival.

In the absence of intensive agriculture, construction tethered to a resource-rich area or occurred at a time where gathering dispersed bands could stockpile collective stores. Seasonality still applied, and the construction window tightened or closed altogether in lean years. Despite these restrictions, durable architecture from communal efforts in nonlocal, marginal zones rose in defiance of environmental circumstances by pooling labour and resources from the periphery, such as occurred at Chaco Canyon (Benson et al. 2003; Betancourt et al. 1986) and Poverty Point (Kidder et al. 2008; Ortmann and Kidder 2013; Sassaman 2008) in North America. Messenian MH tumuli also tended to centre on productive areas that attracted cooperative behaviour against rival claims (Angeletopoulos 2015: 2).

Housing, as another concern of supporting construction, factored less into projects within reasonable daily commutes for the majority of the workforce. Reasonable is relative, as farmers surveyed on Melos routinely walked two hours to fields formed from eroded hillslopes that have exposed up to 40% of the island's rocky surface (Horden and Purcell 2000: 75). Temporary huts in fields facilitated agricultural work further away from the outlying settlements of the fourth-century BC mainland *polis* (Jameson 1990: 94-95). Around this time Athens and its Piraeus port comprised a network of roughly 30 "subordinate communities" with another hundred spread across 2,600 km^2 of Attica (Jameson 1990: 94). In a rough demographic estimate for Classical Greece, Jameson (1990: 94) wrote that in "the acme of the civilization there were perhaps some six hundred city-states, most with populations of two or three thousand persons (some four to five hundred houses) and territories of no more than 400 sq. km". Similar crowded landscapes have been proposed for Mycenaean territories at their height (e.g., Bintliff 2019; Cavanagh et al. (eds) 2002; Davis et al. 1997; Wells and Runnels (eds) 1996; see also Timonen forthcoming), with up to 30,000 Messenians in 2,000 sq. km under Pylos at 112-200 per ha depending on rural/urban context (Bintliff 2019). New cemetery construction would seldom find a periphery in densely settled land, particularly where uninhabited areas were also likely strenuous to traverse. In densely settled areas like the LH II/III Argolid and Messenia, new housing for construction need not apply, but their daily commutes should be considered further.

No matter how symbolically distant from daily routine (Dakouri-Hild 2016: 13, citing Turner 1979: 97 on the concept of heterotopia; see also Hamilakis 1998: 118-119), Mycenaean tombs and public spaces were rarely constructed more than a few kilometres away from settled space (Mee and Cavanagh 1990: 238-239). Chamber tomb cemeteries in the Argolid occurred within 1.5 km of the closest major associated settlements. This was true even for those cited by Cavanagh and Mee (1990: 55) to be surprisingly distant, as at Berbati, Kapakli, Prosymna, Tiryns, and Nauplion – all of which were still within 1.5 km of nearby settlements (Mee and Cavanagh 1990: 225-226). Due to weak correlations in their cluster analysis, however, Cavanagh and Mee (1990: 59-62) determined that "there are no clear choices made in siting the tombs closer or farther away from nearby settlements, so convenience alone holds little weight". There was also no clear pattern of placement for Messenian MH tumuli in relation to nearby settlements apart from a general proximity, in most cases no more than 2 km distant (Angeletopoulos 2016: 5). Together with the isolated Barnavos chamber tomb, the six chamber tombs at Ayia Sotira in the Nemea Valley lay within 1 km of the settlement at Tsoungiza, visible to one another and with reasonable access to water (Smith et al. (eds) 2017: 168). Rather than relate directly to known roads, the cemetery at Ayia Sotira seemed to correlate more with cultivated fields and an apparent desire to protect the tombs from human and natural disturbances. Comparatively rural Achaea, despite research weighted toward tombs, likewise held corresponding settlements within a kilometre of cemeteries (Papadopoulos 1979: 26-31, 49). Considering proximity with established settlements, the location of cemeteries along prominent communication routes may be over-interpreted by modern research (cf. Boyd 2015a: 208-212, 2016; Galanakis 2011; see also Chapter 1, this volume). I would argue that convenience was a principal contributor in siting new tomb construction, at least to the extent that inconvenience was avoidable. Few alternate choices would have been available. Crowded landscapes of broken terrain, crisscrossed by existing optional routes (Boyd 2015a: 214), offered no advantages to wandering far from transport lines, particularly when sensitive cargo demanded wheeled vehicles. Even if smaller stones and tools allowed for overland expeditions, one does not typically sling a prepared corpse across a pack animal or expect a litter team to hike. Tomb construction and funeral processions were not the time for trailblazing. Furthermore, closed chamber tombs, even with markers, are not billboards easily spotted and relocated. Pragmatically, accessibility must have played a role in new tomb locations.

Gendered work

Often overlooked, supporting roles that sustained a workforce must draw from a depleted labour pool, one presumably showing a noticeable gender gap after the departure of the male-dominated workforce (a scenario flipped in the account by Gray 1963: 36-37, see below). Intentionally passing over able-bodied women and children in favour of unfit (e.g., age, illness, disability) men would require powerful taboos preventing others from participating in building itself. Even so, men cannot fill all roles. Historical analogy and its attendant fog of male-centric thinking fostered the fallacy of men alone building monuments. Gender bias in archaeological research has been peeled back for household industries (Dobres 1995: 27-29; Dobres and Hoffman 1994: 240), but communal construction continues to be envisioned as primarily male. Circumstances are few in ruling out half the available labour in prehistory. The first use of “person-day” was linked to Abrams (1984) when the methodology was initially laid out to denote participation by both sexes “on many different scales” and by children (Abrams and McCurdy 2019: 3-4). With this in mind, gender-biased units in descriptions of preindustrial labour costs have diminished.

Preindustrial labour has shown a contested field on diversity in the labour pool. After acknowledging the likelihood of women and children as fuel collectors and light industry assistants making ropes, baskets, and bricks, DeLaine (1997: 106) resignedly stated that her sources for rates restricted her from envisioning a workforce beyond one “composed entirely of men”. This assertion stemmed in part from “the post-classical sources for labour constants”, or in other words, from the revisionist observations of men writing centuries later. Despite a footnote reference to Egypt’s strict division of labour, Cotterell and Kamminga (1990: 217-218, citing Atkinson 1956; Skjolsvold 1961) reported diverse workforces including youths and women in experimental examples of heavy transport for Stonehenge and Easter Island. Daily water retrieval by Mesopotamian households was “probably performed by women or older children, and therefore rarely documented” (McMahon 2015: 32). The advent of a new watermill in the late first century BC led Antipater of Thessalonica to declare an end to women’s labour grinding grain (Cotterell and Kamminga 1990: 43). Into the mid-twentieth century in the villages along the Pindos range of north-western Greece, women handled small-scale herding and farming while men supplemented income from travelling trades, sometimes for intervals of years

(Halstead 1998: 212). Although dwindling, similar rural labour-sharing survives in isolated cases. A young woman shepherded her father's large herd of goats daily along the mountain road at Portes during our 2017 fieldwork season (see Chapter 4).

Few taboos prevented the employment of children in supporting tasks, where ethnological examples have foregrounded a sense of 'all hands on deck' to survive. Cottrell (1955: 36-37) referred to each child as "an economic asset" in the context of field clearing among the Bantu in sub-Saharan Africa, and for rural Yunnan in south-western China during the early twentieth century AD, children likewise supported impoverished adults. Similarly, women and children handled meal preparation and peripherals during ceremonial construction among the Oku of north-western Cameroon, where they also represented – not coincidentally – a measure of male power and economic reach (Argenti 1999: 26). In a case that I discuss further in the section on labour rates below, East African Sonjo women reversed the men-at-work refrain by ploughing, planting, and harvesting all while juggling housework and childcare (Gray 1963: 36-37). For exceptionally large chamber tombs and *tholoi* (see Menidi and VT75, Chapter 4), builders were likely not occupied for more than a season, during which non-builders would cover all other supporting tasks. However, strategic scheduling could alleviate that potential strain and spread communal workloads to fit annual schedules.

Scheduling

One counter to communal construction shifting the labour pool beyond the gender and age divide due to overlapping demands has been the concept of intentional timing during the agricultural offseason, a three-to-four month period typically stretching from late fall to early spring. This offseason has been cast as a window of opportunity for construction in agrarian societies. The window worked where the agricultural offseason coincided with the dry season in tropical climates, but the elevated rainfall in a Mediterranean winter rendered these months more problematic for wheeled transport, giving an advantage to sleds only to the extent that traction was not hindered by mire.

Agrarian scheduling certainly served as an impetus to complete essential construction within an acceptable timeframe. For Abrams (1989: 66), 60 to 100 days sufficed. This followed a reduction from the 120-day window for construction taken from ethnographic analogy (e.g., Bierbrier 1982; Redfield and Rojas 1934; Vogt 1969). Aaberg and Bonsignore (1975: 45) set the minimum as 40 communal working days per household for Mesoamerica, derived from Erasmus (1965), who reported a similar figure (45 days) from New Guinea. Expanding the workforce beyond "the adult male head", each household could expand to 200 working days per year or, for instance, match the frost-free growing season of 220 days in the south-eastern U.S. (Aaberg and Bonsignore 1975: 45, 53). Among the longest preindustrial working calendars, de Haan (2009: 2-3) estimated 328 working days per year (one day off in every ten with 8-hour working schedules) for Egyptian pyramid builders.

For the Roman construction calendar, DeLaine (1997: 105-106) preferred a 12-hour workday and onsite operations totalling 220 days over a 9-month period (March to November), allowing for a longer 290-day window over 12 months with offsite tasks such as timber and stone procurement. This scheduling optimised daylight hours and avoided the frequent rains of shorter winter months. Other tasks were also weather-dependent. The timing of Roman mudbrick manufacture avoided the intense heat of summer and its attendant uneven drying of bricks, wherein the outer layers dried too quickly, causing sufficient cracking to render the entire batch useless (Plommer 1973: 57). For slower, more even drying, spring was recommended by Vitruvius (II, 3) and echoed by Faventinus and Palladius (VI, 12). Referencing Faventinus, Palladius placed the optimal time for mudbrick manufacture in May and timber procurement in November (Plommer 1973: 3).

For Neopalatial Crete, Devolder (2013: 119, 129-131) utilised 8-hour workdays over a 90-day period. In southwest Greece, Walsh (1980: 99-100) cited a 75-day window for house construction at Nichoria. Given the variability of construction seasons used in previous studies, resolving the question of construction duration has depended upon the chronological resolution for the case example. Where this remains unsatisfactory due to limitations in the archaeological record, simulations scheduling work with modern computer-aided efficiency have substituted (e.g., Abrams and Bolland 1999; Harper 2016; Walsh 1980). I have avoided simulating work schedules for fear of outpacing the preindustrial experience of coordinating construction with limited means. As in the discussion of mechanics below, I have compromised with a technical review only to reconstruct the forces Mycenaean tomb builders would recognise by consequence rather than name.

Mechanics

Prior to the invention of the pulley in the early first millennium BC, construction relied upon variations of levers, inclined planes, and wedges to manipulate heavy objects (Blackwell 2014: 453-456; Coles 1973: 78; Cotterell and Kamminga 1990: 89; de Haan 2009: 2). With only muscle and gravity to initiate useful mechanical work, individual limitations are expressed in terms of Système Internationale (SI) units: 1) force, the newton (N); 2) the measure of mechanical work, the newton metre or joule (J); and 3) power, the joule per second or watt (W). Thus expressed, values are not typically transferable as an end-product comparison of preindustrial labour, for which real-time conversions are needed with observed labour rates that align closer to physiological effort. Since the difference between useful mechanical work and physiological effort has already been expressed (e.g., Cotterell and Kamminga 1990: 74-75, 195), I should reiterate that modelling preindustrial logistics measures physiological effort, something I explore further in the section on labour rates below. Before delving into those values for muscle-power, forces affecting structural stability should be discussed. The capability of materials to withstand these forces depends upon their inherent properties as well as construction design, typified in the problem of open space.

As a means of spanning open spaces, such as that required for roofs and bridges, Mycenaean builders could choose between a trabeated system (post-and-lintel) and a corbelled vault. The first confirmed truss did not appear until Andrea Palladio's (1518-1580) sixteenth-century bridge over the Cismone River in northern Italy, although earlier forms have been suggested for Classical Greek and Roman architecture (Cotterell and Kamminga 1990: 116-117; Coulton 1977: 159). The corbelled vault allowed heavier loads, but it did not approach the capabilities of arcuate (true arch) systems developed independently by Roman and Chinese architects. On the delay in inventing the true arch, Cotterell and Kamminga (1990: 121) mused that the instability of the incomplete arch seeded doubt regarding the strength of the completed form. Coulton (1977: 159-160) blamed the disinterest of mathematicians in practical experiments for the comparatively late development of structural theory, with Classical Greek architects deferring to the trusted method of proportionality in form as evident in their lack of understanding and under-utilisation of alternate roofing techniques like arches and trusses. Corbelling, on the other hand, was adopted early for a variety of civilisations, many preceding the LBA Aegean by centuries. Mediterranean examples appeared in Iberia, Sardinia, Malta,

Figure 3.1. Trabeated and corbelled spanning at the Menidi *tholos*.

Anatolia, and the Near East before appearing in the Peloponnese around the sixteenth century BC (e.g., Blackwell 2014: 477; Cavanagh and Laxton 1981: 109; Jones 2007: 168; Maner 2012: 56; Trump 2002: 62-63; Webster 1991: 844-845). The popular load-bearing technique remained susceptible to catastrophic failure if not supported against the tensile stress that later true arches converted safely into compression stress.

Aware of the risks involved in collapse mechanisms if not the theory behind them, many early architects overcompensated with conservative techniques. This was especially true for Classical Greek and Roman structures, which when analysed by modern methods could withstand loads far greater than the daily norm, in turn allowing many to survive violent earthquakes. In limiting the maximum bending stress on lintels at the Temple of Aphaia to a fiftieth of the modulus-of-rupture for limestone, “[t]he Greeks were decidedly timid in their approach to stone lintels because they did not understand the mechanics” (Cotterell and Kamminga 1990: 114). Coulton (1977: 96) found the same conservatism benefiting wider column-spacing in smaller Classical Greek buildings, which performed well since the preferred intercolumniation of larger examples went beyond structural requirements.

Egyptian builders showed similar caution in supporting roofs over the inner chambers of pyramids. Used in place of a relieving triangle, horizontal blocks supported primitive arches by absorbing side thrust from the gabled walls that would otherwise buckle inward along their base. Builders of the Great Pyramid at Giza took extreme cautionary measures by using five of these bridging stones to support the roof above the King’s Chamber (Cotterell and Kamminga 1990: 120). That technique also appeared above the entryway to the Menidi *tholos* discussed as a case study in Chapter 4. Counter to the misleading phrase of “relieving chambers” used by architectural historians, the spaces between these horizontal slabs “do nothing to relieve the load” (Cotterell and Kamminga 1990: 120). Losses in stability countering side thrust offset structural advantages from less weight. Similarly, seventh- and sixth-century BC Greek temples at Prinias, Syracuse, and Naxos attempted to lighten lintel blocks with U- and L-shaped cutaways that provided no structural advantage but at least reduced transport and lifting costs (Coulton 1977: 146). Since the viability of an arch depended on the distribution of weight, too much loading on the sides initiated collapse if the weight of the crown did not force the angle of stress into equilibrium with the angle of the arc (Cotterell and Kamminga 1990: 123). In many cases, cracking did not lead to disaster so long as load apportionment and external stress remained within the failure limits of material and design (see Figure 3.1 for trabeated and corbelled spanning at the Menidi *tholos*).

3.3.2. Labour rates

Before outlining a possible timetable for a preindustrial construction project, an appropriate rate of progress for each task must be suggested. Three types of sources are available: historical records, ethnographic observations/analogies, and experimental studies. Each type carries its own advantages that sustain debate as to which might harbour the closest resemblance to reality. In the end no single type can stand alone, and taken together they allow for a persuasive model of labour progress. This section explains the history of each type, outlining aspects for improvement with representative examples, which have largely been reserved for the relevant subsections on tasks below.

The first source type for labour rates is the historical record. The oldest of the three, historical record has the advantage of being closer in time to the actual construction with fewer intervening anachronisms. Some records bear a direct connection to the builders, while others maintain some indirect relationship through neighbours or successors. This closeness can include shared heritage, values, knowledge, and technology, items only accessible in the present through material remains. Certain constructions were also better preserved at the time of historical observation, giving the recorder access to dimensions and elaborations now lost or diminished (e.g., losses to ploughing, misunderstanding, or reuse, Hammerstedt 2005: 79; Holtorf 1996: 135, 1998: 33; Turner 2010: 68; Maran 2016: 161-162, see *Reuse* below). Timber is a good example, both for its abysmal preservation in certain climates and the historical record's tendency to oversell it. To fulfil Wen Amon's order of timber for the ceremonial barge of Amon-Re, for instance, the prince of Byblos purportedly sent 300 men and as many cattle into the mountains to cut and transport the timber after allowing it to dry for a season (Meiggs 1982: 68). Following the Biblical account from the first book of Kings, Meiggs (1982: 70) highlighted Solomon's dubious monthly rotation of 10,000 corvée labourers from an overall 30,000 reserved to assist Hiram's timber-cutters in Lebanon in the unskilled stripping of logs.

Disadvantages for historical record revolve around glaring inaccuracies in reported numbers, missing or incomplete information, and loss of context. Limitations with measurements and timekeeping, deliberate or poetic exaggeration, and disinterest from the author or audience could all lead to imprecise figures in reported completion times. Where historical reports have undergone review by modern research, discrepancies are unclear when not egregious. For instance, Burford (1969: 251) estimated that 175-200 labourers and craftsmen could complete the Asklepios temple in two years and eight months, leaving two years of leeway with the recorded time of completion and comparing favourably with the 107 men listed for the final construction in the Erechtheion inscriptions. Burford (1969: 193-196) also recorded labour rates for stonework in monetary costs, leaving labour-time estimates for her Appendix III. Her only mention of earthmoving comes in relative costs for digging drains, which prove inconsistent when analysed by measurements (a 10 ft channel is only three times the price of a single foot in one instance, whereas a 4 ft channel is nine times the cost of a single foot in another).

In contrast to incidental inscriptional errors, deliberate misrepresentation of construction magnitude spread fame or infamy on leaders and opponents through propaganda. In the unsuccessful attempt to drain Lake Fucine under the direction of Emperor Claudius, the Elder Pliny excused technical problems as unfinished business left at his untimely death, whereas Tacitus declared the project an instant failure with a mockery of opening ceremonies (Reitz 2013: 78-88). Suetonius's *Life of Claudius* attempted to report numbers for the draining tunnel's construction, but his estimate of 30,000 men working continuously for 11 years to finish a 3,000 ft channel was repudiated by Thornton (1985: 107-112), who could not envision space enough to work for more than 3,000 (Reitz 2013: 92). Authors without a vested interest in a project may omit details in favour of other foci or simply withhold the information to fulfil a grudge, as the Elder Pliny omitted the works of Nero in his list of aqueducts (Reitz 2013: 78-80). Even if details were recorded, many do not survive intact for modern review. Relocated, re-recorded, exchanged and forgotten, historical records have passed through many hands to reach current researchers. Whether closer to fabricated narratives or faithful accounts of past events, historical records remain informative for how contemporary audiences viewed labour, if not for how we measure it.

Before the late fifteenth century AD, most historical records that include observations on preindustrial labour came from Europe, Asia, and northern Africa. Fragmentary reporting on provisions, fortifications, and monumental constructions survived from the earliest writing systems in the Near East and early China (e.g., Abrams and Bolland 1999: 265 with references; Broodbank 2013: 367; Ristvet 2007: 198-199). More complete recordings spread with the Greek city-states and major imperial powers of the last millennium BC (see Burford 1969: 251 on the Erechtheion inscriptions), culminating with Hellenistic and Roman writers of architectural treatises (Plommer 1973). Some of the more useful surviving historical sources on earthmoving include Julius Caesar's dubious observations on the ramparts surrounding the Nervii winter encampment (MacDevitt 1915), early medieval ditches and fortified bridges (Coupland 1991; Squatriti 2002, Tyler 2011), and exhaustive medieval tax records (Bachrach and Aris 1990). The most common historical sources for labour rates still in use are nineteenth-century architectural handbooks (Hurst 1865; Pegoretti 1865; Rankine 1889; see below).

The second source type, ethnography, falls to the observations made among preindustrial populations by outsiders, made popular within the toolkit of cultural anthropology. The fascination with ethnographic accounts of "pure" societies hit its high watermark during the past three centuries, prompting extensive writings attempting total coverage of life for preindustrial or marginalised populations. This has resulted in many cultural histories that often contain direct observations for traditional labour practices. Although not a primary goal for ethnography, detailed recording of labour through interview and observation can enhance comparative labour research with a closer look at construction processes and their immediate effects. Often these observations focus on the age and gender division of labour with food production and crafting sources. Gray's (1963: 36-37) account of irrigation work among the Sonjo of East Africa is an excellent example of ethnographic detail for daily labour, one showing strong gender dichotomy:

> "*Hura* cultivation starts in September, the first task being carried out by the men, who flood the fields to soften the ground and then pull up or dig up the stalks and large weeds from the previous year. This is not difficult work and is usually performed by a man working alone or with the help of his sons. Thereafter, a man's share of the work is limited to flooding the fields periodically with irrigation water.
>
> The women then arrive on the scene with digging-sticks and first clear off and burn the trash which the men have left behind. Then the back-breaking work of loosening the soil begins. A seed bed is prepared by digging up the whole field to a depth of six or eight inches. The only implement is a digging-stick (*molo*, pl. *meleo*) about five feet long with a bevelled point. The digging-stick is used with a special technique which involves a rhythmic movement of the body akin to that of the prevailing dance technique. The stick is grasped by the hand about a foot from the point, the woman's body is flexed sharply [p. 37] at the hips, and she plunges the point into the ground. The loosened clod of earth is then thrown backwards between the legs with the free hand. The woman stands in loose earth and faces the unbroken soil as she works. Groups of from six to twenty women are usually seen working together for the initial cultivating of a field. They form a line which works from one end of the field to the other. When the first woman's fields are finished the whole group moves to the next woman's, and so on until all the fields are ploughed. This work is done during the heat of the day. While working in groups they always sing work songs, without which the work would be intolerably hard and tiresome. The rest of the agricultural work – planting, weeding, and harvesting – is done by each woman alone, or with the help of daughters or perhaps a daughter-in-law. This requires a period of field work almost every day. The daily routine of a housewife starts early in the morning with a trip to the stream for water, which may involve an hour's climb down the steep path and up again. The rest of the morning is spent working at home or resting or gossiping with other women. After an early noon meal with the family she goes to her fields, carrying a digging-stick and calabashes, and perhaps also an infant, if she has one with no older daughter to look after it. The empty calabashes are left at the main stream, as she crosses it, to await her return. When her afternoon's work is finished she stops at the stream to bathe and rest in the shade with other women, then she fills her calabashes and returns home to prepare the evening meal."

Gray's (1963: 45-46) account continues with a thorough economic review of crafting tasks: women handled leatherwork and dyeing, older men strung bows with strips of goat muscle, and other crafts apart from skilled ceramics and metalwork fell individually to those men with aptitude. Irrigation, without which their agricultural system would fail, claimed the time of men and women, flooding and aerating alluvial fields of heavy loam and upland fields of sandier soils with little more than digging sticks (Gray 1963: 36-38).

Advantages of ethnographic observation and analogy for labour rates include extensive detail of people and process, high-accuracy measurements and timekeeping, and residual connections to past construction. As late as the mid-twentieth century, isolated populations in South America, Africa, and the Pacific Islands engaged in earthmoving activities using traditional techniques if not always traditional tools (ECAFE 1957; Shaw 1970). Nineteenth- and twentieth-century examples likewise filtered through from Europe (e.g., Bachrach 1993, 2005: 270; Squatriti 2002: 41). In some cases, observers were present to record task rates, with many expressing surprise at the speed and efficiency of the preindustrial labour process (e.g., Erasmus 1965: 285). Although not always relatable to past construction, some informants indicated motivations behind the work, including inspiration from oral histories, monuments, and material remains all in complex interplay (*sensu* Dakouri-Hild 2016: 16).

Ethnographic observation and analogy falter where modern tools and techniques replaced traditional technologies, recorders incentivised informants to elicit a desired effect, or the author focused elsewhere than construction (see below). Pre- and post-contact elements often became intermixed before records began in earnest. For instance, to symbolically dissolve kin ties and protect family reputations, a Tobelo marriage ceremony in eastern Indonesia was safeguarded through the sacrifice of a Taiwanese tin plate, which had added value from its origins abroad (Platenkamp 1990: 89). In his work on the Yanomamo, Chagnon (1996: 670; Chagnon et al. 2013) repeatedly addressed rumours of his supplying the Amazonian tribes with machetes and other Western supplies, which had arrived more than a century prior alongside the bananas and plantains that overtook native cassava cultivation. In most post-contact encounters, the rapid spread of metal tools eventually resulted in the replacement of traditional digging implements (e.g., shell and stone hoes, antler picks, digging sticks) with the metal spade, shovel, and hoe. Similar technological replacements affected transportation, introducing wheeled containers and pack animals in place of basket loads and tumplines. The difference in efficiency made these clear choices for labourers. Even where traditional technologies survived, the very presence of an outside observer may have altered construction approaches, prompting labourers to dissemble or impress depending on their own feelings toward being watched or questioned about their work. From the above example, Gray (1963: xii) spent the first month in the field under constant supervision before suspicion relented. Even under optimal conditions of traditional technologies and uninterrupted processes, an ethnographer may simply have diverted focus away from quantitative observations in favour of parsing out the qualitative social effects of labour.

The third and final source type for labour rates originates with experimental study. Deliberate and dedicated, these sources offer the highest accuracy with regard to quantitative observations but are the furthest removed from the original construction in time and motivation. Owing to their flexibility in designing the experiment, quality experimental studies focus on recreating the right conditions for the construction process under question, from replicating technology and techniques as closely as possible to matching material properties such as soil compaction and texture (e.g., Ashbee and Jewell 1998: 491; Coles 1973: 74; Erasmus 1965: 285; Hammerstedt 2005: 46; Milner et al. 2010: 106-109). Where they fail to grasp the reality of preindustrial construction, however, is their very attention to detail and its attendant hyperbaric efficiency. Short-duration experiments of an hour or less further raise questions over stamina and rate stability over a full day's work. In order to truly recreate a real-world scenario, experimental studies must remain self-aware and avoid overcomplicating the exercise.

Regardless of source, units to measure labour costs take many forms: labour-time (e.g., Abrams 1987: 489-491; Ashbee and Jewell 1998: 491; DeLaine 1997: 116-121; Devolder 2013: 42-47; Erasmus 1965: 284-287), wages (e.g., Burford 1969: 55-59, supplemented with labour-time estimates 246-251; Pakkanen 2013: 72-74), physiologic conversions (e.g., Consolazio et al. 1963; Durnin and Passmore 1967; Edholm 1967; Edholm et al. 1970: 1099-1101; James and Schofield 1990: 133-135; Lacquement 2009, 2019; Vaz et al. 2005: 1158-1183), and indirect equivalencies obtained through respiration (e.g., Shimada 1978) or a volumetric standard (e.g., Thornton and Thornton 1989: 20-21). Abrams (1989: 64) placed timed observations at the top of the hierarchy of labour rates, above interviews and speculation through biased historical accounts. Labour-time estimates account for the natural work progression that includes unproductive time (e.g., breaks, repeated tasks, interacting personnel), whereas measurements of mechanical work and physiological effort do not. Although Abrams (1989: 65) hesitated to place these quantifications as "*a priori* closer to the truth", it is clear that comparative energetics raises important questions that would otherwise be missed. In a tempered call for more cross-cultural analyses, both Abrams (1989: 75) and Lacquement (2009: 153-156) asserted that future energetics studies would benefit from an expansion of the corpus of labour rates, organised according to variability in cultural choices and environmental circumstances. Several researchers in recent years have begun to address that deficiency, notably in two recent volumes (Brysbaert et al. (eds) 2018; McCurdy and Abrams (eds) 2019).

Reproduction of task rates in the literature has varied from passing mentions of a single rate to comprehensive tables detailing multiple processes. Common practice resulted in uncritical usage with caveats deployed as an afterthought. This led many to treat task rates with suspicion or forbearance, overpowering them with contextual detail en route to answering other research questions. The most often cited task rates come from the timed observations of Erasmus (1965: 283-285), who organised several experiments comparing the efficiency of wooden tools with their modern steel counterparts at Las Bocas, Sonora, and Uxmal, Yucatan, with male Mayo and Maya villagers, respectively. One bold cross-cultural use of these appeared in the aforementioned study by Webster (1991) on the *nuraghi* of Sardinia. Others opted for borrowing from nineteenth-century handbooks on architecture (e.g., Cotterell and Kamminga 1990; DeLaine 1997). DeLaine (1997: 104) cited her main source as the Italian manual by Pegoretti (1865) with occasional cross-referencing to its English counterpart by Hurst (1865). On the accuracy of rates, DeLaine (1997: 109) limited her final calculations to a maximum of three significant figures to avoid the illusion of overly precise estimates, further deferring to the reliable first significant figure. Defending her choice of labour rates, DeLaine (1997: 105) opted for maximum output to express the lowest possible cost, referring to the opposite as "ludicrous" and dismissing equally any notion of averaging.

Among the latest to review problems with task rates for earthmoving, Lacquement (2009, 2019) converted volumetric recalculations at the multi-mound centre of Moundville into units capable of seamless incorporation to studies from natural and medical sciences (e.g., physics, geology, physiology, ergonomics). His use of mass (volume multiplied by density) and energy in kilojoules (kJ) allowed for a comparative medium appropriate for interdisciplinary research, but he acknowledged these units' limitations for reincorporation into the archaeological narrative (Lacquement 2009: 8-10). Despite the impressive figure of 3.8 billion kJ for Moundville's total energy expenditure, Lacquement's (2009: 125-126; 2019: 170) model ran with a least-cost perspective, always taking the low estimation for labour rate at each of the three stages (excavation, transportation, and compaction). He concluded by decrying the use of solid geometry equations in volume estimations and the borrowing of energetic rates, which yields unrealistic results where variables differ, such as the density of soils (Lacquement 2009: 156). In comparing the rates of Erasmus (1965: 285) and Hammerstedt (2005: 46), the differences originated with the lighter, sandy soils of Las Bocas (0.59 m^3/ph or 1.7 ph/m^3) being easier to move than the heavier, silty clays found in many areas of the U.S. Southeast (0.29 m^3/ph or 3.45 ph/m^3). As Lacquement (2009: 153-156) also suggested, more original experiments and more extensive use of studies outside archaeology could settle what constitutes an acceptable workload per task – in other words, comparative labour rates applicable in more contexts.

Procurement

Tools, worker stamina, and soil type significantly influence excavation rate, and the compilation of rates in Appendix 1 reflects this in comparable terms. Already acknowledged as a fault in volumetrics, false equivalencies comparing material volume with various densities have plagued the reproduction of soil excavation rates. Working in sandy soils, participants in Erasmus's (1965: 285) experiments had no trouble posting surprisingly high numbers for soil excavation, including 2.6 m^3 (with a digging stick) and 7.2 m^3 (with a metal shovel) per 5-hour workday, roughly 0.52 and 1.44 m^3/ph (0.7-1.52 ph/m^3), respectively. Working in chalk with antler picks, ox scapulae, and woven baskets, Ashbee and Jewell (1998: 491) recorded a more modest excavation rate (5 ft^3/mh, 0.142 m^3/ph, or 7 ph/m^3) in their Overton Down Experimental Earthwork Project. They derived this figure from weighing basket loads in the hundredweight (cwt) unit, which equates to 112 lbs in the U.K. or 100 lbs in the U.S. With the approximate equivalency that 1 ft^3 of chalk weighs roughly 1 cwt, the original rate states 5 cwt/mh (254 kg/ph or 560 lbs/ph). Seeing the rate adopted uncritically, however, Ashbee and Jewell (1998: 491) reiterated that pace would change radically under different circumstances, slowing as the distance increased from excavation to deposition. Burford (1969: 247) likewise cautioned limitations over labour-time analogies to modern masonry rates with 8-hour workdays.

Timed observations for the range of soil types between sand and chalk have appeared but not in a widely distributed fashion (Turner 2018: 198-199). Manual labour estimations from a report by the UN Economic Commission for Asia and the Far East (ECAFE 1957) give 0.1 to 0.334 person-days as the required effort for "common" and "dry hard clay" soils, respectively. Converted to m^3/ph, this ranges from 0.6 to 2.0 (0.5-1.67 ph/m^3), the fastest manual excavation rate noted outside of historical exaggeration. By comparison, the rate achieved by Penn State University graduate students using a short-handled chert hoe in compact silty loam could only achieve 2.0 m^3 per 7-hour person-day, or 0.29 m^3/ph (3.45 ph/m^3) (Hammerstedt 2005: 45-46). From unspecified ethnographic sources for canal construction and an experimental source from the Bolivian Amazon, Erickson (2009: 303) listed a rate of 1 m^3/ph sustainable through a 5-hour workday.

Other cases make implicit use of data and limit the conversion of rates with missing information. In one early example on labour costs for excavating tombs at Mycenae, Wright (1987: 174) estimated one cubic metre per person-day as an appropriate soil excavation rate. Although the length of the workday was not mentioned, he referred to calculations in man-hours by Atkinson (1961: 292-297). Modifying rates from the Overton Down experimental earthwork, Atkinson (1961: 295) derived the empirical formula $H = V(120 + 8L + 2F) / 1000$, where H is man-hours, V is volume of chalk in cubic feet, and L and F represent the vertical and horizontal distance between the centres of gravity for an adjacent ditch-and-bank system. It is unclear what hourly rate was intended here. Wright (1987: 174) likely meant an hourly rate between 0.1 (10-hour workday) and 0.125

(8-hour workday) cubic metres, rather than 0.2 m^3 when tied to the common 5-hour workday cited as productive time by Erasmus (1965: 285).

Through Pegoretti's (1865) architectural handbook and experimental archaeology on brickmaking, DeLaine (1997: 118) reported clay extraction rates as 14 man-days for 93 m^3 and 7 man-days for 49 m^3, or 0.5536 to 0.583 m^3/ph (1.72-1.81 ph/m^3) when accounting for her 12-hour workday. Loading and carrying the clay to preparation areas for moulding into bricks demanded a further 59 man-days for 93 m^3 and 31 man-days for 49 m^3, or 0.131 to 0.132 m^3/ph (7.58-7.63 ph/m^3). Although reproducing clay extraction rates for the brickmaking process, DeLaine (1997: 133) briefly treated the excavation of clay for the terraces and foundation trenches in the early stages of building the Baths of Caracalla. Rates and quantified details are unclear amid the dismissal of how straightforward this stage of the process was.

To summarise, reported rates for the excavation of soils in just those studies referenced above range from 0.1 to 2.0 m^3/ph (0.5-10 ph/m^3). When viewed critically, neither rate would be appropriate for contexts beyond the original parameters of their parent studies. However, such single-rate adoption has hitherto prevailed. In a hypothetical scenario, an energetics approach to a ditch system requiring the removal of 1,000 m^3 of soil would arrive at 10,000 ph using one rate and just 500 ph using the other. In comprehensible terms, completing the same ditch in two weeks could require 10 or 200 people, enough to sway interpretations to either a light burden for a kin group or a substantial communal effort suggesting more complex labour mobilisation. One counterargument to this problem relies on multiple comparisons using the same rate, but this adds little beyond a simple volumetrics comparison if the rate fails to highlight the differences in each construction process. When comparing multiple earthworks applying rates appropriate to soil type and tools used, however, energetics surpasses the analytical utility of volumetrics without generating false equivalencies or erroneous interpretations. For the simplest energetics comparisons, case studies relying upon multiple timed observations can form a baseline for analysis without adding further variables and calculations. Indeed, so long as the goal is not to model total costs, basic diachronic assessments of ditch systems or rock-cut tombs, for instance, can proceed with multiple rate sources. More robust comparisons, however, require rate sources for more material types and techniques, as well as those that explore beyond procurement.

Alongside the comparatively simple task of earthmoving, wood procurement adds further complications of technique – such as girdling (stripping bark in a ring around the trunk or branch) versus chopping or sawing – to the variability of material and tool type. Citing several Eurasian studies in land clearance with stone axe experimentation, Coles (1973: 20-21) gave rates for tree-felling by tool type and target diameter, with scattered references to wood type. Reported numbers included Iversen's (1956) clearance with flint axes of 2,000 m^2 of oak forest in Denmark – trees greater than 35 cm were girdled, and trees smaller than that were chopped down in roughly 30 minutes, with 3 men able to clear 500 m^2 in 4 hours. Stelci and Malina (1970) showed that a polished stone axe could fell small trees (14-15 cm in diameter) in 7 minutes in a mixed hardwood and pine forest in former Czechoslovakia, with 21 minutes needed for a 40 cm diameter pine and only 3 minutes for a 13 cm diameter spruce (Coles 1973: pl. 3). Semenov (1964: 30) used a polished nephrite axe from a Neolithic site near Leningrad (St. Petersburg) to chop down a 25 cm diameter pine in 20 minutes, matching work by Smith (1893) with hafted flint axes (Coles 1973: 20). Semenov's observation reflects a rate plateau when linked to Stelci and Malina (1970), in that pines 25-40 cm in diameter took roughly the same amount of time to cut with a stone axe.

Stonecutting likewise varies according to tool and material type, with additional costs from manufacturing finished blocks through shaping and polishing. Burford (1969: 246-251) reported labour-time estimates for stonework involved in the Asklepios temple at Epidauros, with rates sourced from modern restorations on other temple works. For example, one man polishing Pentelic marble for eight hours a day could polish 21 m^2 in 40 days. From quarrying to polishing porous limestone, three months were required for one man to produce 0.792 m^3, and it took five times as long to work Pentelic marble (Geddes 1960). Using a range of experimental and historical building manual sources, including those from Abrams (1994: 46-47), DeLaine (1997: 111, 121), and Lehner (1997: 206-207) among others, Boswinkel (forthcoming, Tables 7.2 and 7.3) has compiled stoneworking rates for quarrying, transporting, and dressing stone. Citing a reasonable average as 0.5 m^3/ph (2 ph/m^3) for most stone rubble procurement, Boswinkel (personal communication, 2019) noted many quarrying rates that have an astonishingly burdensome ceiling under channelling (granite, 0.00052 m^3/ph or 1923.1 ph/m^3 from de Haan (2009: 3)) and sawing (*pierres dures*, 0.001 m^3/ph or 1,000 ph/m^3 from Devolder (2013: 43)), beneficial only in reducing later dressing costs to finalise block size.

Transport

Far less variable than procurement are transport rates for human portage. Manual labour reduced or repurposed after industrialisation has shifted perception for what constitutes an acceptable load for a pedestrian bearer, from the 90-kg loads of coal porters in eighteenth-century London to the 30-kg packs of British infantry in World War I (Cotterell and Kamminga 1990: 193; Desaguliers 1745). Excessive loads still appear in developing regions, such as the 90-kg loads of Nepali hill porters (Malville 1999, 2001: 234) and Bhutan examples of 100-kg potato sacks (Cotterell and Kamminga 1990: 193; Scofield 1976: 680). However, occupational regulators (and experimental archaeologists) are reluctant to assign loads greater than half the bodyweight of the bearers, lest they invite personal injury and its attendant losses.

Excavations of platform mounds in the eastern U.S. have supplemented experimental sources for the weight of basket loads from their apparent outlines in the soil. Lacquement (2009: 129) cited a wide range from previous studies at Poverty Point in Louisiana and the Mitchell site in Illinois, from 7.3 to 52.2 kg and averages at 11 and 22.7 kg. For timed observations of earthmoving, basket loads tended to be on the lighter side of the spectrum. Erasmus (1965: 284-285) found the average carry load to be 20 kg (0.02 m^3) for distances of 50 and 100 m, figures that Hammerstedt (2005: 224-225) later adapted for the Annis site in Kentucky. Woven baskets carrying chalk rubble in the Overton Down experiment averaged only 13.5 kg (Coles 1973: 73). Citing studies in North America and South Asia, Aaberg and Bonsignore (1975: 47, 50-57) found a preference for 22 kg (0.011 m^3) basket loads, setting weight limits at 15 (0.008 m^3) and 40 kg (0.020 m^3) and distance-to-source limits at 1 km for clay, 3 km for rock, and an arbitrary 5 km for lime. For earthmoving with nearby soils, the upper transport limit was a 10-minute walk of 600 yards, ca. 545 m (Aaberg and Bonsignore 1975: 53, 57).

Several studies in physiology and ergonomics have reviewed the metabolic cost of unloaded and loaded walking (Abe et al. 2004, 2008a, 2008b; Bastien, Schepens, et al. 2005; Bastien, Willems, et al. 2005; Cavagna et al. 2002; Heglund et al. 1995; Maloiy et al. 1986). Archaeological studies that have adapted these figures in pursuit of kilojoule measurements for transport have avoided the trap of conflating mechanical work and physiological effort (e.g., Lacquement 2009), but it is important to reiterate. Nowhere is the difference between these measurements more prevalent than in the mechanics of walking. Due to limitations on storing potential energy within our joints and metabolic requirements for negative mechanical work (i.e., work done on us as our centre of gravity falls in step), "to provide 1 J of positive and 1 J of negative work we expend 5 J of metabolic energy" (Cotterell and Kamminga 1990: 195). The issue of metabolic cost also arose in experimental woodcutting – coincidentally with costs quintupled from tool inefficiency. Citing Saraydar and Shimada (1971) and their oxygen consumption efficiency tests comparing stone and steel axes, the lighter granite axe apparently consumed 5 times the kilocalories and took 6 times as long as the steel axe, conclusions that Coles (1973: 21) asserted could be reworked with more details on the widths and weights of the tools.

Avoiding wasted energy in moving loads is partly intuitive. Strategies for bearing a load efficiently keep the weight close to the bearer's centre of gravity and distribute the force away from the arms to larger core and leg muscles (Knapik et al. 1996). The modern backpack does so with shoulder straps, and more rugged hiking packs add chest and hip straps to stabilise the load and alleviate shoulder fatigue. Tumplines with head or chest straps appear to be the preferred method of bearing heavy loads in historical Native American contexts (Mason 1896), as well as more recent ethnographic and experimental examples for the Classical Maya (Sidrys 1979), later prehistoric Europe (Webster 1991), and the modern Himalayas (Malville 1999, 2001). Other methods include head-borne baskets among Kikuyu women in East Africa (Maloiy et al. 1986). Evidence for the wheelbarrow does not surface until the second century AD in China, making it unknown in Europe until the Late Medieval Period (Cotterell and Kamminga 1990: 214-215). By the third century AD, wheelbarrows enabled Zhuge Liang's soldiers to each transport a year's ration of rice (180 kg) 10 km per day (Needham et al. 1965: 260).

Since Old World heavy transport has relied upon animal traction for millennia, researchers must compare the benefits of precision in human portage with the raw power available from beasts of burden. The earliest example of wheeled transport comes from pictographic evidence at Uruk near the end of the fourth millennium BC, showing an important figure drawn on a covered sledge held on captive rollers and propelled by a pair of bovids tethered by their horns (Littauer and Crouwel 1979: 14). Mules and bovids are shown pulling baggage carts and commissary wagons in the 1274 BC Battle of Qadesh (Littauer and Crouwel 1979: 84). Referring to the relevant passage in Homer's *Iliad*, Meiggs (1982: 108) recalled that pack mules were purportedly used for transporting oak from Mount Ida in preparations for the cremation of Patroclus, a task for which oak is well-suited as fuel given its high-temperature output. As reported by the Kanesh texts in the early second millennium BC, Mesopotamian merchants (Akkadian *tamkarum*) led donkey caravans carrying metals and cloths, with up to 250 donkeys hauling 60 kg each for 40 days (Broodbank 2013: 367). Burford (1969: 184-187) placed the maximum load of a single-yoke oxcart at 500 kg, limiting wood transport, for instance, to one squared beam of silver fir (366 kg, or 15.9 kg/ft^3).

Land transport capacities compiled by DeLaine (1997: 107-108) mostly through literary sources included maximum values for humans and animals: 50 kg for men carrying baskets with similar volume capacities of 0.026 (Roman 2-modius basket) and 0.03 m^3 (nineteenth-century builder's basket), 55 kg for a small donkey, 120-135 kg for a large mule, 400-640 kg for a single yoke oxcart, and 340-380 kg per yoke for 8 to 9 yoke teams with a guide per yoke. From Xenophon and the Theodosian Code, Burford (1960: 4) reported similar losses in multi-yoke traction largely due to harnessing issues, with 1,100 lbs (ca. 500 kg) or 25 talents as an acceptable maximum load for a single yoke, only a fifth of the limits for their modern counterparts. As she indicates with Plutarch's tripled limit, the lower quota may reflect more on military and state caution regarding roads and valuable transport stock, and may not necessarily be heeded by private interests (Burford 1960: 9-10).

Each animal carried its own advantages and disadvantages. Cuneiform tablets referred to horses nearly exclusively in their role of pulling chariots. Riding was yet unsophisticated according to pictographic representations, and the animals were too valuable for hauling (Burford 1960: 9; Littauer and Crouwel 1979: 83). Speed was the purview of early horses drawing light chariots, being "too precious, too lightly built, and too nervous for heavy work" (Burford 1960: 9). Such was the value of horses that cavalry lagged behind chariotry due to the stronger herd instinct of early domesticates, as well as the need for effective horseshoes to limit the increased wear-and-tear from bearing the full weight of the rider (Littauer and Crouwel 1979: 11-12). Compared to the sensitive horse, the robust ox could handle rougher terrain, heavier loads, and coarser fodder with less risk to capital investment on the hoof (Burford 1960: 7-9; Cotterell and Kamminga 1990: 207). Regarding the importance of that investment, elites rightly worried over the health of their herds, enacting protective measures and showing formulaic courtesy in well-wishing rival stock (Brysbaert 2013: 64-65; Littauer and Crouwel 1979: 83).

Carrying techniques for animal transport depended on terrain, load weight, and harnessing technology. Carts and wagons in the later second millennium BC showed six-spoked wheels and propulsion by bovid pairs or mules in Hittite and Assyrian representations (Littauer and Crouwel 1979: 73-74). Egyptian baggage carts reflected a similar two-wheeled design resembling modified chariots, while the purported reliefs of "Sea Peoples" ca. 1180 BC had central disk wheels and a rare bovid draught setup of four abreast (Littauer and Crouwel 1979: 74). Most evidence from the period focused on the higher-profile, more glamorous form of wheeled transport in chariots. Road quality determined the efficiency of wheeled transport over pack transport, since quadrupedal beasts of burden did not require a smooth surface to keep pace (Cotterell and Kamminga 1990: 196-197). Oxcarts transporting Pentelic marble to Eleusis performed the 22-mile (35.4 km) journey in 2.5 to 3 days (Burford 1969: 189). Payment for transport was not standardised, perhaps for the multiplicity of variables involved for each load. DeLaine (1997: 98) referenced 5 km/h for donkeys, mules, and a man carrying a burden but only 1.67 km/h for a loaded oxcart, thus the only gains expected from cart transport resolved to weight per load. Even so, too much weight threatened to bury wheels or snap axles, making the sledge a safer option for heavier loads despite the amplified friction. Wheeled carts (two-wheel) and wagons (four-wheel) originally developed from the use of rollers with sledges, which remained in use for the heaviest loads to avoid repeated broken axles (Littauer and Crouwel 1979: 8-9). Problems and repairs associated with heavy transport were listed for Eleusis with the reporting, among other figures, of 17 broken axles (Burford 1969: 252). Wheels and timber rollers on tracks, more durable than the martyred axle yet difficult to manoeuvre, behaved in a similar fashion to modern roller bearings in the exchange of elastic strain energy and alleviation of friction (Cotterell and Kamminga 1990: 199).

Empirical comparisons for lubrication in heavy transport rely on physics and mechanical engineering, but the effects are noticeable without this understanding. Scenes depicted Egyptian VIPs standing alongside water-bearers ahead of massive loads being pulled on wooden sledges, such as the 26-person crew dragging the capstone of Sahure's pyramid (Lehner 2015: 465-466). Lubrication could reduce friction coefficients to 0.15-0.20 and drop the required number of haulers to a third of those needed for an unlubricated sliding load, such that 6,000 men exerting 300 newtons (N) each could haul 1,000 tonnes rather than the far less manageable team of 18,000 men (Cotterell and Kamminga 1990: 222). Rollers on a rough track can drop the friction coefficient further to 0.11 to enable six men to drag a tonne, while well-made rollers can take this value as low as 0.002-0.008, giving one the ability to drag 4 tonnes (Cotterell and Kamminga 1990: 223-224). Evidence for the use of rollers in moving monumental items increases with Classical Greece, but "roller stones" have been found in association with megalithic monuments on Malta dating to 5000-3000 BC (Hannah Stöger, personal communication 2017). Use of rollers for smaller loads are known in early examples from Sudan (Cotterell and Kamminga 1990: 224).

Scheduling and coordinating transport demanded further considerations from organisers of preindustrial transport. DeLaine (1997: 100) discussed the logistics of timber transport from mountainous sources to the crowded streets of Rome. Teams of 6-8 men shouldered logs 20-50 ft or more in length and weighing over 250 kg, depositing them where river currents could take over in floating timbers downstream. Seasonal scheduling factored heavily here, requiring delays for sufficient rains and manipulation of stream flow. Coordinating movement of massive loads also involved conveying orders. In work organised by Domenico Fontana in the sixteenth century AD, the threat of execution quieted spectators for the coordinated movement of the 350-tonne Vatican obelisk that required 900 men, 74 horses, and trumpets to call orders (Dibner 1970: 33).

Labour-saving with water transport has been attested as early as the Egyptian 4th Dynasty, where barges borne on Nile floodwaters brought granite blocks to the Giza staging area of Heit el-Ghurab (Lehner 2015: 430-431). For Roman water transport, DeLaine (1997: 108) presented tonnage classes for ships and river boats: 70-80 tonnes (smallest still suitable for long-distance), 300-400 tonnes (common), 1,000-1,200 tonnes ("supercargoes"), 150-200 tonnes (large river boats), and 70 tonnes (maximum for Tiber River up to Rome) (see also Purcell 1996). For other constants, DeLaine cited crews of 4-10 men, speed under favourable conditions at 3-4 knots, and range at 75-95 miles per day. For river transport, 3-man crews sufficed, with towing capacities for oxen given by teams (38 tonnes for 4 pairs, 95 for 5, and 140 for 6, giving the fair estimate of 20 tonnes per pair) (DeLaine 1997: 108-109). The mechanical advantage of water transport survived into later preindustrial times where speed was not a factor, since the advantage was sufficient to allow one horse to pull a loaded coal barge along a canal (Atkinson 1961: 293).

Apart from the large lintel blocks set above the *stomion* of the Menidi *tholos*, few such considerations of heavy transport have been factored into the labour analysis of tombs (Chapter 4). Wheeled transport likely aided work at the *tholos* by bringing bulk loads of stone, such as the small schist slabs that clad its walls, as well as removing material for its construction and that of the largest chamber tombs at Voudeni (VT4 and VT75). The *dromoi* for these three tombs are wide and gently sloping enough to allow wheeled transport without manoeuvring, which would certainly require unhitching the team to rearrange an unloaded cart. For Portes, the largest chamber tomb (PT3) is too deeply set and narrow to allow for wheeled transport within, but that does not preclude removal of materials from its entrance or a system of ropes and rollers to remove loaded sleds as far as the threshold, alleviating a burdensome, basket-chain system continually making the steep climb.

Placement

Placement of culturally modified soils has shown substantial variation depending on the desired effect, from bulk removal of ditch fill into spoil heaps to ritually significant layering of multi-stage mounds. Raising earthworks generally involved some element of soil compaction to stabilise the matrix and retain a desired shape, as well as strategically sourcing less compact fill materials for wholesale volume. Coles (1973: 76) questioned compaction with experimental earthworks reconstructed using heavy machinery and monitored for changes by erosion. Patience with reproduced preindustrial efforts invested soil compaction's effect on earthwork site formation, which has taken generations to observe for British experimental earthworks and world war trenches (Ashbee and Jewell 1998: 485-489, 493-496; Curwen 1930: 98-99). Compaction also affected labour investment but has rarely been measured. Lacquement (2009: 21) tracked compaction energy for earthen mound construction at Moundville, noting substantial differences in density for alternating soil layers used in multi-stage construction: heavy clay for "sheathing" and living surfaces and less dense bulk layers for increasing size. As he pointed out, volumetrics and energetics reliant on construction volume alone have not accounted for differences in expenditure on heavier materials.

For Mycenaean tomb construction, I primarily reverse compaction scenarios to account for the reduced cost of removing bulk fill from reused *dromoi*. Reopening *dromoi* proceeded faster than digging them for the first time, when the undisturbed rocky matrix was at its most compact. Fill compacted over years of rainwash (Smith and Dabney 2014: 150), increasing the required effort for late reuse but not to a level measured here. What might have taken 12 hours to carve initially could likely be reopened with a third of the effort (4 hours with the same team or, more likely, a reduced workforce), and such is reflected in the comparative labour columns on reuse (see Chapter 4 and Appendix 1). Cost of reuse can then be scaled upwards following the number of times a tomb was likely reopened – albeit over an extended period not meant to absorb the burden all at once. Closing the tomb would be among the least costly acts in construction, doubling progress over the standard rate of excavating disturbed fill, from 4 ph/m^3 removing it to 2 ph/m^3 dumping it back and tamping it down (see below). Smith and Dabney (2014: 146-147) addressed the limited evidence for chamber tomb use and reuse by excavating the Ayia Sotira (Nemea) tombs stratigraphically, leaving baulks and examining layers of fill with macro- and microstratigraphic means. Microstratigraphy of these tombs was the subject of another paper (Karkanas et al. 2012). Evidence showed the tombs were filled from above and partially reopened to allow for cost-effective construction of side chambers (Smith and Dabney 2014: 149-153). As a deferred, final stage, closing need not factor into comparative labour modelling.

Measuring soil compaction requires methods from geotechnical engineering and the application of principles from soil mechanics. Doing just that, Lacquement (2009: 102-103) deployed the sand cone density test and the Proctor compaction test to convert his volumetric recalculations for Moundville into mass, accounting for 375 million kg as the total mass of culturally modified soils (mounds plus the artificially levelled plaza) there. The relative weight of soil types hinges partly on compaction with few – like 2,000 kg per cubic metre of 'heavy clay' (Aaberg and Bonsignore 1975: 53)–stated explicitly. Hoping to spark further study on earthwork compaction, Lacquement (2009: 106; 2019: 170) noted the gap waiting to be bridged between his assessment of mechanical energy in reaching mound fill density through the Proctor compaction test and actual human energy expended. The latter remains unknown in the absence of timed observations on compaction technique and details from each soil layer. Where compaction studies have not been published, standard soil densities serve as placeholders (Lacquement 2009: 116; 2019: 169-170).

In calculating compaction energy, Lacquement (2009: 120) found a staggering 31.5 billion ft-lb/ft^3 (43.3 million kN-m/m^3) involved in setting the density of mound fill, taken from his constant of 5,000 ft-lb/ft^3 (240 kN-m/m^3) found on Mound R. The latter value is taken as a reasonable average for mechanical energy invested in compacting soil layers for multi-stage earthworks (Lacquement 2009: 124). This does not reflect the actual physiological cost of compacting the soil, a figure one should expect to push much higher given the disparity between the mechanical effort required and the limitations of human efficiency in achieving this, particularly with burdensome tamping and stamping methods. In a recent paper, Lacquement (2019: 170) updated the energy expenditure for compacting mound layers using the baseline for level-ground marching (1440 kJ/hour per James and Schofield 1990: 134), acknowledging variability in compacting uneven upturned earth but reasonably assuming volumetric progress twice as efficient as excavating.

Reuse

Beyond procurement, transport, and placement, another consideration affected labour input in the preparation of the construction site itself, which included clearing, recycling, or reusing building materials from previous structures. Later construction destroyed elements of the prehistoric cemetery at Mycenae, for instance where the Tomb of Clytemnestra intersected part of the Grave Circle B wall (Button 2007: 89; Gallou 2005: 17). Nelson (2007: 150-151) wrote of Pylian palatial construction that “builders at Pylos let nothing stand in the way of their palace; they built massive retaining walls to expand the hilltop and when it came time for the new megaron, leveled and graded the hill in preparation for it”. For Mycenae and Tiryns, builders likewise terraced in preparation for new construction (Nelson 2007: 151). Curiously at Tiryns, mudbrick walls from the EH III *Rundbau* survived to a substantial height (diminishing partly after excavations in 1912 and 1984) rather than getting stripped to their stone foundations for reuse by buildings on the LH III Upper Citadel (Maran 2016: 161-162). Reuse of local soils would disappear in secondary construction, but other building materials, particularly worked stone, stand out when reused in earth and rubble fill. Abrams (1987: 487-488) equated reuse of faced stones and broken sculptures in wall fill with a much reduced labour input, citing cuts to two time-consuming stages in primary construction with less transport and manufacture required for onsite reuse. He rightly expanded this reuse to include archaeologically invisible recycling of soil and stone rubble, indistinguishable from newly procured materials in fill contexts (Abrams 1987: 488). This reduction of labour input encouraged secondary use for building materials, no matter the difficulty tracking it.

The simplest cost-analysis compromise for tracking reuse would estimate a likely percentage of recycled materials in the final construction, then reduce the corresponding transport costs omitted by having more material nearby. Such could apply for the reuse of fill in blocking *dromoi* in Mycenaean chamber tombs, but only when space allowed for nearby storage while the passage lay open. Raised areas for Roman Ostia in the first century AD incorporated up to a metre of debris from earlier construction to develop solid foundations for large apartment blocks (Hanna Stöger, personal communication 2017). On reuse and repurposing of ruins, Palladius advocated the use of column fragments in preparing threshing floors and, in a departure from earlier writers, included marble within the list of stones to assist lime production for concrete. Plommer (1973: 37) took the latter case to mean the robbing of marble from abandoned buildings, a practice known from the Later Roman and Medieval periods. Procurement of new materials, apart from disturbed soils being easier to excavate, would not influence the total cost of earthen construction as heavily as with stone, since reused stones also shed manufacturing costs in shaping blocks.

Compiling rates into a comparative labour format (Appendix 1) addresses problems in shortcutting scale comparisons for monumental construction, a common refrain in modelling socio-political complexity. Regional specialisation has limited the versatility of comparative study in forcing a shift to secondary and tertiary sources without the balance of primary data, weakening chances for critical review and reinterpretation (Drennan and Peterson 2012). This has become a pervasive problem for energetics studies that adopt labour rates uncritically, such that some rates pass into conventional wisdom. In one example of a self-styled “cocktail napkin” (i.e., simple and expedient calculation) approach to labour estimates, Peterson and Drennan (2012: 88-89) attempted a sweeping comparative view of community growth for eleven “large-scale social formations” dispersed around the globe. They concluded that most had communal labour requirements of less than one five-hour workday per worker per year (Peterson and Drennan 2012: 123), an artificially low estimate for communal effort. Although the full calculations are not explicit, the basic formula compares demographic estimates against the period of use for multi-stage monumental constructions. This suffices for long-term trends and broad comparisons, but revisions using similar data could produce quite different results on regional scales. Their earthmoving rate derives from Erasmus (1965), claiming 5.25 person-days per m^3 of fill for all earthen mound construction. What the original rate measured was the total for rock and earth excavation and transport, the total for earth alone being 1.25 person-days per m^3 (Erasmus 1965: 289). The latter rate would also be problematic in a single-use comparative scenario, since loose sandy soils demand less than a compact silty-loam, which Hammerstedt (2005: 45) measured as requiring 3.45 person-days per m^3. Most energetics approaches can be strengthened with explicit use of labour rates and careful application when taking a wider geographic and temporal set of case studies.

3.4. Measuring success

As illustrated above, comparative labour often surprises with cost estimates that are far lower than expected. Minimal costs, particularly through single rates and diachronic averaging, are largely to blame. Single rates often lose their primary source context and ignore warnings of limited parameters set by their original authors. Dual rates, cited as minimum-maximum, offer radically different scenarios, rightly pointing out the potential for mischief in preferring one over the other. Single rates simplify quantitative comparisons but require rich contextual details to strengthen minimum costs (Abrams 1987: 488; DeLaine 1997: 105). Alternative usage of labour rates, such as trimmed ranges and various indexes of centre, rarely receive consideration within labour analyses. Moreover, the resulting frameworks have remained weakly prepared to counter arguments or prevent tentative interpretations from reinforcing conventional wisdom on complexity. Following the accessible explanations of Drennan (2009: 27-29), the application of appropriate statistical approaches to labour rates strengthens the final model by curbing inadvertent bias, such as the tendency to select numbers that superficially appear more acceptable in calculations. Presented in Appendix 1, the interquartile range of timed observations for earthmoving removes outliers and enables more precise measurements for both expedient and intensive calculations.

With defensible labour rates set in an operational sequence, measurements of built features complete models for preindustrial construction. Many approaches assist with this task: past survey and excavation records, modern and historical maps and photographs, and digital modelling using total station survey, photogrammetry, and 3D scanning (Pakkanen 2009, 2018). Since photogrammetry was the preferred field method for the current study, a separate section below explains this process in detail. Where circumstances limit these field methods, alternate approaches must rely on existing records and other sources accessible remotely through written records or satellite imagery. The section on alternate data collection outlines these tactics.

3.4.1. Modelling tombs with photogrammetry

When site accessibility is not an issue, measurements from total station survey and photogrammetry combine to create efficient, detailed models with high accuracy. Through a simple coding program developed by the Finnish Institute at Athens, the reflectorless setting on two Leica total stations (T500 and T1000) enabled drawing of architectural features, as well as a Digital Elevation Model (DEM) of the local topography. The method has been described in detail by Pakkanen (2009, 2018) from whom it was adopted through training in a field school on Salamis. Combined with a differential GPS, the total station data produced digital models, georeferenced and operational in AutoCAD and ArcGIS, for tombs in their current state of preservation. A daily average of 3,000 measurements with millimetre accuracy goes beyond the needs of logistical labour models but assists local authorities with the preservation of sites.

For earthworks at least, photogrammetry more than suffices for digital reconstruction. The trade-off in much-reduced fieldwork requirements for photogrammetry versus total station survey is a substantial increase in post-fieldwork processing times. Depending on the size of the model and computing power, photo sets of 500 or more for large tombs took weeks to process, with no guarantees that the model would successfully render before the computer ran out of memory. RAM bottlenecks tripled the processing time of several detailed models and occasionally prevented complete rendering, most often during the texturing phase. Lower resolution settings helped where more detail held no useful information for earthen fill and roughly shaped stones. Sparse point clouds captured shapes far beyond those conceivable in hand-drawing under the same time restrictions. They also reproduced volumes within 0.1% of the textured models built under the highest settings. The only alarming discrepancies that occurred were large error margins associated with some photomarkers, presumably from those that shifted slightly or were mistakenly recorded with a different station point.

Despite the accuracy of modern survey technology, the measurements taken are still restricted to the present form of the construction, which in many cases does not represent the original dimensions. If understood, site formation processes can help rewind the denudation of earthworks due to erosion or maltreatment from later activity. Mentioned previously, the Overton Down Experimental Earthwork Project maintains this goal of tracking the denudation of earthworks over the course of multiple generations, with the next cross-section scheduled for 2024 (Ashbee and Jewell 1998: 503). Results thus far have shown that the most dramatic changes to earthworks can occur within the first 25 years, so long as maintenance activities have ceased (Ashbee and Jewell 1998: 496). Under the right conditions (e.g., exposure to inclement weather), denudation of earthworks causes rapid initial loss in shape and total volume before plateauing. This phenomenon allows an earthwork, after its initial decay, to remain relatively unchanged for millennia, barring any extraordinary circumstances. Chamber tombs and *tholoi* are susceptible to ceiling collapse under certain conditions (Cavanagh and Laxton 1981: 114-115; Cavanagh and Mee 1978: 42), potentially inflating estimates for their original construction volume if not taken into account. Known instances – mostly obvious from shallow tombs but with others hidden by reconstruction – were flagged in the labour analysis (Chapter 4).

Alternate data collection

Whether restricted by vegetation, preservation, or permission, limited site access requires alternate means of data collection. Site reports detailing survey and excavation records generally record architectural dimensions, but these can be fraught with inaccuracies and missing data. Some older reports relied on estimations and pacing, especially where local informants recounted features since lost. This has often been the case for smaller earthen mounds destroyed by ploughing in the eastern U.S., as well as the decay berm left behind by the former kilometre-long palisade at Moundville (Turner 2010: 68). Loss from subsequent construction was especially rampant at large and dense settlements like Mycenae (Boyd 2015a: 201), and several tombs surveyed in Chapter 4 appear modified from their original form when lying too near the surface or in an overcrowded cluster. Where systematic recording methods compatible with modern standards finally took hold, accuracy of measurements remained at the mercy of crew consistency and supervisor competency. Despite frequent fallibility, historical records still hold clues to major dimensions and visible architectural techniques.

Augmenting site records from previous investigations, existing maps and photographs open another avenue for remote study. Topographic surveys conducted over the last century revealed the extent of large earthen monuments, and areas undergoing Light Detection and Ranging (LiDAR) survey show smaller anomalies in 0.6 m contour lines, even in near-impenetrable tropical regions (e.g., Chase et al. 2011: 387; Evans et al. 2013). Combining topographic data with aerial images and satellite data, even the remotest sites yield to basic labour analyses. Some clues as to chronology, materials, and techniques would be required for a worthwhile model, but at their core, each labour assessment needs only rates and dimensions.

Reviewing methods of volume measurement in the absence of digital 3D analyses, Lacquement (2009: 27) explained older methods invoking solid geometry, contour lines (planimetry with topographic maps), and his own computer-aided gridding technique by highlighting gradients of measurement points used in each calculation, from least (solid geometry) to most (gridding). Rightly indicating the exaggeration of size from formulas for a rectangular prism (lwh) and much less recognisable formulas deployed in frustums of truncated pyramids, Lacquement (2009: 27-29) acknowledged the sacrifice in accuracy for a reasonable comparison between readily available data sets. With regard to rectangular prism formulas used for several mounds at Moundville, relative comparisons between mound sizes were still possible such that the size rankings matched that obtained from modern volumetric estimations, despite overestimations averaging 35 percent preventing the former's use in energetics (Lacquement 2009: 46). What is not touched upon is the loss of material through erosion, such that the original form of the mound may have been closer to the volume estimations idealised from geometrical forms (Ashbee and Jewell 1998: 493, 496; Curwen 1930: 99). Mercifully, volumetrics have been greatly aided by digital 3D analyses, and in place of a losing battle with formulas for a jigsaw of tetrahedrons and circular paraboloids, a suite of software packages paves the field with far greater accuracy. In this regard, I have relied mostly on Agisoft Photoscan to measure the volume of tombs with cropped photogrammetric models, cross-checking on occasion with solid geometry approximations that frequently varied with their digitally obtained counterparts from -20 to +25% depending on the irregularity of the shape.

3.4.2. Finding sameness with Euclidean distance

In the chapter to follow, I have generally opted for a baseline cost of excavating the tombs, focusing on variation in procurement rates from the initial expense of cutting into the soft rock to the far less burdensome fill removal in reuse. This sheds the confusing list of transport, placement, and elaboration tasks that would throttle the comparative function of a labour index (Turner 2018: 197). The reported cost of construction is meant only as an analogy to the unknowable real cost, as proponents of energetics have explicitly maintained (e.g., Abrams 1989: 65-68, 1994: 40; Abrams and Bolland 1999: 266-267; Webster and Kirker 1995: 379). Critiques of such incomplete empirical approaches have quieted upon reflection, given its pervasive multi-disciplinary anxieties across epistemology (Foucault 1989: 266). Although originally issued as a challenge to opponents of energetics, Webster and Kirker's (1995: 379) phrasing "*on a scale that matters*" is a useful guideline for the method itself to heed, lest it self-destruct with minutiae.

Too many measurements muddy the reconstructed tomb models, encouraging dimension reduction from computer-aided correspondence analysis. In other words, I sought which variables (e.g., *dromos* length, *stomion* width) were most interrelated and which were nearly irrelevant in terms of cost and mimetic design. Casting off extraneous details trimmed data tables from an illegible switchboard of decimals to color-coded patterns intelligible at a glance. To achieve this goal, I used IBM SPSS Statistics 25 to collate data from Microsoft Excel into a dissimilarity matrix with Euclidean distance (imagining each data point as spatially related to another), first a table comparing the tombs and a second derivative one comparing measurements against a new standard tomb, AA01 (Figures 3.2-3.4, see below). The exercise was inspired by Bourgeois and Kroon (2017: 10), who in turn derived the method from similar practices in genetics research. Before launching the program, variables were interrelated and levelled, such that volumes, linear measurements, and present/absent data could be intermixed. Further, spread from the largest outliers was trimmed by a relative index (e.g., Drennan 2009: 275)–in my case, median measurements derived from the most complete tombs. The Tomb Relative Index, styled conservatively as RexT before leaning into the obvious choice (Ann Brysbaert, personal communication 2019), was a late addition to organise my data into a more manageable framework. I settled on the concept after scrawling a schematic tomb into a notepad and finding the dimensions oddly functional.

AA01 standard and the Tomb Relative Index (TRex)

By way of a benchmark for comparing all tombs, I have created a fictional idealised chamber tomb (AA01) based upon the median measurements obtained from the better-preserved case studies presented in Chapter 4 (Figures 3.2-3.4). AA01 has a total volume of 27.75 m^3 and would cost 250-333 ph to excavate using the rates discussed above and simplified here to 9-12 ph/m^3 (4 ph/m^3 for re-opening, 2 ph/m^3 for closing) of compact earth or soft rock (see also Appendix 1). With an arbitrary team of ten labourers – three digging, six carrying, and one supervising – initial construction for a standard tomb would likely be commissioned prior to the death of the first user and require seven working days of five *effective* hours each, allowing for longer, less-efficient working days in practice without tampering with the calendar time to completion. Re-opening the same closed tomb would take less than two days for a five-person team and could shadow closely the deaths of subsequent users. Whether reuse waited for the last breath is an open-ended question. Sudden death, violent or otherwise, gives only reactionary options without prophetic fortuity. Rapid decay of an untreated body lying in state might provoke the macabre scene of reopening a tomb in anticipation of death, something exceptionally large tombs could hardly avoid in warm climates without embalming or charnel storage. Such tombs frequently bore evidence for anticipatory construction with elaborate preparations for display, such as painted surfaces and re-touched clay coatings, as in the case of the LH IIIA2 Prosilio tomb 2 for a lone 40- to 50-year-old male elite of Orchomenos (Bennet 2017; Yannis Galanakis, personal communication 2019; see Chapter 5, this volume). Secondary treatment of remains was common enough for Mycenaeans to imply contact with putrefaction beyond the modern Western intolerance for it. I offer only windows of possibility for construction and reuse, as the question of timing is better addressed by bioarchaeological and micromorphological analyses on a case-by-case basis. Comparing all tombs to one architectural standard at least, based upon a scale recognisable to Mycenaean tomb builders as neither too big nor too small, emphasizes extreme outliers and the extraordinary risk of investment that the largest tombs represent (see Chapter 5). It also highlights where risks of design changes were generally not taken, as is clear with the fairly consistent widths of *dromoi* and *stomia*. AA01 functions best when compared with other chamber tombs, but it is schematically similar enough to the Menidi *tholos* to link its dimensions to the same scale bar.

In order to correlate the surveyed tombs with the AA01 benchmark, I have created relative index variables that highlight variation among certain tomb features (e.g., total volume, *dromos* length). Such variables allow for useful classifications within the catalogue of tomb construction (Chapter 4) and facilitate rapid scanning of otherwise dense tables (see Tables 4.1-4.3 and A1.3-A1.5). They also place the dataset on equal footing, optimised for correspondence analysis and other statistical tools. The classification thresholds are subjective but not entirely arbitrary. For instance, whereas TRex stands for Tomb Relative Index or relative index total (volume and cost):

Undersized (cohesive or group signal) = TRex < 0.75
Standard (pragmatic signal, can be cohesive or assertive in context) = 0.75 < TRex < 1.5
Exceptional (assertive or costly signal) = TRex > 1.5

AA01 Fictional	**Dromos**	**Stomion**	**Vault**	**Total**	**Labour (ph)**	**Workforce**	**Days**
TRex	1		1	1	Low rate	9 ph/m^3	
Volume (m^3)	13.5	0.75[a]	13.5	27.75	250	10	5
Length (m)	6	1[b]	3	10	High rate	12 ph/m^3	
Width (m)	1.5	0.75	3		333	10	7
Height (m)	3	1	2.5		Reuse rate	4 ph/m^3	
					54[c]	5	3

[a] The ***stomion*** volume for all tombs has been included within the total for the vault for ease and consistency with measurements (thus TRex values for vaults are compared against 14.25 m^3). [b] TRex values of ***stomion*** dimensions for length and width are always equal to their recorded measurements, since the AA01 value for these is 1 m. [c] Reuse cost was calculated from ***dromos*** volume multiplied by 4 ph/m^3, representing a single reuse that can be scaled up by the number of proposed opening/closing events.

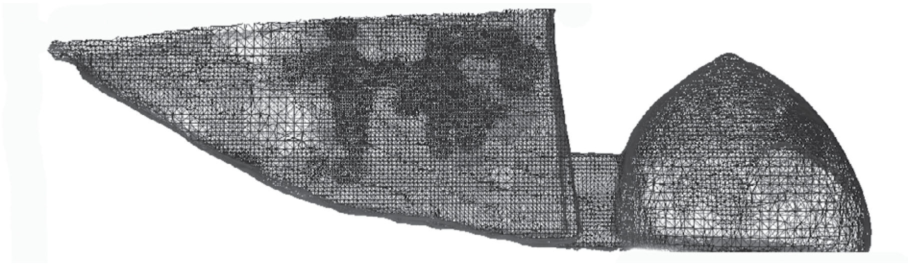
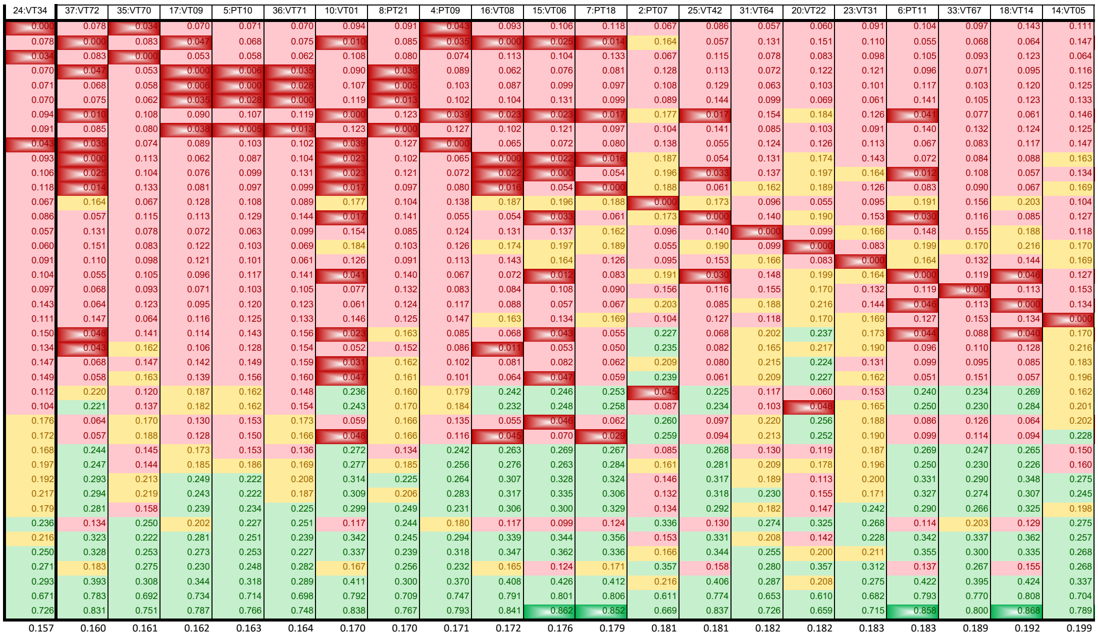


Figure 3.2. Wireframe model (based on the well-preserved VT28) for the fictional AA01 idealised chamber tomb forming the basis of the TRex values (relative index built on median measurements from intact tombs).

Roughly this translates to investment for a working party of 10 tomb builders as either undersized/cohesive (under 5 days), standard/pragmatic (between 5 and 10 days), or exceptional/assertive (greater than 10 days). Mycenaean tomb builders and commissioners may not have seen such strict cost divisions, but they certainly would have recognised the difference in labour input and its attendant message. Other relative index variables break the tombs down into successively smaller (and, as it turns out, less relevant to comparative labour) components, such that RexD is the relative index for *dromos* volume and Rex_sw is the relative index for *stomion* width. As an aside to the label, why not RiT, RID, etc.? Partly the choice is aesthetic, but mostly the inclusion of certain characters (India in the NATO phonetic alphabet and the numeral 1, for instance) in many fonts causes unnecessary coding transcription issues.

A separate list of relative variables appears for tombs that benefit from comparisons with a site-based list of median expected values (e.g., MedT_p for the median expected value of tomb volume at Portes). These function similarly to the AA01 relative index variables and cover the same range of component features, the only difference being restriction to surveyed tombs on site. The Portes chamber tombs especially, with their close adherence to a formal chamber shape (hive type with rounded floors and vaulted or incline-vaulted ceilings, see Chapter 4 Section 4.2), lent themselves to site-based median comparisons.



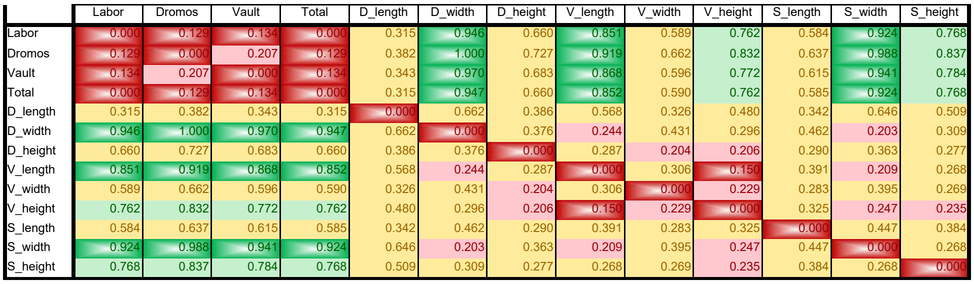
24:VT34	37:VT72	35:VT70	17:VT09	5:PT10	36:VT71	10:VT01	8:PT21	4:PT09	16:VT08	15:VT06	7:PT18	2:PT07	25:VT42	31:VT64	20:VT22	23:VT31	6:PT11	33:VT67	18:VT14	14:VT05
0.000	0.078	0.034	0.070	0.071	0.070	0.094	0.091	0.043	0.093	0.106	0.118	0.067	0.086	0.057	0.060	0.091	0.104	0.097	0.143	0.111
0.078	0.000	0.083	0.047	0.068	0.075	0.010	0.085	0.035	0.000	0.025	0.014	0.164	0.057	0.131	0.151	0.110	0.055	0.068	0.064	0.147
0.034	0.083	0.000	0.053	0.058	0.062	0.108	0.080	0.074	0.113	0.104	0.133	0.067	0.115	0.078	0.083	0.098	0.105	0.093	0.123	0.064
0.070	0.047	0.053	0.000	0.006	0.035	0.090	0.038	0.089	0.062	0.076	0.081	0.128	0.113	0.072	0.122	0.121	0.096	0.071	0.095	0.116
0.071	0.068	0.058	0.006	0.000	0.028	0.107	0.005	0.103	0.087	0.099	0.097	0.108	0.129	0.063	0.103	0.101	0.117	0.103	0.120	0.125
0.070	0.075	0.062	0.035	0.028	0.000	0.119	0.013	0.102	0.104	0.131	0.099	0.089	0.144	0.099	0.069	0.061	0.141	0.105	0.123	0.133
0.094	0.010	0.108	0.090	0.107	0.119	0.000	0.123	0.039	0.023	0.023	0.017	0.177	0.017	0.154	0.184	0.126	0.041	0.077	0.061	0.146
0.091	0.085	0.080	0.038	0.005	0.013	0.123	0.000	0.127	0.102	0.121	0.097	0.104	0.141	0.085	0.103	0.091	0.140	0.132	0.124	0.125
0.043	0.035	0.074	0.089	0.103	0.102	0.039	0.127	0.000	0.065	0.072	0.080	0.138	0.055	0.124	0.126	0.113	0.067	0.083	0.117	0.147
0.093	0.000	0.113	0.062	0.087	0.104	0.023	0.102	0.065	0.000	0.022	0.016	0.187	0.054	0.131	0.174	0.143	0.072	0.084	0.088	0.163
0.106	0.025	0.104	0.076	0.099	0.131	0.023	0.121	0.072	0.022	0.000	0.054	0.196	0.033	0.137	0.197	0.164	0.012	0.108	0.057	0.134
0.118	0.014	0.133	0.081	0.097	0.099	0.017	0.097	0.080	0.016	0.054	0.000	0.188	0.061	0.162	0.189	0.126	0.083	0.090	0.067	0.169
0.067	0.164	0.067	0.128	0.108	0.089	0.177	0.104	0.138	0.187	0.196	0.188	0.000	0.173	0.096	0.055	0.095	0.191	0.156	0.203	0.104
0.086	0.057	0.115	0.113	0.129	0.144	0.017	0.141	0.055	0.054	0.033	0.061	0.173	0.000	0.140	0.190	0.153	0.030	0.116	0.085	0.127
0.057	0.131	0.078	0.072	0.063	0.099	0.154	0.085	0.124	0.131	0.137	0.162	0.096	0.140	0.000	0.099	0.166	0.148	0.155	0.188	0.118
0.060	0.151	0.083	0.122	0.103	0.069	0.184	0.103	0.126	0.174	0.197	0.189	0.055	0.190	0.099	0.000	0.083	0.199	0.170	0.216	0.170
0.091	0.110	0.098	0.121	0.101	0.061	0.126	0.091	0.113	0.143	0.164	0.126	0.095	0.153	0.166	0.083	0.000	0.164	0.132	0.144	0.169
0.104	0.055	0.105	0.096	0.117	0.141	0.041	0.140	0.067	0.072	0.012	0.083	0.191	0.030	0.148	0.199	0.164	0.000	0.119	0.046	0.127
0.097	0.068	0.093	0.071	0.103	0.105	0.077	0.132	0.083	0.084	0.108	0.090	0.156	0.116	0.155	0.170	0.132	0.119	0.000	0.113	0.153
0.143	0.064	0.123	0.095	0.120	0.123	0.061	0.124	0.117	0.088	0.057	0.067	0.203	0.085	0.188	0.216	0.144	0.046	0.113	0.000	0.134
0.111	0.147	0.064	0.116	0.125	0.133	0.146	0.125	0.147	0.163	0.134	0.169	0.104	0.127	0.118	0.170	0.169	0.127	0.153	0.134	0.000
0.150	0.048	0.141	0.114	0.143	0.156	0.023	0.163	0.085	0.068	0.043	0.055	0.227	0.068	0.202	0.237	0.173	0.044	0.088	0.040	0.170
0.134	0.043	0.162	0.106	0.128	0.154	0.052	0.152	0.086	0.011	0.053	0.050	0.235	0.082	0.165	0.217	0.190	0.096	0.110	0.128	0.216
0.147	0.068	0.147	0.142	0.149	0.159	0.031	0.162	0.102	0.081	0.082	0.062	0.209	0.080	0.215	0.224	0.131	0.099	0.095	0.085	0.183
0.149	0.058	0.163	0.139	0.156	0.160	0.047	0.161	0.101	0.064	0.047	0.059	0.239	0.061	0.209	0.227	0.162	0.051	0.151	0.057	0.196
0.112	0.220	0.120	0.187	0.162	0.148	0.236	0.160	0.179	0.242	0.246	0.253	0.045	0.225	0.117	0.060	0.153	0.240	0.234	0.269	0.162
0.104	0.221	0.137	0.182	0.162	0.154	0.243	0.170	0.184	0.232	0.248	0.258	0.087	0.234	0.103	0.048	0.165	0.250	0.230	0.284	0.201
0.176	0.064	0.170	0.130	0.153	0.173	0.059	0.166	0.135	0.055	0.046	0.062	0.260	0.097	0.220	0.256	0.188	0.086	0.126	0.064	0.202
0.172	0.057	0.188	0.128	0.150	0.166	0.048	0.166	0.116	0.045	0.070	0.029	0.259	0.094	0.213	0.252	0.190	0.099	0.114	0.094	0.228
0.168	0.244	0.145	0.173	0.153	0.136	0.272	0.134	0.242	0.263	0.269	0.267	0.085	0.268	0.130	0.119	0.187	0.269	0.247	0.265	0.150
0.197	0.247	0.144	0.185	0.186	0.169	0.277	0.185	0.256	0.276	0.263	0.284	0.161	0.281	0.209	0.178	0.196	0.250	0.230	0.226	0.160
0.192	0.293	0.213	0.249	0.222	0.208	0.314	0.225	0.264	0.307	0.328	0.324	0.146	0.317	0.189	0.113	0.200	0.331	0.290	0.348	0.275
0.217	0.294	0.219	0.243	0.222	0.187	0.309	0.206	0.283	0.317	0.335	0.306	0.132	0.318	0.230	0.155	0.171	0.327	0.274	0.307	0.245
0.179	0.281	0.158	0.239	0.234	0.225	0.299	0.249	0.231	0.306	0.300	0.329	0.134	0.292	0.182	0.147	0.242	0.290	0.266	0.325	0.198
0.236	0.134	0.250	0.202	0.227	0.251	0.117	0.244	0.180	0.117	0.099	0.124	0.336	0.130	0.274	0.325	0.268	0.114	0.203	0.129	0.275
0.216	0.323	0.222	0.281	0.251	0.239	0.342	0.245	0.294	0.339	0.344	0.356	0.153	0.331	0.208	0.142	0.228	0.342	0.337	0.362	0.257
0.250	0.328	0.253	0.273	0.253	0.227	0.337	0.239	0.318	0.347	0.362	0.336	0.166	0.344	0.255	0.200	0.211	0.355	0.300	0.335	0.268
0.271	0.183	0.275	0.230	0.248	0.282	0.167	0.256	0.232	0.165	0.124	0.171	0.357	0.158	0.280	0.357	0.312	0.137	0.267	0.155	0.268
0.293	0.393	0.308	0.344	0.318	0.289	0.411	0.300	0.370	0.408	0.426	0.412	0.216	0.406	0.287	0.208	0.275	0.422	0.395	0.424	0.337
0.671	0.783	0.692	0.734	0.714	0.698	0.792	0.709	0.747	0.791	0.801	0.806	0.611	0.774	0.653	0.610	0.682	0.793	0.770	0.808	0.704
0.726	0.831	0.751	0.787	0.766	0.748	0.838	0.767	0.793	0.841	0.862	0.852	0.669	0.837	0.726	0.659	0.715	0.858	0.800	0.868	0.789
0.157	0.160	0.161	0.162	0.163	0.164	0.170	0.170	0.171	0.172	0.176	0.179	0.181	0.181	0.182	0.182	0.183	0.183	0.189	0.192	0.199

Figure 3.3. Square symmetrical matrix comparing tomb dimensions using correspondence analysis with Euclidean distance. Mirrored across the diagonal, colour-coding indicates tombs that are strongly similar (dark red), similar (light red), weakly similar (yellow), dissimilar (light green), and strongly dissimilar (dark green).

Proximity Matrix

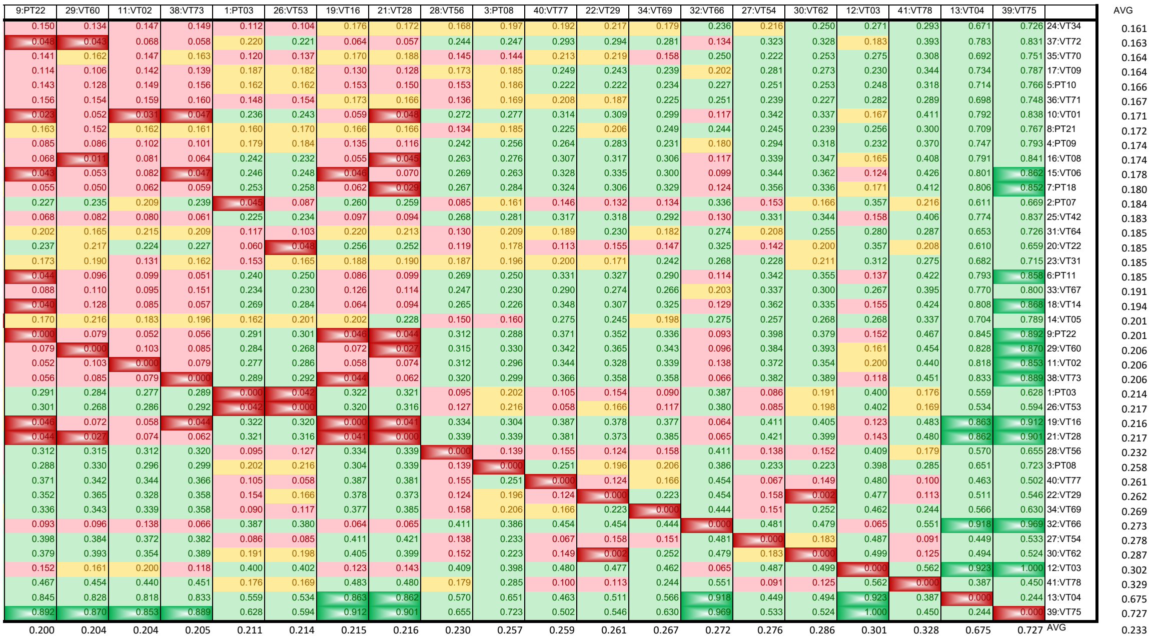
	Rescaled Euclidean Distance												
	Labor	Dromos	Vault	Total	D_length	D_width	D_height	V_length	V_width	V_height	S_length	S_width	S_height
Labor	0.000	0.129	0.134	0.000	0.315	0.946	0.660	0.851	0.589	0.762	0.584	0.924	0.768
Dromos	0.129	0.000	0.207	0.129	0.382	1.000	0.727	0.919	0.662	0.832	0.637	0.988	0.837
Vault	0.134	0.207	0.000	0.134	0.343	0.970	0.683	0.868	0.596	0.772	0.615	0.941	0.784
Total	0.000	0.129	0.134	0.000	0.315	0.947	0.660	0.852	0.590	0.762	0.585	0.924	0.768
D_length	0.315	0.382	0.343	0.315	0.000	0.662	0.386	0.568	0.326	0.480	0.342	0.646	0.509
D_width	0.946	1.000	0.970	0.947	0.662	0.000	0.376	0.244	0.431	0.296	0.462	0.203	0.309
D_height	0.660	0.727	0.683	0.660	0.386	0.376	0.000	0.287	0.204	0.206	0.290	0.363	0.277
V_length	0.851	0.919	0.868	0.852	0.568	0.244	0.287	0.000	0.306	0.150	0.391	0.209	0.268
V_width	0.589	0.662	0.596	0.590	0.326	0.431	0.204	0.306	0.000	0.229	0.283	0.395	0.269
V_height	0.762	0.832	0.772	0.762	0.480	0.296	0.206	0.150	0.229	0.000	0.325	0.247	0.235
S_length	0.584	0.637	0.615	0.585	0.342	0.462	0.290	0.391	0.283	0.325	0.000	0.447	0.384
S_width	0.924	0.988	0.941	0.924	0.646	0.203	0.363	0.209	0.395	0.247	0.447	0.000	0.268
S_height	0.768	0.837	0.784	0.768	0.509	0.309	0.277	0.268	0.269	0.235	0.384	0.268	0.000

This is a dissimilarity matrix



	Labor	Dromos	Vault	Total	D_length	D_width	D_height	V_length	V_width	V_height	S_length	S_width	S_height
Labor	0.000	0.129	0.134	0.000	0.315	0.946	0.660	0.851	0.589	0.762	0.584	0.924	0.768
Dromos	0.129	0.000	0.207	0.129	0.382	1.000	0.727	0.919	0.662	0.832	0.637	0.988	0.837
Vault	0.134	0.207	0.000	0.134	0.343	0.970	0.683	0.868	0.596	0.772	0.615	0.941	0.784
Total	0.000	0.129	0.134	0.000	0.315	0.947	0.660	0.852	0.590	0.762	0.585	0.924	0.768
D_length	0.315	0.382	0.343	0.315	0.000	0.662	0.386	0.568	0.326	0.480	0.342	0.646	0.509
D_width	0.946	1.000	0.970	0.947	0.662	0.000	0.376	0.244	0.431	0.296	0.462	0.203	0.309
D_height	0.660	0.727	0.683	0.660	0.386	0.376	0.000	0.287	0.204	0.206	0.290	0.363	0.277
V_length	0.851	0.919	0.868	0.852	0.568	0.244	0.287	0.000	0.306	0.150	0.391	0.209	0.268
V_width	0.589	0.662	0.596	0.590	0.326	0.431	0.204	0.306	0.000	0.229	0.283	0.395	0.269
V_height	0.762	0.832	0.772	0.762	0.480	0.296	0.206	0.150	0.229	0.000	0.325	0.247	0.235
S_length	0.584	0.637	0.615	0.585	0.342	0.462	0.290	0.391	0.283	0.325	0.000	0.447	0.384
S_width	0.924	0.988	0.941	0.924	0.646	0.203	0.363	0.209	0.395	0.247	0.447	0.000	0.268
S_height	0.768	0.837	0.784	0.768	0.509	0.309	0.277	0.268	0.269	0.235	0.384	0.268	0.000

Figure 3.4. Square symmetrical matrix, original and colourised, comparing variables using correspondence analysis with Euclidean distance. Colour-coding matches that of Figure 3.3.



9:PT22	29:VT60	11:VT02	38:VT73	1:PT03	26:VT53	19:VT16	21:VT28	28:VT56	3:PT08	40:VT77	22:VT29	34:VT69	32:VT66	27:VT54	30:VT62	12:VT03	41:VT78	13:VT04	39:VT75		AVG
0.150	0.134	0.147	0.149	0.112	0.104	0.176	0.172	0.168	0.197	0.192	0.217	0.179	0.236	0.216	0.250	0.271	0.293	0.671	0.726	24:VT34	0.161
0.048	0.043	0.068	0.058	0.220	0.221	0.064	0.057	0.244	0.247	0.293	0.294	0.281	0.134	0.323	0.328	0.183	0.393	0.783	0.831	37:VT72	0.163
0.141	0.162	0.147	0.163	0.120	0.137	0.170	0.188	0.145	0.144	0.213	0.219	0.158	0.250	0.222	0.253	0.275	0.308	0.692	0.751	35:VT70	0.164
0.114	0.106	0.142	0.139	0.187	0.182	0.130	0.128	0.173	0.185	0.249	0.243	0.239	0.202	0.281	0.273	0.230	0.344	0.734	0.787	17:VT09	0.164
0.143	0.128	0.149	0.156	0.162	0.162	0.153	0.150	0.153	0.186	0.222	0.222	0.234	0.227	0.251	0.253	0.248	0.318	0.714	0.766	5:PT10	0.166
0.156	0.154	0.159	0.160	0.148	0.154	0.173	0.166	0.136	0.169	0.208	0.187	0.225	0.251	0.239	0.227	0.282	0.289	0.698	0.748	36:VT71	0.167
0.023	0.052	0.031	0.047	0.236	0.243	0.059	0.048	0.272	0.277	0.314	0.309	0.299	0.117	0.342	0.337	0.167	0.411	0.792	0.838	10:VT01	0.171
0.163	0.152	0.162	0.161	0.160	0.170	0.166	0.166	0.134	0.185	0.225	0.206	0.249	0.244	0.245	0.239	0.256	0.300	0.709	0.767	8:PT21	0.172
0.085	0.086	0.102	0.101	0.179	0.184	0.135	0.116	0.242	0.256	0.264	0.283	0.231	0.180	0.294	0.318	0.232	0.370	0.747	0.793	4:PT09	0.174
0.068	0.011	0.081	0.064	0.242	0.232	0.055	0.045	0.263	0.276	0.307	0.317	0.306	0.117	0.339	0.347	0.165	0.408	0.791	0.841	16:VT08	0.174
0.043	0.053	0.082	0.047	0.246	0.248	0.046	0.070	0.269	0.263	0.328	0.335	0.300	0.099	0.344	0.362	0.124	0.426	0.801	0.862	15:VT06	0.178
0.055	0.050	0.062	0.059	0.253	0.258	0.062	0.029	0.267	0.284	0.324	0.306	0.329	0.124	0.356	0.336	0.171	0.412	0.806	0.852	7:PT18	0.180
0.227	0.235	0.209	0.239	0.045	0.087	0.260	0.259	0.085	0.161	0.146	0.132	0.134	0.336	0.153	0.166	0.357	0.216	0.611	0.669	2:PT07	0.184
0.068	0.082	0.080	0.061	0.225	0.234	0.097	0.094	0.268	0.281	0.317	0.318	0.292	0.130	0.331	0.344	0.158	0.406	0.774	0.837	25:VT42	0.183
0.202	0.165	0.215	0.209	0.117	0.103	0.220	0.213	0.130	0.209	0.189	0.230	0.182	0.274	0.208	0.255	0.280	0.287	0.653	0.726	31:VT64	0.185
0.237	0.217	0.224	0.227	0.060	0.048	0.256	0.252	0.119	0.178	0.113	0.155	0.147	0.325	0.142	0.200	0.357	0.208	0.610	0.659	20:VT22	0.185
0.173	0.190	0.131	0.162	0.153	0.165	0.188	0.190	0.187	0.196	0.200	0.171	0.242	0.268	0.228	0.211	0.312	0.275	0.682	0.715	23:VT31	0.185
0.044	0.096	0.099	0.051	0.240	0.250	0.086	0.099	0.269	0.250	0.331	0.327	0.290	0.114	0.342	0.355	0.137	0.422	0.793	0.858	6:PT11	0.185
0.088	0.110	0.095	0.151	0.234	0.230	0.126	0.114	0.247	0.230	0.290	0.274	0.266	0.203	0.337	0.300	0.267	0.395	0.770	0.800	33:VT67	0.191
0.040	0.128	0.085	0.057	0.269	0.284	0.064	0.094	0.265	0.226	0.348	0.307	0.325	0.129	0.362	0.335	0.155	0.424	0.808	0.868	18:VT14	0.194
0.170	0.216	0.183	0.196	0.162	0.201	0.202	0.228	0.150	0.160	0.275	0.245	0.198	0.275	0.257	0.268	0.268	0.337	0.704	0.789	14:VT05	0.201
0.000	0.079	0.052	0.056	0.291	0.301	0.046	0.044	0.312	0.288	0.371	0.352	0.336	0.093	0.398	0.379	0.152	0.467	0.845	0.892	9:PT22	0.201
0.079	0.000	0.103	0.085	0.284	0.268	0.072	0.027	0.315	0.330	0.342	0.365	0.343	0.096	0.384	0.393	0.161	0.454	0.828	0.870	29:VT60	0.206
0.052	0.103	0.000	0.079	0.277	0.286	0.058	0.074	0.312	0.296	0.344	0.328	0.339	0.138	0.372	0.354	0.200	0.440	0.818	0.853	11:VT02	0.206
0.056	0.085	0.079	0.000	0.289	0.292	0.044	0.062	0.320	0.299	0.366	0.358	0.358	0.066	0.382	0.389	0.118	0.451	0.833	0.889	38:VT73	0.206
0.291	0.284	0.277	0.289	0.000	0.042	0.322	0.321	0.095	0.202	0.105	0.154	0.090	0.387	0.086	0.191	0.400	0.176	0.559	0.628	1:PT03	0.214
0.301	0.268	0.286	0.292	0.042	0.000	0.320	0.316	0.127	0.216	0.058	0.166	0.117	0.380	0.085	0.198	0.402	0.169	0.534	0.594	26:VT53	0.217
0.046	0.072	0.058	0.044	0.322	0.320	0.000	0.041	0.334	0.304	0.387	0.378	0.377	0.064	0.411	0.405	0.123	0.483	0.863	0.912	19:VT16	0.216
0.044	0.027	0.074	0.062	0.321	0.316	0.041	0.000	0.339	0.339	0.381	0.373	0.385	0.065	0.421	0.399	0.143	0.480	0.862	0.901	21:VT28	0.217
0.312	0.315	0.312	0.320	0.095	0.127	0.334	0.339	0.000	0.139	0.155	0.124	0.158	0.411	0.138	0.152	0.409	0.179	0.570	0.655	28:VT56	0.232
0.288	0.330	0.296	0.299	0.202	0.216	0.304	0.339	0.139	0.000	0.251	0.196	0.206	0.386	0.233	0.223	0.398	0.285	0.651	0.723	3:PT08	0.258
0.371	0.342	0.344	0.366	0.105	0.058	0.387	0.381	0.155	0.251	0.000	0.124	0.166	0.454	0.067	0.149	0.480	0.100	0.463	0.502	40:VT77	0.261
0.352	0.365	0.328	0.358	0.154	0.166	0.378	0.373	0.124	0.196	0.124	0.000	0.223	0.454	0.158	0.002	0.477	0.113	0.511	0.546	22:VT29	0.262
0.336	0.343	0.339	0.358	0.090	0.117	0.377	0.385	0.158	0.206	0.166	0.223	0.000	0.444	0.151	0.252	0.462	0.244	0.566	0.630	34:VT69	0.269
0.093	0.096	0.138	0.066	0.387	0.380	0.064	0.065	0.411	0.386	0.454	0.454	0.444	0.000	0.481	0.479	0.065	0.551	0.918	0.969	32:VT66	0.273
0.398	0.384	0.372	0.382	0.086	0.085	0.411	0.421	0.138	0.233	0.067	0.158	0.151	0.481	0.000	0.183	0.487	0.091	0.449	0.533	27:VT54	0.278
0.379	0.393	0.354	0.389	0.191	0.198	0.405	0.399	0.152	0.223	0.149	0.002	0.252	0.479	0.183	0.000	0.499	0.125	0.494	0.524	30:VT62	0.287
0.152	0.161	0.200	0.118	0.400	0.402	0.123	0.143	0.409	0.398	0.480	0.477	0.462	0.065	0.487	0.499	0.000	0.562	0.923	1.000	12:VT03	0.302
0.467	0.454	0.440	0.451	0.176	0.169	0.483	0.480	0.179	0.285	0.100	0.113	0.244	0.551	0.091	0.125	0.562	0.000	0.387	0.450	41:VT78	0.329
0.845	0.828	0.818	0.833	0.559	0.534	0.863	0.862	0.570	0.651	0.463	0.511	0.566	0.918	0.449	0.494	0.923	0.387	0.000	0.244	13:VT04	0.675
0.892	0.870	0.853	0.889	0.628	0.594	0.912	0.901	0.655	0.723	0.502	0.546	0.630	0.969	0.533	0.524	1.000	0.450	0.244	0.000	39:VT75	0.727
0.200	0.204	0.204	0.205	0.211	0.214	0.215	0.216	0.230	0.257	0.259	0.261	0.267	0.272	0.276	0.286	0.301	0.328	0.675	0.727	AVG	0.233

Figure 3.3. continued.

3.5. Summary

Adopted long before the signalling and mnemonic framework presented in preceding chapters, comparative earthmoving laid the groundwork for the methods deployed here and in the following chapter. Timeless and adaptable, earthmoving imposes few technological or economic constraints on monumental expressions, unlike its more demanding wood, stone, and metallic counterparts. Comparatively low cost and intuitive execution led to its pervasive use in defence, infrastructure, and commemorative construction. As such, it forms a manageable baseline for energetics studies comparing large data sets without volumetric false equivalencies or contextual minutiae. Combining sufficient understanding of building material and mechanics with a relative index recognisable to others as a standard example, more time can be devoted to gathering and interpreting data with greater confidence.

For Mycenaean tomb construction, focus naturally falls on dense clusters of comparatively simple rock-cut chamber tombs rather than their more complex stacked-stone counterparts in *tholoi* and built chamber tombs. The shared tripartite character of *tholoi* and chamber tombs affords baseline comparisons for the excavation costs of their footprints, but the vagaries of stonecutting and transport derail all but the most contextually rich total-cost examples where quarry source and masonry techniques are firmly established. In developing the Tomb Relative Index (TRex), I opted for a chamber tomb closely tied to the median values of as many reliable photogrammetric measurements as I could gather in two seasons of fieldwork. The results of that work are presented in the following chapter.

4

A labour catalogue with multi-use tombs

“*What needs my Shakespeare for his honoured bones,*
The labor of an age in pilèd stones,
[…]
Dear son of Memory, great heir of fame,
What need’st thou such weak witness of thy name?
Thou in our wonder and astonishment
Hast built thyself a live-long monument.
[…]
And so sepúlchred in such pomp dost lie,
That kings for such a tomb would wish to die.”
Excerpts from “On Shakespeare” by John Milton (1630)

Much as Milton described, memories endure through the stories we tell, outliving monuments that can decay or change ownership with prevailing narratives (e.g., Cummings 2003: 38, with references). This chapter introduces the results of labour modelling at Mycenaean tombs in Attica and Achaea, three of which (Menidi, VT4, and VT75) may qualify for Milton’s closing line if *kings* could be unpacked from its loaded etymology. Undoubtedly an exceptional nameless few built the largest tombs, and no better phrase may describe those who built the mega-*tholoi* of palatial centres like Mycenae and Orchomenos. The tombs of Menidi, Portes, and Voudeni were not merely conceived as pale reflections of larger tombs elsewhere, but as a grand testament to local memories, group identities, or assertive individuals (*sensu* Čučković 2017: 528; Cummings 2003: 25; Gittins and Pettitt 2017: 470; see previous chapters). Each deserves an appraisal of its constructed form, one that may add to past and ongoing research into their contents and place in the wider Mycenaean world (e.g., Kolonas 1998; Moutafi 2015; Moschos 2000, 2009). The following sections prioritize individual descriptions of tomb shape, scale, and location, deferring social implications to the subsequent discussion chapter. Simple and systematic descriptions offer a guide for future research through practical details of fieldwork and data processing, since quantitative tools can be replicated more readily than theoretical assumptions. The Menidi *tholos* and the cemeteries of Portes and Voudeni have their own contextual depth, part of which this chapter attempts to capture. Snapshots of photogrammetric models accompany each tomb, and their major features are explained. Later discussion will attempt to explain these features as the builders may have understood them.

I present the case studies in the order of fieldwork: Menidi (July 2016), Portes (June-July 2017), and Voudeni (July 2017). The tombs within the two Achaean cemeteries appear according to their known alphanumeric labels, preceded by the initial of the site (P or V) to differentiate tombs of the same number. In the case of unlabelled tombs, an approximation is suggested by (?) or a numbered U (unidentified tomb) in the order of fieldwork. Multi-chambered tombs without individual labels at Portes are listed according to their location relative to the nearest known tomb (e.g., PT8 inner vault). If the narrative description of location is ambiguous, the maps (see Figures 4.1.1, 4.2.1, 4.3.1) indicate the location of each feature relative to the layout of the archaeological parks. Where digital modelling failed, I give an overview of the error (if known) and the metadata for the tomb in Appendix 2. Some failed models may prove successful under alternate settings or as technical capabilities improve. The base data (e.g., photos and coordinates) have been secured for long-term storage and future reference.

The structure of this chapter follows a common format, with a brief history of research contextualising an overview of fieldwork proceedings and data processing for each site. The closing lines for each tomb successfully modelled introduce the labour estimate to be expanded upon in Chapter 5. The catalogue of tomb descriptions are accompanied by orthophoto mosaics (plan view oriented with north always up and cross-section defined by direction in the caption), as well as a table listing dimensions, labour costs, and how these relate to the Tomb Relative Index (TRex). I chose to include the *stomion* volumes with those of the vault (burial chamber) for consistent measurements, being easier to replicate when cropping the model based on the clear break from the *dromos*. The typical *stomion* widened toward the burial chamber, particularly with rounded vaults where it anticipated the arc. Tables 4.1-4.3 compile dimensions and TRex values for the tombs, allowing their relative size to be viewed at a glance (see also Tables A1.3-A1.5 for scale ranking). Chronological resolution for the tombs and the order of their construction stems from reported finds, which often spanned centuries of use or were limited to later periods for having been cleared during reuse. Generations of reuse in some cases and loss of information for looted or damaged tombs hinder detailed construction sequences for the cemeteries, but efforts have been made to reconstruct the chronology available. Since the cemeteries of Portes and Voudeni are largely unpublished, contextual snapshots are provided by preliminary reports, visitor information signs, and articles referencing the materials found there and on display in the Patras Museum. My permitted access focused on excavated tombs that could be safely entered and surveyed with the non-invasive methods outlined in Section 3.4.

Table 4.1 (opposite). Summary of tomb dimensions.

Tomb	Total (m^3)	Dromos (m^3)	Vault (m^3)	Dro_L (m)	Dro_W (m)	Dro_H (m)	Sto_L (m)	Sto_W (m)	Sto_H (m)	Vault_L (m)	Vault_W (m)	Vault_H (m)
AA01	27.75	13.50	14.25	6.00	1.50	3.00	1.00	0.75	1.00	3.00	3.00	2.50
Menidi	618.00	349.00	269.00	27.00	2.90	6.74	2.74	1.70	3.02	8.25	8.35	8.81
Prosilio_T2	276.80	122.00	154.80	20.00	2.20	5.55	2.40	1.35	2.40	7.10	5.84	3.50
PT02	18.56	3.86	14.70	2.26	1.09	1.75	1.03	0.71	1.52	2.58	2.34	1.55
PT03	60.50	38.10	22.40	8.87	2.01	4.74	1.23	0.78	1.28	3.44	3.58	2.81
PT07	44.80	24.80	20.00	8.48	1.79	3.90	0.98	0.77	1.36	3.61	3.94	2.48
PT08	32.00	18.40	13.60	8.15	1.82	3.73	0.61	1.17	1.51	2.97	2.95	2.17
PT08_In	10.00		10.00							3.02	2.96	2.09
PT09	27.50	17.40	10.10	7.11	1.34	3.37	0.93	0.61	0.88	2.85	2.35	2.36
PT10	32.80	20.30	12.50	8.04	1.80	3.69	0.49	0.71	0.95	2.77	3.47	2.32
PT11	16.33	11.60	4.73	7.31	1.49	2.26	0.78	0.64	0.96	1.97	1.95	1.82
PT12	4.37	4.37		5.13	0.78	2.07						
PT13	19.40	19.40		6.42	1.22	4.12						
PT16	35.62	3.22	32.40	3.79	1.51	1.18	0.68	0.83	0.87	2.33	2.55	1.11
PT18	18.95	10.60	8.35	5.31	1.39	3.21	0.47	0.50	1.01	2.77	2.73	1.82
PT21	31.60	17.90	13.70	6.74	1.88	4.14	0.44	0.67	1.15	2.92	3.35	2.16
PT22	12.03	4.86	7.17	4.02	1.19	1.94	0.58	0.59	0.91	2.25	2.27	1.96
PTA	166.88		166.88									
PTA1	4.57		4.57									
PTA2	1.22		1.22									
PTA3	1.55		1.55									
PTA4/A6	0.03		0.03									
PTA5(A8)	0.02		0.02									
PTE1	5.98		5.98									
PTE1A	0.76		0.76									
PTE2	1.22		1.22									
PTE3_NM	0.00											
PTE4_NM	0.00											
PTh1_NM	0.00											
PTh2	26.10		26.10									
PTST1	2.49		2.49									
PTST2	1.11		1.11									
VT01	20.63	6.83	13.80	4.71	1.30	2.33	0.89	0.59	1.06	2.47	2.94	2.05
VT02	17.42	4.32	13.10	3.39	1.05	2.36	0.82	0.62	1.13	2.20	4.04	1.83
VT03	4.88	4.02	0.86	4.32	1.65	1.48	0.57	0.47	0.84	1.00	1.18	0.92
VT04	240.70	165.00	75.70	19.20	2.65	5.63	2.22	1.20	2.41	4.58	5.78	3.55
VT05	21.16	7.06	14.10	3.62	1.89	1.83	1.14	0.89	1.47	3.03	3.25	1.94
VT06	16.98	9.44	7.54	4.87	1.53	2.24	0.84	0.68	0.89	2.16	2.51	1.76
VT07	47.03	43.10	3.93	12.40	1.47	3.47				3.21	1.11	1.14
VT08	21.90	12.20	9.70	5.53	1.44	2.84	0.69	0.62	0.86	2.79	2.73	1.79

Tomb	Total (m^3)	Dromos (m^3)	Vault (m^3)	Dro_L (m)	Dro_W (m)	Dro_H (m)	Sto_L (m)	Sto_W (m)	Sto_H (m)	Vault_L (m)	Vault_W (m)	Vault_H (m)
VT09	27.30	12.90	14.40	6.52	1.68	2.71	0.57	0.80	1.01	3.01	2.96	2.40
VT11	5.85	2.05	3.80	2.92	1.10	0.95	0.71	0.58	0.71	1.71	2.03	1.32
VT13	18.29	4.49	13.80	4.66	1.55	1.55	0.77	0.85	1.05	2.65	2.84	1.98
VT14	15.31	6.65	8.66	4.05	1.38	1.99	0.58	0.75	1.37	1.99	2.34	1.94
VT15_Dro.	13.02	12.30	0.72	7.30	1.15	3.06						
VT16	11.14	5.59	5.55	3.34	1.21	2.37	0.51	0.65	0.89	1.96	2.82	1.36
VT18_Dro.	8.86	8.86		4.96	1.48	2.65						
VT19	17.30	10.80	6.50	4.53	1.94	2.10	0.78	0.62	1.03	2.27	2.35	1.57
VT21	74.90	35.00	39.90	8.63	2.44	3.43	1.00	0.93	2.35	2.99	4.58	2.93
VT22	42.60	23.80	18.80	8.62	1.68	4.50	1.09	0.85	1.29	3.37	3.36	2.91
VT24	17.83	11.10	6.73	5.86	1.76	2.04	0.75	0.70	0.86	2.38	2.46	1.60
VT25	126.30	52.00	74.30	13.20	1.98	4.29	1.13	0.98	1.84	4.79	3.90	4.09
VT26_Dro.	38.80	38.80		11.50	2.02	4.03						
VT27_Dro.	13.10	13.10		6.66	1.43	3.24						
VT28	13.49	7.00	6.49	5.33	1.18	2.21	0.46	0.49	0.86	2.39	2.65	1.96
VT29	82.10	31.00	51.10	9.73	1.77	3.93	0.85	0.93	2.09	3.66	4.70	3.29
VT30_Dro.	2.15	2.15		4.46	1.08	0.78						
VT31	35.20	14.40	20.80	6.24	1.32	4.05	0.86	0.76	1.56	2.67	4.04	2.62
VT33	3.48		3.48									
VT34	32.90	19.00	13.90	8.83	1.57	3.16	1.15	0.77	1.14	3.16	3.09	2.33
VT36	45.00	17.20	27.80	7.26	1.33	3.15	1.64	0.76	1.16	2.83	3.81	2.53
VT40	13.24	7.30	5.94	5.00	1.08	2.85				2.21	2.19	1.91
VT42	18.70	11.00	7.70	6.36	1.45	2.11	1.11	0.58	1.14	2.48	2.66	1.71
VT43_Dro.	18.20	18.20		7.92	1.68	3.13						
VT44	21.66	7.30	14.36	5.00	1.08	2.85				2.79	2.71	2.82
VT53	65.50	38.10	27.40	10.90	1.91	4.34	1.38	0.86	1.17	3.57	3.71	2.79
VT54	81.40	46.80	34.60	9.43	2.19	5.09	1.56	0.99	1.59	3.15	4.55	2.87
VT55_Dro.	23.10	23.10		8.45	1.75	3.89						
VT56	47.80	25.80	22.00	6.77	2.29	3.56	0.91	0.97	1.68	3.76	3.85	2.92
VT57	2.57	1.41	1.16	2.16	0.88	0.49	0.47	0.80	0.56	1.60	1.23	0.65
VT59	15.72	7.13	8.59	5.10	1.33	1.72				2.45	2.28	1.42
VT60	18.90	12.00	6.90	6.42	1.34	2.61	0.67	0.53	0.61	2.69	2.62	1.96
VT61_U1	4.49	2.46	2.03	3.03	1.51	0.58				1.36	1.56	0.92
VT62	94.90	32.30	62.60	10.60	1.84	3.48	0.82	0.94	2.15	3.74	5.18	3.17
VT63	5.31	1.96	3.35	3.57	1.47	0.66				1.76	1.72	0.95
VT64	40.00	25.80	14.20	9.23	2.06	2.85	1.00	0.76	0.97	3.25	3.27	2.41
VT65	10.38	1.39	8.99	2.83	0.92	0.78	0.83	0.63	0.85	2.31	3.24	0.92
VT66	6.58	4.92	1.66	5.99	1.15	1.85	0.54	0.50	0.75	1.45	1.49	1.28
VT67	22.06	9.06	13.00	6.35	1.17	2.04	0.69	0.79	1.00	3.46	3.59	2.41

Table 4.1 (continued).

Tomb	Total (m^3)	Dromos (m^3)	Vault (m^3)	Dro_L (m)	Dro_W (m)	Dro_H (m)	Sto_L (m)	Sto_W (m)	Sto_H (m)	Vault_L (m)	Vault_W (m)	Vault_H (m)
VT68	25.15	4.55	20.60	3.23	1.86	1.03				3.09	3.63	2.81
VT69	51.20	19.10	32.10	6.52	1.94	3.34	1.75	1.11	1.16	3.86	3.32	3.45
VT70	25.30	11.40	13.90	5.33	1.65	2.89	1.06	0.90	1.15	2.95	3.31	2.45
VT71	28.30	15.50	12.80	6.06	1.64	3.64	0.61	0.78	1.33	3.18	3.15	2.70
VT72	17.11	8.56	8.55	4.87	1.39	2.92	0.74	0.67	0.98	2.63	2.71	2.21
VT73	10.88	7.49	3.39	5.34	1.24	2.82	0.77	0.59	1.14	1.76	1.90	1.62
VT74	10.55	2.20	8.35	4.19	1.25	1.06	0.76	0.96	1.14	2.67	2.67	1.58
VT75	257.00	118.00	139.00	23.40	1.88	6.60	1.99	1.17	2.13	5.08	7.60	4.57
VT76	2.38	0.88	1.50	1.20	1.01	0.36				1.97	1.87	0.44
VT77	96.40	52.00	44.40	11.00	1.89	4.88	1.26	0.91	1.33	3.56	4.71	3.27
VT78	106.00	51.40	54.60	11.90	2.17	5.47	1.27	0.94	2.06	3.80	4.58	3.23
VTU2_Dro.	5.73	5.73		5.51	1.07	1.77						
VTU3_Dro.	12.40	12.40		6.21	1.45	3.37						

Table 4.1 (continued).

Tomb	Low rate (ph)	High rate (ph)	5-hr days	Reopen rate (ph)	(Reopen) 5-hr days	Reopened x 5 (ph)	Reopened x 10 (ph)	Reopened x 20 (ph)	Closing (ph)	(Closing) 5-hr days
AA01	250	333	7	54	2	270	540	1080	27	1
Menidi	5562	7416	149	1396	28	6980	13960	27920	698	14
PT02	168	223	5	16	1	78	155	309	8	1
PT03	545	726	15	153	4	762	1524	3048	77	2
PT07	404	538	11	100	2	496	992	1984	50	1
PT08	288	384	8	74	2	368	736	1472	37	1
PT08_In	90	120	3							
PT09	248	330	7	70	2	348	696	1392	35	1
PT10	296	394	8	82	2	406	812	1624	41	1
PT11	147	196	4	47	1	232	464	928	24	1
PT12	40	53	2	18	1	88	175	350	9	1
PT13	175	233	5	78	2	388	776	1552	39	1
PT16	321	428	9	13	1	65	129	258	7	1
PT18	171	228	5	43	1	212	424	848	22	1
PT21	285	380	8	72	2	358	716	1432	36	1
PT22	109	145	3	20	1	98	195	389	10	1
PTA	1502	2003	41							
PTA1	42	55	2							
PTA2	11	15	1							
PTA3	14	19	1							
PTA4/A6	1	1	1							

Table 4.2. Estimated excavation costs for labour teams of 10 (continued overleaf).

Tomb	Low rate (ph)	High rate (ph)	5-hr days	Reopen rate (ph)	(Reopen) 5-hr days	Reopened x 5 (ph)	Reopened x 10 (ph)	Reopened x 20 (ph)	Closing (ph)	(Closing) 5-hr days
PTA5(A8)	1	1	1							
PTE1	54	72	2							
PTE1A	7	10	1							
PTE2	11	15	1							
PTE3_NM	0	0	0							
PTE4_NM	0	0	0							
PTST1	23	30	1							
PTST2	10	14	1							
PTh1_NM	0	0	0							
PTh2	235	314	7							
VT01	186	248	5	28	1	137	274	547	14	1
VT02	157	210	5	18	1	87	173	346	9	1
VT03	44	59	2	17	1	81	161	322	9	1
VT04	2167	2889	58	660	14	3300	6600	13200	330	7
VT05	191	254	6	29	1	142	283	565	15	1
VT06	153	204	5	38	1	189	378	756	19	1
VT07	424	565	12	173	4	862	1724	3448	87	2
VT08	198	263	6	49	1	244	488	976	25	1
VT09	246	328	7	52	2	258	516	1032	26	1
VT11	53	71	2	9	1	41	82	164	5	1
VT13	165	220	5	18	1	90	180	360	9	1
VT14	138	184	4	27	1	133	266	532	14	1
VT15_Dro.	118	157	4	50	1	246	492	984	25	1
VT16	101	134	3	23	1	112	224	448	12	1
VT18_Dro.	80	107	3	36	1	178	355	709	18	1
VT19	156	208	5	44	1	216	432	864	22	1
VT21	675	899	18	140	3	700	1400	2800	70	2
VT22	384	512	11	96	2	476	952	1904	48	1
VT24	161	214	5	45	1	222	444	888	23	1
VT25	1137	1516	31	208	5	1040	2080	4160	104	3
VT26_Dro.	350	466	10	156	4	776	1552	3104	78	2
VT27_Dro.	118	158	4	53	2	262	524	1048	27	1
VT28	122	162	4	28	1	140	280	560	14	1
VT29	739	986	20	124	3	620	1240	2480	62	2
VT30_Dro.	20	26	1	9	1	43	86	172	5	1
VT31	317	423	9	58	2	288	576	1152	29	1
VT33	32	42	1							
VT34	297	395	8	76	2	380	760	1520	38	1
VT36	405	540	11	69	2	344	688	1376	35	1

Table 4.2. (continued).

Tomb	Low rate (ph)	High rate (ph)	5-hr days	Reopen rate (ph)	(Reopen) 5-hr days	Reopened x 5 (ph)	Reopened x 10 (ph)	Reopened x 20 (ph)	Closing (ph)	(Closing) 5-hr days
VT40	120	159	4	30	1	146	292	584	15	1
VT42	169	225	5	44	1	220	440	880	22	1
VT43_Dro.	164	219	5	73	2	364	728	1456	37	1
VT44	195	260	6	30	1	146	292	584	15	1
VT53	590	786	16	153	4	762	1524	3048	77	2
VT54	733	977	20	188	4	936	1872	3744	94	2
VT55_Dro.	208	278	6	93	2	462	924	1848	47	1
VT56	431	574	12	104	3	516	1032	2064	52	2
VT57	24	31	1	6	1	29	57	113	3	1
VT59	142	189	4	29	1	143	286	571	15	1
VT60	171	227	5	48	1	240	480	960	24	1
VT61_U1	41	54	2	10	1	50	99	197	5	1
VT62	855	1139	23	130	3	646	1292	2584	65	2
VT63	48	64	2	8	1	40	79	157	4	1
VT64	360	480	10	104	3	516	1032	2064	52	2
VT65	94	125	3	6	1	28	56	112	3	1
VT66	60	79	2	20	1	99	197	394	10	1
VT67	199	265	6	37	1	182	363	725	19	1
VT68	227	302	7	19	1	91	182	364	10	1
VT69	461	615	13	77	2	382	764	1528	39	1
VT70	228	304	7	46	1	228	456	912	23	1
VT71	255	340	7	62	2	310	620	1240	31	1
VT72	154	206	5	35	1	172	343	685	18	1
VT73	98	131	3	30	1	150	300	600	15	1
VT74	95	127	3	9	1	44	88	176	5	1
VT75	2313	3084	62	472	10	2360	4720	9440	236	5
VT76	22	29	1	4	1	18	36	71	2	1
VT77	868	1157	24	208	5	1040	2080	4160	104	3
VT78	954	1272	26	206	5	1028	2056	4112	103	3
VTU2_Dro.	52	69	2	23	1	115	230	459	12	1
VTU3_Dro.	112	149	3	50	1	248	496	992	25	1

Table 4.2. (continued).

Tomb	TREX	RexD	RexV	Rex_ dl	Rex_ dw	Rex_ dh	Rex_ sl	Rex_ sw	Rex_ sh	Rex_ vl	Rex_ vw	Rex_ vh
AA01	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Menidi	22.27	25.85	18.88	4.50	1.93	2.25	2.74	2.27	3.02	2.75	2.78	3.52
Prosilio_T2	9.97	9.04	10.86	3.33	1.47	1.85	2.40	1.80	2.40	2.37	1.95	1.40
PT02	0.67	0.29	1.03	0.38	0.73	0.58	1.03	0.95	1.52	0.86	0.78	0.62
PT03	2.18	2.82	1.57	1.48	1.34	1.58	1.23	1.04	1.28	1.15	1.19	1.12
PT07	1.61	1.84	1.40	1.41	1.19	1.30	0.98	1.02	1.36	1.20	1.31	0.99
PT08	1.15	1.36	0.95	1.36	1.21	1.24	0.61	1.56	1.51	0.99	0.98	0.87
PT08_In	0.36	0.00	0.70	0.00	0.00	0.00	0.00	0.00	0.00	1.01	0.99	0.84
PT09	0.99	1.29	0.71	1.19	0.89	1.12	0.93	0.81	0.88	0.95	0.78	0.94
PT10	1.18	1.50	0.88	1.34	1.20	1.23	0.49	0.94	0.95	0.92	1.16	0.93
PT11	0.59	0.86	0.33	1.22	0.99	0.75	0.78	0.85	0.96	0.66	0.65	0.73
PT12	0.16	0.32	0.00	0.86	0.52	0.69						
PT13	0.70	1.44	0.00	1.07	0.81	1.37						
PT16	1.28	0.24	2.27	0.63	1.01	0.39	0.68	1.10	0.87	0.78	0.85	0.44
PT18	0.68	0.79	0.59	0.89	0.93	1.07	0.47	0.66	1.01	0.92	0.91	0.73
PT21	1.14	1.33	0.96	1.12	1.25	1.38	0.44	0.90	1.15	0.97	1.12	0.86
PT22	0.43	0.36	0.50	0.67	0.79	0.65	0.58	0.79	0.91	0.75	0.76	0.78
VT01	0.74	0.51	0.97	0.79	0.87	0.78	0.89	0.79	1.06	0.82	0.98	0.82
VT02	0.63	0.32	0.92	0.57	0.70	0.79	0.82	0.83	1.13	0.73	1.35	0.73
VT03	0.18	0.30	0.06	0.72	1.10	0.49	0.57	0.63	0.84	0.33	0.39	0.37
VT04	8.67	12.22	5.31	3.20	1.77	1.88	2.22	1.60	2.41	1.53	1.93	1.42
VT05	0.76	0.52	0.99	0.60	1.26	0.61	1.14	1.19	1.47	1.01	1.08	0.78
VT06	0.61	0.70	0.53	0.81	1.02	0.75	0.84	0.90	0.89	0.72	0.84	0.70
VT07	1.69	3.19	0.28	2.07	0.98	1.16				1.07	0.37	0.46
VT08	0.79	0.90	0.68	0.92	0.96	0.95	0.69	0.82	0.86	0.93	0.91	0.72
VT09	0.98	0.96	1.01	1.09	1.12	0.90	0.57	1.06	1.01	1.00	0.99	0.96
VT11	0.21	0.15	0.27	0.49	0.73	0.32	0.71	0.77	0.71	0.57	0.68	0.53
VT13	0.66	0.33	0.97	0.78	1.03	0.52	0.77	1.13	1.05	0.88	0.95	0.79
VT14	0.55	0.49	0.61	0.68	0.92	0.66	0.58	0.99	1.37	0.66	0.78	0.78
VT15_Dro.	0.47	0.91	0.05	1.22	0.77	1.02						
VT16	0.40	0.41	0.39	0.56	0.81	0.79	0.51	0.87	0.89	0.65	0.94	0.54
VT18_Dro.	0.32	0.66	0.00	0.83	0.99	0.88						
VT19	0.62	0.80	0.46	0.76	1.29	0.70	0.78	0.83	1.03	0.76	0.78	0.63
VT21	2.70	2.59	2.80	1.44	1.63	1.14	1.00	1.23	2.35	1.00	1.53	1.17
VT22	1.54	1.76	1.32	1.44	1.12	1.50	1.09	1.13	1.29	1.12	1.12	1.16
VT24	0.64	0.82	0.47	0.98	1.17	0.68	0.75	0.94	0.86	0.79	0.82	0.64
VT25	4.55	3.85	5.21	2.20	1.32	1.43	1.13	1.31	1.84	1.60	1.30	1.64
VT26_Dro.	1.40	2.87	0.00	1.92	1.35	1.34						
VT27_Dro.	0.47	0.97	0.00	1.11	0.95	1.08						
VT28	0.49	0.52	0.46	0.89	0.79	0.74	0.46	0.66	0.86	0.80	0.88	0.78

Table 4.3. Tomb Relative Index (TRex) (continued overleaf).

Tomb	TREX	RexD	RexV	Rex_ dl	Rex_ dw	Rex_ dh	Rex_ sl	Rex_ sw	Rex_ sh	Rex_ vl	Rex_ vw	Rex_ vh
VT29	2.96	2.30	3.59	1.62	1.18	1.31	0.85	1.24	2.09	1.22	1.57	1.32
VT30_Dro.	0.08	0.16	0.00	0.74	0.72	0.26						
VT31	1.27	1.07	1.46	1.04	0.88	1.35	0.86	1.01	1.56	0.89	1.35	1.05
VT33	0.13	0.00	0.24									
VT34	1.19	1.41	0.98	1.47	1.05	1.05	1.15	1.02	1.14	1.05	1.03	0.93
VT36	1.62	1.27	1.95	1.21	0.89	1.05	1.64	1.01	1.16	0.94	1.27	1.01
VT40	0.48	0.54	0.42	0.83	0.72	0.95				0.74	0.73	0.76
VT42	0.67	0.81	0.54	1.06	0.97	0.70	1.11	0.77	1.14	0.83	0.89	0.68
VT43_Dro.	0.66	1.35	0.00	1.32	1.12	1.04						
VT44	0.78	0.54	1.01	0.83	0.72	0.95	0.00	0.00	0.00	0.93	0.90	1.13
VT53	2.36	2.82	1.92	1.82	1.27	1.45	1.38	1.15	1.17	1.19	1.24	1.12
VT54	2.93	3.47	2.43	1.57	1.46	1.70	1.56	1.32	1.59	1.05	1.52	1.15
VT55_Dro.	0.83	1.71	0.00	1.41	1.17	1.30						
VT56	1.72	1.91	1.54	1.13	1.53	1.19	0.91	1.29	1.68	1.25	1.28	1.17
VT57	0.09	0.10	0.08	0.36	0.59	0.16	0.47	1.07	0.56	0.53	0.41	0.26
VT59	0.57	0.53	0.60	0.85	0.89	0.57				0.82	0.76	0.57
VT60	0.68	0.89	0.48	1.07	0.89	0.87	0.67	0.71	0.61	0.90	0.87	0.78
VT61_U1	0.16	0.18	0.14	0.51	1.01	0.19				0.45	0.52	0.37
VT62	3.42	2.39	4.39	1.77	1.23	1.16	0.82	1.25	2.15	1.25	1.73	1.27
VT63	0.19	0.15	0.24	0.60	0.98	0.22				0.59	0.57	0.38
VT64	1.44	1.91	1.00	1.54	1.37	0.95	1.00	1.02	0.97	1.08	1.09	0.96
VT65	0.37	0.10	0.63	0.47	0.61	0.26	0.83	0.85	0.85	0.77	1.08	0.37
VT66	0.24	0.36	0.12	1.00	0.77	0.62	0.54	0.66	0.75	0.48	0.50	0.51
VT67	0.79	0.67	0.91	1.06	0.78	0.68	0.69	1.05	1.00	1.15	1.20	0.96
VT68	0.91	0.34	1.45	0.54	1.24	0.34				1.03	1.21	1.12
VT69	1.85	1.41	2.25	1.09	1.29	1.11	1.75	1.48	1.16	1.29	1.11	1.38
VT70	0.91	0.84	0.98	0.89	1.10	0.96	1.06	1.21	1.15	0.98	1.10	0.98
VT71	1.02	1.15	0.90	1.01	1.09	1.21	0.61	1.04	1.33	1.06	1.05	1.08
VT72	0.62	0.63	0.60	0.81	0.93	0.97	0.74	0.89	0.98	0.88	0.90	0.88
VT73	0.39	0.55	0.24	0.89	0.83	0.94	0.77	0.78	1.14	0.59	0.63	0.65
VT74	0.38	0.16	0.59	0.70	0.83	0.35	0.76	1.28	1.14	0.89	0.89	0.63
VT75	9.26	8.74	9.75	3.90	1.25	2.20	1.99	1.56	2.13	1.69	2.53	1.83
VT76	0.09	0.07	0.11	0.20	0.67	0.12				0.66	0.62	0.18
VT77	3.47	3.85	3.12	1.83	1.26	1.63	1.26	1.21	1.33	1.19	1.57	1.31
VT78	3.82	3.81	3.83	1.98	1.45	1.82	1.27	1.25	2.06	1.27	1.53	1.29
VTU2_Dro.	0.21	0.42	0.00	0.92	0.71	0.59						
VTU3_Dro.	0.45	0.92	0.00	1.04	0.97	1.12						

Table 4.3. (continued).

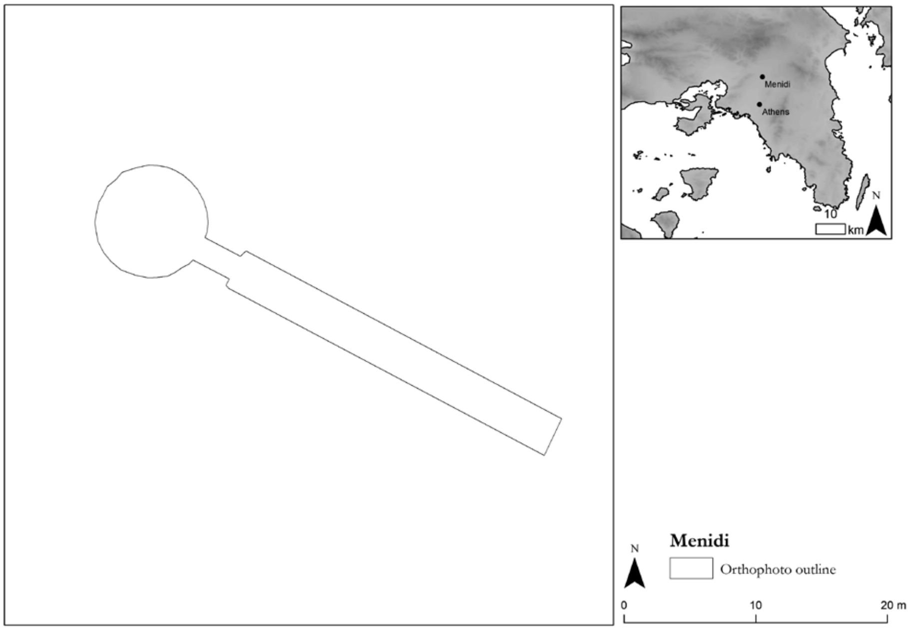


Figure 4.1.1. Ground plan of the Menidi *tholos*.

4.1. Menidi

Excavated in the 1870s, the Menidi *tholos* and its major finds have been published and revisited, such that the following architectural survey can be combined with previous work (Lolling et al. 1880; Stubbings 1947). The narrative and techniques were a product of their time, but the overall measurements and *stomion* drawings for the tomb are remarkably consistent with the photogrammetric models presented here (Lolling et al. 1880: pl. I-II). The tomb now lies just east of Filadelfias road in the Acharnes district 11 km north of the Acropolis in Athens (Figure 4.1.1). Although traffic from the road can be distracting outside the tomb, the vault insulates the noise of the city into near-perfect silence. The narrow *stomion* and long *dromos* muffle footsteps along the gravel path for much of its length, but the acoustics within the vault amplify the slightest sound originating within the tomb. The triple click of two total stations recording points, heard 64,000 times over two weeks, wrote the earworm soundtrack of outlining the tomb's stone cladding. Work began in June 2016 with the assistance of Esko Tikkala from the Finnish Institute at Athens, who set the grid of fixed points using a Leica differential GPS (dGPS).

Digital modelling of the Menidi *tholos* was a trial run for the remaining case studies (Figure 4.1.2). Recording practices here could stretch the limits of meticulous coverage prior to ironing out the most efficient methods. With few time constraints and novice optimism, we drew each of the visible stones below the safety netting of the vault and acquired representative sections of the *dromos* before the season ended. In hindsight, outlining each of the vault's stones – irregular, fractured, and largely hidden by shadows or netting – added little information in return for the time invested. The AutoCAD file looked impressive but could not inform beyond confirming what was captured much more rapidly by photogrammetric modelling. With that lesson in mind,

Figure 4.1.2. Architectural survey of the burial chamber for the Menidi *tholos* with Y. Boswinkel (left) and D. Turner (right), facing southeast.

Figure 4.1.3. Menidi *dromos*, facing northwest.

the AutoCAD method was not prioritised for the Achaean cemeteries, where the absence of stone cladding in the chamber tombs limited total station drawing to rough outlines and point clouds (arbitrary measurements taken in dense clusters showing relative surfaces). The latter contributed to basic orientation maps and digital elevation models (DEMs). Photogrammetric modelling alone would serve to reconstruct the volume for all tombs independent of the laborious total station method.

Among the first observations when arriving at Menidi was a conspicuous break in the stonework of the *dromos* (Figure 4.1.3). Roughly level with the ground surface where the modern stairwell led into the *dromos* and continuing at a variable height to the *stomion*, the stone cladding on the upper half of the entrance passage and facade appeared to have been reconstructed. Below the line sat small laminar stones–"rough schist slabs" as described by Cavanagh and Laxton (1981: 111)–in visible rows if not regular courses similar to those found within the vault. Above it, both the incongruous stone types and their haphazard placement suggested the hurried reconstruction of a retaining wall to maintain the integrity of the tomb passageway. When this section of the tomb was reconstructed is unknown. Remnants of what superficially appeared to be concrete used as a stabiliser between the mismatched stones indicates that the repairs were made after excavations by the German Institute in 1879. Their cross-section is not detailed to the level of the stones, but a careful drawing of the *stomion* façade seems to indicate that the upper cladding had fallen away (Lolling et al. 1880: pl. I-II).

The original masonry of the tomb mimics the design described as Type II by Pelon (1976: 338-339) and shares this label with the *tholoi* at Thorikos and Marathon, as well as the Epano Phournos, Aegisthus, and Panagia tombs at Mycenae (Konsolaki-Yannopoulou 2015: 490). Menidi is large enough to fit within Pelon's (1976: 391) Class C. The tomb has been compared "in terms of construction technique and dimensions" to *tholoi* at Tiryns, Prosymna, and Vapheio (Fitzsimons 2006: 153, citing Dragendorff 1913: 353; see also Müller 1975), although even at a glance, the larger limestone blocks of the Tiryns *tholos*, its spacious *thalamos*, and remnants of painted plaster at its entrance are markedly different from the schist slabs at Menidi. A further difference is evident in the relieving systems above the tomb thresholds. Although missing the masonry surrounding its relieving triangle, enough is known from Tiryns to predict its more conventional *stomion* (Fitzsimons 2006: 151-152). The *stomion* at Menidi, however, features a relieving system of horizontal slabs separated by empty spaces, reminiscent of the relieving device above the King's Chamber in the Great Pyramid at Giza (Cotterell and Kamminga 1990: 120-121; Fitchen 1986: 208; see Chapter 3, this volume), though Laffineur (2007: 122) rightly suggested that the Menidi relieving system simply represents another example of experimental engineering with Mycenaean tombs. A cross-wall running perpendicular to the *dromos*, now traversed by steps for visitors, marks the leading edge of the *dromos* entrance (Papadimitriou 2015: 94). Such entrance transverse walls are also common to *tholoi* in the Argolid, including at Kokla, Mycenae (Atreus and Clytemnestra), and Tiryns (Demakopoulou 1990: 113).

The Menidi *tholos* and its rich finds indicate the relative wealth and influence of local leadership (Stubbings 1947: 3-4; Thomas 1995: 354). Pottery finds identified within the tomb included thirteen fragmented, flat-topped stirrup jars (Stubbings 1947: 18), angular shouldered Canaanite jars (Konsolaki-Yannopoulou 2015: 498; Lolling et al. 1880: 48), the remains of an undecorated ladle for pouring libations (Stubbings 1947: 34), fragments of painted kraters and a wide-mouthed bowl (Stubbings 1947: 39-40), a broad neck globular jug (Stubbings 1947: 50), and "three wide-mouthed jars with two handles at the rim" for cooking (Stubbings 1947: 54). Sustaining a tomb cult for an extended period from the eighth (Antonaccio 1994: 402) until the fifth century BC (Alcock 1991: 451), later offerings associated with Menidi include Late Geometric and Archaic kraters, black-figure vases, and clay shields showing seventh century BC design (Whitley 1988: 176).

Based on relative chronologies of the earlier ceramics, the tomb's construction and primary use was in the LH III period, likely LH IIIA2-B1 (Arena 2015: 5). An ivory plaque depicting men wrestling bulls further corroborates the tomb's use in an LH IIIA/B context (Younger 1995: 527). Other finds deposited among the tomb's six burials were lead wire originating from Laurion (Lolling et al. 1880: 45-47; Stos-Gale and Gale 1982: 471), two inscribed amphorae and two plain amphorae, and six engraved gems (Stos-Gale and Gale 1982: 479, citing Lolling et al. 1880: 45-47). The collection of materials from Menidi and other similarly rich tombs, particularly regarding the inclusion of prestigious metallic vessels, suggests the practice of exclusionary feasting among peers (Borgna 2004: 263). Among the shared convivial customs in mortuary contexts visible in the archaeological record, the intentional breaking of drinking vessels seems common here and for other Mycenaean tombs (Borgna 2004: 263-264; Hamilakis 1998: 120-122).

Travelling east-southeast from the tomb across the valley where the river Kephissos and a tributary run, the Mycenaean settlement of Nemesis lies roughly a kilometre away (Hope Simpson 1959: 292). Within view of the Menidi hilltop at the time of Hope Simpson's (1959) investigation, Nemesis yielded LH III ceramics and was put forward as the most likely candidate (rather than the medieval Yerovouno hill to the west) for the population that built and used the tomb. It has been suggested that those who built Menidi operated independently of administrators in Athens, with Mee and Cavanagh (1990: 239-242) arguing on the grounds of tomb distribution and preferred style reflecting political and cultural divisions in Attica.

Given the position occupied by the Menidi *tholos*, both spatially and culturally in the Attica milieu, digital modelling of its architecture and labour requirements hinted at its potential before fieldwork began. The fieldwork itself presented its own challenges. Practically, due to its size and the lighting difference between the bright *dromos* and dark vault, the tomb was modelled in two parts and recombined (Figure 4.1.4). With 10 photopoint markers each, the vault and *dromos* models were captured by 138 and 157 photos, respectively. Volume estimates in Agisoft PhotoScan were obtained by trimming excess details outside the area of interest for each model and closing the remaining mesh of the point cloud. The *dromos* measures 349 m^3, and the *thalamos* with *stomion* measures 269 m^3. The total conserved volume of the tomb is 618 m^3. Using the centre indexes of reported task rates with metal and non-metal toolkits moving compact earth (Turner 2018, Table 1), excavating the Menidi *tholos* could take 1,112-2,596 ph. This would represent the simplified excavation cost range, not accounting for the stone cladding, design, or operations management that arranges the actual workflow. The range of labour rates (1.8-4.2 ph/m^3) is also significantly faster than the preferred range for quarrying chamber tombs in soft rock (9-12 ph/m^3).

Recalling the intuitive demands of digging in that work must begin at the surface, excavation of the *stomion* and vault could not coincide with excavation of the *dromos*. Neither could the stonework commence before the outline of the tomb began to take shape. The latter initiated a balancing act of maintaining the structural integrity of the walls, whether through temporary shoring or rapid stone-laying to prevent collapse. A further restriction on the construction sequence lies in the removal of materials from the vault due to the size of the *stomion*, which serves as a bottleneck limiting the number of workers who can enter. The

Menidi tholos	Dromos	Stomion	Vault	Total	Labour (ph)	Workforce	Days
[TRex]	[25.85]		[18.88]	[22.27]	Low rate	9 ph/m^3	
Volume (m^3)	349		269	618	5562	50	23
Length (m)	27 [4.5]	2.74	8.25 [2.75]	38	High rate	12 ph/m^3	
Width (m)	2.9 [1.93]	1.7 [2.27]	8.35 [2.78]		7416	50	30
Height (m)	6.74 [2.25]	3.02	8.81 [3.52]		Reuse rate	4 ph/m^3	
					1396	25	12

Figure 4.1.4. Texture model of the Menidi *tholos* showing its south-western cross-section.

shape of the *dromos* itself also funnels movement in two directions. The gradient at Menidi does not measurably affect labour totals, unlike some of the more extreme scenarios observed at Portes and Voudeni where rope was required to safely enter and leave. One option available to Menidi's builders that was not pursued for the rock-cut chamber tombs of Portes and Voudeni was to dig the vault from above. Although a larger volume would need removing and replacing than the tomb's footprint would indicate, this option would circumvent some of the movement constraints on entering and exiting via the *stomion* and *dromos*. Even so, the tripartite shape of *tholoi* and chamber tombs does not allow simultaneous construction of its parts without considerable formwork (Fitchen 1986: 21, 85-87).

In practice, these demands translate to increased labour costs based on actual workflow and real-world challenges. The range for simplified excavation costs, 1,112-2,596 ph, is quite low, and it would be a remarkable feat in itself if excavation of Menidi's footprint could be completed within that time. The range remains viable as a comparative to other tombs, representing a more detailed alternative to simple volumetrics that do not account for material cost differences, such as digging unconsolidated colluvium at Menidi (4-9 ph/m^3) rather than dense marlstone or chalk at Voudeni (9-12 ph/m^3). Just as energetics yield more information than volumetrics, the latter yields more information than the common practice of simply reporting tomb dimensions (e.g., diameter of vault, length of *dromos*). Several cases herein show a mismatch between tomb size rankings by diameter and those ranked by volume, with the Menidi *tholos* showing a strong disparity between its runaway volumetric first rank (618 m^3 vs. 257 m^3 at VT75) and the similarity of its diameter with much smaller tombs (8.35 m vs. the 7.66 m maximum width of VT75).

Modelling construction for the Menidi *tholos* adds compounding costs of labour via logical steps and restrictions. Traditionally, a spreadsheet analysis performs this function, and I returned to a similar modelling procedure in the end. Previously, I explored alternative means by coding a simple program using Python that would account for the most likely scenarios. In this way, each step would be explained via comments in the program itself, preserving intermediate long-form calculations and reasoning that would normally be discarded or make little sense out of context. The functions performed for "real_time_cost" could not affect the base cost for excavation in person-hours, for instance, since the idealised range would remain the same. The workforces and calendar costs, however, would fluctuate depending on the workflow and steps being performed, thus the vault, *stomion*, and later stages of the *dromos* would receive fewer concurrent workers than the early stages of the *dromos*, extending the calendar time necessary for performance of the work.

While I used Python as a practical and visual aid in modelling the Menidi construction, the code stopped short of optimising the work itself. None of the functions written into it required technical expertise beyond an elementary approach to operations management, following the step-by-step process from breaking the surface to laying the final stone. More could be added to the variables for stonework rates, but absent the wide corpus of experimental and ethnographic rates that earthmoving has, the code would operate in such a way as to accept further values when they become available. Without a user-friendly experience, however, early versions of the Python labour modelling program would require considerable revision to replace spreadsheet analyses. The process and syntax are too opaque to improve energetics modelling on a wider scale, but individual users proficient in coding may benefit from creating similar programs.

Tallying the rates from the real cost scenarios, a full-time crew of 50 labourers could complete the outline or bare footprint of the Menidi *tholos* in as little as five days on a 10-hour professional schedule or 10 days for the more reasonable 5-hour peak efficiency schedule for exhausting labour. Typical delays, however, could push the total construction into more than a month of toil. Fewer available labourers stretch the calendar cost even further, though it is difficult to imagine more than a year of investment for any known Mycenaean tomb. Whatever the case, the labour investment for the Menidi *tholos* is comparable to the smaller *tholoi* at Mycenae (Panayia and Kato Phournos, e.g., Boyd 2015a: 206) but far short (ca. 18%) of the estimated 3,500 m^3 removed to shape the Treasury of Atreus (Cavanagh and Mee 1999: 95). For comparison, the labour investment in the Menidi *tholos* eclipses that of the largest chamber tombs at Portes by an order of magnitude, being 10.2 times the size of PT3. In fact, in terms of volume, all 26 surveyed tombs at Portes could fit comfortably within the Menidi tomb. Only the largest chamber tombs at Voudeni (VT4 and VT75) approach – and yet still fall well short of – the size and level of investment of Menidi, requiring the third largest (VT25) to surpass Menidi with their combined volumes. Even so, calendar time to completion does not vary significantly except for the smallest tombs. The key variable showing the greatest variation is the size of the workforce needed to keep construction time reasonable. Menidi's requirements exceed all 93 other cases examined herein and are more than thirty times that of a near-median chamber tomb at Voudeni (20 m^3), despite being on a similar level with VT75 based on vault diameter and *dromos* length alone. Compared with the fictional AA01 (see closing sections to Chapter 3), the length of the Menidi *dromos* and the height of its vault stand out as the greatest deviations that propel the tomb to a scale more than 22 times larger than a recognisable median example like VT9 (or the fictional AA01). Adding to its exceptional scale, the stonework cladding found at Menidi significantly increases labour investment over simply cutting into marl, not least because the former demands greater technical expertise and a more complex operational sequence.

The stonework of the Menidi *tholos*, by virtue of its small laminar stones, required a substantial investment, far more than the cost of simply excavating the roughly 618 m^3 footprint (4-9 ph/m^3) and extracting the stone itself elsewhere (9-12 ph/m^3). Even with local sources, transportation costs alone might average 30 ph/m^3 for stones brought on foot (tumpline, 23 kg loads, 1 km to source) or by oxcart (400 kg loads, 5 km to source) (DeLaine 1997: 98, 107-108; Erasmus 1965: 285-287; Appendix 1.1b, this volume). Coordinating the placement of the stones at Menidi, similar to the repetitive motions of experienced bricklaying (Andrew Bittle, personal communication 2016), likewise would claim additional assembly costs (9.5 ph/m^3), subordinate only to transportation of materials in the total cost (Devolder 2013: 43; Appendix 1.1b-c, this volume). A similar relationship of high stone cost versus low digging costs predominated at the North Cemetery of Ayios Vasilios (Laconia), albeit on the much reduced scale of built chamber and cist tombs (Voutsaki et al. 2018: 176-179).

Estimating the volume of stone used at Menidi would require wall thickness measurements, difficult to acquire from the surface view of the photomodel. For a rough estimate, surface measurements (Table 4.1) may be combined with an arbitrary thickness (0.50-1 m) and oversimplified area formulae (two right triangles for the *dromos* [182 m^2], one rectangle for the façade [20 m^2], three rectangles for the *stomion* shortened by the façade and chamber [15 m^2], and half an ellipsoid for the chamber with a ca. 5 m^2 entrance gap included to account for waste [195 m^2]). The result of 206-412 m^3 for Menidi's stone cladding would add extraction (2,472-4,944 ph), transport (6,180-12,360 ph), and assembly costs (1,957-3,914 ph) that total 10,609-21,218 ph. Together with the excavation of the footprint (1,112-2,596 ph), the majority of construction tasks at Menidi may have required 11,721-23,814 ph, or no more than 32 (5-hour) working days for 150 labourers. For perspective, this investment equates to 47-71.5 times the expected cost for building a standard chamber tomb (333 ph, AA01). This is likely an overestimation and is presented more for general cost comparisons, in that the expected cost of built tombs more than triple that of rock-cut tombs of comparable size. Overestimating transport distance and stone volume likely inflated the cumulative labour rate of 19-38.5 ph/m^3 backsolved for all construction tasks at Menidi. Focusing on more reliable extraction costs (3,584-7,540 ph), however, the cumulative extraction rate (5.8-12.2 ph/m^3) for Menidi pairs well with the tabular assessment of tomb costs (Table 4.2). For these reasons I have included Menidi in Table 4.2 at the simplified 9-12 ph/m^3 rate range (5,562-7,416 ph) to compare its extraction costs (footprint plus stone for cladding) with that of rock-cut tombs. Calendar estimates do not change so much as the size of the required workforce: 50 dedicated labourers could perform the majority of extraction tasks in 30 working days (again using the 5-hour conservative simulation for peak efficiency), leaving room for 100 additional labourers to handle the majority of transport and assembly tasks roughly concurrently. Staggered tasks to avoid bottlenecks (*sensu* Abrams and Bolland 1999) have not been calculated here, but variability in labour rates, conservative 5-hour workday windows, and a two-day jumpstart on extraction should absorb most reasonable delays and avoid complications from cramped working spaces. Capturing the relative scale of Menidi's investment alongside smaller tombs in Table 4.2, cumulative extraction costs show 149 (5-hour) working days for an unlikely team of 10 labourers (3 digging and 6 transporting under a lone supervisor). Although a 10-person team building Menidi is unrealistic, multi-season calendar investment may not have been far from reality, even with a more reasonable team of 50-150. Elaborations, if any, and the technical challenge of raising the largest blocks above the threshold would certainly boost the total cost of construction for Menidi even further – at this stage a few variables too removed to estimate with confidence.

Considering the increase to total cost where the absence of stone cladding might threaten structural stability, as might have happened with Menidi, the benefits to site locations in geology favourable to chamber tomb construction bring another dimension to the oft-repeated priorities of defence, water, exploitable resources, and high-traffic trade routes (e.g., Runnels and van Andel 1987: 329). For the cemeteries of Portes and Voudeni in Achaea, to which the following sections turn, Mycenaean populations won the physiographic lottery. The results in terms of funerary costs are a significant reduction in time and energy without sacrificing the illusion of substantial investment. In other words, the largest tombs at Portes and Voudeni convey no less power and influence on the surface, but the logistics hidden just below that costly veneer sharply reduce the labour requirements from that of constructing *tholoi* of comparable size.

4.2. Portes

Excavation at Portes began in the early 1990s after looting targeted its tumuli and associated cist and built chamber tombs (Kolonas and Moschos 1994, 1995; Moschos 2000: 13-14, 2009). Although not fully published, the site has undergone extensive preliminary reporting and presents a rare case of a multi-tomb-type cemetery spanning the entirety of the LH. The cemetery lies 2 km southeast of the modern eponymous village on the southern slopes of Mount Skollis, otherwise known as Santameri or Portaiko for the villages on its western and southern slopes (Moschos 2000: 11). The site is 50 km south-southwest of Patras. More remote than the other locations, the Portes cemetery spreads across a pine-covered hilltop and its lower south-eastern shoulder with an audible waterfall nearby fed by the Kefalovryso spring (Figures 4.2.1-3). The only sound that filters through the trees, apart from the wind and waterfall, is the tinkle of bells from a large herd of goats that passes on the mountain road daily.

Two weeks were sufficient to create the base data to model accessible tombs here. As work progressed, the landscape impressed upon us the importance of the site's location. The location of Portes – the cemetery, settlement, and modern village – is identifiable from afar by the steep, rocky massif of Mount Skollis, whose multiple peaks stand alone amid upland fields and low hills (Figure 4.2.4). The medieval name itself refers to a gateway passage, and its multi-peak outline, visible from the Ionian Sea, has been used as a navigational aid since antiquity and likely served a similar purpose in prehistory (Moschos 2000: 10-11). Papadopoulos (1979: 24) characterised Skollis as "a limestone mass 965 m. high", from which much of the Dyme area of south-western Achaea could be seen. One of the challenges of the broken Skollis terrain was its comparatively low agricultural potential and difficulty with communication compared with Araxos in the vicinity of Teichos Dymaion. However, proximity to the perennial Kefalovryso spring and cave systems made the Portes area ideal for habitation since the Neolithic and Early Bronze Age, confirmed by deposits at the Porta Petra settlement to the north and Korakopholia cave (Moschos 2000: 11).

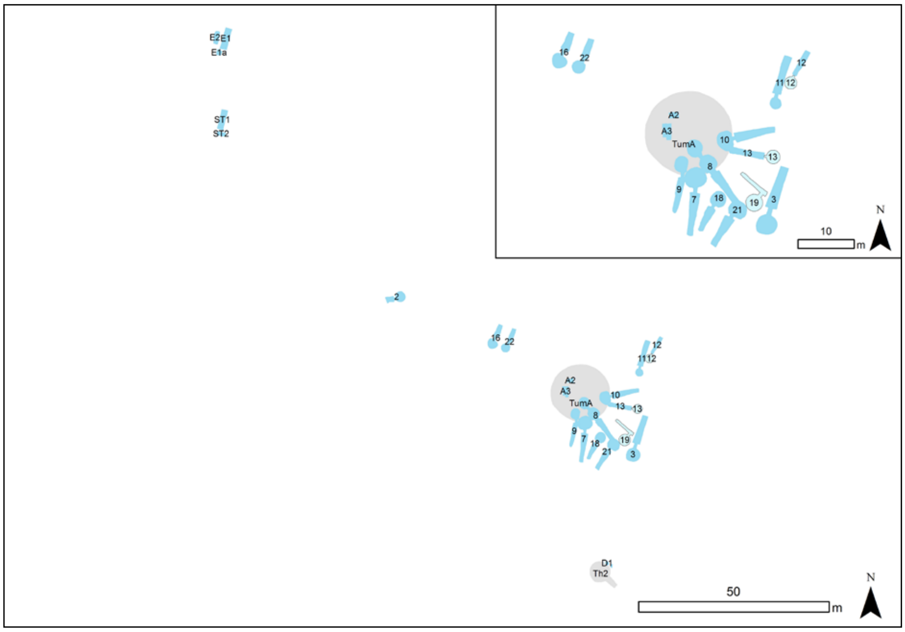


Figure 4.2.1. Map of Portes showing the locations of known tombs. Shapes in blue and grey were modelled successfully, while light green indicates missing sections.

If strategic positioning of the site is not enough to suggest its regional importance, its long chronology reinforces that position with generations of investment. The cemetery at Portes was in use for more than half a millennium, from the LH I to the LH IIIC period (Jones 2014: 11), with the site's three tumuli (A, B, C) potentially following closely on late MH traditions known from the region at Aravonitsa and Mirali (Eder 2003: 40; Moschos 2000: 10-16). Based on pottery recovered from the disturbed setting of the built chamber tombs, tombs PA1-3 and PC1-3 were likely constructed in the early LH I-IIA-B periods (Moschos 2000: 21). The two *tholoi*, though poorly preserved, date to the LH IIB-IIIA1 period (Papazoglou-Manioudaki 2015: 321). A naturalistic figurine depicting a seated figure on an elaborate throne recovered from the tumulus area corroborates the early date (Kolonas 2009a: 22-23, 44, fig. 28, 60; Papazoglou-Manioudaki 2015: 320). The chamber tombs follow the preferred mortuary traditions of later Mycenaean times and date to the LH IIIA-IIIC periods, disturbing earlier tumuli burials and reusing materials for blocking entrances and reinforcing the walls of entrance passages (Moschos 2000: 12). Built cist graves were also sunk into Tumulus A and B during the LH IIIA-B periods (Moschos 2000: 21). Multi-generational use stretching from the LH IIB/IIIA-C period appeared in finds reported from the poorly preserved western (PT2 and 24) and southern tombs (PT7, 9, 17, 18, 21, 25, 26, and 29) (Kolonas et al. 2002: 1-2).

With the site's location and chronology relatively secure, its people can be described in part through their apparent choices regarding mortuary architecture and practices. Human remains from Portes have been recorded in several tombs despite poor structural preservation from unstable rock. On the southern slope, where all but one of the chamber tombs (PT28) had been found sealed with a dry stone wall and filled *dromoi*, five of the

Figure 4.2.2. Portes 2016 aerial orthomosaic by J. Pakkanen and A. Brysbaert.

Figure 4.2.3. Portes settlement and cemetery (dense cluster of trees left-centre frame) as viewed from the lower slopes of Mount Skollis, facing south.

Figure 4.2.4. Mount Skollis from the western mountain road approaching the modern village of Portes, facing east-northeast.

nine chamber tombs contained deep burial pits reminiscent of a style seen on Kephallonia (Kolonas et al. 2002: 2). These are tombs PT9, 18, 25, 26, and 29. For primary burials, single inhumations occupied pits alone (except in the case of a double burial from PT29), primarily within the chambers and with bodies placed on their backs or sides and contracted by pulling the knees toward the chest. Secondary burials contained the mixed contents of previous inhumations swept to the side of chambers or within pits in the *dromos* (PT17, 18, 21, and 29) or chamber (PT9 and 18). Deliberate clay layers were also identified, one sealing the slab covering the deep pit in PT9 and the other beneath a primary burial in PT18 indicative of “a funerary bier” (Kolonas et al. 2002: 2). One primary burial was noted in the partially destroyed cist tomb PA4 on the eastern side of Tumulus A, revealing “the flexed lower limbs of a primary burial […] accompanied by a small golden leaf decorated with linked argonauts and a steatite sealstone, dating to the LH IIIA:2-B period” (Moschos 2000: 13). Signalling a potential ossuary, a layer of crushed bones blanketed the floor of another cist tomb (PTD2) set atop the remains of the northern wall of the destroyed *tholos* PTh2 (Kolonas et al. 2002: 3). Adjacent to this, the LH IIIA built cist tomb PTD1 contained secondary burials and beads swept to its north-western edge. The remains of a child’s burial survived in the unfinished *dromos*/slab-covered pit PT23, also evidently from the LH IIIA period. Infant burials were suggested for the tiny cist tombs A6 and A8 (Kolonas et al. 2002: 5). In an ongoing project (Aktypi 2014: 136), skeletal materials from Portes have been analysed by Olivia A. Jones (2014) alongside those from the Agios Vasileios (Chalandritsa) cemetery and the Petroto *tholos* in Achaea, with a focus on secondary burials.

Limitations on direct evidence for a site’s people prompt a closer look at their material footprint, particularly regarding portable objects and the contacts these suggest. Remnants of dealings abroad offer some clues as to Portes’s place in the wider world. Contacts with Central Europe and the Italian peninsula via the Adriatic are reflected in some of the finds from Portes, including the S-shaped bronze wire that accompanied the greaves from PT3 (Giannopoulos 2009: 119; Kolonas 1997: 474; see also van den Berg 2018). Other rich personal gear shows distinct regional traditions, like the bronze headgear from PT3 variously referred to as a "diadem" (Giannopoulos 2009: 119) or a "bucket shaped" crown (Eder 2003: 40). Remarkably, the headgear retained evidence of its straw lining, a unique find for Mycenaean assemblages (Kolonas et al. 2002: 7). In addition to the greaves and headgear, other LH IIIC items from PT3 included a Naue II sword, spear, knife, and bronze bowl (Eder 2003: 40; Kristiansen and Suchowska-Ducke 2015: 375). Several other warrior graves have been recorded from cemeteries across Achaea at "Klauss, Krini, Kallithea and Lousika" near Patras and Kangadi in the western part of the region, with each intact example yielding a Naue II sword alongside "at least one other offensive or defensive weapon" (Eder 2003: 40).

Minoan artefacts have also appeared at the site in the form of LH IIIC stirrup jars "with the typical continuous band around the handles, false neck and spout" (Eder 2003: 49). A stirrup jar from PT7 and another with a tall pedestal from PT3 indicate early to middle LH IIIC dates (1150-1090 BC) (Moschos and Gazis 2008: 252), and residue analysis of white precipitates from similar contexts point to limestone dust from the pottery fabric interacting with organic residue within the vessels (Giże *et al.* 2008: 163). The offerings were in use at some point prior to their deposition within the tomb, rather than being presented in mint condition. That does not preclude offerings made-to-order for the funeral, as the residue simply shows that certain vessels contained goods meant to be used by mourners or accompany the deceased.

Rather than reflect on what the Portes population acquired in the form of portable objects, part of my main focus has centred on their immovable material expressions, namely the tombs cut into the folded landscape below Mount Skollis. If the push and pull of personal choices, cultural taboos, and spiritual prescriptions governed the shape and scale of mortuary architecture (see Chapter 2), then Portes had reached an equilibrium with its chamber tombs. These followed a few broadly similar patterns, suggesting that generations of builders adhered to a set idea of how to construct the tombs. Of the chamber tombs modelled here, all had rounded chamber floors with vaulted or incline-vaulted ceilings reminiscent of a flattened version of the beehive vaults of *tholoi*. Restrictions on scale also seem to be in play, as even the largest (PT3) did not flagrantly overshadow the median size for the site, at least not in the same sense as Voudeni's largest (VT4 and VT75). Small adjustments kept all tombs roughly similar but allowed for measurably increased investment in certain cases. Whether there was a conscious effort to stay within acceptable limits can be explored through a dissimilarity matrix comparing tomb dimensions alongside those at Voudeni (see Figures 3.2-3.4). From the perspective of correspondence (Euclidean distance) with standardised measurements, the Portes chamber tombs are more alike than those at Voudeni with their wider spectrum of shapes and scales. This is highlighted in Tables 4.1-4.3 and explored further in Chapter 5 (see also Tables A1.3-A1.5).

For all the Portes tombs' adherence to a particular shape and acceptable scale, deviation – particularly with regard to the size and profile of the *dromoi* – was not entirely out of the question. With the north-eastern hillside tombs, such as PT11 and PT12, as an exception, many *dromoi* descend steeply into the low vaults of the chamber tombs sunk into Tumulus A. The narrow wedges that these passages create in profile sharply reduce the volume of the tombs but increase the angle at which materials have to be removed. In several instances, the *dromoi* were excavated through the wall of an adjacent tomb, leaving no other point of entry save with a rope and vertical rappelling, as with PT10/PT13. Whether adjacent tomb access was the method of construction or a matter of convenience for modern excavators is debatable. Considering the dense concentration of tombs on the eastern and south-eastern

Figure 4.2.5. Mount Erymanthos as viewed from the lower slopes of Mount Skollis near the Portes cemetery, facing east.

edges of Tumulus A, Mycenaean labourers may have had no other recourse than to chain a system of vaults and *dromoi* to maximize the available space. The honeycomb complex of PT7, PT8, and PT9 is a strong example of less space, less waste. The dense cluster of collapsing tombs on the southern slope, however, shows the limitations of space conservation where the rock weakens with differential settlement and ground loss (see Chapter 2).

Whether elevation relative to each other advantaged one tomb in the eyes of investors – both initial commissioners and later claimants – is worth considering. The deepest tomb (PT3) corresponds to the most iconic and valuable offerings at the site, but absent an adjacent vault like PT7/PT8, no firm connections can be made. Though likely a coincidence, the largest tomb (VT75) at Voudeni is also the lowest on the hillside, and the next largest (VT4) occupies one 'level' upslope. Both, however, blend into the hillside of tombs, being no more or less visible to the settlement 1 km to the northwest (see Chapter 1). Lower and angling away from its settlement, the Portes cemetery focused more on easterly views toward its fertile valleys. Rather than elevate relative tomb depth to a conscious decision on the part of the builders, it is more likely that they had little choice in positioning later tombs as the summit of the narrow Portes ridge became overcrowded. Offsetting downslope and away from the cemetery's central locus, if the smaller tombs found there are any indication, was less desirable. Working on the slope elevated risk for injury, slowed progress, and threatened structural stability with accelerated erosion from runoff and slumping. On more gradual inclines, however, opening tombs further downslope offered more options for increasing scale to the levels seen in Voudeni's two largest tombs.

With these patterns in mind, descriptive cases indicate where each tomb lies in the overall scheme of the cemetery. As with the other case studies, my emphasis here lies on architectural form, spatial layout, and the challenges of digital modelling in dark, cramped spaces. General challenges to fieldwork are included below. What follows is the individual treatment of tombs at Portes where modelling was at least partially successful or where enough is known to complement the narrative of those with similar designs. A full account of tombs omitted here can be found in Appendix 2, though these are generally limited to reasons why I could not include them.

Given the remoteness of Portes from modern populous areas, fieldwork here encountered the first problems with wildlife. A substantial colony of bats made its home in the vaults of the main chamber tomb clusters beneath Tumulus A. At least one toad was resident in the Warrior Tomb (PT3)–originally an adrenaline rush of unidentified ground movement in a pitch black tomb – and a flea infestation in the far south-eastern corner of the cemetery made itself known after several days of investigation. The only serious impediment to work, however, was the trees. Consistent lighting is crucial for successful photogrammetric modelling. Moving shadows at all hours, while a welcome reprieve from the summer sun, removed any optimum times to photograph the *dromoi* and tumuli. Early morning light cast fewer shadows but did not sufficiently illuminate tomb interiors, as Mount Erymanthos effectively diffuses the rising sun (Figure 4.2.5). The vaults themselves were fairly consistent in lighting but difficult to access quickly, requiring rope to descend the steeper *dromoi*. Attempting to maintain the same angle of lighting for the *dromos* and the vault, especially for adjacent tombs, required a fitness check of scrambling for photo angles within and above the tombs. Stationing a separate photographer in a hidden corner would be the preferred route for those with multiple cameras of identical capabilities, but this would also add significantly to the post-processing time of organising photos for modelling.

Preparing the tombs for safe entry and photos involved removing the tractionless blanket of pine needles that accumulated within the steeper *dromoi*. Acquiring a wheelbarrow, bucket, rake, and rope from the patient site attendant through miming and the eventual exchange of Greek and English terms for these devices, we easily relocated the debris to one of many brush piles consolidated by the attendants after a series of powerful storms in a prior season. Sparse grass along the edges of the *dromoi* was ignored for safety. Steeper sections of the site outside pathways, as well as unstable tombs with partially collapsed ceilings, were also omitted from survey. Some smaller entryways required prone crawling. We limited total station use within vaults too low to crouch comfortably, though where sufficient room allowed setup and movement without bumping the station, we proceeded successfully with movable backsight points painted on logs.

Battery-powered camping lanterns provided lighting within darker vaults, such as the inner chamber of PT8 and the deep and covered PT3. Light coverage was never uniform but so long as we were mindful of our shadows, the models still captured high-quality detail. Since the telescopic lens of the total station often failed to register the markers in dark corners, LED lights assisted the recording of points where low lighting hindered progress. Extreme low lighting affected photo clarity as well, but the camera's default settings and robust autofocusing enabled successful shooting for a majority of attempts.

Accuracy of the models ultimately hinged upon the reliability of the georeferenced grid. The forest canopy slowed but did not prevent setting up the fixed-point grid with a Leica dGPS. Accuracy was limited due to the weak and intermittent signal, but a sufficient grid was established within an hour on site on 26 June 2017. Since few areas were open enough to lower the error on the Leica's location accuracy, the total stations extended the web of fixed points to visible features on the site. Thus we were able to leapfrog from the main path intersection northwest of the collapsed PTh1 to the steel T-beam, lattice-frame light tower east of Tumulus A, transferring the most accurate fixed points from the dGPS to the significantly

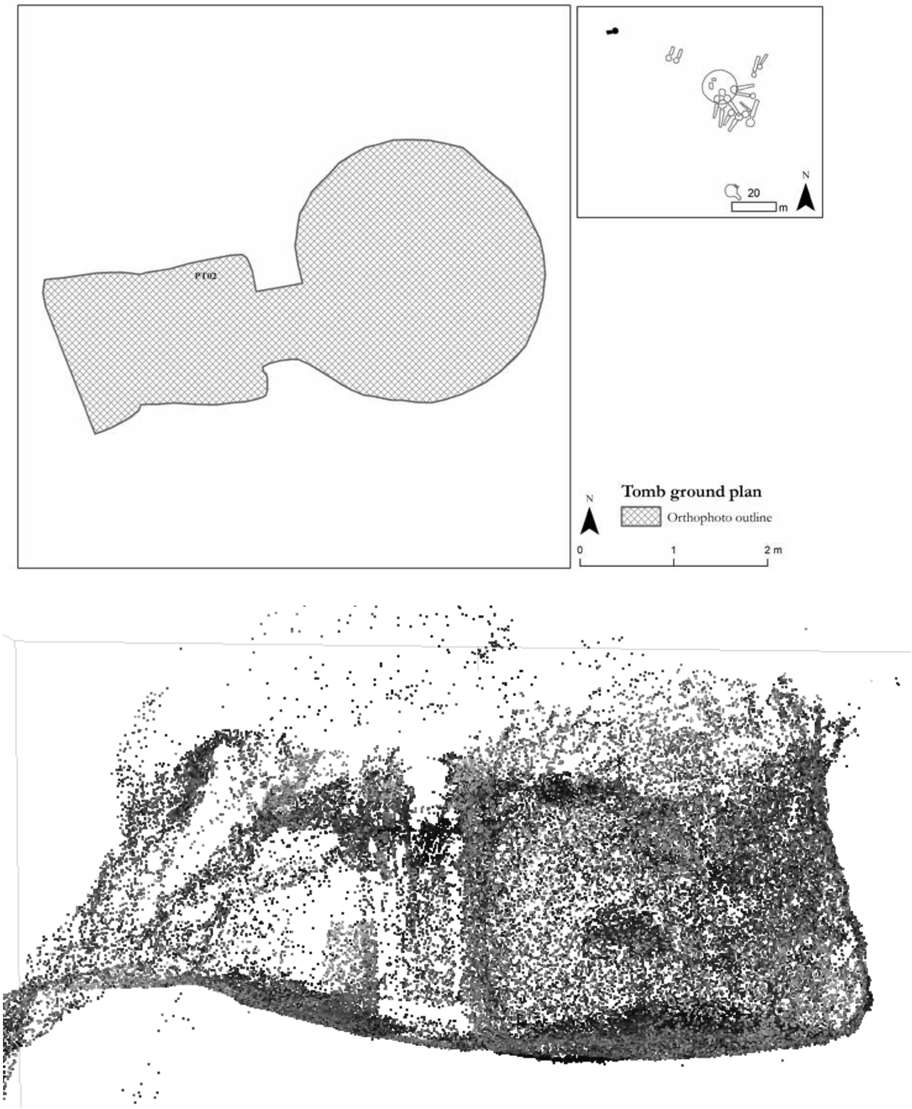


Figure 4.2.6. PT2 plan and sparse cloud model (northern cross-section), in which the collapsed ceiling partially obscures the original shape of the vault.

higher relative accuracy of the total station's local grid. Overall the models can only be as accurate as the least accurate step in the grid setup process, but relative to one another, the local grid maintained a consistent average error of no more than a few centimetres. As with Menidi, blue and orange (not recommended in hindsight for its low contrast) paint markers on modern surfaces or removable unmodified cobbles served as fixed points and photopoint markers. Modern wire-cut nails were spotted within several vaults and likely served as mapping points for previous fieldwork. Some were recorded as height references where the eroded surfaces of the vaults did not already provide a niche for a photopoint stone.

Portes Chamber Tomb 1

See Appendix 2.

Portes Chamber Tomb 2

Unremarkable apart from its location, PT2 excels at introducing the layout of the cemetery. Slopes near the intersection of navigable routes motivated its building site, much as they influenced Portes at large. Northwest of PT2, modern paths from the visitors' centre split to traverse and encircle the hill crowned by the cluster of built chamber tombs occupying the cemetery's peak elevation. Screened from sight as one travels southeast, the main locus of chamber tombs, tumuli, and *tholoi* can only be accessed easily via a narrow saddle where the paths meet, ushering traffic onto a steep-sided ridge that rises to a secondary peak at Tumulus A. Adjacent to the north of PT1, PT2 is the first open tomb encountered along the southern path after the fork. With the total collapse of the ceiling, only the timber-framed protective awning gives the impression of being in an enclosed space (Figure A3.1). The path and abrupt slope trim the *dromos* to a negligible size compared with most of the tombs. The plan view of the remaining tomb thus appears as a mushroom with a globular shape on a narrow stem (Figure 4.2.6). With a round base and likely once a vaulted or incline-vaulted roof, the PT2 burial chamber conforms to the common form for chamber tombs at Portes. A rectangular depression along the left flank as one enters the vault signals an excavated feature near the *stomion*, likely a former burial.

Modelling of PT2 attempted to combine two nearby tombs (PT24 and PT27) that were in a worse preservation state. Concave depressions in the steep slope above the path signalled their locations but offered few clues as to their complete original form. Similar issues occurred further along the path where the slope has eroded and portions of tombs have either collapsed inward or slumped downslope into the southern ravine. The advantaged position clearly had its drawbacks with regard to stability and longevity, though it is doubtful either shortcoming would have become clear in the short term.

With a remaining volume estimated at 15.2-18.56 m^3, or 48-59% the median volume for intact chamber tombs at Portes (MedT$_P$ of 31.6 m^3), PT2 is among the smallest third of tombs on site. This is largely due to the stubby *dromos* and missing vaulted ceiling. With a maximum diameter of 2.58 m (93% MedVL$_P$ of 2.77 m), the original chamber of PT2 could have been comparable with all but the largest of the vaults seen in PT3 and the PT7/8/9 cluster, but the builders did not sink it deeply enough into the hillside. Soil and rock density here seem more friable than other surveyed locations, influencing the estimated range for excavation rates. Rather than radically alter that range to predict reduced digging costs, I have chosen instead to maintain a consistent range comparing intrasite investment with intersite variation in mind. For clarity in the narrative descriptions, the same simplified range for excavation costs (9-12 ph/m^3) allows quick one-to-one comparisons. In a similar vein, the idealised median scale from AA01 (TRex) places PT2 in a context easily transferable to the others, while median site values compare tomb features strictly within its cemetery.

Given the footprint of PT2, it is reasonable to assume that the original volume was at least half again (1.5x) as large as that of the remaining volume as measured in the model. A volume of 25-34 m^3 places the tomb in a similar size class to the shallow PT11, with the upper limit of that range closer to that of the well-preserved PT10. These projections can also link to the median rankings for PT2's known dimensions, with the vault length and width being 86-93% the median expected site value, by which one can scale up the unknown original dimensions

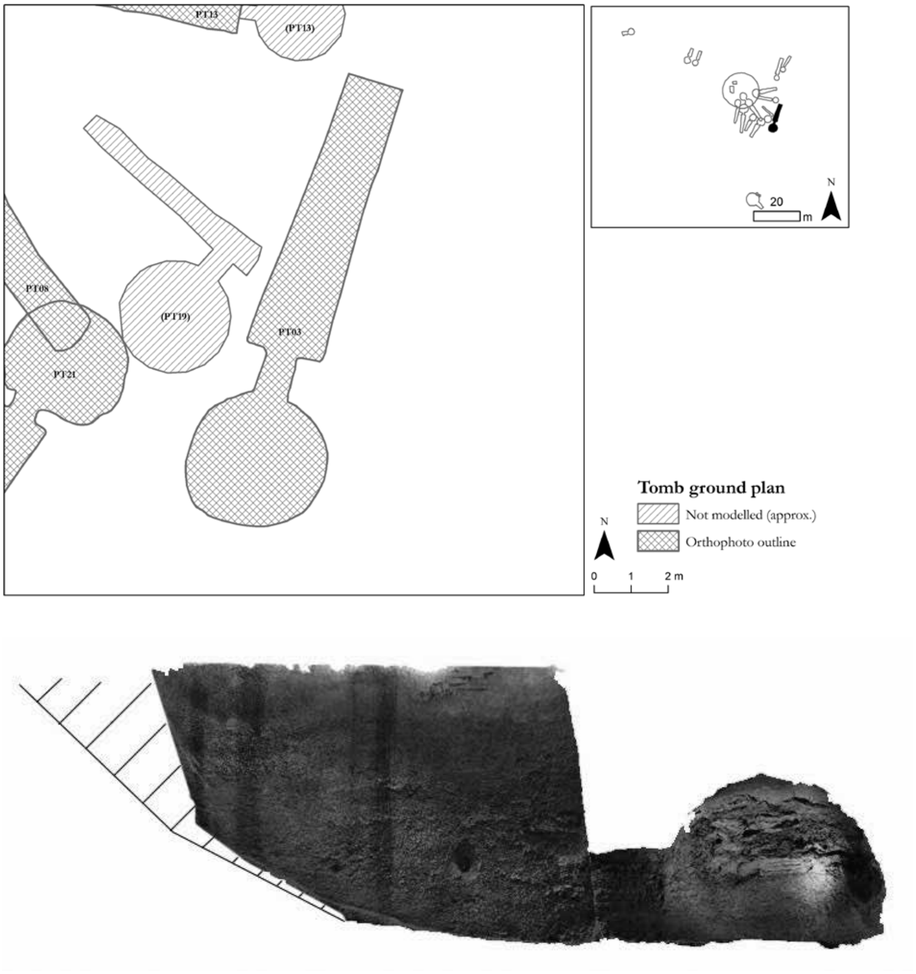


Figure 4.2.7. PT3 plan and south-eastern cross-section with schematic indicating missing model section (disrupted by modern access stairwell).

of the poorly preserved *dromos* and missing vault height. Acknowledging that measurements derived from projections are highly speculative, the estimates still yield to a loose model for labour investment. A range of estimated volumes stretches the range already included by varying digging efficiencies but keeps PT2's investment below 310 ph. Even at the highest probable difficulty, PT2 could hardly exceed 410 ph under reasonable circumstances. That means that a dedicated team of ten labourers – comprising three diggers, six carriers, and one supervisor – could finish PT2 in a little over a week, or on a dedicated 10-hour daily work schedule, in less than five days. Compared with the larger, deeper-set tombs around Tumulus A, PT2 was highly visible to processions entering the cemetery from the adjacent hill and saddle that funnelled traffic from the settlement. It was also a bargain to build.

Portes Chamber Tomb 3

Perhaps the most recognisable tomb at Portes, the PT3 "Warrior Tomb", was the first of the site's 26 tombs surveyed here to be targeted for labour investment modelling (Figure A3.2).

With the reduction in total station use and AutoCAD modelling, the number of photos taken as well as photopoint anchors recorded per model was increased to maintain full coverage of architectural remains around the site. For PT3, 1,034 photos were incorporated within its photo model, more than tripling the number for the Menidi *tholos*. Photopoint markers were also increased from 10 at Menidi to 28 for PT3, the main concern being the fidelity of the model with the extreme low lighting of the deep and covered tomb. None of these concerns turned out to be well-founded apart from the negative knock-on effects of too many photos. The model was a success *in spite of* rather than *with the aid of* the high number of photos and markers. Caution with field recording backfired in substantially increasing processing times, resulting in an unwieldy, albeit highly detailed, model of the tomb (Figure 4.2.7).

Volume measurements for PT3 yielded 60.5 m^3, less than 10% the size of the Menidi tomb despite having a similar feeling of monumental scale. Although the park's efforts to highlight the tomb for visitors contribute to its aura of grand scale, the depth of the tomb would convey similar feelings then as now. The sense of passing into a different world is evident in the sharp contrast of temperature, humidity, and lighting, to say nothing of the difference in scents with the surface. The changes are gradual as one descends but easily perceived. Only near midday and without a canopy would the tomb carry enough light for functions to proceed without an alternate source of lighting. Use of an open flame for this would further enhance the feeling of otherworldliness, casting shadows and acrid smoke to assault already-dilated pupils and noses more accustomed to mountain air. When sealed, 38.1 m^3 of earth separating the tomb from the surface would help to alleviate anxieties over theft and supernatural reprisals (e.g., Paschalidis and McGeorge 2009: 84). The subject of tomb closing will return again in Chapter 5, where visibility and forgetting collide with life's threatening boundaries (Douglas 1966: 121).

The materials accompanying the burials in PT3, particularly the diadem-like object, bronze greaves, and Naue II type longsword mentioned previously, reinforce the architectural investment's message that the users of this tomb had no shortage of influence. Undoubtedly important at the local, perhaps even regional level, the inclusion of materials originating beyond Achaea show at the very least a strong network of long-distance exchange. Given the late LH IIIC date, it is possible that the final burials in PT3 were among the last generations to enjoy this network prior to an inward shift in focus at the end of the eleventh century BC.

The two burials found within the tomb were placed on a thin layer of unfired clay, similar to that reported for PT18. Humid conditions within the chamber ensured that the bones "were practically powdered", making further identification of gender and age difficult (Kolonas et al. 2002: 7). Accompanying materials, particularly the warrior's kit and the large, diverse assemblage of beads (carnelian, gold, and glass) suggested to excavators a male and female. The two were unquestionably wealthy or revered, and the sword in its leather sheath was positioned away from the burials in such a way as to be visible from outside the chamber, making it the last (closing) or first (opening) object seen when manipulating the entrance.

Constructing the tomb involved digging into soft rock, much more compact than the earth removed for Menidi, raising the base rate of excavation cost from the 4-9 ph/m^3 range at Menidi to the 9-12 ph/m^3 range at Portes. Even with the greater challenge to progress at this early stage, the estimated cost of the tomb nowhere approaches the investment of most larger tombs cut into softer materials. Common and reasonable differences in excavation rate can nullify size advantages as large as 300% depending on context (see Chapter 3). The chance for equal investment – from higher excavation rates driving similar costs to larger tombs with lower excavation demands – evaporates, however, with softer materials requiring temporary and permanent shoring to reduce the risk of collapse. Having to transport those shoring materials, even from local sources, would greatly increase the total cost.

Base excavation costs for PT3 fall in the 545-726 ph range, with the reasonable expected maximum at 726 ph under the manageable pace of 12 ph/m^3. This places PT3 in the highest tier of investment for Portes, nearly doubling the median expected value (MedL$_P$ of 380 ph). This would either stretch the completion time for the tomb or, more likely, increase the size of its workforce. Even with a modest 20 labourers – 6 diggers, 12 carriers, and 2 supervisors fulfilling the roles of designer and on-site director – excavating PT3 should not have taken much more than a week. Adopting a smaller workforce of ten to better navigate the tight spaces of the deep tomb, a fortnight would suffice even with the five-hour workdays palatable to teams performing exhausting physical tasks. Adding to the base excavation cost enough time for assembling the workforce, designing the tomb, and selecting its location, the true cost of PT3 climbs higher but should not under most acceptable circumstances exceed a month from conception to completion. Reopening the tomb (assuming a completely backfilled *dromos*) would have taken less than a week with as few as five labourers. Although the timing of closing remains an open-ended question tied to tomb visibility and performance (e.g., Boyd 2002: 92, 2015a: 204, 2016: 65; Karkanas et al. 2012: 2731; Mee 2010: 287; Mee and Cavanagh 1990: 228; Papadimitriou 2015: 103; Wilkie 1987: 128-129; see Chapter 1, this volume), backfilling the *dromos* would be the least labour-intensive act in tomb construction and closely comparable to the estimated reopening cost. No matter how delayed, closing the tomb is a terminal construction stage disconnected from building, use, and reuse, and is thus not considered as part of the narrative for labour estimates. Nonetheless, Table 4.2 indicates how closing costs might compare with other more burdensome tasks.

Although PT3 separated itself from the pack in terms of scale, many of its dimensions strongly correlated with those of PT7. In plan view, the length and width of their *dromoi* and vaults typically fall within 88-95% the size of the other. If not for the taller ceiling of PT3, the PT7 vault would exceed its size. The most significant discrepancy between the two is the depth of the PT3 *dromos*. This clearly contributes more than other variables to its higher cost, without even accounting for the inflation caused by practical knock-on effects from digging further from the surface and at a steeper angle.

Aside from its higher cost relative to the other Portes chamber tombs, PT3 is rare for its orientation and relative position not following the slope. The prevailing trend for chamber tombs is to delve into an elevation with *dromoi* pointing downslope. With two exceptions (PT3 and VT3), this is almost universally true for the 94 tombs with entrance passages examined in this study. The preference is well-documented elsewhere (e.g., Maravelia 2002 for Mycenae's *tholoi*), such that exceptions raise immediate suspicions. For PT3, its chief excuse might have been the proximity of the dense tomb cluster ringing Tumulus A and the C group of partially intact built chamber tombs lying almost directly above it. There simply was no space for the later tomb. The missing summit of Tumulus C and steep slopes to the northeast would offer a potential alibi for PT3 and its errant alignment if slope orientation was in fact a strict concern.

Figure 4.2.8. Remains of Tomb C1 near PT3, facing southwest.

Tomb C1, the largest recorded built chamber tomb in mainland Greece, is also located here, mapped above the vault location for PT3 (Kolonas et al. 2002: 5). With its design, positioning on an earlier tumulus, and disturbed contents reflecting an early LH I-II origin and use (Kolonas et al. 2002: 6), C1 preceded PT3 by several centuries. Though the outline of C1's massive size (8 x 1.6 m) could have encouraged later affiliative construction, it would not have been intact by the time of PT3's construction. The stacked flat stone walling of the C group of built chamber tombs had been repurposed as needed in the LH III period chamber tombs. Many of their stones ended as dry stone walls sealing nearby chamber tombs or repairing weakened sections (Kolonas et al. 2002: 6), as is visible where C1 abuts the top of the PT3 *dromos* near its narrow upper façade (Figures 4.2.8, A3.3-A3.4). C1 itself had partly destroyed its earlier neighbouring built chamber tombs C2 and C3. Whatever the case, a relatively flat ground surface prompted an exceptionally steep *dromos* for PT3 to reach the target depth for a stable vault with enough undisturbed rock matrix overhead to maintain its shape without imploding (see Chapter 2).

Portes Chamber Tombs 4-6

See Appendix 2.

Portes Chamber Tomb 7

PT7 lay in the cluster of interconnected vaults and *dromoi* on the southern side of Tumulus A (Figures 4.2.9, A3.5). The PT7 vault opens in three places, with the main entrance to its unshared *dromos* leading south-southwest toward the slope and trail above the collapsed *tholos* tomb PTh2. The other openings interrupt the vault wall at roughly a metre above the floor and allow access to the adjacent *dromos* for PT9 to

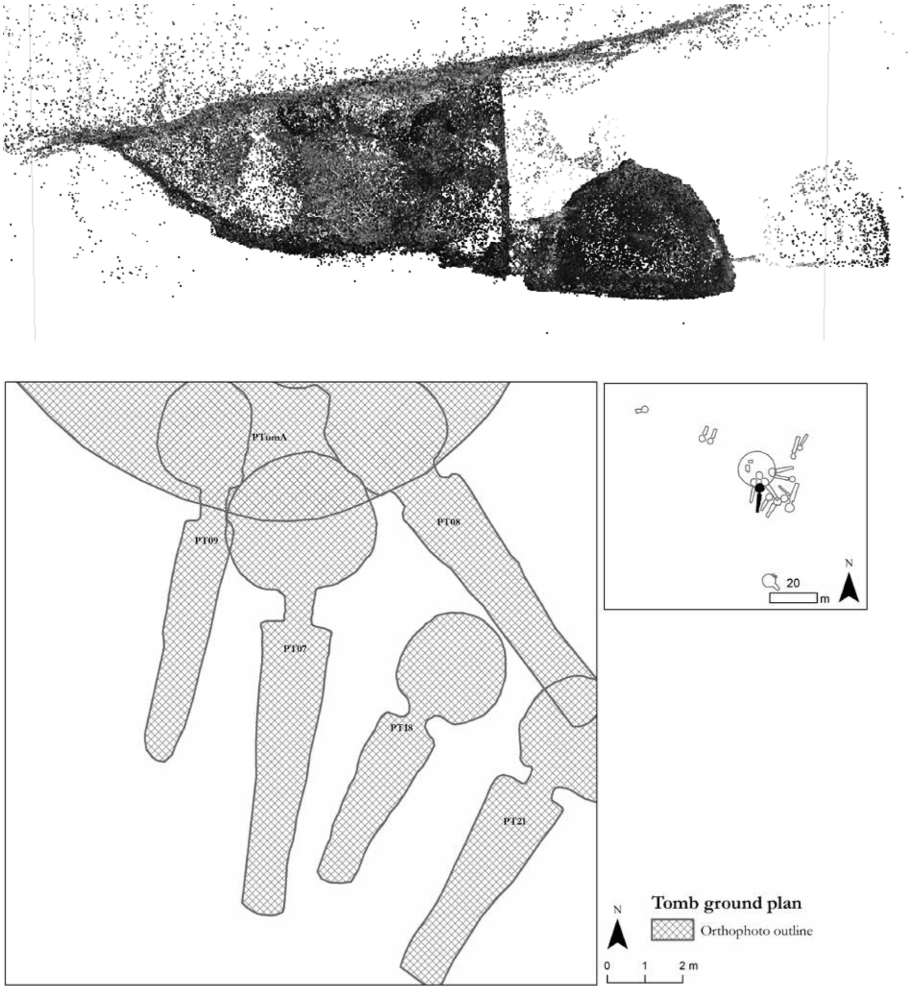


Figure 4.2.9. PT7 plan and sparse cloud model (western cross-section) showing the relative location of the adjacent PT8 main vault.

the west and the PT8 primary vault to the east. PT7 is the largest of the PT7/8/9 cluster and, by virtue of its multiple outer openings, the best-lit of the well-preserved chamber tombs at Portes. Due to its connections with another cluster of tombs to the west via the PT9 *dromos*, PT7 also harboured one of the deeper concentrations of bat faeces.

I modelled PT7 in tandem with PT8 and PT9, largely due to the sheer drop preventing simple entry from the PT9 *dromos* and the already secured tie-off descending into PT8. Processing the models captured the vaults in sufficient detail but left the *dromoi* with the need to 'chunk' (separate) clusters of photos that did not align. The alignment difficulties offered a chance to alter the settings to expedite processing, lowering accuracy by decreasing the number of faces the program would create. Cross-checking these lower resolution models with volume estimations of models conducted under the highest settings revealed that losses would be minimal. Volume estimations routinely differed by less than 5% among the different settings and far exceeded the accuracy attainable with solid geometry estimations

Figure 4.2.10. PT8 entrance with Tumulus A visible in the background, facing northwest.

(see Chapter 3). Lowering the mesh face count was especially useful later for the PT11/12 pairing where the photopoint markers were limited by the slope.

The vault of PT7 measured 20 m^3, nearly matching the volume of the double-vaulted PT8 (23.6 m^3). Such a comparison was hardly expected intuitively from their heights and diameters. The surprising scale of PT7 nearly equalled the dual effort of PT8 and its inner chamber. Individually, PT7 had by far the largest vault in the PT7/8/9 'honeycomb cluster' and would have exceeded that of the largest on site at PT3 if not for a lower ceiling. When facing the outer *stomion*, a large defilade in the left flank slumped from the *dromos* surface, creating a noticeable hump on the *dromos* floor. One of the site attendants indicated that this resulted from an earthquake, though destabilisation from other nearby *dromoi* also likely contributed. Despite these disturbances, the PT7 *dromos* measured 24.8 m^3 for a total tomb volume of 44.8 m^3. Expected excavation costs are 404-538 ph or 11 days for 10 labourers. This places it only 4 days short of the expected excavation cost for the PT3 Warrior Tomb. Construction of the two would likely have been separated by years rather than conducted within the same season, giving imperfect memories enough time to blur the disparity in construction investment. For the later tomb, there would be no reason to doubt one's own work as the preeminent example for the site.

Portes Chamber Tomb 8

PT8 represented a special case on site for its two vaults serviced by the same *dromos*. Behind the primary vault, directly in line with the *dromos* and initial *stomion*, lay a second *stomion* with a low stone threshold leading into a smaller inner chamber (Figures 4.2.10-11). Isolated from the surface apart from a weak shaft of light, artificial lighting was a necessity here. Upon placing the camping lanterns, shadows framed the inner vault's current residents, a large and diverse array of spiders. The smaller size of the inner vault ensured brushing against the walls as I angled the camera to capture the model, dislodging on several occasions the webs and

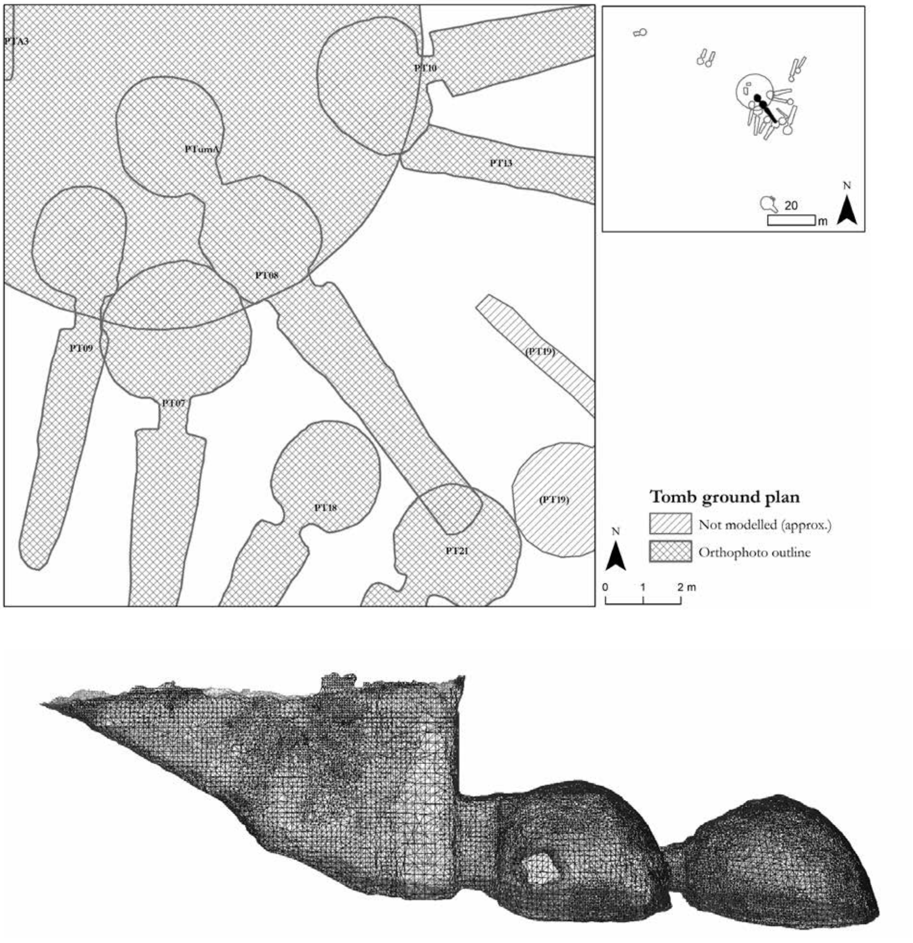


Figure 4.2.11. PT8 ground plan and wireframe model (south-western cross-section). The gap in the main vault opens into the adjacent PT7 burial chamber.

their architects. A second opening in the western corner of the primary vault allowed access to the lower and larger PT7 vault with its welcome lighter and drier atmosphere.

Photos for PT8 and its immediate neighbours began with the *dromos*, the only passage captured by the initial photo alignment. The fidelity of the model with the layout of PT8 and its honeycomb of adjacent vaults surpassed my initial expectations. It came as a relief to have the program perform better than expected, as the difficulty of accessing the tombs with equipment was elevated for its rope-bound descent into the *dromos* and prone entry through the narrow *stomion* of the inner vault.

The dual vaults of PT8 measured 13.6 (primary vault) and 10 (inner vault) m^3. Although significantly smaller than PT7 individually, together the PT8 cluster surpassed the investment in the larger single tomb. Blocking the inner *stomion* with a dry stone wall further added to the effort of a double chamber. It also represented another chokepoint in the sequence of construction, slowing efforts in extracting material from the inner chamber. More than two labourers would not have operated efficiently in the tight quarters, and from a comfort and safety perspective, one could have fulfilled the role

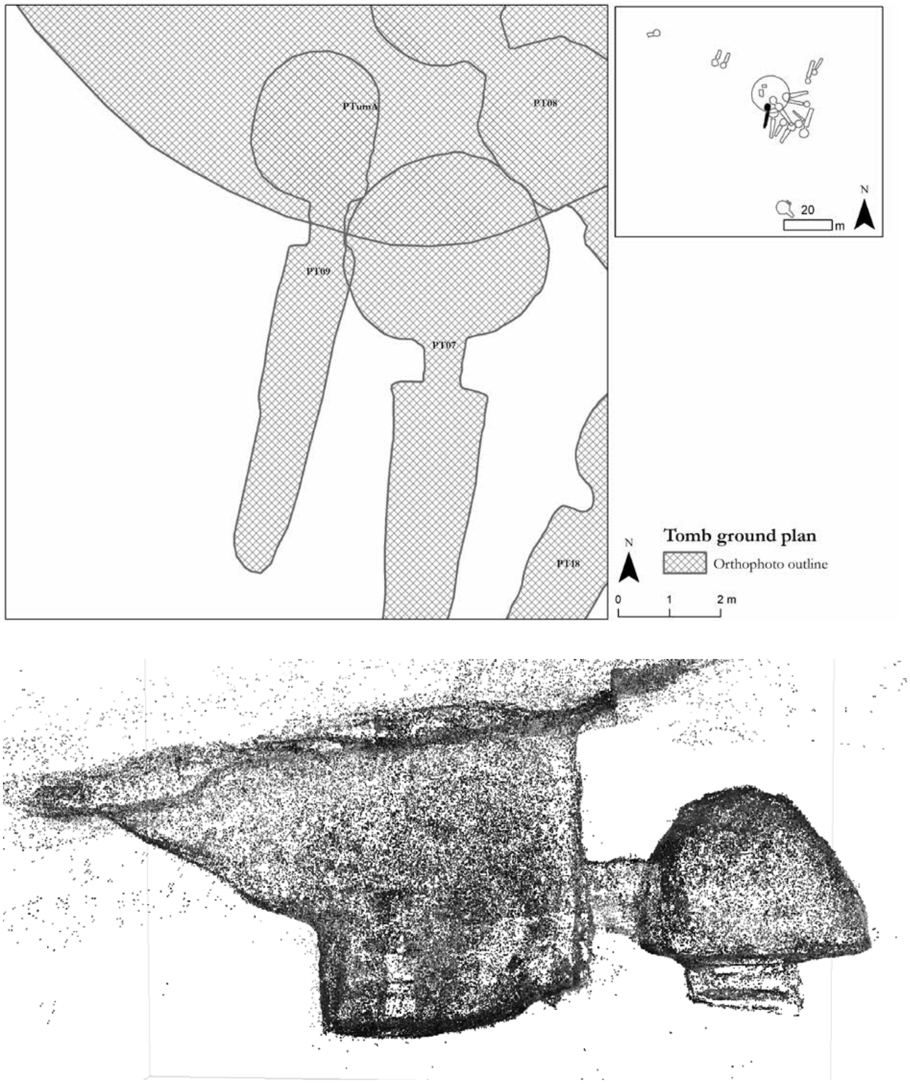


Figure 4.2.12. PT9 ground plan and sparse cloud model (western cross-section) showing *dromos* ledge and excavated pit.

more easily than two. Teams of carriers passing through the primary vault could have assisted the excavator working within the inner vault, keeping the labourers working as a traditional unit and limiting the need to stagger excavation in a sequence visible in the final labour estimates. Simplifying the costs to the base excavation rates used for the other tombs here, the double-vaulted PT8 required 378-504 ph or 11 days for 10 labourers to remove its 42 m^3. Similarity to PT7 would be superficial based on scale alone, since the inner chamber is needed to bring PT8 to within 94% of its larger neighbour. Without it, PT8 would be closer to 70% of PT7's investment and less than 2% more than the median expected value for the site.

Portes Chamber Tomb 9

PT9 was the last of the ‘honeycomb cluster’ of PT7/8/9 to be modelled. PT9 was also the smallest and the most awkward to enter, given the sheer drop of its own *dromos* and an elevated *stomion* (Figures 4.2.12, A3.6). With further complications from a resident wasp, roughly half the floor of the vault was excavated into a large rectangular depression, restricting movement to the south-eastern half. Similar to a type seen in Kephallonia, this deep, rectangular pit contained a single, contracted burial and had been covered with slabs “sealed by green clay” (Kolonas et al. 2002: 2). Another pit in the *dromos* was apparently reserved for secondary burials. I photographed PT9 on our final day at Portes, trusting the program to align the photos without issue. No time was allotted to remodel or fill gaps where they appeared. Stepping carefully around the deep excavated section, camera positioning was not ideal but still managed to collect sufficient angles to complete the vault model.

The *dromos* proved more problematic. With a sheer drop separating the first third from the rest of the passage, the safest point of entry was via the opening into the vault of PT7. The elevation difference between the floor of PT7 and the *dromos* of PT9 still forced some ungraceful shimmying contortions to gain access, but the route succeeded without damaging the walls. Trouser legs and skinned knees were occasionally sacrificed across the low stone thresholds of PT9 and the PT8 inner vault.

Digital reconstruction of PT9 succeeded by dividing the model, re-optimising cameras, and aligning via photo frames rather than the marker references, which originally misaligned the vault position. The resulting volume estimations reflected 10.1 m^3 for the vault (9.58 m^3 without the rectangular depression) and 17.4 m^3 for the *dromos*. Fully excavated, the *dromos* would have expanded by several cubic metres, up to the expected 18-25 m^3 seen for its neighbours PT7 and PT8. Much like the excavation of the Prosilio tomb directed by Yannis Galanakis (personal communication, 2019; Bennet 2017) in Boeotia, excavation of that unfinished first third of the *dromos* could have been postponed to account for scheduling, but more likely it was a product of preserving the ceiling of adjacent tombs. It is unlikely that the sheer drop would be the original intended form for the entrance passage into the tomb. A small opening in the western corner of the drop shows the collapsing vaults of the nearby southern slope cluster of tombs. That instability alone may have discouraged further excavation and weakening of the adjacent vault ceilings. At 27.5 m^3, expected excavation costs for PT9 fall in the range of 248-330 ph or a week for 10 labourers. Assuming that the original volume of PT9 exceeded 30 m^3, excavation may have taken little more than an additional day.

Apart from the anomalous excavation of its *dromos*, PT9 exhibits the third-smallest departure of the Portes chamber tombs from the median expected values, with only PT10 and PT21 showing a closer-to-standard form. Plans for a classic chamber tomb may have been thwarted by limited space from close neighbours. Respecting that proximity seems to have manifested as a shallower depth for the chamber. Elevating the chamber closer to the surface of the overlying tumulus wisely prompted a reduction in vault size to 81% the median expected value ($MedV_P$ of 12.5 m^3). The builders did so by narrowing its width (86% $MedVW_P$ of 2.73 m), uncertain perhaps of the balk’s stability separating PT9 from its neighbours. Rather than showcasing another tomb reliant upon its large scale for its primary architectural message, the builders of PT9 sited it where finesse was key to avoid setbacks in its own construction or damage to other tombs, whether or not this was

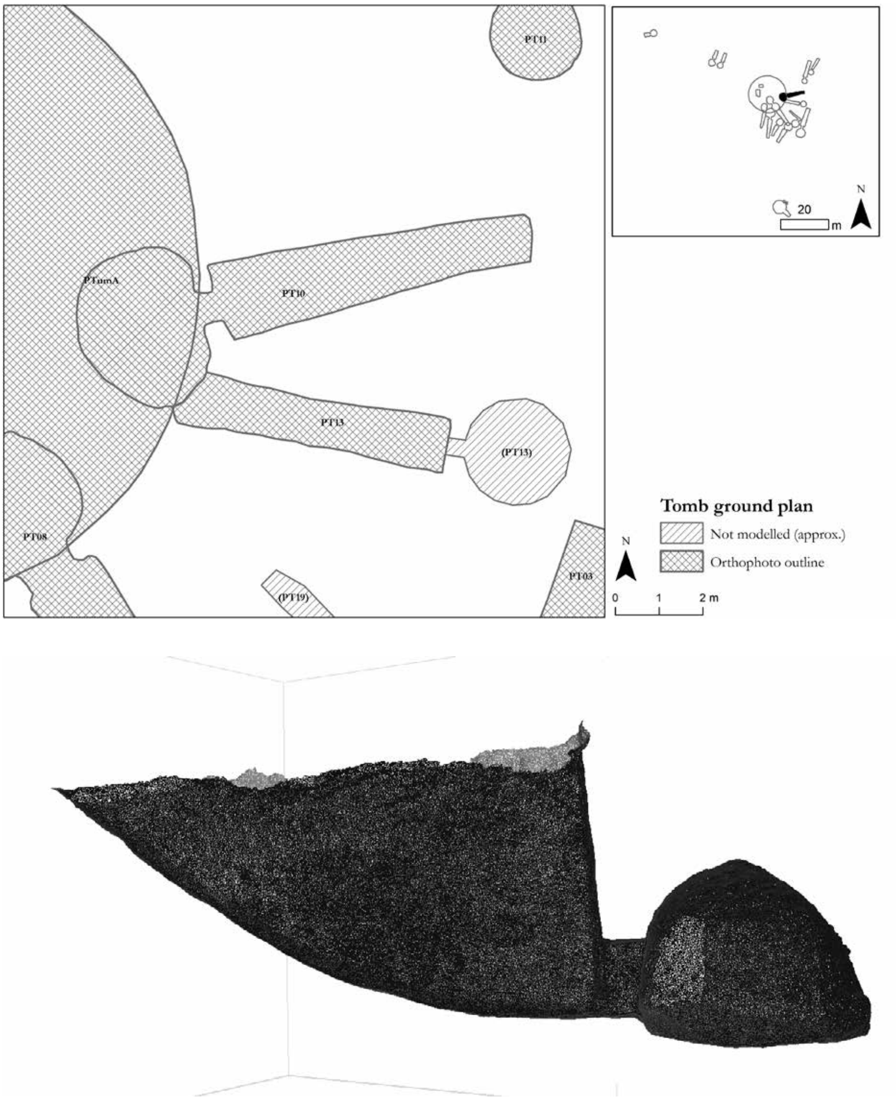


Figure 4.2.13. PT10 ground plan and wireframe model (southern cross-section).

intended from the planning phase or incidental from crowding by earlier and later tombs. From the excavators' perspective, it was clear that PT9 and the other southern slope tombs (PT7, 9, 17, 18, 21, 25, 26, and 29) were arranged in two successive rows and tightly packed to save space. Though early successful tombs demonstrated the suitability of the rock here, overcrowding weakened walls and eventually led to a series of small collapses.

Portes Chamber Tomb 10

PT10 was modelled in conjunction with the *dromos* of PT13, where a second opening in the wall of the PT10 vault allowed the only point of access apart from a vertical fall of more than 4 m (Figures 4.2.13, A3.7). The switchback pattern that the two tombs form is seen more as a convenience of excavation. It is unlikely that those constructing the tombs would knock out the wall of an existing chamber tomb to gain access to another *dromos*. Rather, an earthen ramp leading to the edge of Tumulus A is expected as the primary form of entry for PT13. As discussed in its own section, the PT13 vault was inaccessible with equipment due to its very small *stomion*.

The presence of side chambers in many chamber tombs might challenge the notion that the chamber walls were inviolate. Indeed, few strict patterns of use have emerged from previous analyses at other sites (Kontorli-Papadapoulou 1987: 147-148; Gallou 2005: 76-81; Smith and Dabney 2014: 150-153), and Portes itself has at least one (PT8) if not more instances of side chambers. To open an entirely new *dromos* from an existing chamber to lead into another is fundamentally different, and an unusual choice if this was the intention of the original builders of PT10 and PT13.

Oriented east-west along the eastern edge of Tumulus A, PT10 and PT13 are spatially among the closest chamber tombs to the Warrior Tomb (PT3), not counting the partially destroyed built chamber tomb C1. Entrance to PT10 and PT3 can be gained within a few steps of the other. Whether or not the tombs are closely related chronologically, spatially their relationship seems one of at least marginal affiliation. Construction of subsequent tombs must have acknowledged the proximity of completed ones nearby or otherwise risked their collapse, a consideration prevalent for PT9 as discussed above. Escalating grandeur would have been most acutely felt by the inheritors of the nearest inferior competitor, provided they knew or cared about the scale of other tombs. If PT10 was constructed before PT3, as the finds might indicate, then PT3 noticeably surpassed its predecessor in scale.

Not taking into account the additional 19.4 m^3 of the PT13 *dromos*, the estimated volume of PT10 is 32.8 m^3, little more than half the volume of PT3. The base range of excavation costs for PT10 is 296-394 ph, or no more than 8 days for a team of 10 labourers working in earnest for five hours each day. This is well within the capabilities of an extended family and its closest contacts. For those with a larger network, as would be expected for the commission and use of this type of tomb, the cost of construction is almost negligible from an economic stress perspective. Impact, however, would not be lessened by costs largely hidden from public view. With the human body as the only measuring stick, PT10 would not obviously differ from tombs up to and including the size of PT3, especially once closed. The footprints of the filled *dromoi* around Tumulus A would show vague outlines of tombs with apparent parity. Only those with access to the excavated interiors could discern the differences in cost and scale. It is even more unlikely that one would access both tombs within a short enough span of time to offer a vivid eyewitness comparison.

Portes Chamber Tombs 11 and 12

PT11 and PT12 occupy the north-eastern slope of the main cemetery roughly 10 m from Tumulus A (Figures A3.8-A3.9). Separation from the main cluster of tombs radiating from Tumulus A, when coupled with the difference in orientation for PT11/12 from the main cluster, shows their relative detachment from other chamber tombs. PT11/12 are in general far smaller than the others, with low and narrow passages forcing entrants into prone crawling to gain access to the vaults. Cut into the hillslope without need for steep angles, the *dromoi* maintain one of the closest to level paths directly into their vaults. The surrounding slope and the threat of a steep drop just outside the *dromoi* complicated camera angles and photopoints, but the model largely succeeded apart from the missing north-eastern half of the PT12 vault. The latter was dropped from the model after repeated attempts failed to close the gap in recognised points, despite the appropriate camera angles being present.

With a *dromos* (11.6 m^3) and vault (4.73 m^3) of unremarkable size, PT11 is the smallest of the intact chamber tombs successfully modelled at Portes. PT2 and PT22 are smaller largely due to their abbreviated *dromoi*. Had the model succeeded for PT12, it too would have fallen under PT11 in terms of size. Excavating 16.33 m^3 of fill from the steep north-eastern slope of the cemetery would have proven uncomfortable at best. The ever-present hazard of sliding off the dropoff metres away must have impeded progress to some degree. Stepping carefully around the tomb's *dromos* taking photos was enough to inspire fear of losing one's footing. Carrying tools or containers of heavy earth fill during construction would certainly exacerbate that risk.

The smaller size and disadvantaged location of PT11 is suggestive of its ranking relative to larger tombs in more prominent (and safer) positions on the summit of the hilltop. Purely from an excavation cost comparison, however, PT11 does not markedly differ from the others in terms of time to completion or necessary workforce. Subtracting a day of work or a few labourers could hardly be noticeable for observers, especially if construction did not occur within the same year as another tomb on site. Expected excavation costs would range from 147-196 ph or no more than 4 days for 10 labourers.

Portes Chamber Tomb 13

PT13 formed the latter half of the PT10/13 switchback with its *dromos* connecting to the vault of PT10 (Figure A3.10). The *stomion* for PT13, however, was among the smallest on site, discouraging entry with equipment for fear of inadvertent damage or entrapment should part of the tomb collapse. The *dromos* alone was modelled in conjunction with the much more easily accessible PT10. Although some indication of labour investment can be given for this portion of the tomb, it is not useful to speculate on its share of the total cost. Due to its rectangular profile, the *dromos* for PT13 is among the larger excavated examples on site, measuring 19.4 m^3. If taken to this extreme in prehistory, moving material away from the feature would require more effort, particularly if work parties snaked through the vault and *dromos* of PT10. In the likely event that the tomb was dug normally with a ramp-like *dromos*, excavation would proceed with costs (175-233 ph) similar to PT18 (171-228 ph), taking no more than 5 days for 10 labourers. As for the unknown scale of the PT13 vault, proximity to the *dromos* of PT3 limited the available space for one of similar size to PT10. Perhaps of more concern then as now, the stability of PT13 and its nearest neighbours PT10 and PT3 depended upon their chronological sequence. The last in the sequence navigated the compounding threat of collapse from the destabilised matrix of rock around it.

Portes Chamber Tombs 14 and 15

PT14 and PT15 are not included within this study owing to access difficulties, but some brief comments can be made based on their supposed locations. PT14 was not identifiable on the signposted site maps, although these are limited by circumstance to lower resolution, especially with regard to the orientation and location of the dense Tumulus A cluster of tombs. PT15 lies near large brush piles created during site clearing activities after storm damage. Mapped as a double tomb, PT15 might have been visible on the slope above the trail leading away from PTh2. Without a network of fixed points in the area for the total stations, the inclusion of PT15 would have diverted more than the average share of time used for coverage of the other tombs. The location of PT15 away from the main cluster around Tumulus A, like the oddly placed PT11 and PT12, suggests detachment from the others. What manner of detachment is unknown, but one could envision like Cavanagh and Mee (1990: 59-62) a separation of families and their allies. Perhaps the commissioners of PT15 felt more distant or preferred an easier road for construction away from the crowded summit.

Portes Chamber Tomb 16

PT16 shares the northern slope with PT22 adjacent to the east-west trail looping north of Tumulus A (Figures A3.11-A3.12). Apart from their shared location and orientation, the tombs are fairly isolated compared with most others on site, which typically occur in clusters of three or more. PT16 is poorly preserved with a collapsed ceiling but is now protected by a wood-frame awning. Total station survey and photogrammetry models for PT16 and PT22 were completed by Yannick Boswinkel while I worked on the Tumulus A chamber clusters. As such, my firsthand memory of these tombs is considerably reduced, though I did check them for noticeable irregularities that might be worth further investigation.

The original outline of PT16 has been obscured by a series of collapses that have erased the roof and widened the walls. The current cavity measures 32.4 m^3 with a stubby *dromos* of only 3.22 m^3. The *dromos* was almost certainly abbreviated by the slope, due either to a partial collapse or simply being interrupted by the path leading around the cemetery. The total current volume for the tomb measures 35.62 m^3, but it is not immediately clear how that measurement relates to the original dimensions. Based on more common shapes, PT16 was likely much smaller. The shape of PT16 with its collapses and abbreviated *dromos* clearly pushes it into anomalous territory when comparing typical ratios of vault and *dromos* sizes. Generally I have opted to ignore it in the similarity matrices in favour of better preserved tombs. Assuming that the original and measured dimensions do not wildly differ, however, estimating excavation costs should at least be a relatable representation of both. At 321-428 ph or 9 days for 10 labourers, the expected maximum cost for excavating PT16 is comparable to the investment in PT10.

Portes Chamber Tomb 17

See Appendix 2.

Portes Chamber Tomb 18

PT18 appears on the outer southern edge of the central cluster alongside PT21 (Figures 4.2.14, A3.13). PT18 lies between the *dromoi* of PT7 and PT8. With its relatively short *dromos* and cramped vault, PT18 intrudes on neither of its immediate neighbours, unlike the vault of PT21 with its opening into a higher unlabelled vault to the northeast. Excavation of the tomb revealed two modes of mortuary practice, suggesting multi-generational use. A final primary burial had been arranged on the floor of the chamber atop a thin layer of unfired clay, possibly the remnant of a funerary bier (Kolonas et al. 2002: 2). In addition to this, a deep rectangular excavated feature along the right flank of the vault as one enters held a pit for secondary treatment of remains, similar to those found in the chambers of PT17, 21, and 29. If taken into account during modelling, the vault with excavated feature measures 8.35 m^3, or 8.09 m^3 without. Adding the *dromos* (10.6 m^3), the total conserved volume of PT18 prior to the pit for

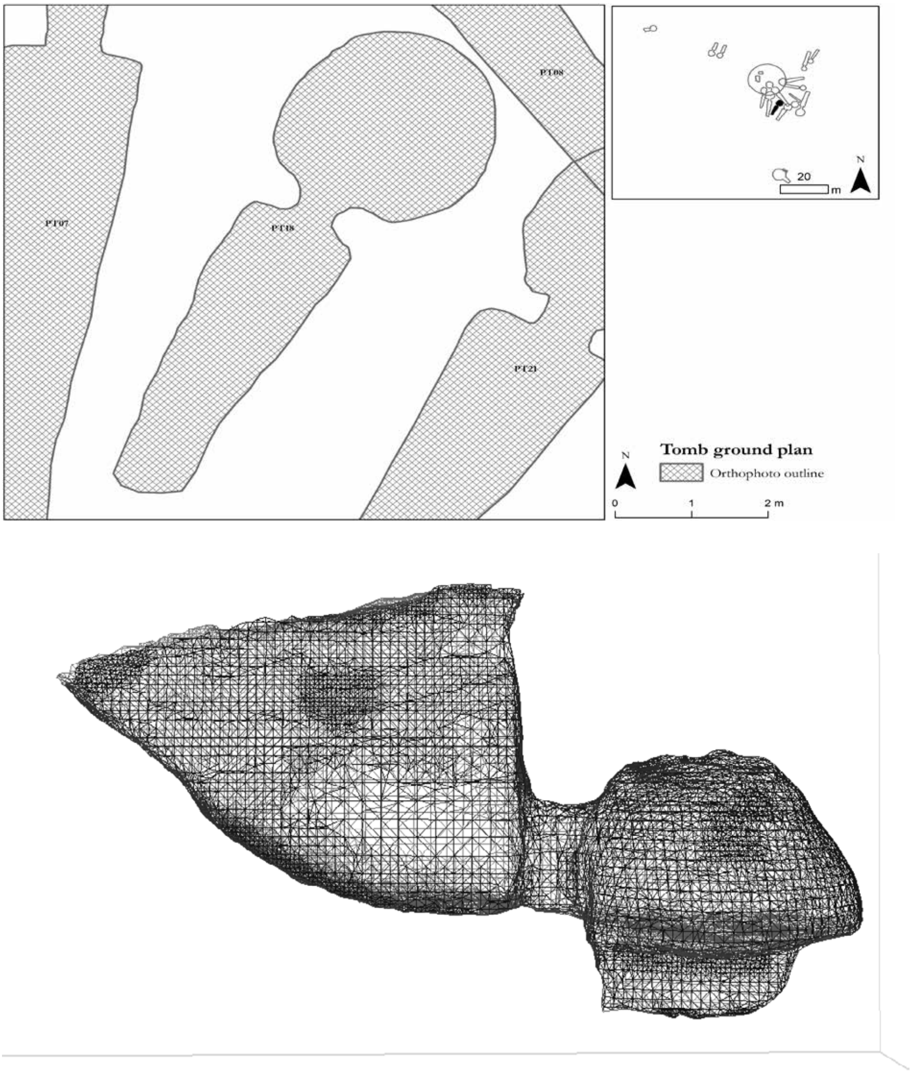


Figure 4.2.14. PT18 ground plan and wireframe model (north-western cross-section).

secondary remains was 18.95 m³. Roughly 171-228 ph (or no more than 5 days for 10 labourers) covers the excavation cost, making PT18 comparable with PT11 and PT2 in its current state.

At 60% the median volume for the site and 68% the size of AA01, PT18 is among the smallest of the completed and well-preserved chamber tombs at Portes. Located between the *dromoi* of the larger PT7 and PT8, PT18 is only partially integrated within the central cluster of tombs radiating around Tumulus A, being slightly offset in orientation and location further away from the tumulus edge. Unlike other smaller tombs that were constructed on steep, seldom-used slopes away from this apparent hub, PT18 appears to have belonged with the Tumulus A cluster. However, PT18 could also mark a transition in focus alongside PT21 from the rebuilt Tumulus A to

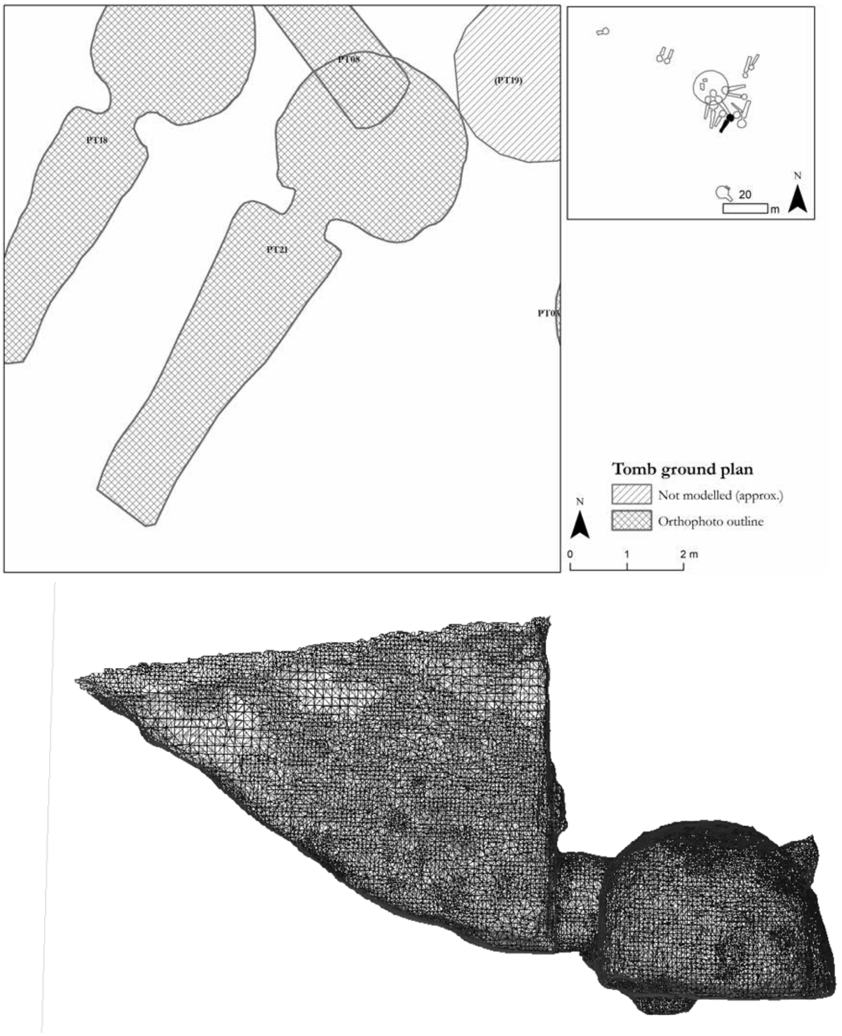


Figure 4.2.15. PT21 ground plan and wireframe model (north-western cross-section).

the destroyed Tumulus C. From the perspective of the site's excavators, PT18 relates more to the upper row of the two-tiered cluster of southern slope tombs along with its neighbours PT7, 9, and 21 (Kolonas et al. 2002: 2). Whether it preceded or followed the construction of neighbouring tombs would not jeopardize spatial associations. A clear timeline of construction, however, would help to explain, or at least rule out, scenarios accounting for its reduced scale. Crowding again may have played a role, as the *dromos* opens less than a metre away from the eastern wall of the PT7 *dromos*. Stretched much further, the orientation of PT18 would also lead it directly into the *dromos* of PT8 to the northeast. The second and third tombs in the sequence had much more to consider in planning and execution than the first.

Portes Chamber Tombs 19 and 20

See Appendix 2.

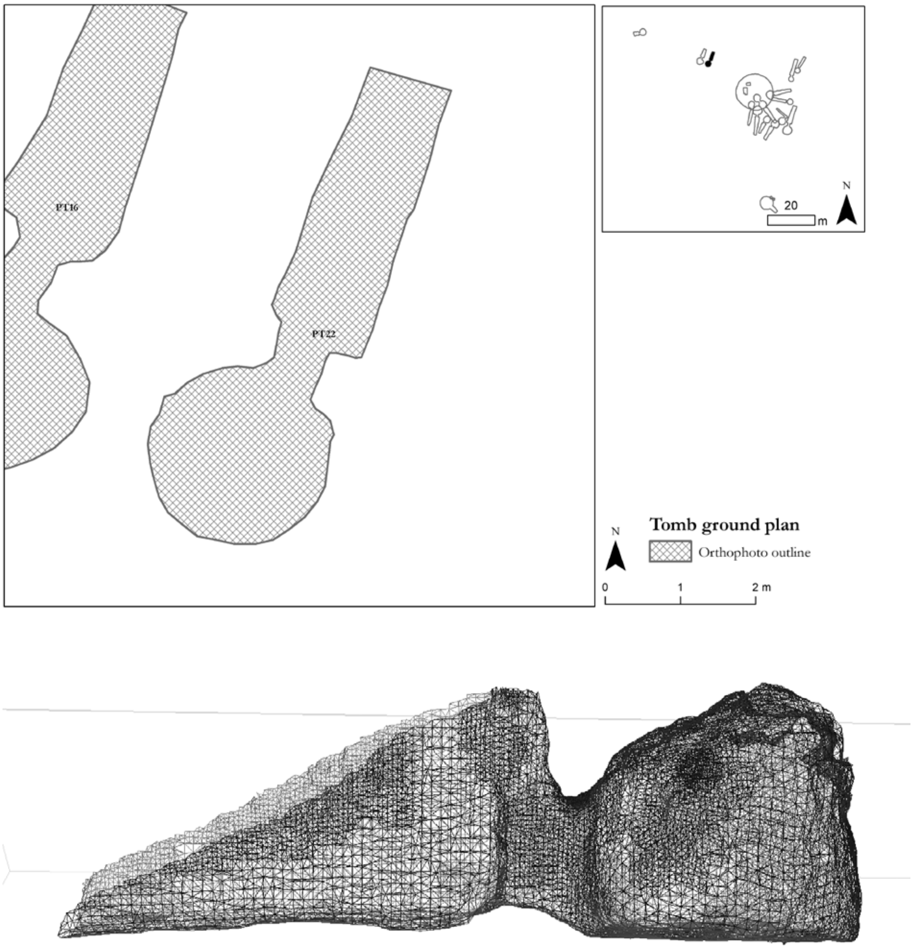


Figure 4.2.16. PT22 ground plan and wireframe model (eastern cross-section).

Portes Chamber Tomb 21

PT21 represents the southern terminus of the central cluster radiating from Tumulus A (Figures 4.2.15, A3.14). As mapped, PT21 and PT18 may relate less to that grouping than to their own transitional pairing between Tumulus A and the earlier Tumulus C. The portion of the latter not already destroyed in antiquity has been excavated and, unlike Tumulus A, not reconstructed. The vault of PT21 contains a second opening around 1.5 m above its floor that offers a window into the second, higher vault mentioned in conjunction with PT19 and PT20.

PT21 shows a shallow excavation along the right half of the vault, as viewed from one entering the tomb. Unlike other excavated burials and pits for secondary remains, the depression is not directly adjacent to the wall. Some stone slabs remain along the base of the *stomion* as it opens into the vault, elevated slightly above its floor. Facing into the tomb, the window portal opens in the upper right back wall of the tomb toward the unlabelled vault associated with PT19/20. Photos into this area were too dark to successfully model, with or without flash. For PT21, its dimensions fall directly on the median for the cemetery's chamber tombs, with a *dromos* (17.9 m^3) and vault (13.7 m^3) combining for a total of 31.6 m^3. At 285-380 ph, excavation costs for the tomb resemble those of PT10 and fit within the familiar construction window of no more than 8 days for 10 labourers.

Portes Chamber Tomb 22

PT22 forms the second half of the northern path pairing of tombs with its neighbour to the northwest PT16 (Figures 4.2.16, A3.15). With a mostly intact vault, PT22 is in better condition than PT16. Both have abbreviated *dromoi* likely cut off by the adjacent path and slope. The current shape of PT22 has a volume measuring 12.03 m^3 split across the *dromos* (4.86 m^3) and vault (7.17 m^3). At 109-145 ph, the tomb has among the lowest excavation costs on site, with PT2 and PT11 demanding 50-80 ph more. This translates to 3 days for 10 labourers, less than half the cost of the site's median chamber tombs like PT21.

Although it is tempting to combine the reduced scale of PT22 with its apparently unprivileged location away from the crowded hub around Tumulus A, there can be no firm correlations of scale and location when the costliest tombs on site (PTh2 and PT3) occur alongside some of the cheapest chamber and cist graves in wildly different positions relative to the ridge. Much like Cavanagh and Mee (1990: 62) have already indicated for the Argolid, clear patterns of scale and location for Mycenaean chamber tombs are elusive.

Portes Chamber Tomb 23

PT23 is mapped as a *dromos* on the opposite southwest slope parallel to the PT16/22 pairing. Although omitted from survey due to its isolation and apparent unfinished form, the tomb remains informative for others similarly designed. According to one of the park's information placards (Kolonas et al. 2002: 1), PT23 is an unfinished *dromos* converted into a slab-covered pit for the LH IIIA burial of a child accompanied by miniature vessels. The repurposed design shows rapid adaptation to unforeseen circumstances, perhaps unstable rock that discouraged completion of a small chamber tomb similar to PT1, also speculated as a child's burial based on its size (the smallest chamber tomb at Portes). Unlike PT1, PT23 retained evidence of the burial and is curiously distant from other tombs. One explanation to that separation may lie with the failure of the rock to support a completed chamber tomb, encouraging relocation of subsequent tombs away from this area of the cemetery.

Portes Chamber Tomb 24-29

See Appendix 2.

Portes Tumulus A

Since its discovery and restoration by 2003, Tumulus A has remained a major focal point in the cemetery and served as such throughout the LH period (Kolonas et al. 2002: 8; Figure 4.2.17, this volume). First used in the early LH I period with the construction of built chamber tombs (A1-A3) on its summit, the tumulus continued to host LH IIIA-B cist graves and the central hub around which many LH III chamber tombs radiated (Kolonas et al. 2002: 6). Tumulus C appears to have preceded and coincided early with Tumulus A, but their uses diverged as the cemetery adapted new tomb forms. Unlike its protected and repurposed neighbour, Tumulus C did not survive the cemetery's shift to chamber tomb use by the LH IIIA period, with its massive early LH I built chamber tombs systematically dismantled for their flat stones

Figure 4.2.17. Portes Tumulus A (PTumA), facing northwest.

(Kolonas et al. 2002: 6). The tale of the two tumuli suggests a change in fortunes for the leading families of Portes, not surprising over the course of two to four centuries.

Spatially, Tumulus A dominated the cemetery even after the LH IIB/IIIA shift to rock-cut chamber tombs. Central to the radial clusters of chamber tombs 7-9, 10, 13, 17-21, 25-26, and 29, Tumulus A overlooks more than half of the excavated chamber tombs at Portes. Positioning and suitability of the stone was undoubtedly key here. It occupies the topographic high point of the southern ridge that defines much of the cemetery, with only smaller built chamber tombs and cist graves on the higher hill to the north (tomb groups E and ST). The low wall encircling the tumulus, no more than 20 cm or a few flat courses of stone in height, was reconstructed as excavations concluded on site in the early 2000s (Moschos 2000: 12-13).

In addition to the models of its surrounding chamber tombs, a separate photogrammetric recording of Tumulus A was attempted from the ground (Figure 4.2.18). Drone photography was performed by Ann Brysbaert and Jari Pakkanen for this area of the site as well, but the tree canopy hindered the clarity of these photos for use in more detailed models (see Figure 4.2.2). With arms fully extended, I managed an elevation difference exceeding two metres between crouched and standing positions. The resulting camera angles were sufficient to give the model its proper depth. With 904 photos and 18 markers, the model succeeded in all areas apart from the missing detail of the *dromoi* bases, many of which were captured separately in models of the individual tombs.

As recorded in the model, the dimensions of Tumulus A include a diameter between 14.9 m (southwest-northeast) and 15.5 m (north-northwest to south-southeast) and a circumference of 57.8 m. Tumulus A currently maintains a depth of at least 1.38 m. Solving for half the volume of an ellipsoid ($^2/_3\,\pi abc$) with the radial dimensions of a (7.75), b (7.45), c (1.38) yields 166.875 m^3 as its current (reconstructed) volume. If Tumulus A was built as a single-stage construction rather than multi-stage or gradual accumulation, then total

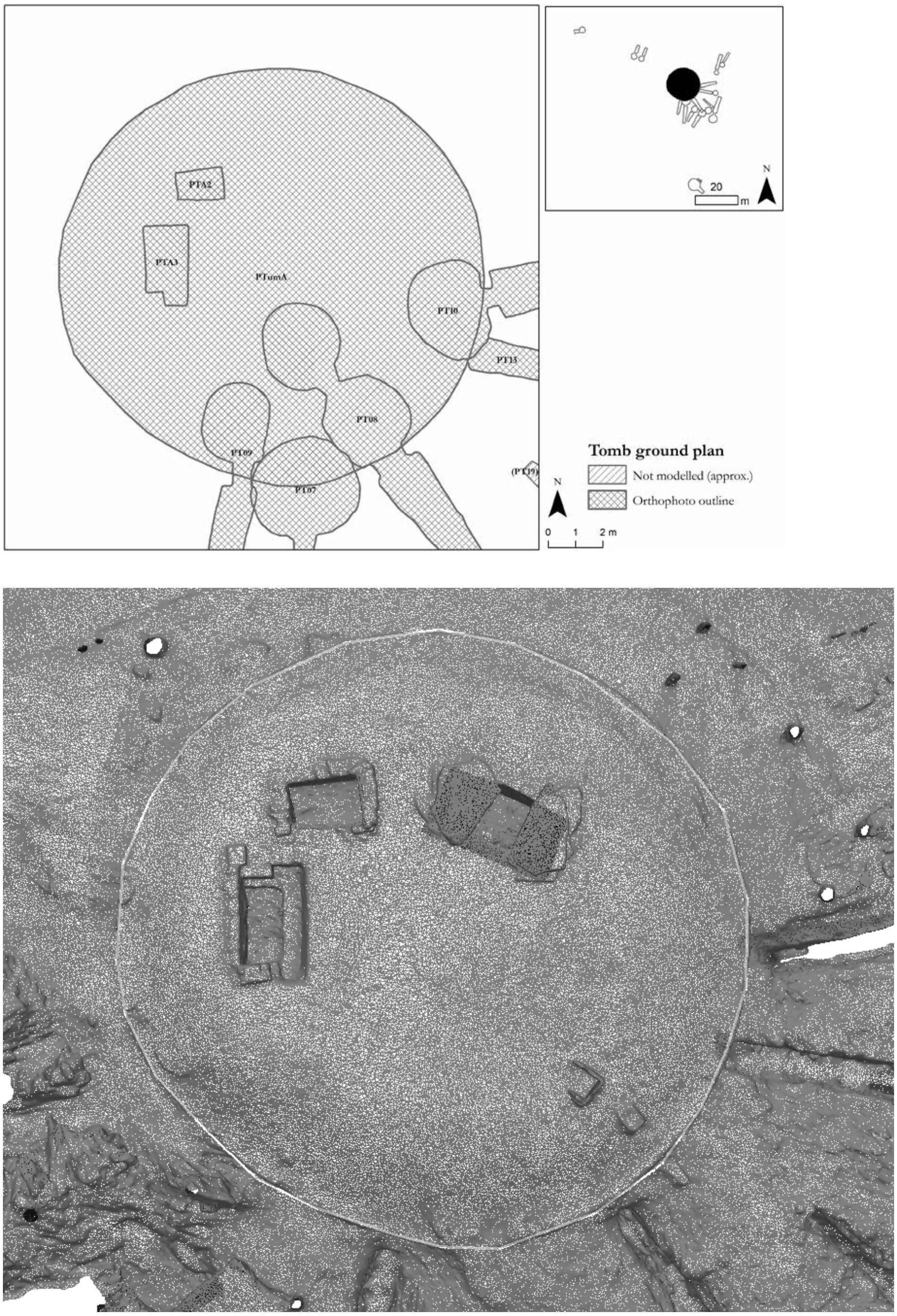


Figure 4.2.18. PTumA ground plan and wireframe model showing the relative locations of chamber tomb *dromoi* and BCTs.

Figure 4.2.19. Portes *Tholos* 2 (PTh2) with built/cist tombs D1 and D2 (left-centre frame), facing east.

costs could surpass 2,000 ph for direct excavation and deposition. Bringing stones for the *peribolos* wall from further afield would demand transport costs factored from the distance to the source. Given the unknowable variables and early construction preceding each of the chamber tombs, construction of Tumulus A is not a central concern of this study. It does, however, place the costliest chamber tombs into perspective, nearly tripling the excavation cost of the PT3 Warrior Tomb. The advantage behind constructing and maintaining Tumulus A as a focal point lay in its enhancement of all other tombs placed within and around it. If future associations were considered by its builders, Tumulus A was worth the cost and care of arranging later tombs around it.

Portes built chamber and cist graves (Groups A, E, and ST)

Several tombs comprising stone or slab-lined built chamber and cist graves were also modelled during this study (see Figure 1.6). Tombs in the A group occupy the summit of Tumulus A and include the early built chamber tombs (A1-A3) and the much smaller cist graves (A4, A6, and A8). Near the entrance of the archaeological park, tombs from the E (E1, E1a, and E2) and ST (ST1-2) groups lie atop the higher hill north of the main chamber tomb clusters. Since excavating these tombs would take less than a day, the only discernible difference in labour would be investment in moving, shaping, and placing the stones, particularly the larger covering slabs. The slabs would encourage movement via cart or sled to avoid breakage during transport from the source, and several additional hands would be required to lift and set them into place. Some comparisons can be made

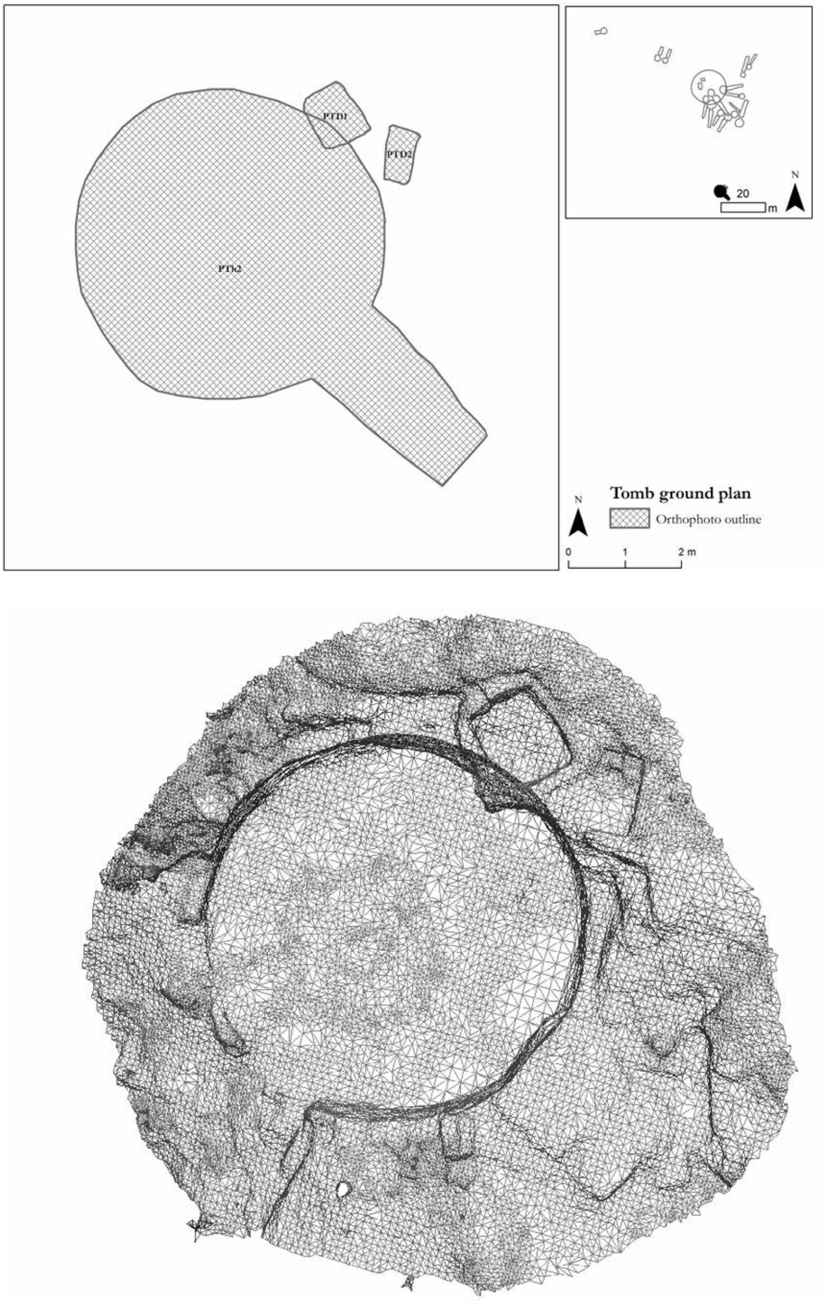


Figure 4.2.20. PTh2 ground plan and wireframe model.

with other tombs of this type, but even the smallest chamber tomb would supersede the labour investment of built chamber and cist graves. Only the exceptional built chamber tombs of the C, E, and ST groups narrow the gap with their nearest chamber tomb peer, due to the groups' well-laid courses of stone rather than their size.

Portes Tholos 2 and D group

The LH II PTh2 is a partially preserved *tholos* tomb that occupies the southern extremity of the cemetery, clinging to the slope above the ravine that likely swallowed its missing covering mound and upper courses (Figures 4.2.19-20). From its mostly above-ground construction, PTh2 is thought to be among the earlier examples of *tholoi* in the region (Kolonas et al. 2002: 3). On the upper edge of the tomb closest to the trail (to the northeast), an LH IIIA built cist tomb (D1) and a smaller classic slab cist tomb (D2) were modelled within the same frame as the *tholos*. Built into or adjacent to the *tholos*'s destroyed northern wall and debris-filled vault, D1 and D2 made use of PTh2 in a similar way as the cist graves (A4, A6, and A8) on Tumulus A. Although the original extent of the *tholos* vault would have exceeded the size of PT3, the cost of transporting and placing its stone cladding propelled it to the highest discernible labour investment at the Portes cemetery. With less than half the tomb still standing, its labour requirements would still have exceeded those of the three largest chamber tombs on site. Not enough of PTh2 remains to indicate an estimated labour cost.

Portes Tumuli B and C groups

See Appendix 2.

4.3. Voudeni

The Mycenaean cemetery of Voudeni lies 9 km east of Patras in the foothills of the Dasos Chimarron, Mount Panachaicon massif (see Figures 1.10-11). The settlement is roughly a kilometre northwest of the cemetery on the Bortzi plateau between the Meilichos and Karava (Margarita) rivers (Kolonas 2009b: 6-9). Although the E5 highway passes through a tunnel beneath Voudeni's settlement area, the simplest route to the site follows the winding mountain roads from Ampelokipi via Ano Sichena. With well-maintained grassy slopes and winding concrete paths providing a grand view of the bay and northern districts of Patras, this sprawling site is visually striking and pleasurable to visit (Figures 4.3.1-2). Several tombs remain open to the public and are accessible via ribbed concrete ramps.

The cemetery at Voudeni was in use for more than 500 years, from the LH IIB to the Submycenaean period (1500-1050 BC) (Kolonas 2009b: 8; Table 4.4, this volume). It stretches across two locales: Agrapidia, with limited excavation by Nikolaos Kyparisses from 1923, and Amygdalia, where over 77 tombs have been excavated by Kolonas in 1988-1994 and 2004-2008 (Kolonas 2009b: 8). In total, more than 150 tombs may lie scattered across the adjacent hills and tableland (Kolonas, personal communication with Brysbaert, 2018). Papadopoulos (1979: 26) mentioned a LH cemetery "on the hill Asprochoma" that may correspond to Voudeni under the catalogue entry "10 – 11. *Ano Sychaina* (*Agrapidia*)", at that point only known from Kyparisses's unpublished 1923-1924 excavations of eight Mycenaean chamber tombs, five of which were plundered. Though the tombs were badly damaged, Kyparisses found similarities with the Kephallenian chamber tombs, and the finds included "stirrup-jars and small piriform jars, steatite buttons, fragments of a bronze dagger and some jewellery [as well as] fifty LH vases" from an apparently undisturbed context of two interments (Papadopoulos 1979: 26). A further two LH tombs were excavated by Yialouris "east of Ano Sychaina in September 1960", who also "observed a LH cemetery west of

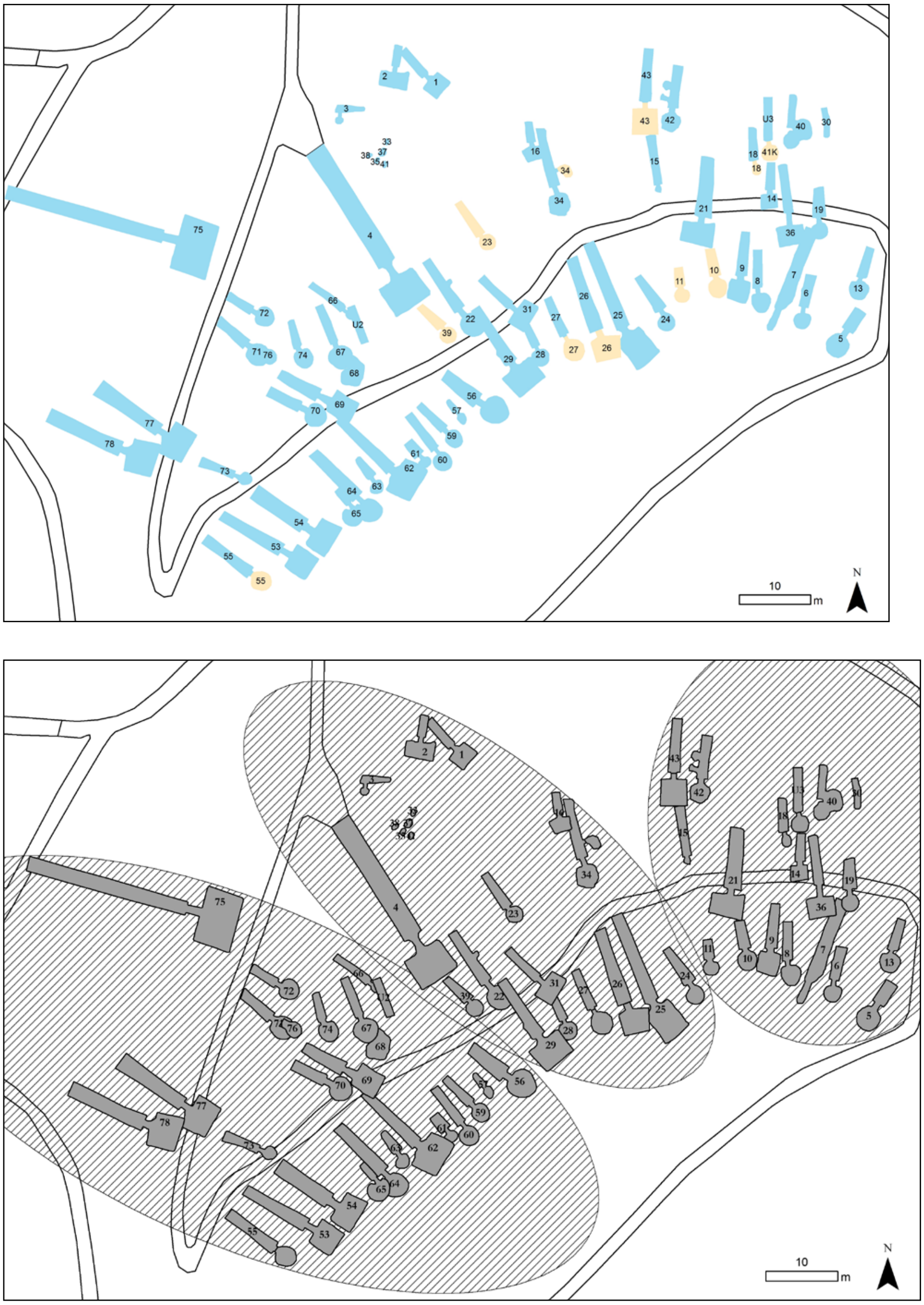


Figure 4.3.1. Maps of Voudeni showing the locations of known tombs. (Top) Shapes in blue were modelled successfully, while beige indicates missing sections. (Bottom) As a navigation aid, I assigned tombs to arbitrary cardinal groups, shown here as superclusters of west, central, and east. Tombs were further split in the text based on their relative location above (south) or below (north) the modern path.

Figure 4.3.2. Gulf of Patras as viewed from the Voudeni cemetery, with the Bortzi plateau and settlement – as well as the roof covering VT4 (foreground)–visible on the left side of the frame, facing northwest.

Tomb	Date Surveyed	Moutafi (2015)	Kolonas (2009b)	Range	LH IIB	LH IIIA	LH IIIB	LH IIIC	SUB
1	2017.07.24					x	x x	x x	
2	2017.07.24							x	
3	2017.07.23								
4	2017.07.24	IM	LK	LH IIB – IIIC		x	x x	x x	
5	2017.07.25	IM	LK	LH IIB – IIIC	x	x		x	
6	2017.07.19					x			
7	2017.07.19						x		
8	2017.07.19							x	
9	2017.07.19	IM	LK	LH IIIA2 – IIIC		x	x	x	
10	2017.07.25	IM				x		x	
11	2017.07.19							x	
11a	Buried?					x	x	x	
12	Missing							x	
13	2017.07.25	IM						x	
14	2017.07.24	IM						x	
15	2017.07.23	IM							x
16	2017.07.23	IM				x	x	x	
17	Missing	IM				x	x	x	
18	2017.07.24								
19	2017.07.24					x			x
20	Missing	IM					x	x	
21	2017.07.24						x	x	

Table 4.4. Voudeni chronology based on Kolonas (1998) (continued overleaf).

Tomb	Date Surveyed	Moutafi (2015)	Kolonas (2009b)	Range	LH IIB	LH IIIA	LH IIIB	LH IIIC	SUB
22	2017.07.23	IM				x	x	x	x
23	2017.07.23				x			x	
24	2017.07.20	IM			x	x	x	x	
25	2017.07.20		LK	LH IIIA1 – IIIC		x		x	x
26	2017.07.20	IM	LK	LH IIIA – IIIC		x	x	x	x
27	2017.07.25	IM			x	x	x	x	
28	2017.07.25	IM				x		x	
29	2017.07.20					x	x	x	
30	2017.07.24								
31	2017.07.23	IM						x	
32	Skipped								
33	2017.07.23								
34	2017.07.23					x	x	x	
34a	Dro. Chamb.					x			
35	Model 33								
36	2017.07.24					x			
37	Model 33								
38	Model 33								
39	2017.07.25	IM				x		x	
40	2017.07.24	IM			x	x			
41	Model 33								
41a	Unknown							x	
42	2017.07.24	IM				x	x	x	
43	2017.07.24					x	x	x	
44	Model 40	IM				x		x	
45	Buried?								
46	Buried?								
47	Buried?								
48	Buried?								
49	Buried?								
50	Buried?								
51	Buried?								
52	Buried?								
53	2017.07.21								
54	2017.07.21								
55	2017.07.21								
56	2017.07.25								
57	2017.07.19								
58	Missing								

Table 4.4. (continued).

Tomb	Date Surveyed	Moutafi (2015)	Kolonas (2009b)	Range	LH IIB	LH IIIA	LH IIIB	LH IIIC	SUB
59	2017.07.20								
60	2017.07.20								
61.U1	2017.07.21								
62	2017.07.21		LK	LH IIIA – SUB					
63	2017.07.21								
64	2017.07.21								
65	2017.07.21								
66	2017.07.23								
67	2017.07.23								
68	Model 67		LK						
69	2017.07.21								
70	2017.07.21								
71	2017.07.22								
72	2017.07.22								
73	2017.07.21								
74	2017.07.22								
75	2017.07.24		LK	LH IIIA – SUB					
76	2017.07.21								
77	2017.07.23		LK	LH IIIA1 – SUB					
78	2017.07.23								
U2	2017.07.22								
U3	2017.07.24								

Table 4.4. (continued).

the village" (Papadopoulos 1979: 27). It is unclear how these relate to the extensive Voudeni cemetery as it is known from the work of Kolonas (1998), whose extensive, multi-volume PhD thesis remains unpublished.

At least eight different chamber shapes were identified among those excavated at Voudeni (cf. Kolonas 2009b: 13; Figure 4.3.3, this volume), similar to or exceeding the variation in chamber tomb forms seen at several sites throughout Achaea and southern Greece. For clarity, I list the closest matching form from the eight shapes with the narrative description for the surveyed tombs. For simplicity, I further categorised the tombs according to two major styles: 1) hive, for the *tholoi*-like chambers with round or horseshoe bases and vaulted or incline-vaulted roofs, and 2) house, for the house-like chambers with rectangular or square bases and four-sided (also referred to as pyramidal, pitched, or hipped), arched (saddle), and arched with grooved sidewall (semi globular vaulted) roofs (Kolonas 2009b: 13). Tombs with square bases and vaulted or incline-vaulted roofs seem more related to hive types in cross-section (Figure 4.3.3), but arbitrary type-sets draw more reliable data from durable base shapes. Far more than their bases, vault ceilings were susceptible to collapse or deformation, limiting inference from their current shapes. A transitional type category, 'hybrid', subsumes those tombs with abundant irregularities that failed to conform to any of the above designations.

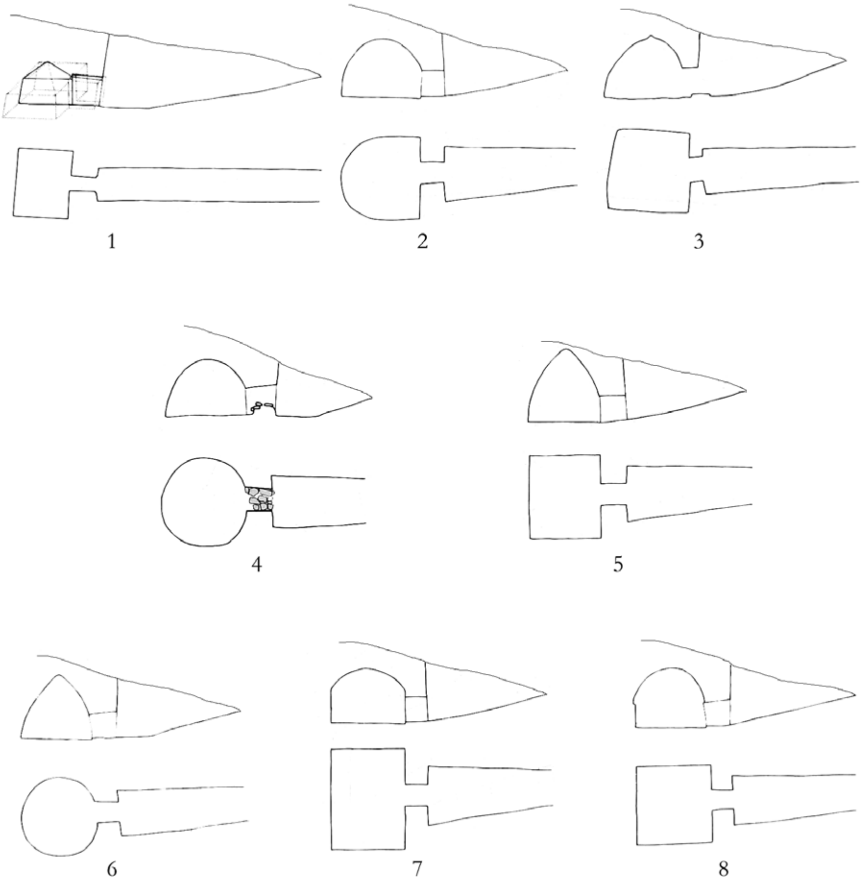


Figure 4.3.3. Voudeni tomb shapes identified by site excavators on a park information sign (Kolonas et al. 2007; see also Kolonas 2009b: 13): (1) Square with four-sided roof, (2) Horseshoe-shaped with vaulted roof, (3) Square with vaulted roof, (4) Circular with vaulted roof, (5) Square with inclining vaulted roof, (6) Circular with inclining vaulted roof, (7) Square with arched roof, and (8) Square with arched roof and a groove around the sidewalls. A simplified type system would collapse these into house (1, 7, and 8), hive (2, 4, and 6), and hybrid (3 and 5) types.

With crowded tomb clusters (especially to the northeast) yet an expansive area on the whole, the layout of Voudeni is informative regarding spatial preferences for Mycenaean tomb builders (see Figure 4.3.1). The slope of the Amygdalia locale creates the impression of terraced rows of tombs, similar to that found at the Rambandania location of the Kallithea chamber tombs (Papadopoulos 1991: 35). Several tombs at Voudeni also share Kallithea's short and steep *dromoi* leading to low-cut entrances. The largest tombs excavated at Voudeni, VT4 and VT75, have substantially longer *dromoi* than most others in the cemetery – with those that tunnel under the walkway like VT29 showing a less extreme but still large variant – and indeed rival the exceptionally large example known from the LH IIIA2 tomb 2 at Prosilio in Boeotia (Yannis Galanakis, personal communication 2019).

Despite the cemetery's long use and apparent freedom with tomb form, practices in disposal of the dead were remarkably consistent and have been preserved in several tombs, such as the human remains on public display *in situ* in VT5. Similar to Portes, primary burials were inhumed directly on the floor of the chamber, on an elevated surface or thin layer of unfired clay, or rarely in deep rectangular pits (Kolonas 2009b: 13; Kolonas et al. 2002: 2; Kolonas et al. 2007). Earlier burials and their offerings – chiefly of household items, especially closed ceramic vessels for liquid storage – were cleared into secondary pits dug beneath the floors of chambers or *dromoi* (Kolonas et al. 2007). VT4 contained the earliest known Achaean example of a burial placed on a bed in the LH IIIA1 period (Moschos 2009: 366). Deep rectangular pits in VT13 and VT67, alongside slabs in the latter, show further variation in mortuary preferences within individual tombs at the site. Apart from transportation of the slabs – and to a much smaller degree, digging the deep pits – these burial practices do not significantly affect the labour invested in tombs. Reuse of tombs, if involving the reopening of filled *dromoi*, would increase costs through time but not on a level commensurate with building a new tomb (see Chapter 3). These are therefore treated as secondary concerns to the primary focus on initial tomb construction as partly told through digital modelling.

Several practical challenges to digital modelling of tombs at Voudeni appeared during survey. The main difficulty for fieldwork at Voudeni was the reverse of Portes. Too few trees sharply reduced secure anchor points to tie off our rappel line for entering steep *dromoi*. A steel T-beam fence allowed tie-offs for tombs upslope of the main pathway, but steep lower tombs required a crawling motion to prevent sliding while entering. Only one tomb was omitted due to its lack of a secure tie off, VT39 above the canopy protecting the massive VT4. Steel rebar and wire mesh stabilised the topsoil around most open *dromoi*, creating another challenge to entry. Although safely navigated by two athletic surveyors, steep entrances would not allow unassisted, upright entry, especially when carrying a heavy or delicate burden. Unbalanced, entrants would require a rope or some other means of stabilising themselves to avoid injury.

Far more tombs could not be surveyed due to a breakdown in the modelling itself. Strong differences in lighting, low contrast from homogeneous rock (or in some cases modern cement repairs), and long, narrow *dromoi* combined to prevent the completion of several photomodels. Unlike the friable rock of Portes, the chalk or marlstone *(kimilia*, see Chapter 2) into which the tombs were cut at Voudeni provided few opportunities to place the photopoint stones with height variation in mind. Only in tombs where a second vault opened into another, usually at a different elevation, were we able to elevate photopoint stones away from the floor. For the *dromoi*, points along the excavated base below and ground surface above gave us sufficient depth for the photomodels to function. Protective canopies for the largest tombs, VT4 and VT75, were helpful for fixed points near the entrances but hindered photos from above the deepest portions of their *dromoi*. The exceptionally long passageways of VT4 and VT75 also frustrated photo alignment due to their narrow uniformity and lack of recognisable features. Dozens of failed alignments preceded the final models. Despite these challenges, Voudeni's large number of well-excavated tombs provide an ample comparative index for tomb sizes and relative investment.

One further consideration must accompany the completed models of tombs at Voudeni. Part of the difficulty in measuring tomb volume using photogrammetric models is the tendency to record anomalies of post-depositional processes, whether partial ceiling collapses or a convenience of excavation to enter nearby tombs from an artificial entrance in a sidewall (which likely had also collapsed in antiquity). The major point here is that the current dimensions of a tomb seldom coincide with the dimensions as originally constructed. Rather, the dimensions recorded in photogrammetric models are a baseline to reconstruct the original measurements. Even the comparatively well-preserved VT4 experienced a major ceiling collapse in the interim between its closing and excavation (Kolonas 2009b: 16). Enough of the tomb has survived to show its most probable architectural form, that of a four-sided pitched or pyramidal roof. Perhaps more accurate from architectural terminology, the ceilings of the house-like tombs roughly match that of a hip roof with four sides pitched inward. Gabled is the more recognisable term but would require two vertical and two pitched sections to fit the description as it is used in modern architectural survey (Stacey Griffin, personal communication 2015).

As a final aside to introducing Voudeni, its privileged location connecting coastal shipping with the mountainous interior gave it the economic advantage to support conspicuous investment in tomb architecture and portable objects, which in turn tied the site into a wider network. Achaea itself has often been defined by its broken topography, and Voudeni lies at one of its most important interfaces. Papadopoulos (1979: 25) explained the importance of this central Achaea region in no uncertain terms:

> *“The Patras region is the most accessible, richest and most heavily populated area of Achaea, thanks not only to the great fertility of its plain and surrounding hills, but even more to the convenience of its situation for sea communication with the adjacent islands, with the whole western coast of Greece, and with Italy and the Adriatic, as well as with eastern Greece and the Aegean by the Canal of Corinth.”*

Three miles east of modern Patras, Mount Panachaicon offers extensive forests of oak and fir and falls toward the Gulf in a series of “green knolls and fertile glens” watered by the Meilichos and Glafkos rivers (Papadopoulos 1979: 25).

Papadopoulos (1979: 21-22) tied communication throughout Achaea along three major routes that either follow the plateau between Patras and Kalavryta or the major river valleys of Selinous and Vouraikos. The division of Achaea based on apparent ease of communication began early. Distinct eastern and western subdivisions can be traced back from Classical and Hellenistic unifications evident in the second-century AD writings of Pausanias, through the mythological migrations of Agamemnon’s descendants from the Argolid and Laconia and apparent pottery exchanges stretching into the Late Neolithic (Petropoulos 2016: 219-223). For instance, supporting evidence for the north-eastern Peloponnese-leaning eastern Achaeans comes in part from a Geometric period sanctuary on Mount Panachaicon (Petropoulos 2002), the dominant geographic feature splitting Achaea and disrupting communication between east and west (Moschos 2002: 17; Papadopoulos 1979: 182; Petropoulos 2016: 219-220). The northern extension of the Mount Panachaicon massif (known as Ziria) blocks western Achaea from the eastern coastal route toward Corinth and the Argolid, which manifests strongly in pottery influences (especially in the LH IIIB/C periods) that align western Achaea with Elis-Olympia, Messenia, parts of Arcadia, and the proximal Ionian islands (Petropoulos 2016: 220, citing Papadopoulos’s (1979: 182) Western Mycenaean Koine).

Whatever the case for division, Voudeni’s position played to its advantage in economic potential. Several key finds have reinforced the impression of wealth suggested by tombs of exaggerated proportions at Voudeni. Prestigious items from the tombs include a tinned kylix from VT4 that is similar to one found at coastal Aigion 35 km east of Patras (Papazoglou-Manioudaki 2015: 321). A silver ring was also reported at Voudeni early in the excavations

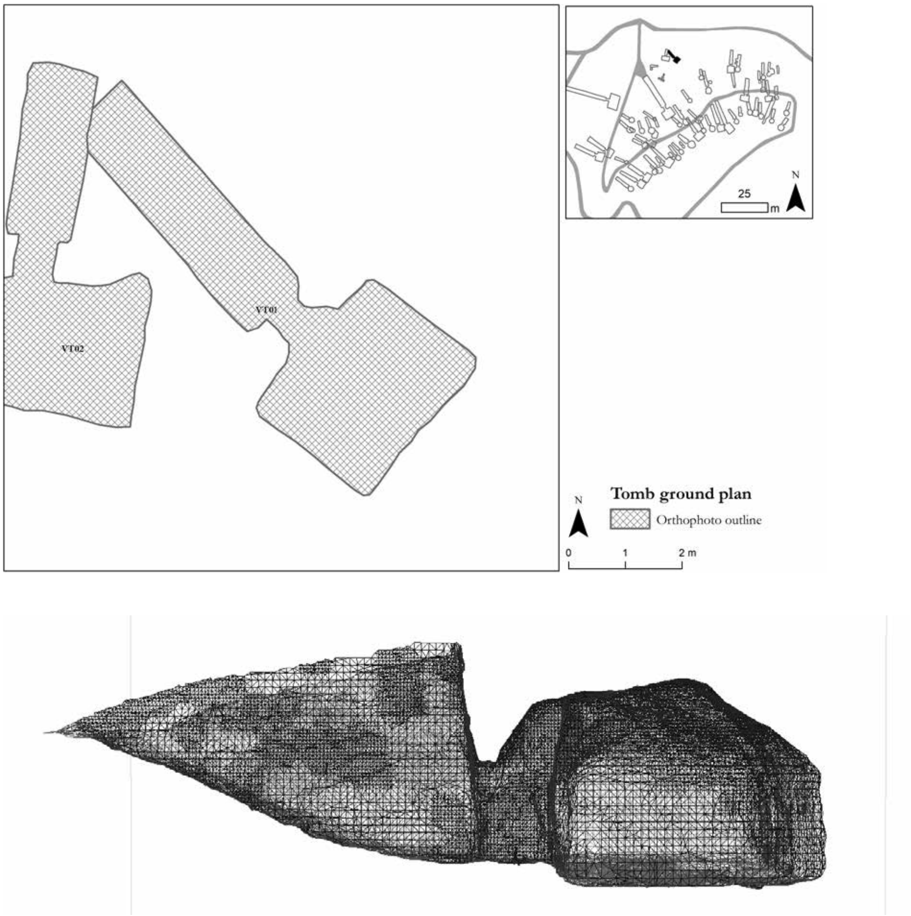


Figure 4.3.4. VT1 ground plan and wireframe model (north-eastern cross-section).

and compared to one (PM 3329) found in the warrior tomb at Krini, whereas most plain rings in Achaea seem to be made of bronze (Papazoglou-Manioudaki 1994: 185). As with Portes, finds at Voudeni strongly indicate a well-connected population with no shortage of wealth and regional influence. Unlike Portes, the Voudeni chamber tombs vary considerably in size and shape, showing more freedom from the expected norm. The following descriptions treat the tombs individually and attempt to compare relative excavation costs with their nearest peers. The subsequent discussion chapter examines how these costs may have been perceived by the population that invested in the tombs.

Voudeni Tomb 1

Relative to the other excavated tombs, VT1 is located in the central north with its nearest neighbour VT2. Their *dromoi* nearly converge at their entrances, which have been stabilised with concrete and rebar (Figures 4.3.4, A3.16). The slope here is milder, forcing both *dromoi* to drop sharply rather than tunnel gradually into the hillside. Thus the *dromos* for VT1 falls significantly short of the site median, lacking the length and depth that rapidly elevates volume. Its vault, however, matches closely with the median, dragging its total volume and labour costs upward to 87% of the median totals for the site (MedT$_V$ of 23.65 m^3) or 74% (TRex 0.74) of the idealised AA01.

Unremarkable in scale, the builders of VT1 pursued a chamber shape reminiscent of the largest five examples at Voudeni, all of which follow the "house-like" form with rectangular or square bases. For this tomb shape chamber ceilings, where intact, either fold inward to a point (pyramidal, four-sided, or hip roof) or roll to create a barrel effect (vaulted or arched roof). Although the second most common chamber form at Voudeni, none of the surveyed tombs from Portes opted for the house-like vault form, an important note for the signalling discussion in Chapter 5. The original form of the VT1 chamber roof appears to be arched with a sidewall groove but has been obscured by irregular faults assumed to stem from partial collapses.

Measurements of VT1 are illustrative of the accuracy issues raised by photogrammetric volume calculations. Diminishing returns in labour modelling discourage higher resolution settings and closer cropping of models to fit the tomb outline, especially where part of it has collapsed. At slightly more than 20 m^3, final measurements of the void cut by VT1 fluctuated from 20.55-20.63 m^3 depending on the noisy mesh detected by Agisoft Photoscan and time spent cropping the model as closely as possible. Shortcut measurement of the tomb's dimensions, sourced directly from the point cloud, reveal a close 21 m^3. Keeping measurements within 2% variability, the dimensions of the tomb follow a consistent resolution appropriate for labour modelling irrespective of processing time in Photoscan. The differences in terms of labour, even at its most burdensome, amount to only a few hours for one builder, easily absorbed and forgotten by larger work parties.

As slight variations in dimensions show, modelling labour in tomb construction conforms better when pairing denser soils with higher excavation rates while also maintaining a consistent range (9-12 ph per m^3). Thus the soils at Voudeni and Portes, denser than that of Menidi, would trend toward the higher excavation rate. Ranges absorb internal variability and allow for comparisons at a glance, while the narrative thread focuses on the full weight of the more demanding labour possibilities. Isolated for comparison, excavation costs appear deceptively low. To combat this, the higher rate of 12 ph/m^3 has been used in all cases as a *reasonable expected maximum*, otherwise called here a *setback cap* or *hardship buffer* to denote its accounting for unforeseen circumstances delaying construction. Declaring a true maximum chases the impossible as construction can be postponed indefinitely (DeLaine 1997: 105), so reasonable or expected maximums demarcate what would be unexpected rather than what is technically possible. This discourages hasty dismissal of smaller tombs as simple to build, as planning and restrictive spaces add to the difficulty and time-to-completion of even the smallest tomb.

Again deferring to the range approach of modelling higher-cost excavation phases, the labour range for excavating VT1 falls in the upper half of 186-248 ph, with a reasonable hardship or setback cap at 248 ph. For teams of 10 labourers operating in 5-hour daily increments, five days are sufficient for excavating the tomb. Even under duress, a week would suffice. Halving the available labour barely pushes the excavation phase over a week's worth of work, and doubling the available daily hours cuts completion time into a three-day task. In a short summary of the probable construction sequence for VT1, it was expedient but not simple. Caution was necessary where the threat of collapse quite literally hovered over the heads of workers carving out the vault. As shown by the many partial collapses around the site, slumping and ground loss could and did strike. Excavation of VT1 is not a

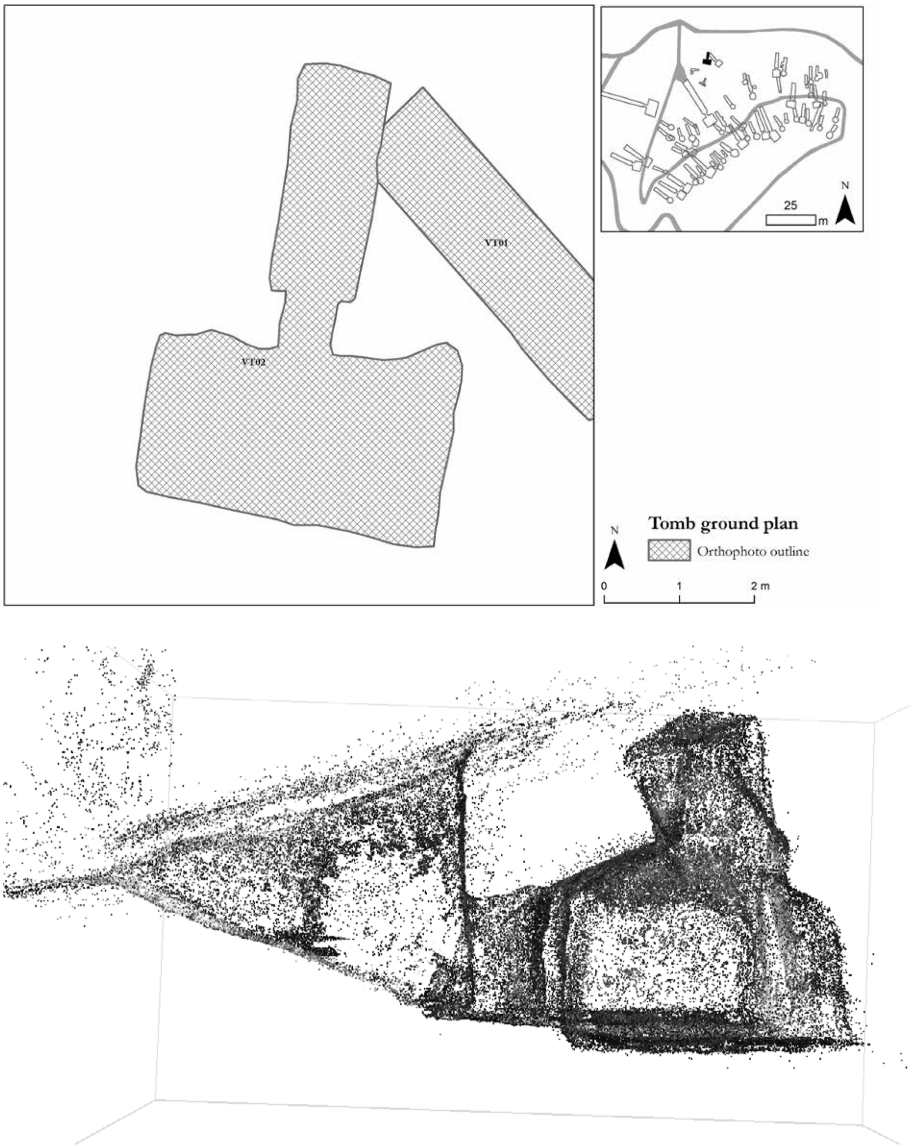


Figure 4.3.5. VT2 ground plan and sparse cloud model (eastern cross-section), showing the extent of its ceiling collapse.

taxing investment for the wealth and influence exercised by inhabitants of the surrounding settlements. Comparing VT1 with a modern grave, however, which can be manually dug by one person in a few hours of strenuous work, VT1 remains a significant investment.

Voudeni Tomb 2

Similar to VT1, VT2 conforms to the short *dromos* and rectangular vault plan with pyramidal ceiling (Figures 4.3.5, A3.17). Unlike VT1, VT2 has a visible ceiling collapse that lowers its usability in labour modelling through an additional step to estimate its original construction volume. The setback is slight, however, as the outline is still clear from the remaining walls and ceiling of the vault. The collapsed portion artificially inflated its size by as much as 1.5 m^3. The original dimensions of the tomb are estimated at 13.1 m^3 for the vault/*stomion* and 4.32 m^3 for the *dromos*, for a total of 17.42 m^3. VT2 is thus 3.2 m^3 smaller than its nearest neighbour VT1 but still well within the upper tier for the ubiquitous variant of undersized tombs at Voudeni.

As expected, the difference in labour between VT1 and VT2 relies on excavation phases that can only reasonably deviate by 29-39 ph. Even such a slight change in the labour requirements, however, can translate to more than a day's work for several. So either fewer labourers would have been needed in the team that dug VT2, or they were able to complete the tomb with several hours less effort expended. Even at the upper limit of reasonable load, the VT2 team shouldered as much as 39 ph less than VT1, meaning it could shed up to a day's work for eight labourers and complete the task within the same amount of time. For those not wishing to compare the labour rates of VT1 and VT2 directly, this simplifies to VT2 excavation requirements of 157-210 ph, with the upper end being the expected maximum. Comparing the dimensions by component, however, the similar chambers of VT1 and VT2 essentially required the same input, but the shorter *dromos* of VT2 took less effort to complete.

Voudeni Tomb 3

VT3 also lies in the north-central part of the cemetery near the entrance to the massive VT4 (Figures 4.3.6, A3.18). Singular at Voudeni, VT3 uses a vault opening perpendicular to the line of the *dromos*. Its *dromos* is comparable in size to that of VT2, measuring 4.02 m^3. However, the shallow circular chamber with low vaulted roof, at 0.859 m^3, is the smallest on site when compared with other completed tombs recorded here. The difference is such that I recall having difficulty moving for camera angles within the vault of VT3 while crouched partially within and outside the *stomion*, whereas the chambers of larger tombs like VT2 felt comparably spacious. The combined volume of VT3 is 4.88 m^3, far below the median and among the lowest recorded on site (TRex 0.18). VT3 is representative of the rare smallest tier of undersized chamber tombs excavated at Voudeni and surveyed herein.

Excavating shallow tombs with limited space requires, or rather in the case of VT3, permits, at most a pair of labourers with carriers alternating outside the tomb. Thus two pairs would divide the required labour of 44-59 ph, as either a long day's task or, at most, half a week's worth of digging. With limited personnel, as two teams of two would certainly qualify, both cannot always operate concurrently at full efficiency. Carriers and diggers can rotate tasks in teams of four or more to limit fatigue and maintain the efficiency that one or a pair can only maintain at the surface. Further below the surface, removing material is optimized by rotation within larger labour groups. Any attempt at maintaining surface efficiency at depth sharply reduces individual stamina, so the shallow form of VT3 plays to its advantage in maintaining an acceptable workload for small teams.

The remarkably small size of VT3 raises the question whether the tomb was meant for a family of lesser importance, or a family of great importance reserved it for one of diminished physical stature, such as a child or juvenile. At first glance, it is tempting to doubt the latter explanation. Early investigations seldom connected Mycenaean subadult burials to chamber tombs, and when they did occur, the remains were poorly preserved or mixed indiscriminately with adults, as Blegen (1937) recorded at Prosymna and Smith (1998: 29) at the Mycenaean cemetery on the Athenian Agora. One spectacular exception is the LH IIIC Perati cemetery in Attica, where infant or child burials occurred in 67 chamber tombs, 23 of which appear

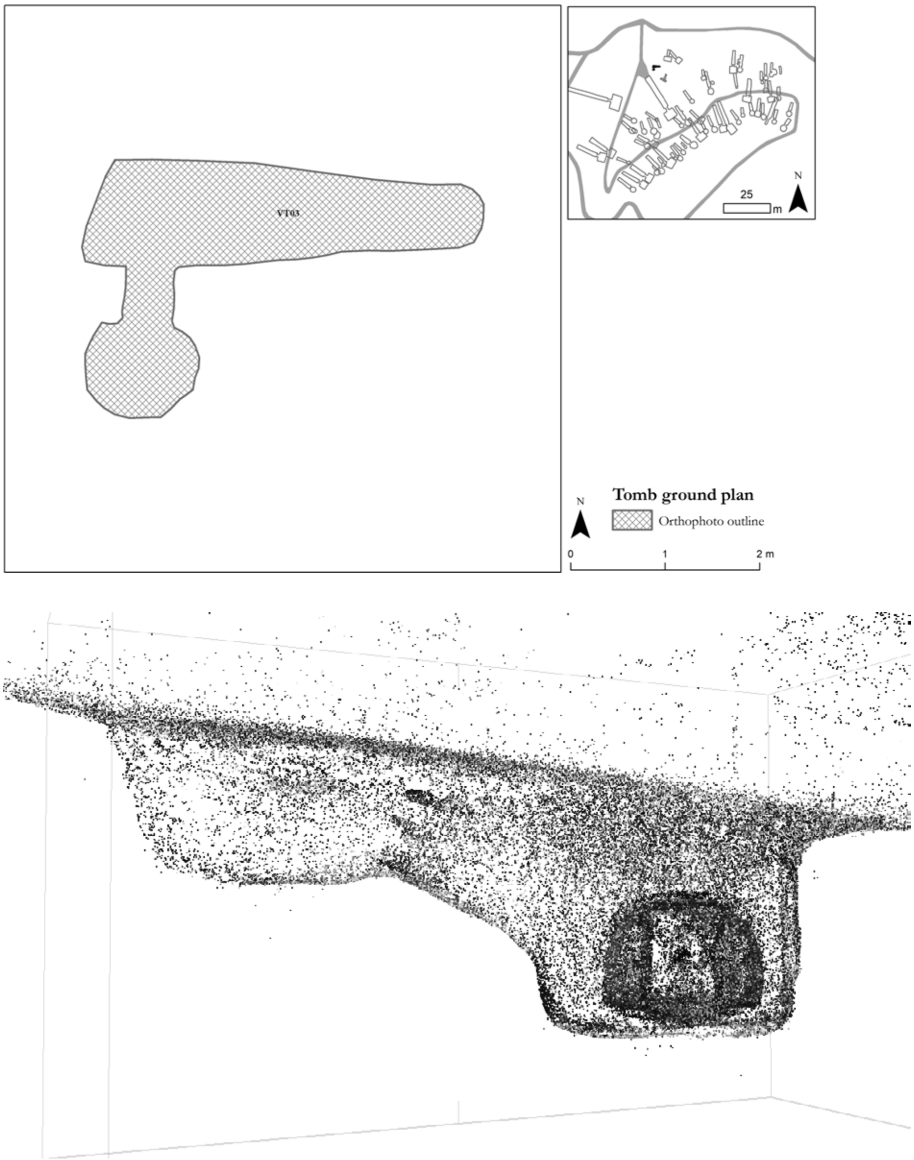


Figure 4.3.6. VT3 ground plan and sparse cloud model (southern cross-section).

to have been reserved exclusively for that purpose (Gallou-Minopetrou 2015: 58; Iakovides 1969, 1970a, 1970b; Murray 2018: 48-49). Side chambers connected to the *dromos* and vault of Tomb 5 at Ayia Sotira (Nemea) held beads, a psi-type figurine, and an LH IIIB feeding bottle but lacked skeletal traces, prompting Smith and Dabney (2014: 150-151) to label both as child burials. Closer to Voudeni, the Achaea Clauss cemetery yielded a child burial with a duck *askoi* from chamber tomb Δ (Paschalidis and McGeorge 2009: 96, also mentioned by Gallou-Minopetrou 2015: 58). Two examples of a “child’s tomb” at Drakotrypa and Ayios Athanasios were also mentioned in the vicinity of Mycenaean settlements at Chalandritsa and Katarraktis in the hills southwest of Mount Panachaicon (Papadopoulos 1979: 30-31).

Preferred mortuary treatment for children and juveniles fluctuated significantly with societal changes. Subadult burials from the Geometric period (ca. 900-700 BC) were notably treated differently from their adult counterparts, denoting the latter's ascension to full status in society (Pappi and Triantaphyllou 2007: 677). In the case of many LH I-II chamber tombs, severe deficits for all osteological data have prevented conclusions on the paucity of child burials (Voutsaki 1995: 62, citing Dickinson 1977: 59). Caught between periods where the visibility of children diminished alongside a general reduction in richer burials, children in high-status contexts in the LH III period support the idea that prosperity benefited all ages (Gallou-Minopetrou 2015: 58; but see also Voutsaki 2010: 81 on rich child burials in Mycenae's earlier Grave Circles). Again, some of the differences can be blamed on the vagaries of preservation. Part of the difficulty in identifying primary funerary treatment for subadults stems from the mixing of human remains in secondary treatment (Gallou-Minopetrou 2015: 57). Juveniles at LM III Mochlos on Crete, for instance, "were never found alone" though infants occasionally were (Triantaphyllou 2011: 4). Juvenile or not, the multi-use intention behind chamber tombs generally works against pinning construction on the death of one individual, although someone must go first.

Whatever the case for its occupants, VT3's odd alignment, together with its overall smaller size, suggests a role somewhat different from the median chamber tomb at Voudeni. Its placement near the entrance to VT4, the second largest tomb on site, could prove more informative if VT4 is the older tomb. The cluster of five pit graves (VT33, 35, 37, 38, 41) less than 10 m to the southeast of VT3 could also play into a loose pattern of small graves in this area, inadvertently enhancing the massive scale of VT4. Otherwise VT3 simply occupied a lesser used portion of the cemetery, unrelated to other tombs that usually occurred in pairs or in a row higher up the slope.

Voudeni Tomb 4

Located in the central group downslope of the main path, VT4 is the second largest tomb on site and one of the largest excavated chamber tombs in Greece (Figures 4.3.7, A3.19). The iconic tomb is fully covered with a wood-frame protective awning, but as noted before, it experienced a partial ceiling collapse within its vault prior to excavation that obscures a *hypotholion* ("shallow hollow") at the chamber apex (Kolonas 2009b: 16). Other nearby tombs, like VT77, share this trait along with evidence of burning within the chamber (Kolonas 2009b: 16, 30), solidifying evidence for shared traditions in architecture and funerary practice. Enough of the VT4 chamber form was preserved to indicate a four-sided, pitched or pyramidal ceiling over a rectangular floor, with a damaged *stomion* ending in "an angular lintel, reminiscent of a relieving triangle" (Kolonas 2009b: 16). This angular effect to the damaged *stomion* was an unintended consequence of forced entry, likely from looting during the LH IIIC period or later as seen also with VT75 and Prosilio tomb 2 in Boeotia (Yannis Galanakis, personal communication 2020). Like many others at Voudeni, the *stomion* of VT4 was blocked by a carefully constructed wall of mostly river-stones, but conglomerate is notably present in this instance (Kolonas 2009b: 16). Also mentioned earlier, VT4 contained an LH IIIA1 inhumation placed on an elevated surface or bed within the vault, the earliest known example of this practice in Achaea (Moschos 2009: 366). This is within an earlier period of use for the tomb, whose contents suggest extended use (LH IIB/IIIA1 to LH IIIC Late period). Similarities to the elevated inhumation can be

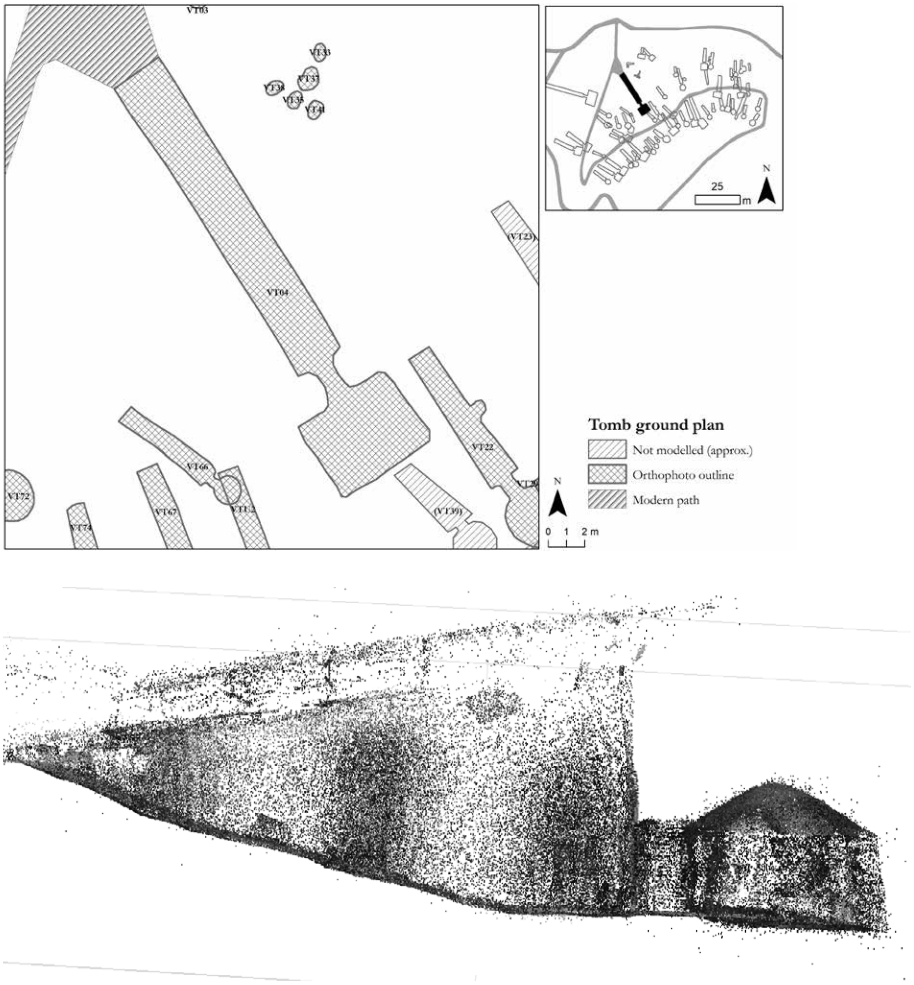


Figure 4.3.7. VT4 ground plan and sparse cloud model (north-eastern cross-section).

seen with benches found in certain *tholoi*. Citing Tsountas and Manatt (1897: 136), Kontorli-Papadopoulou (1995: 118) noted that the benches found in *tholos* tombs at Menidi, Aigisthos, Akourthi (T.3), Dimini, and Kokla could have served as temporary gathering points for bodies and offerings since the remains were mostly missing at the time of recording (see also Demakopoulou 1990: 117, 119; Demakopoulou and Auslebrook 2018: 121).

The contents of VT4 have been described by others (Kolonas 1998, 2009b; Moutafi 2015). Moutafi (2015) completed bioarchaeological analyses of several Voudeni chamber tombs. Here I include a brief overview to contextualise the labour analysis for the tomb. Burials within VT4 included six primary and one secondary "placed in a radial fashion, as well as bones belonging to earlier burials that had been pushed aside along the center of the chamber's southwestern wall" (Kolonas et al. 2007). Plan drawings suggest that the central and north-western (closest to the *stomion*) portions of the tomb may have been deliberately empty. Also noted by the excavators were signs of fire use near the south-western cluster, potentially the remains of purification ceremonies (Galanakis 2016a: 190 with references; Kontorli-Papadopoulou 1995: 118; see Chapter 2, this volume). Among the many valuable offerings recorded in the tomb, tin-plated *kylikes* and a papyrus-shaped gold bead necklace were exceptional finds (Kolonas 2009b: 17). Other golden objects (bands, sheet, coils, beads, and discs) and sealstones of semi-precious stones were also notable (Kolonas 2009b: 17; Kolonas et al. 2007).

The exorbitant dimensions of VT4 and its larger neighbour downslope (VT75) flaunted size disparity over the others. Previously recorded dimensions included the following (Kolonas 2009b: 15-16; Kolonas et al. 2007): *dromos* (19.7 m length, 1.10 – 2.86 m width, 6.45 m height); *stomion* (2.65 m height, 0.95-1.17 m width); and vault (4.62 m height with 5.93 m sides). At 241 m^3, VT4 is more than 10 times the median size for Voudeni and more than 8 times the size of AA01 (TRex 8.67). The VT4 *dromos*, at 165 m^3, comprises two-thirds of that impressive volume, flipping the proportions typical of other tombs with their short *dromoi* often representing (as in the case of VT1 and VT2) less than half of their total volumes.

As a test of the accuracy benefits measuring tomb volume using Photoscan, I performed simple solid geometry calculations for the VT4 *dromos* and vault and compared them with an early iteration of the VT4 Photoscan model. Half the volume of a rectangular prism, the closest simple geometric form approximating the shape of the VT4 *dromos*, yielded 179.4 m^3 when adopting the dimensions length (20 m), width (2.76 m), and maximum height (6.5 m). Thus the earlier Photoscan model (VT4 *dromos* volume of 177 m^3) revised the solid geometry volume by 2.4 m^3, or 1.3%. Likewise, the simplified volume of the chamber itself (rectangular prism plus pyramid for the ceiling) yields 75.7 m^3, within 2% of its earlier digitized estimate and matching exactly the latest Photoscan version. Thus more variation occurred between Photoscan models based on how closely tomb features were cropped. Redeeming the Photoscan model, a further 5.57 m^3 should be tacked onto the simplified total to account for the rectangular prism of the *stomion*. Revising the simplified total of 260.67 m^3 down to Photoscan's 254.2 m^3 or its latest iteration of 241 m^3, solid geometry calculation is indeed outpaced, but one loses much more over which iteration of the model matches reality for a tomb difficult to capture in digital form. Irregular shapes and narrowing near the ground surface prevent a predictable ratio between the Photoscan volume measurements and their solid geometry approximations, with variation between 21% deflation and 25% inflation in estimated volume.

Precision in measuring volume aside, the manual excavation requirements for a tomb the size of VT4 are enormous. Even at a blistering pace (4.2 ph/m^3), as improbable as that might be at depth, 1,068 ph would still be needed to shape the tomb. More likely, labour requirements would soar over 2,000 ph (2,167 ph at 9 ph/m^3 efficiency, the lowest acceptable for the dense stone here) and land in the vicinity of the expected maximum at 2,881 ph. As massive as VT4 is, it is still less than half the size of the Menidi *tholos* (618 m^3) at 39% its volume. Operating at greater efficiency in Menidi's less dense soils, labourers could excavate its outline likely in less than 2596 ph, making it remarkably similar to the expected costs of VT4. The added cost of stone-cladding at Menidi, however, pushes it far beyond the maximum expected costs for rock-cut tombs of comparable size.

Since person-hour requirements of this magnitude are not intelligible in practice, breaking the cost down into potential calendar days enables a clearer comparison of investment in completing VT4 versus other smaller tombs on site. Dismissing the highest efficiency (1,068 ph) in favour of more reasonable figures, 20 excavators working 5-hour days could cut the rough outline of VT4 in 22 days at 9 ph per m^3. More likely, those same 20 labourers could take 29 days at the expected maximum digging rate (12 ph per m^3). Not only does the suggested workforce double the size of the crew from VT1, completion of VT4 would still take 4-6 times the calendar days as its smaller neighbour to the north.

Voudeni Tomb 5

Few consecutively labelled tombs could show more variation than VT3, VT4, and VT5 (Figures A3.20-A3.21). Found sealed with a well-constructed wall of river stones blocking its *stomion* (Kolonas 2009b: 18; Kolonas et al. 2007), VT5 has a short and shallow *dromos* (7.06 m^3) with a chamber (14.1 m^3) showing the remains of a vaulted roof and circular floor. It lies higher up the slope than most tombs and sits near the edge of the park's tour path at the eastern extent of the excavated cemetery. Two layers of burials separated by a thin layer of marl were recorded, with the lower layer containing six primary burials and five secondary burials on display *in situ* (Kolonas 2009b: 19; Kolonas et al. 2007). The primary burials were arranged directly on the floor with all but one in an east-west row on the tomb's southern half opposite the *stomion*. The secondary burials were collected in an ovoid pit adjacent to the east wall just to the left of the *stomion* as one enters. The tomb is covered with a protective awning sealing the ceiling and partial wall collapse, with the chamber preserved only to a height of 1.25 m (Kolonas 2009b: 18).

Given its surviving contents, repeated reuse is unquestionable. Rich finds of ceramic vessels, bronze weapons, and clothing accessories suggested to the excavators nearly four centuries of use from the LH IIB/IIIA1 to LH IIIC period (1400-1000 BC) (Kolonas 2009b: 18-19; Kolonas et al. 2007). With an expected excavation cost range of 191-254 ph, VT5 would take a labour crew of 10 no more than 6 days to shape. Leaving its occupants on the floor also circumvented the cost of digging individual graves within the tomb, though a minuscule effort compared with the tomb itself.

Voudeni Tomb 6

VT6 is located in the eastern part of the cemetery alongside VT7. It is covered with a partial ceiling collapse artificially expanding its height in initial modelling (Figures 4.3.8, A3.22). The tomb shows a smaller-than-average vault (7.54 m^3) with a circular base, a vaulted roof, and a low short *stomion*. Its *dromos* (9.44 m^3) is considerably larger than those of VT1-3, not being abbreviated by the path and limited space along the slope. High initial error (more than 30 cm) prompted re-evaluation of the photopoints, revising down quick volume estimations of the tomb by as much as 2.6 m^3. Such errors occurred seemingly at random and may have stemmed from our use of angled metallic tent stakes or movable stone photopoints, which could migrate slightly on the grass. Generally, high initial errors in one or two points disrupt the point cloud enough that the model clearly fails early in the process. The culprit point for VT6 was removed, and the average error settled around 5 mm.

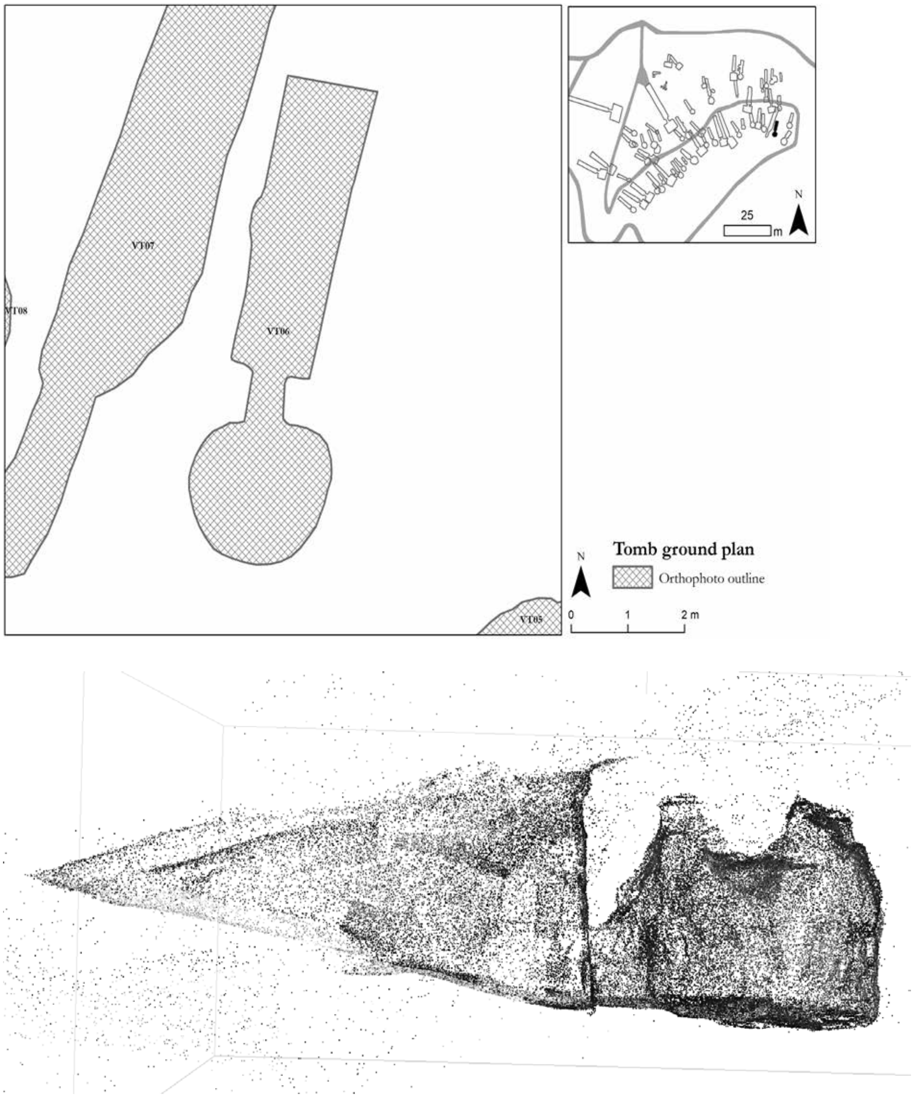


Figure 4.3.8. VT6 ground plan and sparse cloud model (eastern cross-section).

Similar to VT1 and VT2, VT6 would take 153-204 ph to excavate, requiring no more than 5 days for 10 labourers.

Voudeni Tomb 7

VT7 lies near VT6 in the east group (Figures A3.23-A3.24). The tomb has a low rectangular, sarcophagus-shaped vault that could indicate that work began on the tomb but was not completed (either in construction or excavation). The long *dromos* (48 m^3) more than quintuples the size of the VT6 *dromos*, but the unfinished VT7 vault drops its size to roughly 2.8 times that of its close neighbour VT6. Again, a large initial error prompted the deleting of problematic photopoints. Two were removed to drop the error from 2 m to 1.3 cm, subtracting 5.5 m^3 of erroneous volume from the *dromos*. Even so, the *dromos* seems excessive compared

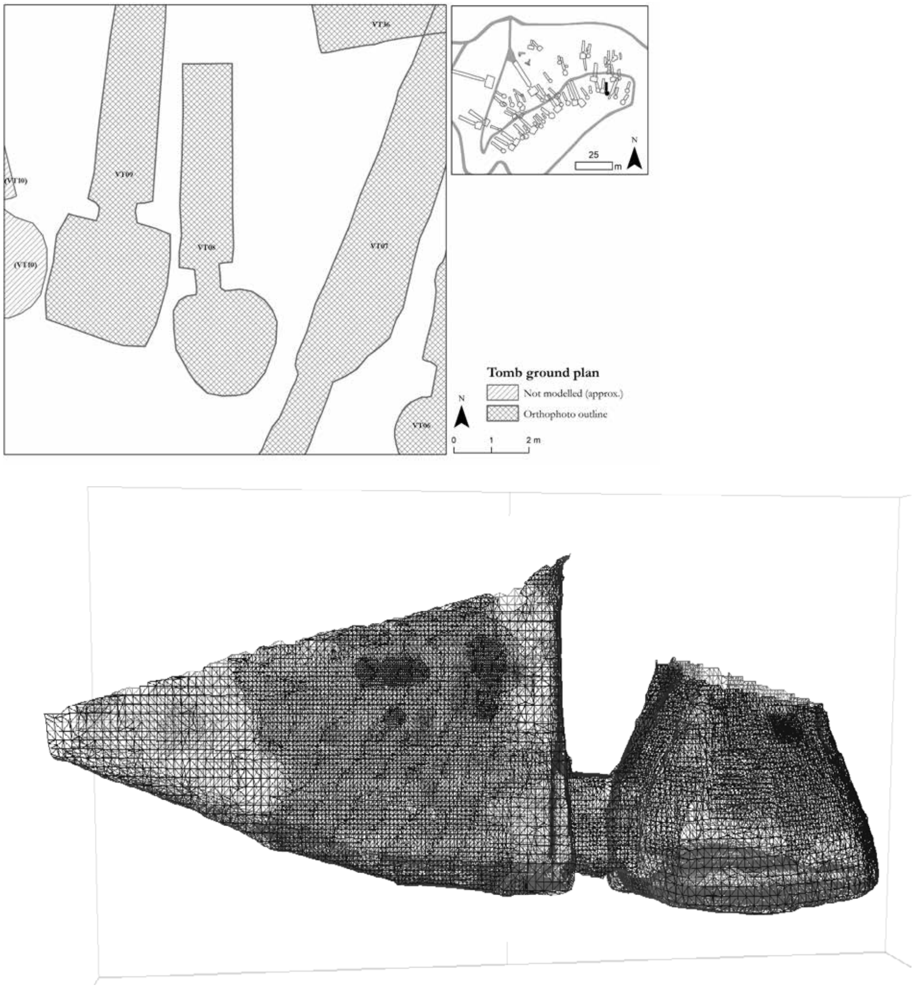


Figure 4.3.9. VT8 ground plan and wireframe model (eastern cross-section).

with others nearby. The unfinished vault is also surprisingly large when compared with the completed (yet tiny) vault of VT3. In terms of excavation cost, VT7 would require 424-565 ph or no more than 12 days for 10 labourers, more than doubling the cost of tombs like VT5 and VT6.

Voudeni Tomb 8

VT8 is a hive-type tomb with a collapsed ceiling in the east group, most closely associated with VT9 (Figures 4.3.9, A3.25). Like many of the others, the VT8 vault shows a circular base and vaulted roof, though much of the ceiling has collapsed and subsequently been covered. Peculiar to VT8 and a few others (e.g., VT25, VT31, VT56, VT60, VT62), however, is the location of the *dromos* and *stomion* relative to the vault. The effect is such in plan-view that the vault appears weighted to one side in a slight offset that could be deliberate or incidental. Two round pits appear along the walls separated by a rectangular depression visible in the floor of the 'weighted side'. These are almost certainly excavated features, potentially graves. The collapsed ceiling, if accounted for within volumetric calculations,

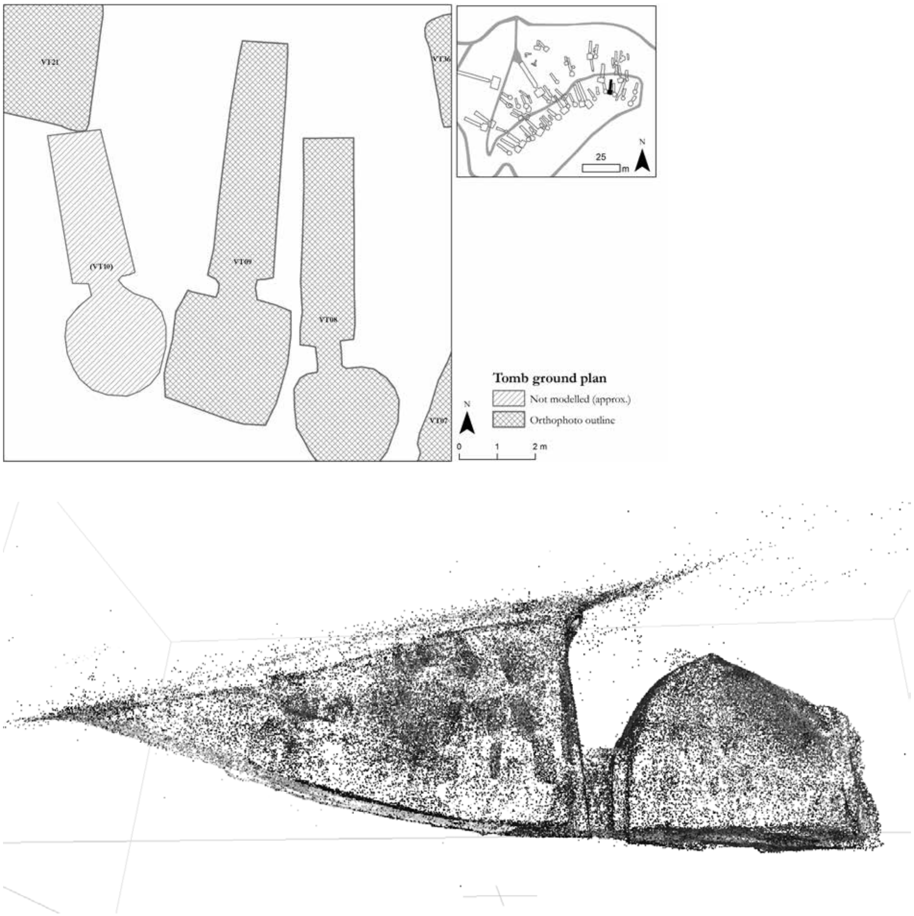


Figure 4.3.10. VT9 ground plan and sparse cloud model (eastern cross-section).

would artificially inflate the volume of VT8 by as much as 3 m^3. Estimates of the original dimensions of the tomb show a well-balanced 12.2 m^3 for the *dromos* and 9.7 m^3 for the vault. Excavation cost should fall in the 198-263 ph range, requiring no more than 6 days for 10 labourers like many other tombs on site.

Voudeni Tomb 9

VT9 is more intact than its nearest neighbour VT8 in the east group (Figures 4.3.10, A3.26). Much like VT5, VT9 was found sealed with a well-stacked dry stone wall of river stones. In addition to one primary burial and the remains of earlier burials swept to the side, the tomb contained a rich array of grave goods including piriform jars, two-handled amphorae, bronze weapons, beads, sealstones, and gold and silver jewellery (Kolonas 2009b: 19-20; Kolonas et al. 2007). The finds indicate use between the LH IIIA2 and LH IIIC periods, ca. 1375-1100 BC (Kolonas 2009b: 20). Modelling of the tomb encountered an unknown problem with the error margin of the photopoints. Prior to a correction of problematic photopoints, the total volume had been artificially deflated by as much as 18.5 m^3, two-thirds of the tomb's total volume! The correct total of 27.3 m^3 is split nearly evenly across the *dromos* (12.9 m^3) and vault (14.4 m^3), requiring 246-328 ph to excavate, or no more than 7 days for 10 labourers. Generally, the VT9 vault reflects a variant shape of the smaller tombs at Voudeni, showing a four-sided base and vaulted roof with a sidewall groove and a shallow hollow or *hypotholion* at the chamber apex (Kolonas 2009b: 20). Its contents suggest important users, and one wonders whether the four-sided shape brought the tomb more in line with the construction ideals of Voudeni's elite largest tombs. With a volume similar to the AA01 median (TRex 0.98), VT9 lies closest to the median ideal out of all the tombs surveyed herein.

Voudeni Tomb 10

VT10 proved problematic with its ceiling collapsed vault refusing to appear with the *dromos* in initial modelling, despite the relatively even spread of 668 photos and 9 photopoint markers. The tomb lies within the large and dense eastern grouping of excavated tombs. The vault model failed despite repeated attempts to force an alignment, likely due to an insurmountable error caused by the light difference between the dark vault and the *dromos* in full sunlight (Figures A3.27-A3.28). This suspected lighting failure occurred more frequently on the largely treeless slopes of the Voudeni cemetery, with shady Portes offering a more limited contrast between vault and *dromos* that seemed more successful at the time. Since the *dromos* model of VT10 did succeed with an average error around 6 mm, its volume (9.31 m^3) was used to calculate a comparative benchmark with the excavation costs of other *dromoi*. That range falls in 84-112 ph, or 5 days for 5 labourers. Doubling the team and adding a day to delay construction of the vault, it is easy to imagine excavation of the full VT10 tomb coinciding closely with similar tombs of the undersized variant (less than 75% of the AA01 median or TRex <0.75, see Chapter 3) found around the site. Like most in that category, the VT10 vault shows the common shape of a circular base and vaulted roof.

Voudeni Tomb 11

Also bearing a collapsed ceiling, VT11 was modelled with far fewer photos (263) than its problematic counterpart in the east cluster, VT10. The VT11 model succeeded partly due to the uniform lighting from its damaged vault, the total ceiling collapse of which left it shallow and open (Figures A3.29-A3.30). With a circular base and suspected vaulted roof if it had one (see below), the remaining vault is only 3.8 m^3. Adding the short and shallow *dromos* (2.05 m^3), VT11 is only 5.85 m^3 in its current form. Excavation cost estimates for a tomb in this state of preservation are admittedly of little value on their own and can skew the site range and centre indexes when compared with the others. Labour models for VT11 and similar open-air tombs should be taken with these caveats in mind. The open-air variant of short and shallow tombs may be more closely related to elaborate pit graves that mimic the tripartite chamber tomb form than a collapsed version of a full chamber tomb. Even accounting for ground loss, the current depth of VT11 (1.32 m) and similar tombs would not allow a fully developed chamber tomb without substantial modification (such as a built ceiling and overlying tumulus). At 53-71 ph, excavation requirements for the remaining portion of VT11 are predictably low, requiring no more than 4 days for 5 labourers. Whatever the case for its original form, VT11 was among the least costly tombs at Voudeni, similar in investment to VT3.

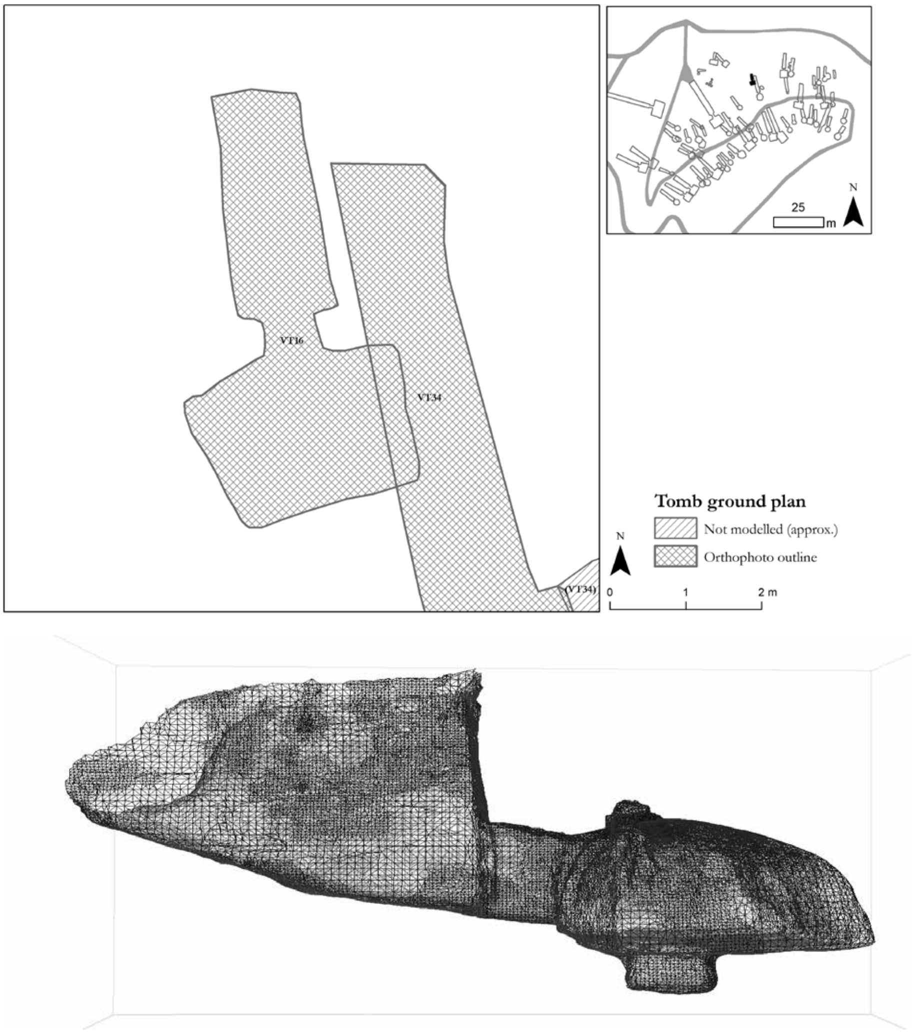


Figure 4.3.11. VT16 ground plan and wireframe model (eastern cross-section).

Voudeni Tomb 12

See Appendix 2.

Voudeni Tomb 13

VT13 lies immediately downslope of VT5 at the eastern extent of the excavated cemetery (Figures A3.31-A3.32). The tomb shows a circular base with likely a former vaulted roof, though the ceiling has since collapsed and been covered with a wood-frame protective awning. Two deep rectangular pits within the vault run parallel with the line of the *dromos* and *stomion*. If that line were extended it would run between the two pits, which likely represent excavated features for primary and/or secondary burials with associated portable objects and small finds. The *stomion* is still partially closed by a stone wall, making entry onto the narrow remaining ledge of the tomb floor a delicate balancing act between the deep pits on either side of the vault. The excavated pits account for an additional cubic metre of tomb volume, without which the vault volume lies at 12.8 m^3 in its current form. Measuring up to the awning would add another 5.5 m^3.

Not knowing precisely how much volume its missing upper reaches would add to the vault, labour modelling for the VT13 vault is weaker than other more complete examples. The current volume totals for VT13 account for the excavated pits and amount to 13.8 m^3 for the vault, 4.49 m^3 for the *dromos*, totalling 18.29 m^3. This is representative of the undersized variant (TRex 0.66 or roughly two-thirds the size of AA01) and is comparable to VT6 and VT19. Excavation cost estimates are 165-220 ph, or roughly 5 days for a team of 10.

Voudeni Tomb 14

VT14 lies in the north-eastern group downslope of the main path separating it from the eastern group of VT5 and its neighbours (Figures A3.33-A3.34). VT14 has a four-sided base vault with a possible pyramidal roof, though partial wall and ceiling collapses have given it an undulating shape. An extraordinarily tall *stomion*, also likely a product of a partial collapse, allows standing or stooped entry. Unusually small for the four-sided house type (TRex 0.55), volume measurements for VT14 show 6.65 m^3 for the *dromos* and 8.66 m^3 for the vault. The total 15.31 m^3 thus excludes a day of work needed for its excavation when comparing it with the common 5 days for 10 workers. Excavation of VT14 would take 138-184 ph, or 4 days for 10 labourers.

Voudeni Tomb 15

Also in the north-eastern group, VT15 is limited to its *dromos* as a labour comparative (Figures A3.35-A3.36). The vault is either unfinished or unexcavated and fully collapsed, leaving only a slight void to measure (0.719 m^3). The *dromos*, however, is fairly large at 12.3 m^3 (RexD 0.91), pushing what remains of the tomb total volume higher on the scale of the undersized variant at just over 13 m^3 (TRex 0.47). For the sake of comparison, this would require 118-157 ph or 4 days for 10 builders, similar to VT14. Assuming VT15 had a vault of comparable size, this would take 2-3 days more.

Voudeni Tomb 16

VT16 is among the smaller complete tombs on site, lying in the north-eastern group closely paired with VT34 (Figures 4.3.11, A3.37). The VT16 vault has a four-sided base with an arched or barrel-shaped roof, minimal ceiling collapse and a circular excavated pit offset to one side of the vault floor. The short and shallow *dromos* (5.59 m^3) limits the scale of the tomb but balances with the volume of the vault (5.55 m^3) for a total tomb size of 11.14 m^3. Excavation costs for VT16 are 101-134 ph, requiring 3 days for a team of 10. More likely, excavation could comfortably fit in a two-day window with a working-day extension beyond the 5-hour dedicated schedule used for most tombs in this study.

Voudeni Tombs 17-20

See Appendix 2.

Voudeni Tomb 21

At 74.9 m^3 (TRex 2.70), VT21 far exceeds the scale set by the undersized and standard variants of tombs that largely comprise those of the north-eastern group (Figures 4.3.12, A3.38). Like VT19, the outer edge of the *stomion* and part of the *dromos* lie under the paved

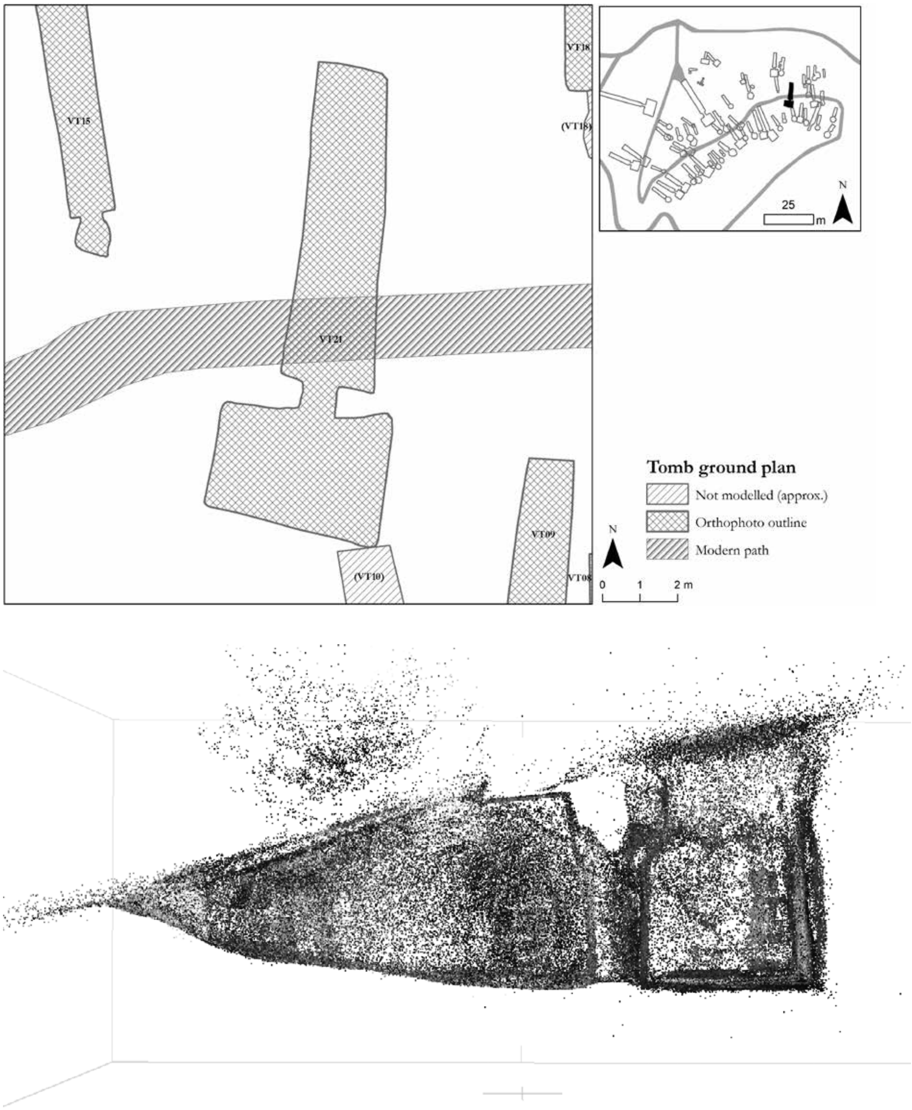


Figure 4.3.12. VT21 ground plan and sparse cloud model (eastern cross-section), showing the extent of its ceiling collapse.

walkway upslope. Large evergreens flank and shade the *dromos* from either side, negating any possibility of quick measurements from Photoscan without first cropping the model. A tall and narrow *stomion* opens into a vault whose measurements also proved problematic. The four-sided base is clear, but the roof shape is unknown due to a complete ceiling collapse now covered by a wood-frame protective awning high above at the surface of the slope. That disturbance alone would add 16 m^3 to the volume if not carefully removed at the estimated original level of the ceiling. A close approximation of the original dimensions reflects 35 m^3 for the *dromos* and 39.9 m^3 for the vault, roughly six times larger than the VT19 vault. The measurements, if correct, show a significant size disparity with the 10-30 m^3 undersized and standard tombs that populate much of the eastern half of the cemetery. Excavation costs are

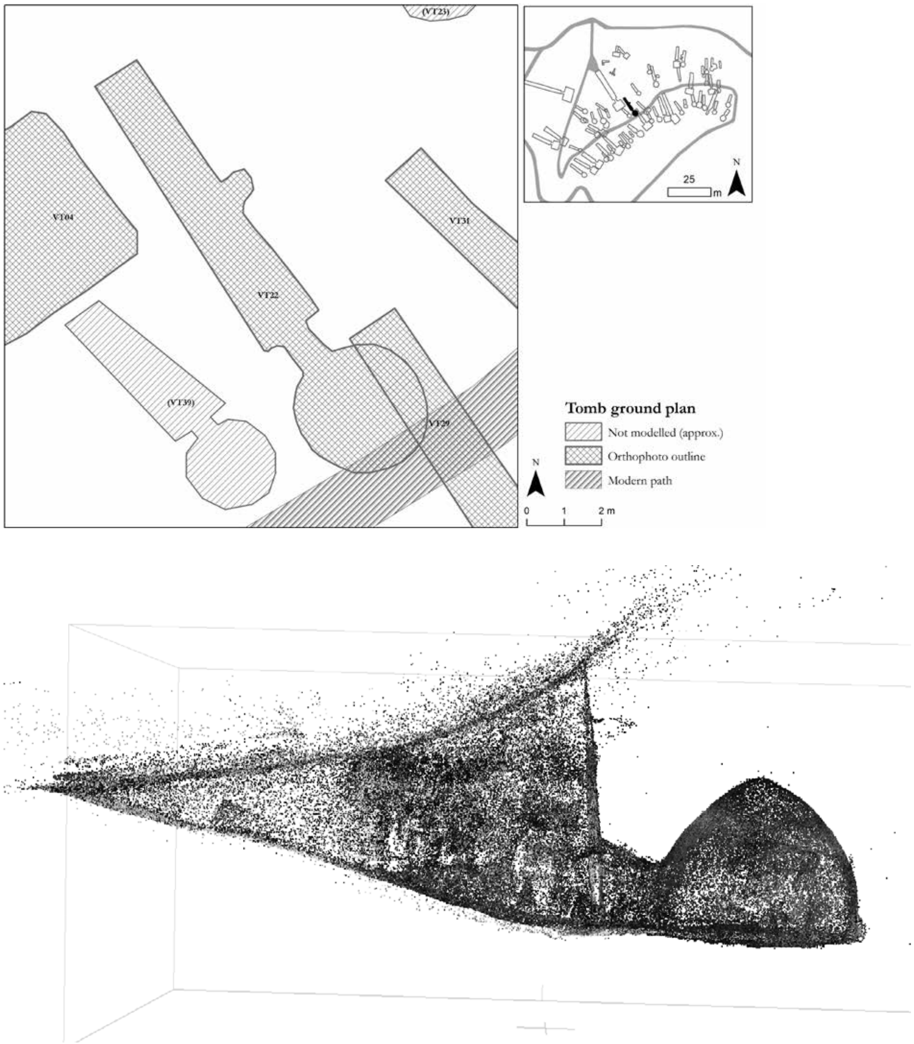


Figure 4.3.13. VT22 ground plan and sparse cloud model (north-eastern cross-section).

estimated at 675-899 ph or as many as 18 days for 10 labourers. This places VT21 among the largest 10 tombs surveyed on site in terms of scale of investment. VT21 compares closely with VT29 (south-eastern group) and VT54 (south-western group).

Voudeni Tomb 22

VT22 is another tomb of exceptional size (TRex 1.54) but is not among the ten largest tombs surveyed on site (Figures 4.3.13, A3.39). The tomb lies adjacent to the northeast of the protective awning covering VT4 in the central group. The VT22 *dromos* begins upslope roughly where the *stomion* of VT4 opens into its vault 6 m below. Whatever the order of construction, builders of the later tomb must have been acutely aware of the location of the other. VT22 has a largely intact chamber with a round base and vaulted roof. The *dromos* shows a well-executed wedge narrowing near the surface. This tapering triangular prism shape gives the effect of a projectile point

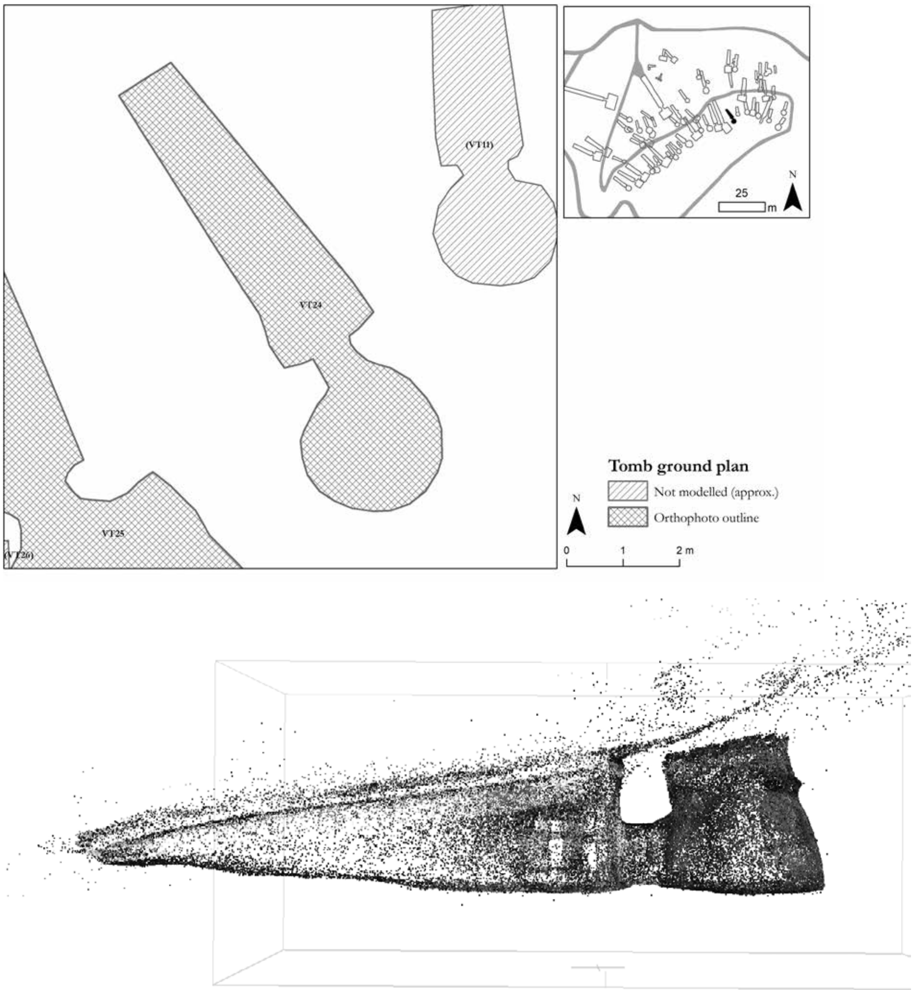


Figure 4.3.14. VT24 ground plan and sparse cloud model (north-eastern cross-section), showing the extent of its ceiling collapse.

when viewed in profile and discourages solid geometry estimates cross-checking the photogrammetric volume. A square cut flanks the north-eastern side of the *dromos* (opposite wall from VT4) at the ground surface midway along its length. What the excavators investigated here is not immediately clear, but another square cut in the vertical wall above the *stomion* could reflect a deliberate mock design of the relieving systems above the entrances to *tholoi* (see also VT77; Kolonas 2009b: 31). The *stomion* itself opens with a crude arch, and the ground surface directly above it was among the steepest parts of the slope on the surveyed portion of the cemetery.

Modelling of VT22 exceeded expectations on the details captured, though the procedure did not differ markedly from other nearby tombs. Much of the tomb's volume came from its *dromos* at 23.8 m^3. The vault added 18.8 m^3 for a total of 42.6 m^3. Using the same method as the others, the VT22 volume translates to expected excavation costs of 384-512 ph or 11 days for 10 labourers.

Voudeni Tomb 23

See Appendix 2.

Voudeni Tomb 24

VT24 can be found in the south-eastern group with VT25-29. The group is oriented differently from the nearby eastern group due to the curving slope and is separated from the north-eastern and central groups by the modern path (Figures 4.3.14, A3.40). VT24 (TRex 0.64) is among the undersized tombs similar to VT6 (TRex 0.61). The VT24 vault (6.73 m^3) has a circular base and a likely vaulted roof obscured by a ceiling collapse that has since been stabilised. The slope of the ground surface splits into two gradients and steepens above the vault. The VT24 *dromos* (11.1 m^3) is shallow (Rex_dh 0.68) but long (Rex_dl 0.98), with the Photoscan point cloud preserving its entrance later cut off by the mesh model. At 17.83 m^3, excavation of VT24 would require 161-214 ph or the usual 5 days for 10 labourers commonly seen near the undersized/standard threshold at TRex 0.75.

Voudeni Tomb 25

VT25 is the third-largest tomb by volume and labour investment on site (Figures 4.3.15, A3.41). Alongside exceptional cases like the much larger VT4 and VT75, VT25 is one of only three tombs surveyed on site to surpass 1,500 ph of expected excavation costs. Although it reaches this arbitrary upper tier, VT25 bears more resemblance to VT78 in terms of scale. The VT25 vault shows a clear four-sided base but has an unknown roof shape due to a total ceiling collapse. This is covered by a wood-frame awning overlapping the second (steeper) gradient of the sloping ground surface. The *stomion* had been found sealed with a well-built wall of river stones blocking access to a chamber with at least six primary burials, “as well as piles of bones and offerings that had been pushed aside towards the chamber’s sidewalls” (Kolonas et al. 2007; see also Kolonas 2009b: 21). Reflecting an extended period of use (LH IIIA1 to LH IIIC Middle-Late phase, ca. 1425-1160/1130 BC), the offerings included several painted jars (stirrup and piriform), beads, and a steatite sealstone among other finds (Kolonas 2009b: 21; Kolonas et al. 2007). The vault is offset slightly from the orientation of the large *dromos* (52 m^3), which has a ribbed concrete pathway to facilitate entry for site visitors. The walls of the *dromos* appear partially plastered in what might be another preservation measure by modern site officials. The ceiling collapse of the vault would add over 30 m^3 to its volume. Assuming a former four-sided or pyramidal roof at a reasonable height, the vault prior to collapse would measure 74.3 m^3, not the 95.1 m^3 opened by the collapse. Pre-collapse, the total volume for the tomb is estimated at 126.3 m^3. The expected excavation cost range is 1,137-1,516 ph or 31 days for 10 labourers. More likely, double the standard workforce could excavate the tomb footprint in 16 days.

Voudeni Tomb 26

Cut facing north-northwest with a slight vault deviation west of its orientation, VT26 lies in the east-central (upslope) group adjacent to VT25 (Figures A3.42-A3.43). Its *stomion* (1.62 m high x 0.72-0.92 m wide) was found sealed with irregular stonework indicating two phases of construction (Kolonas 2009b: 23), likely resulting from the tomb’s reuse. The four-sided (3.30 x 3.15 m) ground plan of the chamber converts at 1.55 m high to an incline-vaulted, *tholos*-like roof. Remains within the chamber included four burials

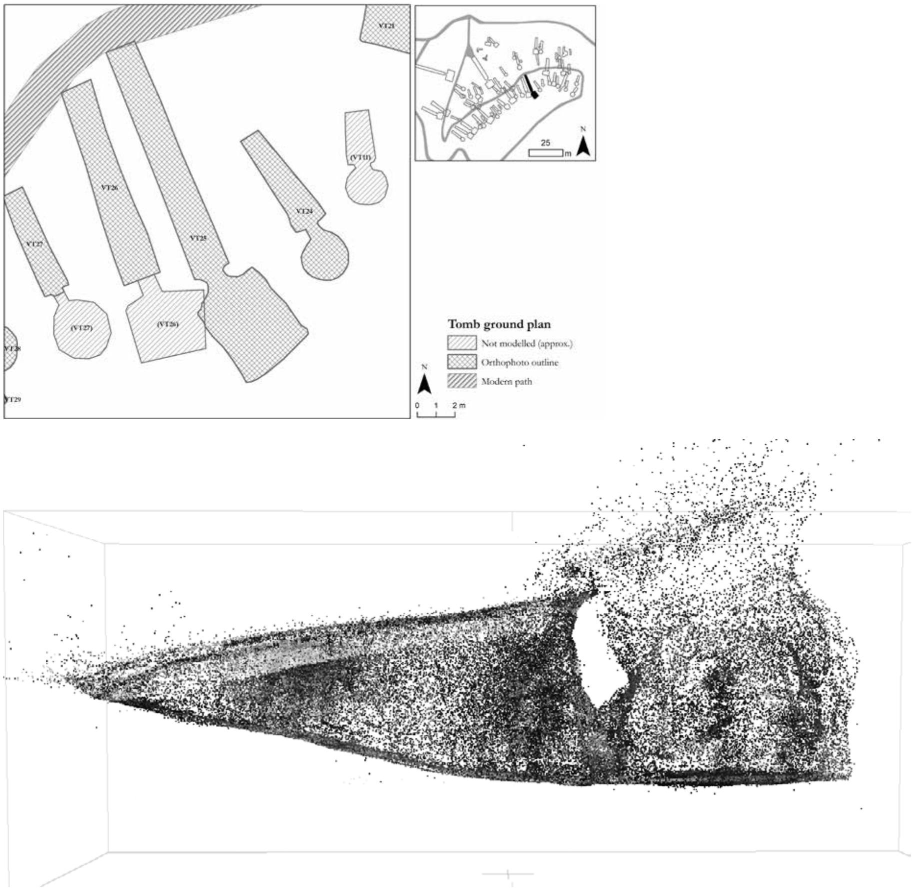


Figure 4.3.15. VT25 ground plan and sparse cloud model (north-eastern cross-section), showing the extent of its ceiling collapse.

with accompanying grave goods and offerings shifted to the back wall in groups, presumably from earlier use (Kolonas 2009b: 23). Notable finds included Phi-type figurines, cornelian and glass beads, a bronze knife, and elaborately painted jars of various shapes (e.g., squat alabastra, three-handled *pithamphoriskos*). These indicate use from the LH IIIA-IIIC periods, ca. 1425-1100 BC (Kolonas 2009b: 22-23).

The VT26 vault failed to render in the photogrammetric model without a clear cause. The *dromos* model is used here as a comparative with others. Given the size of the *dromos* (38.8 m^3, RexD 2.87), closely comparable to that of VT53 (38.1 m^3), VT26 may be among the largest tombs by volume on site after VT25. Due to the missing vault model, however, it falls sharply into the standard range (TRex 0.75-1.50) for estimated excavation costs. VT26 lies adjacent to the west-southwest (right when facing the tombs) of VT25 along a similar axis of orientation, converging slightly. The VT26 *dromos* alone would require 350-466 ph or 10 days for 10 labourers. Assuming the VT26 vault was similar in size to that of VT53 (27.4 m^3) but less than that of VT54 (34.6 m^3) with its larger *dromos*, excavation of the VT26 vault could add another 6-10 days for 10 labourers, assuring its place among the exceptional size variant of tombs at Voudeni.

Figure 4.3.16. VT28 entrance, facing south-southeast.

Voudeni Tomb 27

The VT27 vault model also failed, but volume estimates from its deep and steep *dromos* (13.1 m^3, RexD 0.97) suggest that it is not exceptional. Rather, VT27 sits closer to the median standard in scale (Figures A3.44-A3.45). The tomb is located in the south-eastern group between VT26 and VT28. Independent from its vault of unknown size, excavation of the VT27 *dromos* would require 118-158 ph or 4 days for 10 labourers. It is most similar in terms of scale to the *dromos* of VT9. If, like VT9, the VT27 vault matched closely with the volume of its *dromos*, this could add another 3 days for excavation.

Voudeni Tomb 28

VT28 lies adjacent to VT29 in the south-eastern group. Part of the vault wall has collapsed and opens into the lower vault of VT29 to the west-southwest (to the right as one enters the VT28 vault) (Figures 4.3.16-17). Apart from the wall collapse, it has a circular base and vaulted roof with an estimated volume of 6.49 m^3. The VT28 *dromos* (7 m^3) is short and shallow with a steep, tractionless entrance demanding cautious entry with the help of a rope. The tomb is better lit than most due to electric lighting pouring in from VT29, one of the site’s showcase tombs for visitors. A small depression indicates an excavated feature between the inner *stomion* and the wall collapse in the north-western corner of the vault. Part of the undersized variant, the total measured volume for VT28 is only 13.49 m^3, barely more than a standard *dromos* like that of VT27. Expected excavation costs are 122-162 ph or 4 days for 10 labourers.

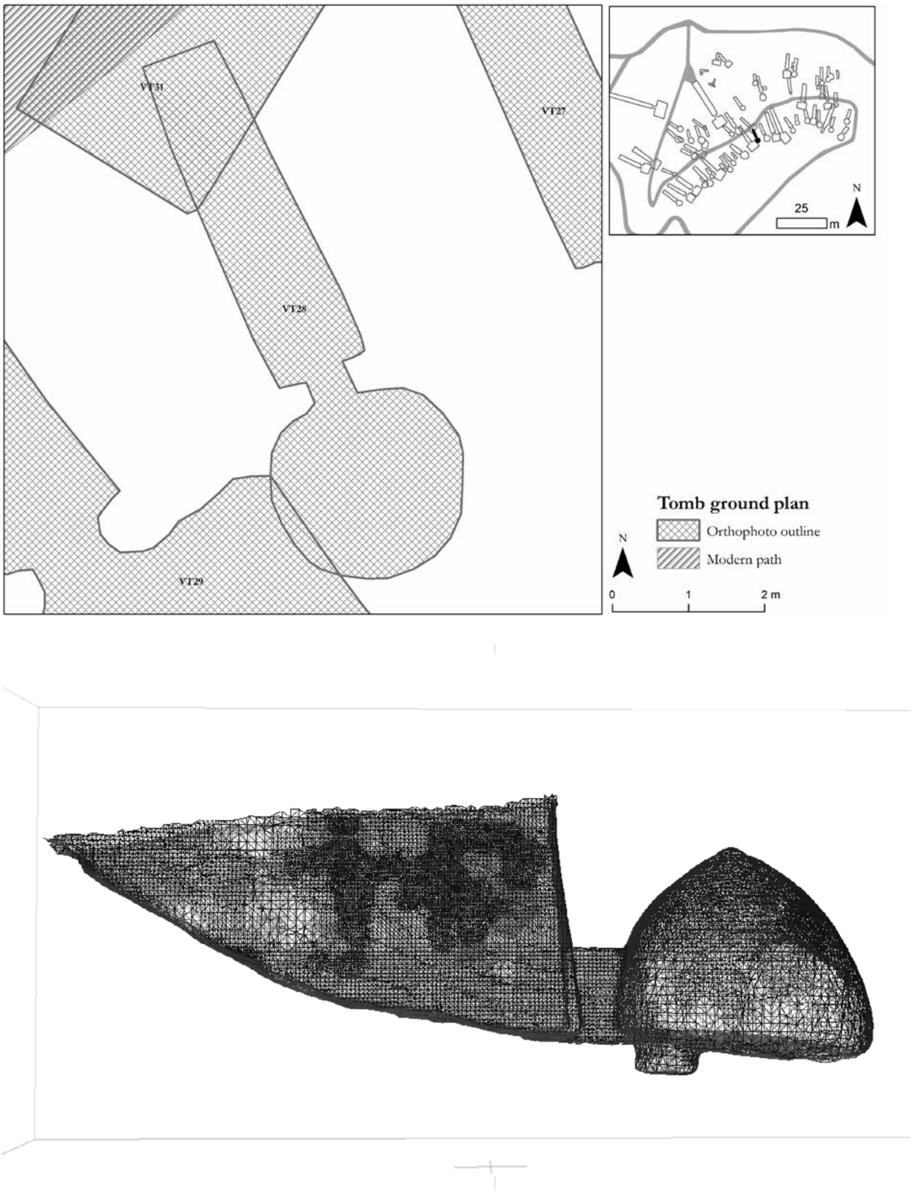


Figure 4.3.17. VT28 ground plan and wireframe model (eastern cross-section).

Voudeni Tomb 29

VT29 is among the larger tombs on site and is similar in scale to VT21 and VT54 (Figures 4.3.18, A3.46). It lies adjacent to VT28, whose smaller elevated vault is visible via a wall collapse on the left flank as one enters VT29. The excavated VT29 is clearly meant for park display with its spacious vault and electric lighting. A bridge for the modern concrete path upslope spans roughly the middle of the *dromos*, offset slightly to the first (upper) half. Access now requires looping around the entrance to VT4 downslope on a seldom-used path of stepping stones diverging from the main pathway.

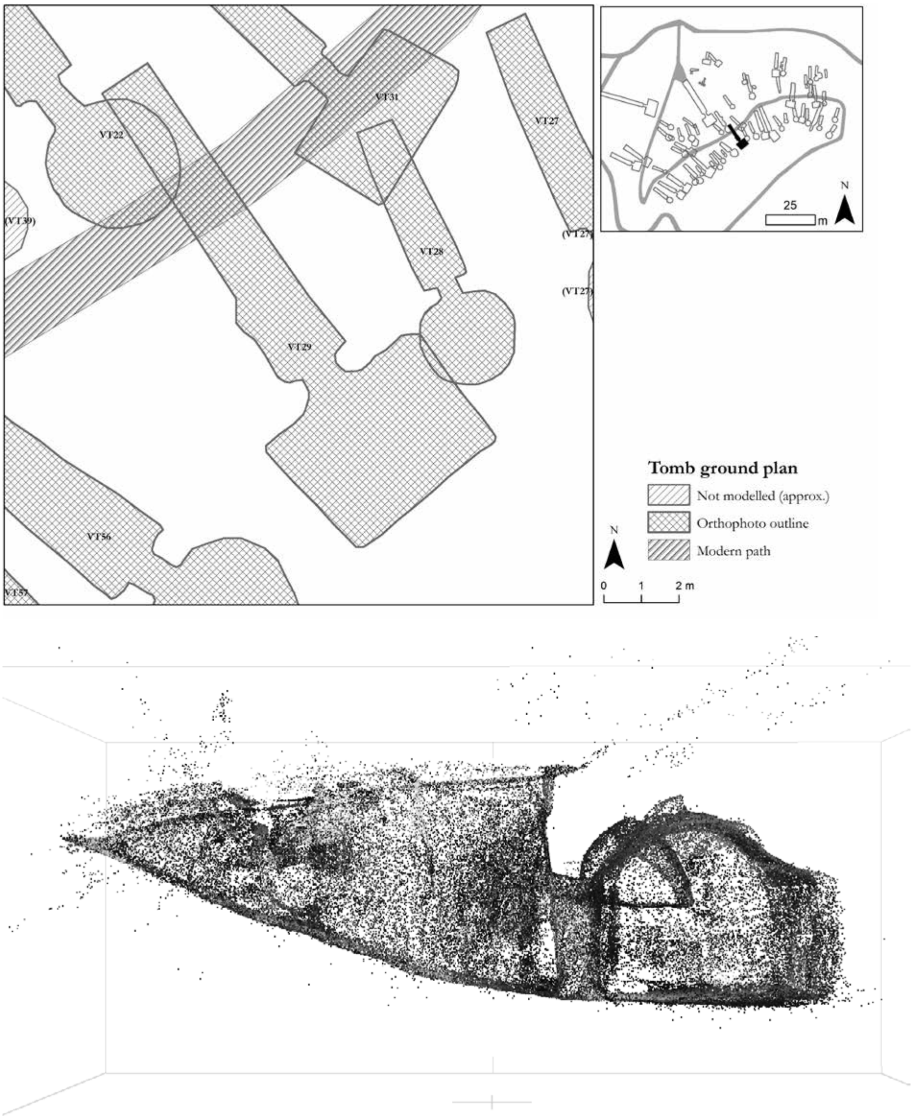


Figure 4.3.18. VT29 ground plan and sparse cloud model (north-eastern cross-section), showing the relative location of the adjacent VT28 chamber.

Modelling of VT29 allowed an independent check for the accuracy of the VT28 vault (5.21 m^3). Adding the *stomion* would place that figure close to its measured volume of 6.49 m^3, attesting the reliability of Photoscan's volume measurement tool, at least where models can be reliably cropped. The shape of the VT29 vault shows a four-sided base, arched roof (barrel-shaped), and a cragged ceiling of partial stress fractures and linear slumping. Although part of the *dromos* wall has collapsed leaving a depression to the right of the *stomion* (when facing it) leading up to the surface, the disturbances appear to be isolated and contained thus far. Volume measurements for VT29 reflect 51.1 m^3 for the vault and 31 m^3 for the deep *dromos*. The total volume of 82.1 m^3 would lead to expected excavation costs of 739-986 ph or 20 days for 10 labourers.

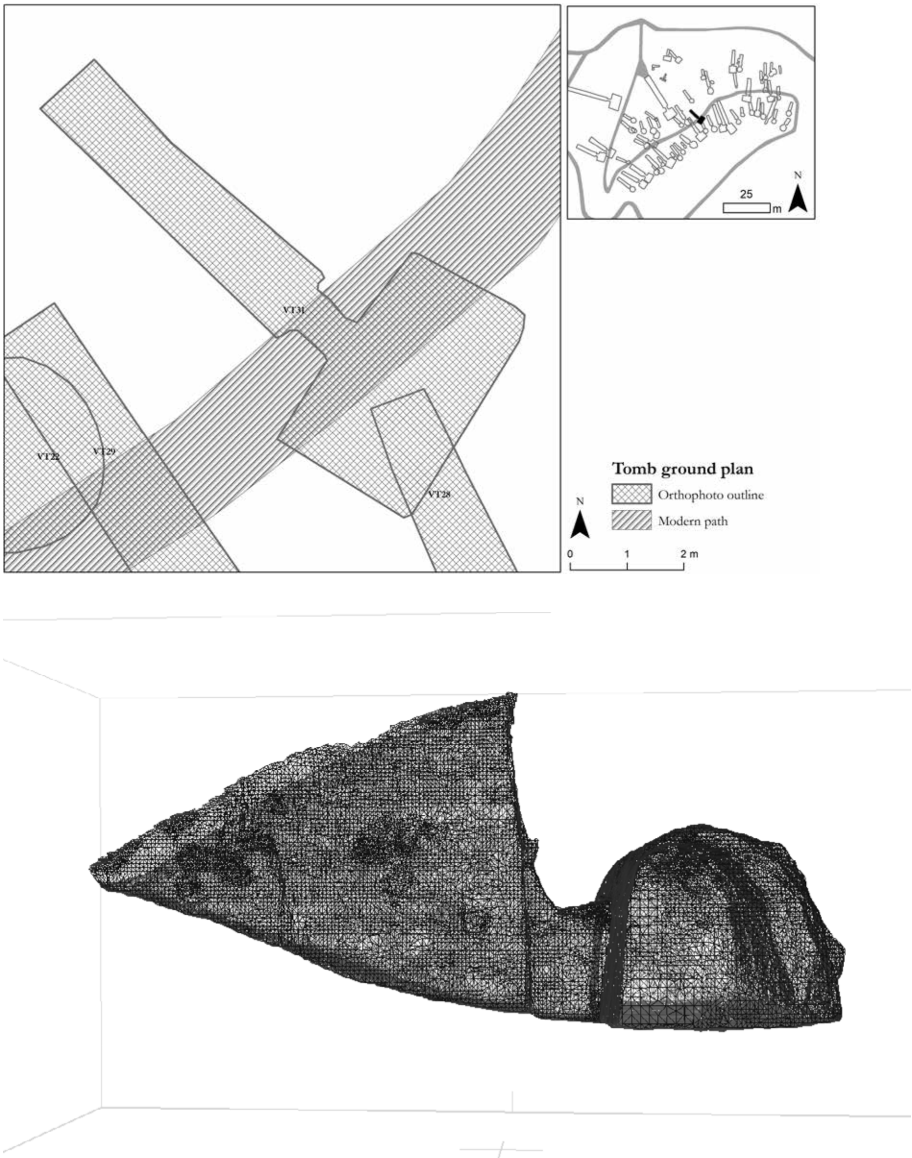


Figure 4.3.19. VT31 ground plan and wireframe model (north-eastern cross-section).

Voudeni Tomb 30

See Appendix 2.

Voudeni Tomb 31

Beneath the modern path, VT31 is a well-preserved example of a standard variant tomb in the central group (Figures 4.3.19, A3.47). The VT31 vault has a rectangular base, arched (barrel) roof, and cragged ceiling of stress fractures with no major collapse. The vault is well-lit with a slight offset from the orientation of the tall and narrow *dromos*. The *dromos* tapers near the steeply sloping surface, showing the wedge or "projectile point" profile.

Volume measurements reflect 14.4 m^3 for the *dromos* and 20.8 m^3 for the vault, totalling 35.2 m^3 for the tomb (TRex 1.27). Expected excavation costs for VT31 are 317-423 ph or 9 days for 10 labourers, roughly a day more than the investment seen at VT34.

Voudeni Tomb 32

See Appendix 2.

Voudeni Pit Graves 33, 35, 37-38, and 41

A cluster of five circular pit graves lies in the north-central part of the cemetery between VT3 and VT4. The simple, shallow graves are arranged in two perpendicular rows of three joined in a T-shape (Figure A3.48). Together the tombs account for a volume of 3.48 m^3, the expected excavation costs for which are 32-42 ph or no more than 2 days for 5 labourers. If excavation proceeded on a 10-hour schedule, completion of the pits could easily be accomplished within a day. Individually excavated, construction of the pits are well within the capability of one operating for a few hours. Given the different form of the tombs and their much reduced investment relative to the smallest (completed) chamber tombs at the cemetery, their construction must comprise a separate conversation (see Chapter 5).

Voudeni Tomb 34

VT34 is adjacent to the east of VT16 in the gap between the central, northeast, and north groups (Figures 4.3.20, A3.49). The *dromoi* converge at their leading edges, leaving a narrow balk. The VT34 chamber has a rounded base, vaulted roof, and cragged ceiling of linear stress fractures without major collapses. A square cut opens into the eastern (left when facing tomb) *dromos* wall near the *stomion*. VT34 is nearly triple the size of its neighbour VT16, with volume measurements of 19 m^3 (*dromos*), 13.9 m^3 (vault), and 32.9 m^3 (total). Expected excavation costs for the tomb range from 297-395 ph or 8 days for 10 labourers.

Voudeni Tomb 36

VT36 burrows into the slope beneath the modern path in the northeast group between VT14 and VT19 (Figures A3.50-A3.51). VT36 doubles the size of VT19 and quadruples that of VT14. Due to a total ceiling collapse covered at the surface by a wood-frame awning, the original roof shape is unknown. The disturbance would add 11.5 m^3 to the estimated vault volume of 27.8 m^3 taken by cropping the model at the expected original height. The base of the vault is rectangular, and the *stomion* narrows at the top into a tall trapezoidal shape. Absent a secure tie off, the steep entrance to the *dromos* (17.2 m^3) prompted a squatting crawl to access the tomb without falling. At 45 m^3 (TRex 1.62), VT36 lies just above the arbitrary threshold between tombs of standard and exceptional investment. Expected excavation costs range around 405-540 ph or 11 days for 10 labourers.

Voudeni Tomb 39

See Appendix 2.

Voudeni Tombs 40 and 44

VT40 and VT44 represent a double-vault system in the northeast group near the edge of the maintained lawn bordered by dense secondary vegetation downslope to the north (Figures 4.3.21-23). The original *stomion* for each tomb appears to have been left closed in

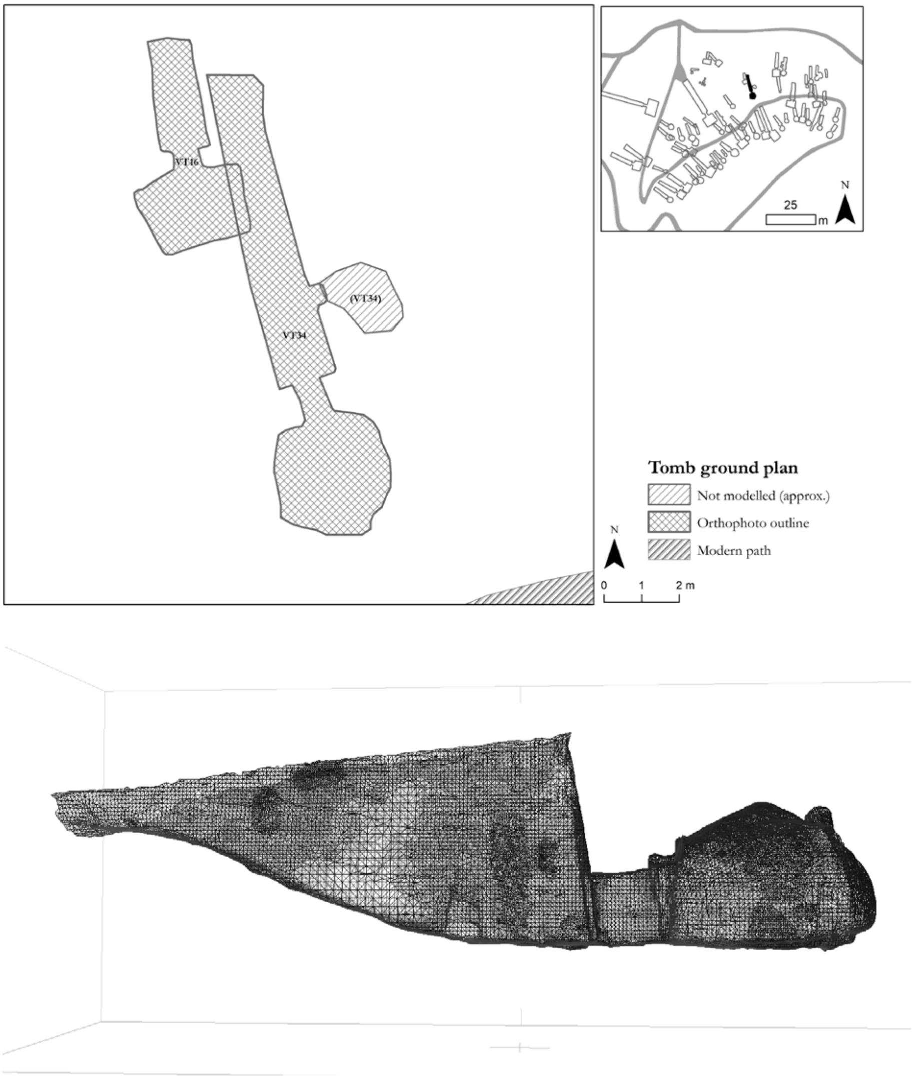


Figure 4.3.20. VT34 ground plan and wireframe model (eastern cross-section).

favour of sidewall access into the adjacent vaults. With that in mind, the larger and lower vault of VT44 (14.36 m^3) likely had a separate (unexcavated) *dromos* near the open VT40 *dromos* (7.3 m^3). The open VT40 *dromos* orients to the north, while the closed VT44 *dromos* appears to veer east based on the location of its blocked *stomion*, potentially intersecting with the anomalous VT30 cutting. Without volume measurements from the closed *stomion* and suspected *dromos* of VT44, the excavated *dromos* of VT40 has been substituted. At over double the size of the VT40 vault, investment in VT44 easily eclipsed its nearest neighbour without need for its *dromos* – its vault size alone exceeded the total volume for VT40. In reality, both vault sizes would also rise slightly to account for each closed *stomion*. Stones and earth fill block the *stomia*, and the *dromos* walls near the surface have become overgrown. Some slumping has occurred on the *dromos* wall opposite the VT44 sidewall entrance.

Figure 4.3.22. VT40 and 44 blocked *stomia*, facing northeast.

Figure 4.3.21. VT40 and 44 entrance, facing south.

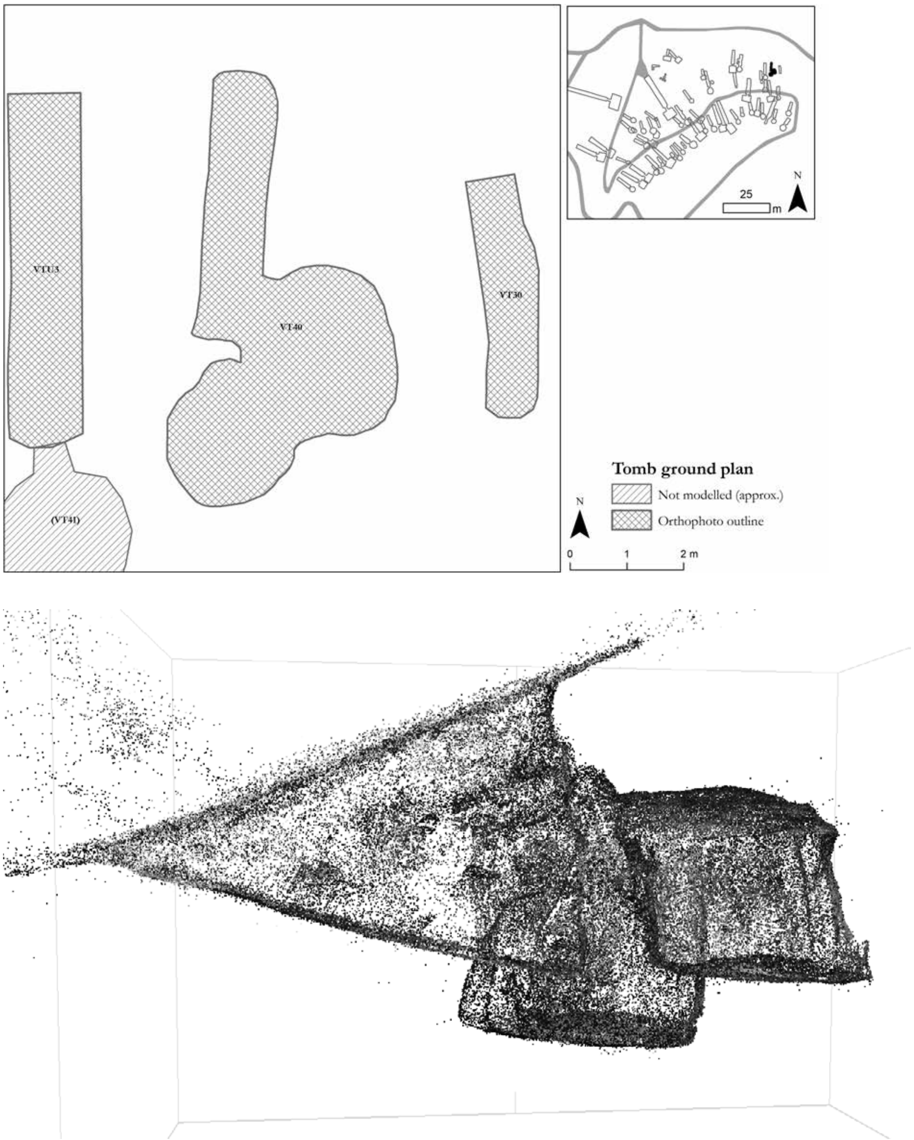


Figure 4.3.23. VT40 and 44 ground plan and sparse cloud model (eastern cross-section), showing the relative location of each burial chamber.

Both VT40 and VT44 show chambers with rounded bases, vaulted roofs, and cragged ceilings of isolated stress fractures. Acknowledging the limitations of labour modelling for the excavated outline, with its ratio to the original form unknown, expected costs range from 120-159 ph (VT40) and 195-260 ph (VT44) or 4-6 days for 10 labourers for each tomb.

Voudeni Tomb 42

VT42 lies west of the VT40/44 pair and just east of its nearest neighbour VT43 in the northeast group (Figures 4.3.24, A3.52). Several architectural features appear here that are not common to other tombs on site. Two shallow pockets interrupt the

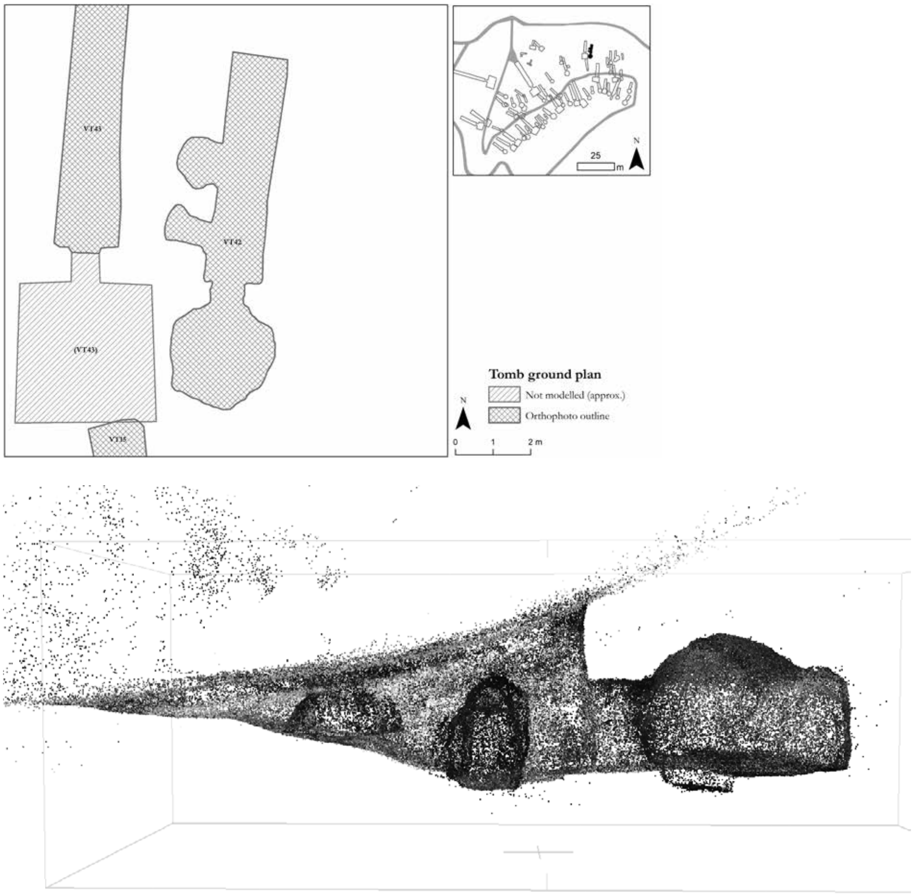


Figure 4.3.24. VT42 ground plan and sparse cloud model (eastern cross-section).

western (right when facing tomb) *dromos* wall. The floor of the *dromos* also exhibits a two-tier slope, beginning with a shallower angle and transitioning to a steeper angle before the first pocket. The main chamber shows a rounded base, arched roof with grooved sidewalls, and cragged ceiling. The grooved sidewalls create the visual effect of an upper latitude ‘ring shelf’ that could indicate an aborted plan for a four-sided tomb shape or simply one of the rarer variant designs. The end result is a distinctive, ‘fried egg’ or Saturn shape for the upper third of the vault. A depression in the western half of the vault likely indicates an excavated feature. Tomb dimensions reflect 11 m^3 (*dromos*), 7.7 m^3 (vault), and 18.7 m^3 (total). In terms of scale, VT42 is most similar to VT13 and VT24. Expected excavation costs for VT42 are 169-225 ph or 5 days for 10 labourers.

Voudeni Tombs 43, 45-52

See Appendix 2.

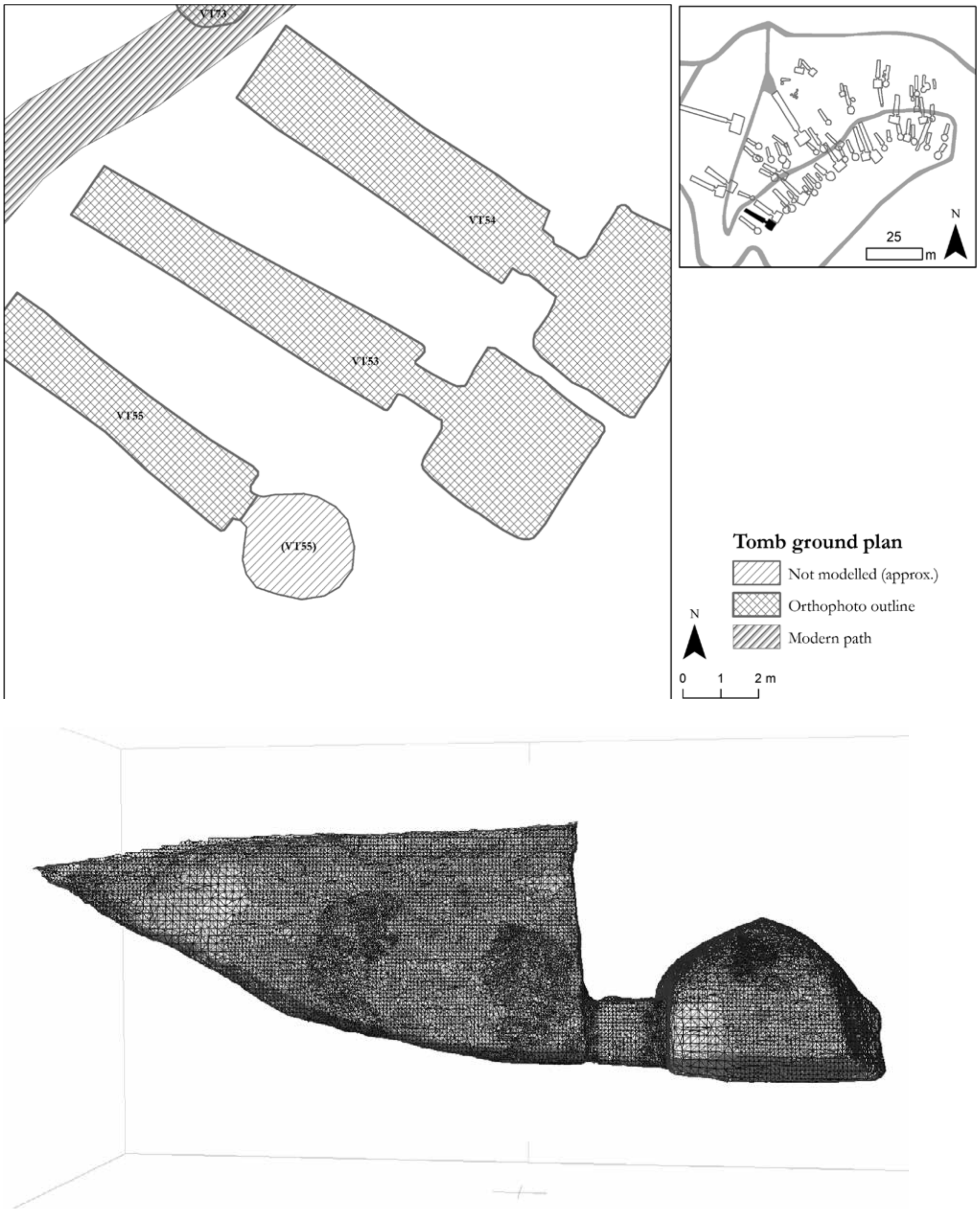


Figure 4.3.25. VT53 ground plan and wireframe model (north-eastern cross-section).

Voudeni Tomb 53

VT53 is the tenth-largest tomb by volume successfully modelled on site (Figures 4.3.25, A3.53). It lies upslope of the modern path in the south-western part of the cemetery. The VT53 chamber has a rectangular base with an incline vaulted roof and appears well-preserved. The chamber shape is iconic for the hybrid variant with its four-sided base transitioning into a *tholos*-like ceiling showing elements of the house and hive variants. The width of the steep *dromos* diminishes near the surface forming the distinctive wedge with tapering façade. Topsoil has been cut back at the surface surrounding the *dromos*,

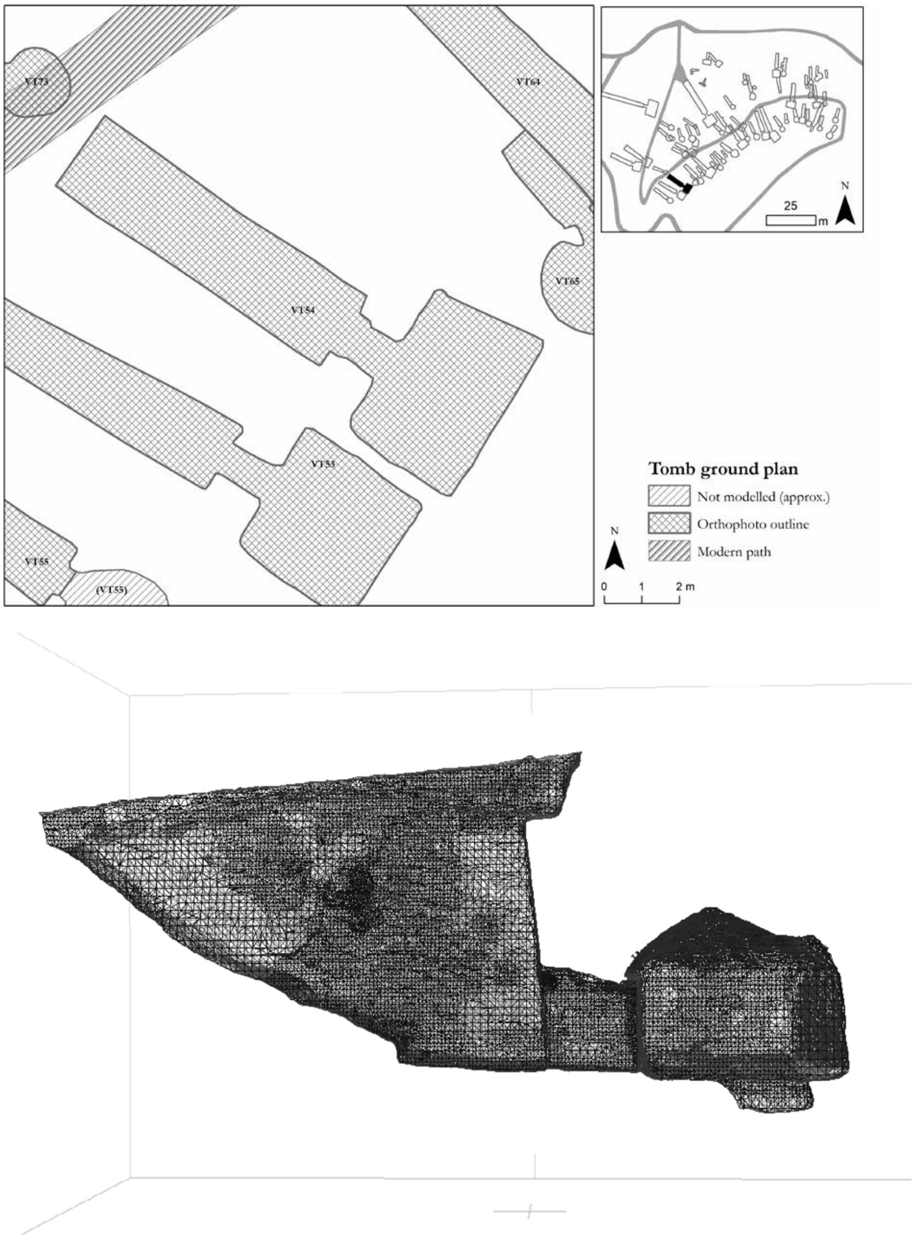


Figure 4.3.26. VT54 ground plan and wireframe model (north-eastern cross-section).

exposing the marl. Volume measurements reflect 38.1 m^3 (*dromos*), 27.4 m^3 (vault), and 65.5 m^3 (total). The substantial length (10.9 m, Rex_dl 1.82) and depth (4.34 m, Rex_dh 1.45) of the *dromos* accounted for much of the investment in the tomb's construction. Expected excavation costs are 590-786 ph or 16 days for 10 labourers.

Voudeni Tomb 54

In the sprawling southwest group, VT54 (TRex 2.93) is also among the ten largest tombs observed on site, being closely comparable with VT21 and VT29 (Figures 4.3.26, A3.54). Opening directly onto the modern concrete path, the steep *dromos* exhibits multiple gradients, including a square-stepped cutting adjacent to the *stomion* and a multi-tiered surface with topsoil cut back from the edge of the sloping and slightly slumping marl. A square depression marks the surface of the *dromos* above the façade. The VT54 chamber shows a rectangular base with a pyramidal roof and appears largely intact. A deep rectangular depression occupies the south-western half of the vault (to the right as one enters), potentially signifying an excavated grave or pit for secondary remains and offerings. Much like VT53, most of the tomb's volume stems from its deep *dromos* (46.8 m^3). The larger vault (34.6 m^3) pushes VT54 further beyond the investment of its nearest neighbour VT53 to the southwest. At 81.4 m^3, expected excavation costs for VT54 range from 733-977 ph or 20 days for 10 labourers.

Voudeni Tomb 55

VT55 lies in the southwest group upslope of the modern path (Figures A3.55-A3.56). Light differential between the sunny surface and the dark vault prevented successful initial modelling for the VT55 vault, the sixth and final such failure on site. The tomb is similar in form but smaller in scale to VT53 and VT54 to the northeast. Labour modelling for the tomb is based on the *dromos* alone and serves only as a comparative with other *dromoi*. Similar to nearby tombs, topsoil has been cut away from the surface of the *dromos* and stabilised with wire mesh and rebar. Some deterioration of the *dromos* wall has occurred, but the overall shape remains apparent in a tapering width near the surface and an estimated volume of 23.1 m^3. Expected excavation costs for the *dromos* would include 208-278 ph or 6 days for 10 labourers. *Dromoi* of comparable size include those of VT56 (25.8 m^3) and VT64 (25.8 m^3). Assuming the VT55 vault size is similar to those tombs (14.2-22 m^3), expected excavation costs for VT55 could rise an additional 4-6 days for 10 labourers.

Voudeni Tomb 56

VT56 can be found in the south-central part of the cemetery above the main path overlooking the VT4 awning (Figures 4.3.27, A3.57). The steep *dromos* opens directly onto the path and steps into a rectangular depression adjacent to the *stomion*. Some deterioration has occurred at the surface where the marl has slumped. The arched *stomion* also shows a small collapse at its apex. The VT56 chamber has a rounded base, incline-vaulted roof, and cragged ceiling with linear stress fractures but no major collapses. The vault offsets slightly from the orientation of the *dromos*, to the northeast or left when entering. Volume measurements for the tomb reflect 25.8 m^3 (*dromos*), 22 m^3 (vault), and 47.8 m^3 (total). Expected excavation costs range around 431-574 ph or 12 days for 10 labourers.

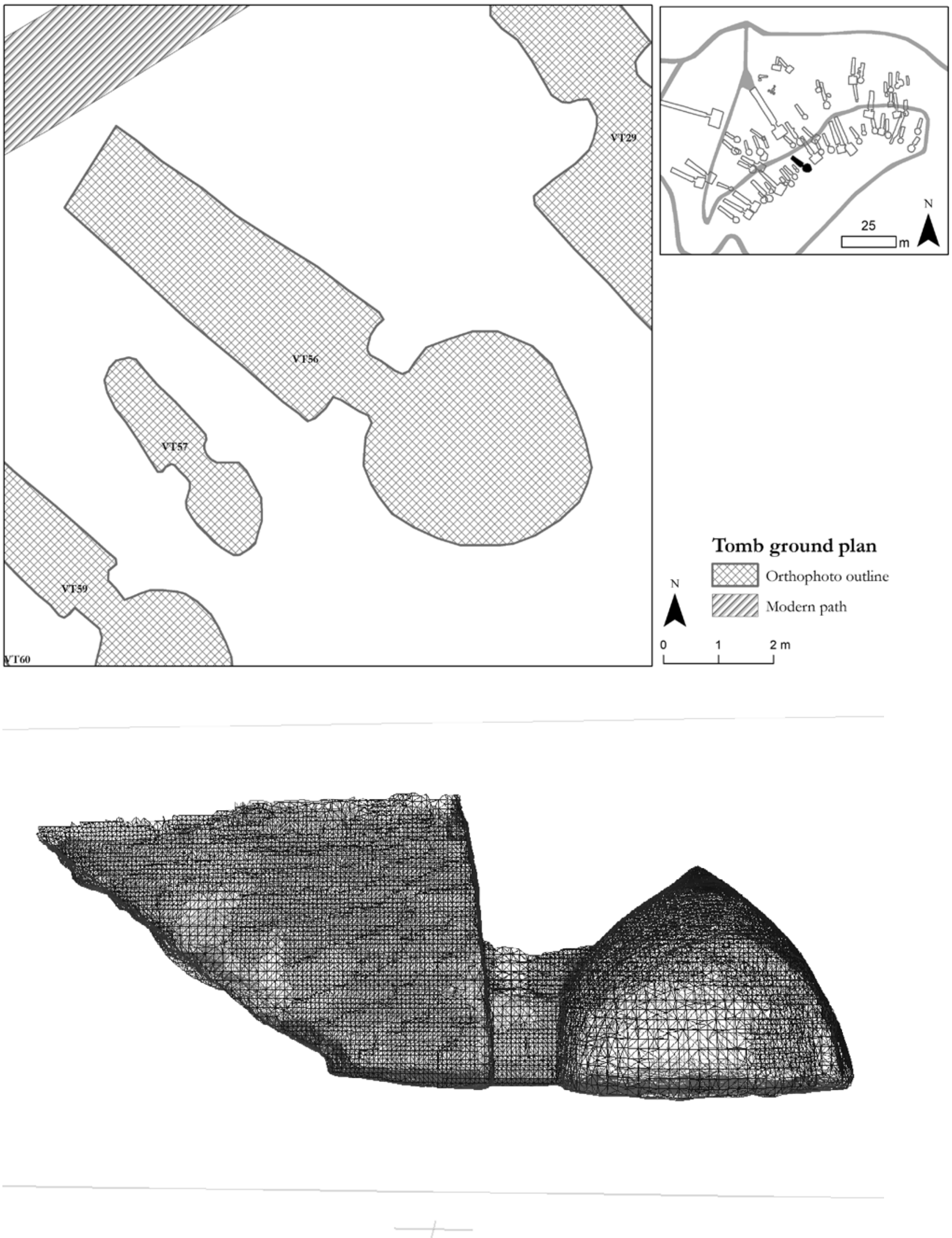


Figure 4.3.27. VT56 ground plan and wireframe model (north-eastern cross-section).

Voudeni Tomb 57

VT57 is a small, shallow open-air tomb with a total ceiling collapse left uncovered to the southwest of VT56 (Figures A3.58-A3.59). The remaining vault has a horseshoe base or D-shaped plan view with its flat edges along the inner *stomion* and its south-western flank (to the right when entering). The outer *stomion* shows flanking ledges of unexcavated balks employed as pedestals for photopoint markers. The ring-like effect of the remaining marl edge and cutback topsoil gives VT57 a halo-effect similar to other open-air tombs on site. Volume estimates for the tomb are limited to what remains and can only be extrapolated with caution. The measured volume of the tomb's current form shows only 1.41 m^3 for the *dromos* and 1.16 m^3 for the vault. As it stands, expected excavation costs for VT57's 2.57 m^3 are 24-31 ph or no more than 2 days for 5 labourers. Based on its shallow depth, the actual figure would not climb much higher, adding no more than a day of additional labour.

Voudeni Tomb 58

See Appendix 2.

Voudeni Tomb 59

VT59 is another open vault with a total ceiling collapse left uncovered southwest of VT57 (Figures A3.60-A3.61). The *stomion* remains blocked by large stones and earth fill, and the *dromos* is relatively shallow. The VT59 vault shows a rounded base and halo of the remaining marl edge with the slumping topsoil cut back from the edge. The bowl shape of the sloping ground surface above the vault would add to the model's volume measurements if not cropped. With no safe entry into the vault, inaccessible without a ladder, some detail was lost in the final model. That poorer quality stems directly from not having lower camera angles beyond crouching at the surface above the vault. Surprisingly, the point cloud and mesh still managed to capture the vault in sufficient detail to reconstruct its volume. Volume measurements include 7.13 m^3 (*dromos*), 8.59 m^3 (vault), and 15.72 m^3 (total). Expected excavation costs are 142-189 ph or 4 days for 10 labourers. In terms of scale, VT59 is most similar to VT14.

Voudeni Tomb 60

VT60 lies directly adjacent to the southwest of VT59 in the southern portion of the cemetery upslope of the main path (Figures 4.3.28, A3.62). Unlike most of the tombs on site, the vault is offset but not differently oriented from the *dromos*, meaning more of the rounded vault lies off to the right of the *stomion* as one enters. The roof of the chamber closes with an incline vaulted shape. Although part of the shaded *dromos* in the lowest corner near the *stomion* did not render in the mesh model, enough of the tomb was captured to yield volume estimates of 12 m^3 (*dromos*), 6.9 m^3 (vault), and 18.9 m^3 (total). Expected excavation costs are 171-227 ph or 5 days for 10 labourers.

Voudeni Tomb 61 (U1)

Although missing its numbered sign, VT61 is assumed to be the same tomb as VT U1, signifying the first unlabelled tomb at Voudeni surveyed herein (Figures A3.63-A3.64). It is in the vicinity of VT59, VT60, and VT62 in the southern part of the cemetery upslope of the main path. The tomb is shallow and small, with an open vault left uncovered after a total ceiling collapse. The *stomion* remains blocked with stones and earth fill, but the shallow

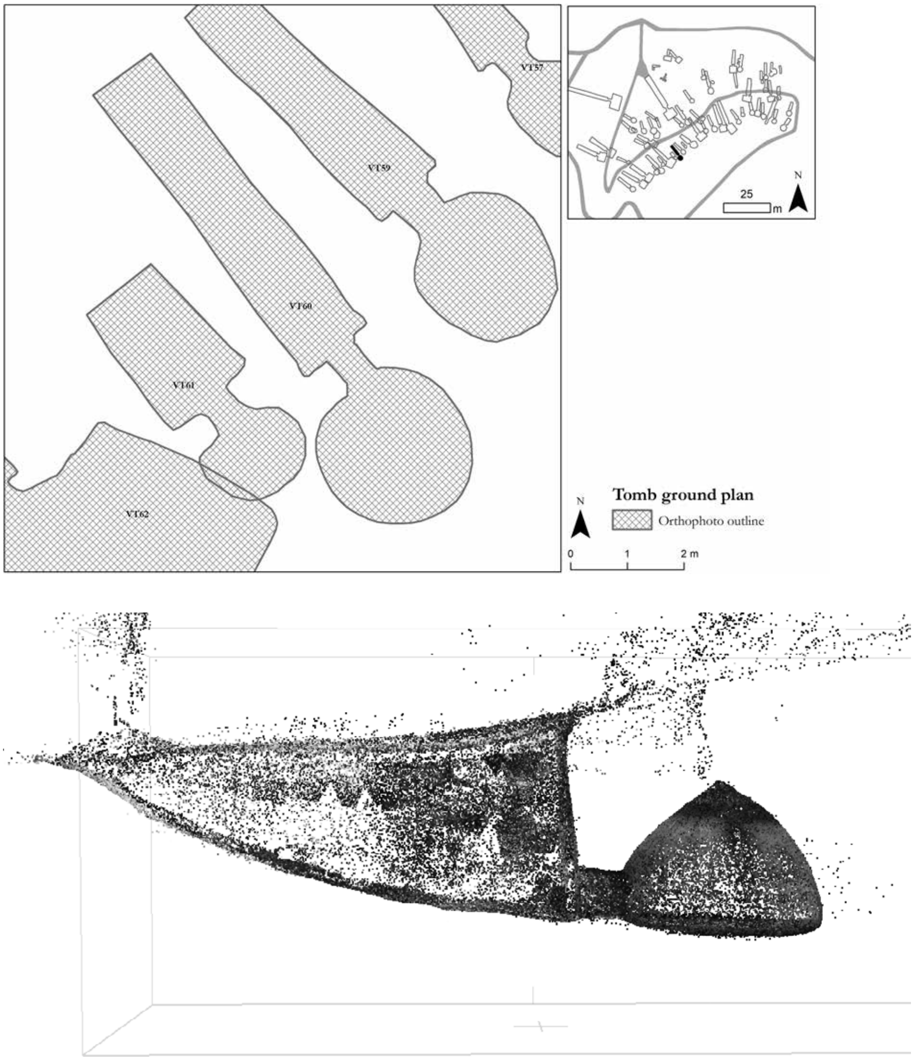


Figure 4.3.28. VT60 ground plan and sparse cloud model (north-eastern cross-section).

rounded vault is easily accessed from the surface. The *dromos* is short but tractionless, prompting cautious entry. Marl left exposed by cutting back the topsoil produces the familiar halo effect around the open vault. Acknowledging the limitations of labour costs for such a shallow tomb, volume estimates show 2.46 m^3 (*dromos*), 2.03 m^3 (vault), and 4.49 m^3 (total). This translates to expected excavation costs of 41-54 ph or no more than 2 days for 10 labourers. Perhaps more informative are the stones used to block the *stomion*, which could indicate the average size used for that purpose. Depending on the distance traversed, hauling the stones may have been more costly than excavating the tomb itself.

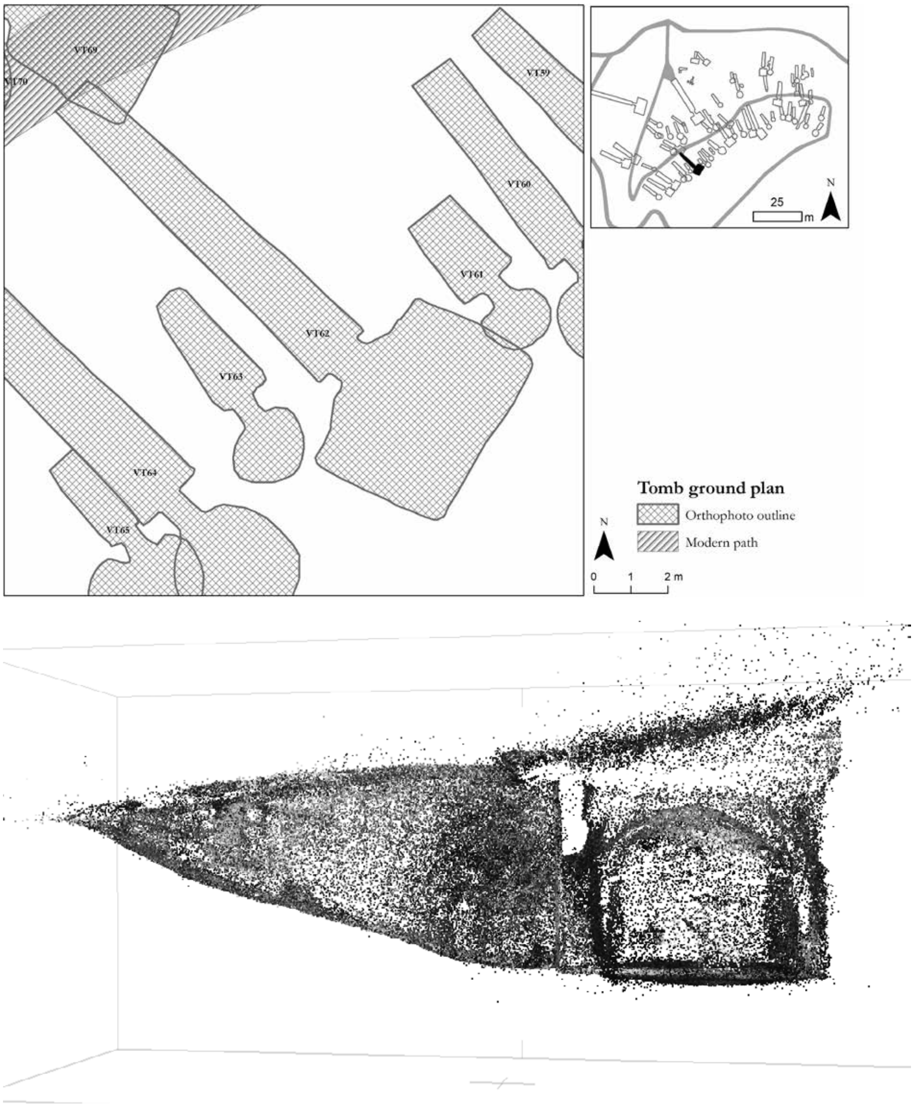


Figure 4.3.29. VT62 ground plan and sparse cloud model (north-eastern cross-section), showing the extent of its ceiling collapse.

Voudeni Tomb 62

Surrounded as it is by shallow collapsed tombs, VT62 marks a return to the larger, more complete examples in the southern and south-western groups upslope of the main path (Figures 4.3.29, A3.65). It is a tomb of exceptional size (TRex 3.42), among the ten largest tombs successfully modelled on site, and most comparable to the larger VT77 (TRex 3.47) downslope. Offset slightly to the northeast from the *dromos* orientation (left when entering), the electrically lit VT62 chamber has a rectangular base (5.27 x 3.73 m) with the suggestion of an arched or barrel roof. The sidewalls of the vault remain vertical up to a height of 1.92 m (Kolonas 2009b: 24). More than half the ceiling has collapsed and has since been covered with a wood-frame awning. The remaining ceiling is heavily cragged with significant stress fractures. Another small collapse marks a gap at the apex of the tall *stomion*, which could follow the shape of a tapering rectangle (trapezoidal) or the remains of a partial arch. Cropping away the missing ceiling, which would artificially inflate the vault volume by roughly 25 m^3, volume estimates for VT62 yielded 32.3 m^3 (*dromos*), 62.6 m^3 (vault), and 94.9 m^3 (total). Expected excavation costs range from 855-1,139 ph or 23 days for 10 labourers.

Like many of the better-preserved tombs around site, the VT62 *stomion* was found blocked by unmodified river stones protecting a chamber of important finds (Kolonas 2009b: 24). Five burials were identified within the chamber, among which one had been placed "on a clay litter, and a layer of burning" (Kolonas 2009b: 25). Notable finds included lead sheeting, carnelian and glass beads, bronze tools (knife, spearhead, and razor), and elaborately painted vases of intriguing shapes (e.g., tripod stirrup jar, double *kernos*) (Kolonas 2009b: 24-25). The finds place the tomb's period of use from the LH IIIA1 to Submycenaean period, ca. 1425-1050 BC (Kolonas 2009b: 25).

Voudeni Tomb 63

VT63 lies directly adjacent to the southwest of VT62 (Figures A3.66-A3.67). It is an open-air, shallow tomb with a *stomion* blocked by stone rubble and earth fill leading to a rounded vault exposed by a total ceiling collapse. A corner of the wood-frame awning covering VT62 encroaches on the northeast edge of VT63. A second, higher and shallower open-air outline extends to the south of the main vault. Though almost exclusively cut into the topsoil rather than the underlying marl, the cutting shows a plan-view suggesting a short *dromos* leading into a rounded vault. It could represent one of the missing numbered tombs but is not a substantial feature in its current form. Five shallow, poorly defined depressions in the floor of the upper outline could represent excavated features. The upper outline measures only 2.02 m^3 in volume and has been discarded from the labour estimate for VT63. The main VT63 vault may have had a dome roof but has no remaining ceiling to confirm the original shape. In its current form, the excavated volume is limited to 1.96 m^3 for the *dromos* and 3.35 m^3 for the vault (5.31 m^3 total). This translates to expected excavation costs of 48-64 ph or 2 days for 10 labourers. Even completed, the shallowness of the tomb would limit additional costs to another day of labour.

Voudeni Tomb 64

VT64 occupies the space between VT63 and VT65 but differs from both in its orientation, tilted several degrees to the west (Figures 4.3.30-31). The tomb has a rectangular *stomion* and relatively intact vault ceiling that bears a strong resemblance to the typical *tholos* form (rounded base and incline-vaulted roof). The steep entrance to the *dromos* adopts a more gradual slope toward the *stomion*. When facing the *dromos*, its profile expands at the base, creating the trapezoidal facade. The walls are not entirely uniform, with the cutting offset too far into the lower right flank when facing the outer *stomion*. Approaching the arbitrary standard/exceptional threshold but lying just below it at TRex 1.44, volume estimates for VT64 yielded 25.8 m^3 for the *dromos* and 14.2 m^3 for the vault, totalling 40 m^3. Expected excavation costs are 360-480 ph or 10 days for 10 labourers.

Figure 4.3.30. VT64 entrance, facing southeast.

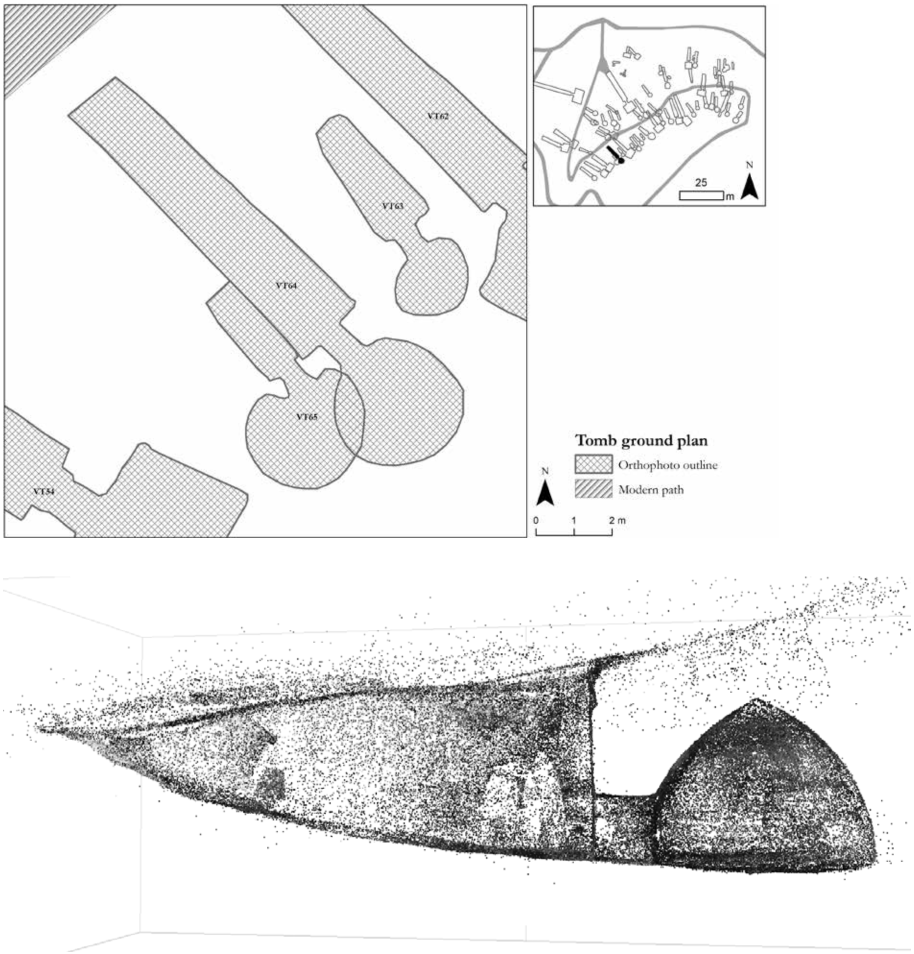


Figure 4.3.31. VT64 ground plan and sparse cloud model (north-eastern cross-section).

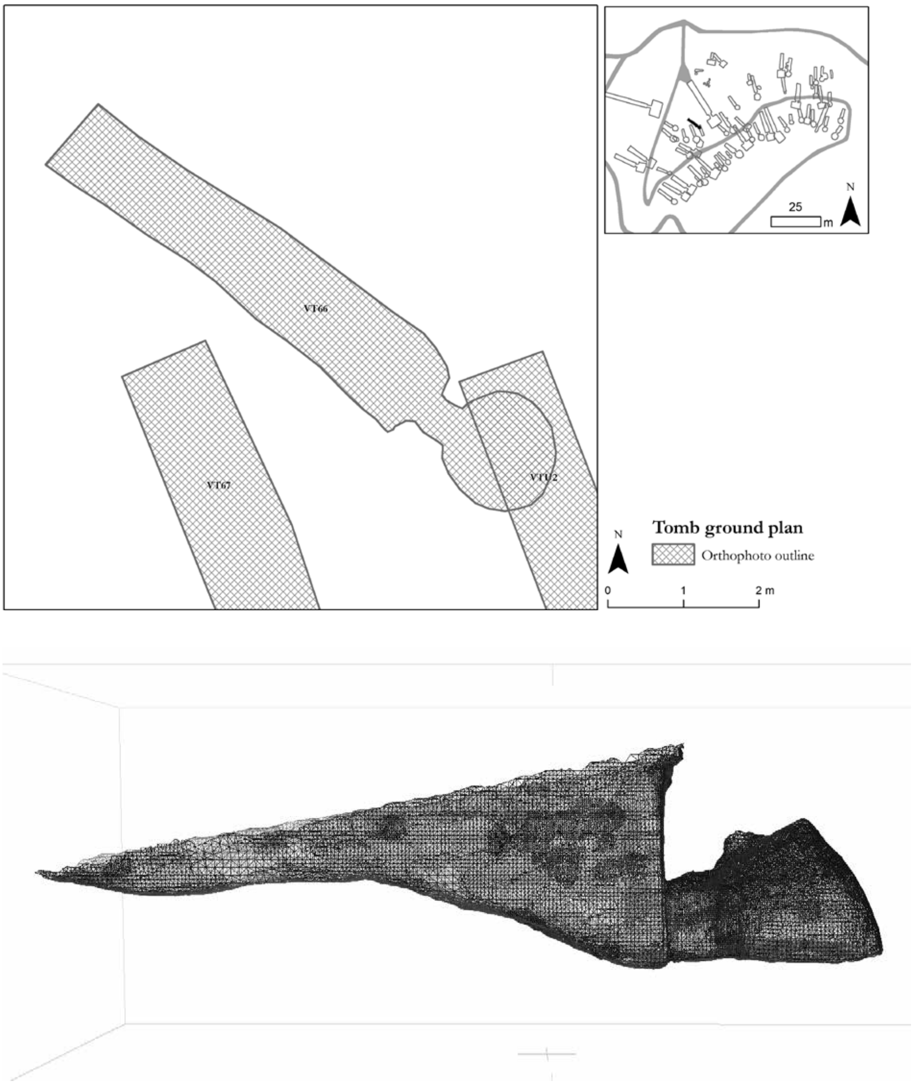


Figure 4.3.32. VT66 ground plan and wireframe model (north-eastern cross-section).

Voudeni Tomb 65

Juxtaposed to VT64, VT65 is underwhelming (Figures A3.68-A3.69). Shallow, collapsed, and uncovered, the kidney-shaped vault is offset from the *dromos* orientation and weighted to the right flank upon entering. The *dromos* itself is shallow and extremely short, with only flanking balks to mark the open *stomion*. The entire feature fits into a single frame, leading to a low pre-optimised error. The halo effect returns with the topsoil cut back to expose a collapsing marl ring near the surface of the tomb. Labour estimates for the tomb are limited to its current, poorly preserved form. Given its shallowness, however, expected excavation costs would not rise more than another day in its completed form. As with the other shallow, open-air tombs, questions arise as to whether this tomb form fits more with undersized chamber tombs or exceptional pit graves elaborated with chamber tomb-like features. In either case, the tripartite terminology for typical chamber tomb architecture applies. Volume estimates show 1.39 m^3 (*dromos*), 8.99 m^3 (vault), and 10.38 m^3 (total). Expected excavation costs are 94-125 ph or no more than 3 days for 10 labourers.

Voudeni Tomb 66

VT66 lies in the west-central part of the cemetery southwest of VT4 (Figures 4.3.32, A3.70). Its vault shows a rounded base, incline-vaulted roof, and cragged ceiling with no major collapses. The *dromos* begins as a shallow cutting before dropping steeply midway along its length toward the *stomion*. This likely indicates a product of modern excavation in which the upper *dromos* floor may not have been fully removed. The tomb orientation offsets several degrees to the west, cutting across the north-western orientations of nearby tombs. Dimensions of the small tomb place much of its volume in the *dromos* (4.92 m^3), with the vault of 1.66 m^3 bringing the total to 6.58 m^3. Expected excavation costs are low at 60-79 ph or no more than 2 days for 10 labourers. With the *dromos* fully excavated into a more reasonable slope, that cost may have risen another 1-2 days.

Voudeni Tombs 67-68

VT67 and VT68 are adjacent tombs that through excavation or collapse have overlapped (Figures 4.3.33, A3.71-A3.72). The lower, more complete vault of VT67 (13 m^3) leads into the exposed, larger vault of VT68 (20.6 m^3) via a high ledge to the southeast. The beginning of a shallow and short *dromos* appears to overlay the top of the VT67 vault but has since mostly collapsed, reducing the available measured volume for the suspected VT68 *dromos* (4.55 m^3). The main *dromos* leading into VT67 is still intact at 9.06 m^3, with some deterioration along the surface that has been stabilised with wire mesh and rebar. Several features, including deep rectangular pits and stone slab inclusions within the VT67 vault, indicate burial variety but, more relevant for the current study, severely complicated camera angles. Despite the wall and ceiling collapses, the VT67 chamber form is still visible with its rounded base and incline-vaulted roof. The low trapezoidal *stomion* opened directly onto one of the excavated depressions, prompting an awkward crab-walk to enter. The location of that initial depression is oddly located at the inner edge of the *stomion*, noteworthy in its absence at other tombs on site.

Risk of injury and further collapse limited access to the VT68 vault. The model performed admirably despite restricted views into the far corners of the vault, partially obscured by the overhanging ledge of the ground surface. Some sparse cloud gaps occur in the far wall where camera angles could not be easily obtained. In their current form, the total volumes for VT67 and VT68 are 22.06 and 25.15 m^3, respectively. This translates to expected excavation costs of 199-265 and 227-302 ph, or 6 and 7 days for 10 labourers, respectively. Those costs are not expected to deviate drastically from the completed form of the tombs. If anything, the openness of their partially collapsed shapes inflates their volumes and excavation costs slightly. Adjustments were made in cropping the model to render a faithful estimate, as quick estimates show an overly large 62 m^3 for both tombs.

Given the proximity of VT67 and VT68, construction of the later tomb must have proceeded with at least some knowledge of where the earlier one lay. Measurements need not have been known exactly, but estimates are more palatable than blind luck in

Figure 4.3.33. VT67 entrance, facing south-southeast.

determining acceptable limits for a new tomb. Otherwise catastrophic structural failure would have threatened both the new and old tomb in the short-term. Whatever the case, the tombs were indeed placed too close together, as the current interconnection through partial collapses suggests. Roman use of VT68, evidently as a house based on recovered finds (roof-tile fragments, pottery, glass, and a bronze coin), destroyed the earlier burial layer and further complicated the shape of the tomb, which Kolonas (2009b: 26) suggested would have been four-sided if not for two overlapping tombs (VT67 to the northwest and, presumably, VT U2 to the northeast).

Voudeni Tomb 69

Among the smaller of the exceptional size class of tombs (TRex 1.85), VT69 is located in the southwest part of the cemetery downslope of the main path (Figures 4.3.34, A3.73). A bottleneck *stomion* opens into a deep-set vault (32.1 m^3) with a rectangular base and transitional roof between a pyramidal and incline-vaulted shape that closely mimics an overshot *tholos* ceiling. Much like the larger VT53, VT69 forms a hybrid shape between the house and hive types. The relatively short but deep *dromos* adds 19.1 m^3 to support the tomb's total volume of 51.2 m^3. Isolated slumping has altered the angle of the *dromos* at the surface of its north-eastern flank (left when facing). Expected excavation costs are 461-615 ph or 13 days for 10 labourers.

Voudeni Tomb 70

Parallel and adjacent to the southwest of VT69, VT70 is deceptively less than half its size, with a total volume of 25.3 m^3 (Figures 4.3.35, A3.74). One notable feature from VT70 is a scooped-out, hull-shaped floor of the *stomion* that is lower than the adjacent *dromos* and vault. Although their purpose is unclear, similar floor depressions stretching

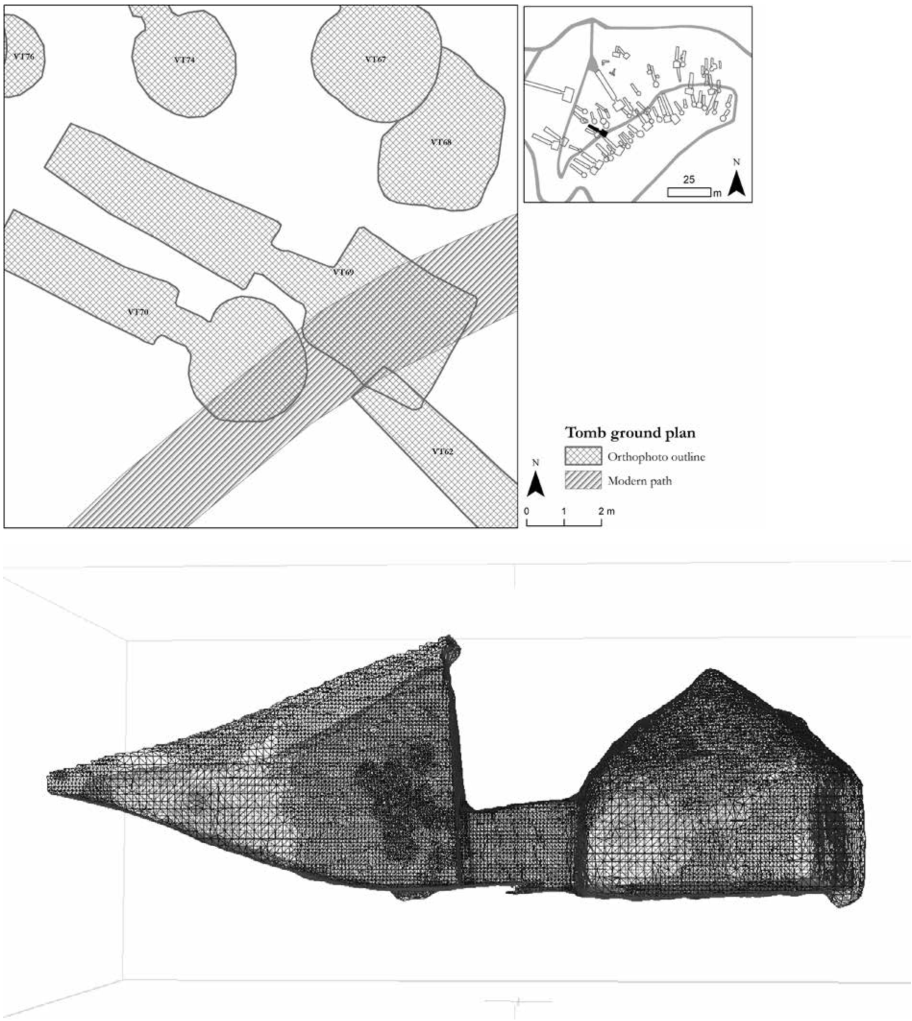


Figure 4.3.34. VT69 ground plan and wireframe model (northern cross-section).

across thresholds – mostly in LH I-II Messenian *tholoi* at Peristeria, Tragana, and Routsi – have been organised into a typology (Papadimitriou 2015: 89). The volume of VT70 is fairly balanced between the relatively short *dromos* (11.4 m^3) and the rounded chamber with its intact, incline-vaulted roof (13.9 m^3). Expected excavation costs range from 228-304 ph or 7 days for 10 labourers.

Voudeni Tomb 71

VT71 opens directly onto the lower main path in the south-western part of the cemetery (Figures 4.3.36, A3.75). The path cuts off the entrance to the *dromos*, creating a steep ledge that demands roped entry. The *dromos* continues from that ledge into a short and steep wedge. The VT71 chamber shows a rounded base with the remains of an incline-vaulted roof that has slanted due to an alarming interior slumping from the *dromos*-side of the vault. Three possible excavated burials or features mark the floor

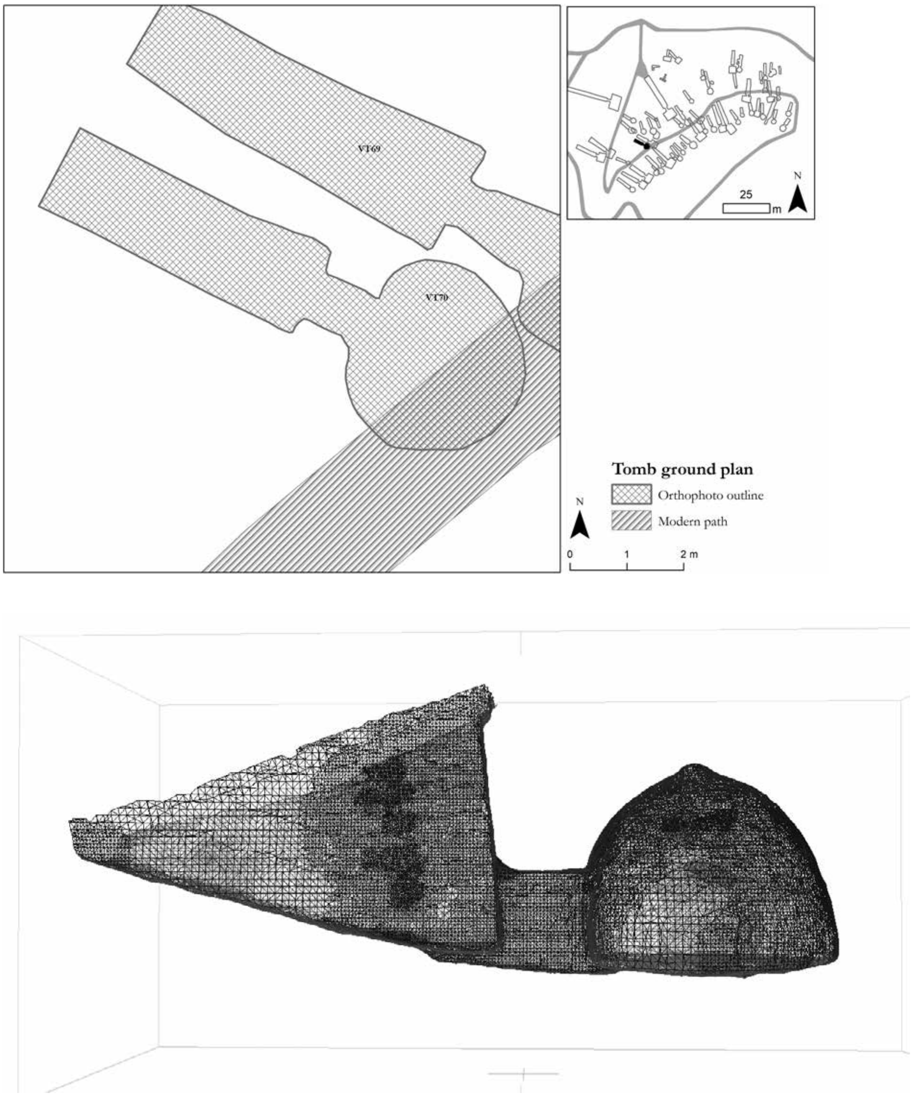


Figure 4.3.35. VT70 ground plan and wireframe model (northern cross-section).

at the centre and northeast vault edge (left when entering). Volume measurements show 15.5 m^3 (*dromos*), 12.8 m^3 (vault), and 28.3 m^3 (total). Expected excavation costs for VT71 are 255-340 ph or 7 days for 10 labourers.

Voudeni Tomb 72

Adjacent to the northeast (left when facing) and parallel to VT71, VT72 is also cut off by the lower main walkway (Figures 4.3.37, A3.76). The *dromos* is very steep and also required roped entry. The vault is similar in form to that of VT71, only smaller and without the slumping ceiling, showing a rounded base and incline-vaulted roof. Volume measurements reflect 8.56 m^3 (*dromos*), 8.55 m^3 (vault), and 17.11 m^3 (total). Expected excavation costs range from 154-206 ph or 5 days for 10 labourers.

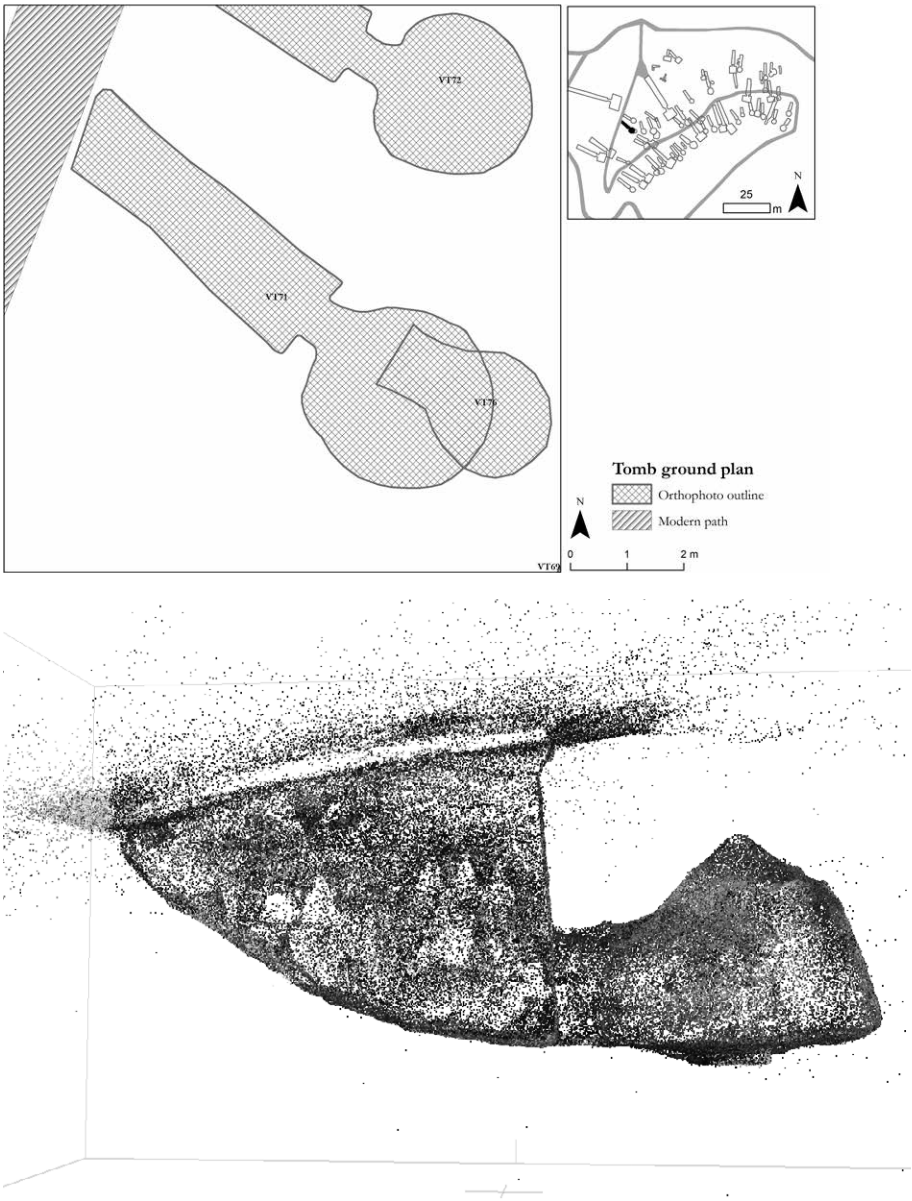


Figure 4.3.36. VT71 ground plan and sparse cloud model (north-eastern cross-section).

Voudeni Tomb 73

VT73 is a relatively intact undersized tomb (TRex 0.39) in the west group (Figures A3.77-A3.78). The chamber has a rounded base with an incline-vaulted roof slumping from the *dromos*-side toward the interior. The cragged ceiling gives the impression of a multi-peak profile that was likely much smoother upon completion, before stress fractures caused isolated linear collapses of the roof. The floor of the *dromos* slopes gradually toward the *stomion*, contrasting with a parabolic upturn at the ground surface as the slope steepens

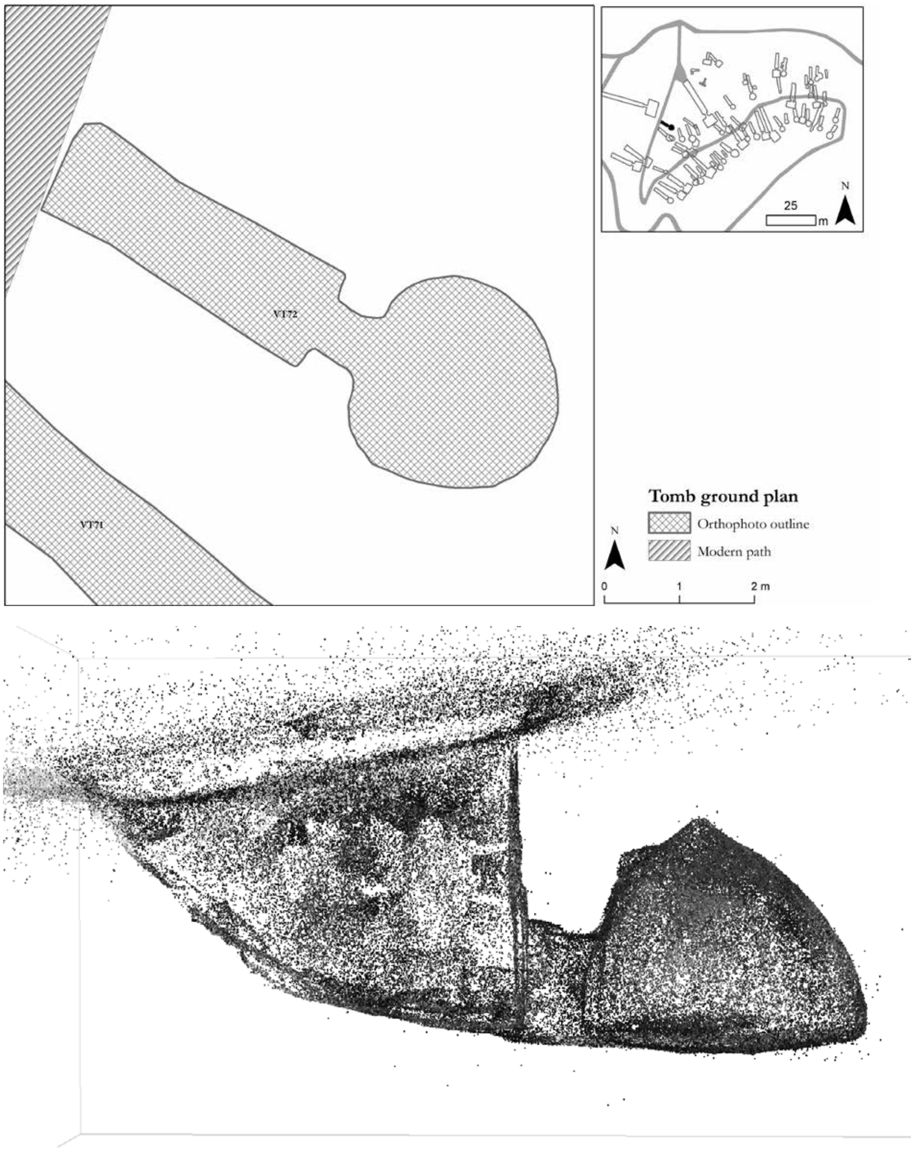


Figure 4.3.37. VT72 ground plan and sparse cloud model (north-eastern cross-section).

above the vault. Volume measurements are 7.49 m³ (*dromos*), 3.39 m³ (vault), and 10.88 m³ (total). Expected excavation costs are 98-131 ph or no more than 3 days for 10 labourers.

Voudeni Tomb 74

VT74 is a shallow, open-air collapsed tomb in the west group (Figures A3.79-A3.80). In plan-view, the vault follows the shape of a hatched egg, with a jagged opening at the former *stomion*. Topsoil cut away from the eroding marl gives the familiar halo effect around the tomb at the surface. Enough of the slumping right flank of the vault (upon entering) is preserved to suggest a former vaulted or arched roof. Chamber orientation offsets slightly to the left of the *dromos* line when entering the tomb. An ovoid depression near the far wall (interior opposite *stomion*) could indicate an excavated feature or grave. Part of the stone-and-earth fill blocking the *stomion* remains between two balks. Volume measurements are limited by the tomb's poor preservation but still provide a sense of the reduced scale of the tomb (TRex 0.38), with a diminutive *dromos* (2.2 m^3) and incomplete vault (8.35 m^3). Given the shallowness of the tomb, labour investment should not rise substantially above the estimate provided for the remaining portion of the tomb. At 10.55 m^3, expected excavation costs for VT74 range from 95-127 ph or 3 days for 10 labourers. Additional volume for the missing upper part of the tomb would add no more than a day to excavation.

Voudeni Tomb 75

Built in the late fifteenth century (LH IIIA1 period, ca. 1425 BC; see Figure 1.1), VT75 is the largest tomb by volume on site and one of the few tombs reused for burials in the final phase of the cemetery's use around 1050 BC (Kolonas 2009b: 29; Figures 4.3.38, A3.81, this volume). It is also singular in its location among the mapped tombs, being the furthest west, on the shallowest slope, with the lowest elevation, and oriented more toward the west than the north. For all its grand scale, it is surprisingly only 16 m^3 larger than VT4. At the base of the long and wide VT75 *dromos*, a tall *stomion*, likely once flat at the top, opens into a cavernous vault with a rectangular base and pyramidal roof. Both the upper *stomion* and vault had partially collapsed by the time of the tomb's excavation, but enough remained to suggest their shape (Kolonas 2009b: 27-29).

Six niches were cut into the *dromos*, including one miniature facsimile of a chamber tomb sealed high in the trapezoidal façade above the *stomion* (Kolonas 2009b: 27). All apart from the sealed façade niche were found empty and apparently disturbed (Kolonas 2009b: 27). Dry-stone walling blocked the *stomion* and the miniature one above it, but the remnant of a door frame painted red is noteworthy here (Kolonas 2009b: 27-28). Painted elaborations on *stomia* may have been quite common for *tholoi* and similar exceptional chamber tombs, with other notable examples at Asine, Deiras, Kokla, Mycenae, Prosymna, Tiryns, and Thebes (Demakopoulou 1990: 113, 115).

The main chamber of VT75 contained nineteen burials and notable finds including amber and carnelian beads, boar's tusks, bronze weapons and fibulae, ivory plaques, painted stirrup jars, tin-plated *kylikes*, and sealstones (Kolonas 2009b: 29). The finds led the excavator to assign the tomb's initial construction to an LH IIIA1 leader of the nearby settlement, though the tomb's final use came four centuries later in the Submycenaean period (Kolonas 2009b: 29).

Many of the elaborations recorded during excavation are now difficult to detect. An apparent layer of thin concrete plaster overlays most surfaces in the *dromos* and vault, giving an artificial impression of superb preservation. One significant drawback to that uniformity came in modelling, as camera alignment has fewer defining features to orient locations. The large wood-frame awning protecting the tomb also limited photo angles from above the *dromos* where the surface rises nearly to the awning itself.

Kolonas (2009b: 27-28) recorded tomb measurements from VT75 as follows: 21.5 m length, 1.75 m average width, and 6.70 m maximum height for the *dromos*, 1.90 m (base width) and 0.81 m (top width) for the façade, and 7.97 m by 4.14 m for the chamber, with no height given presumably due to the collapsed ceiling. These measurements compare favourably with those recorded using the photogrammetric model, deviating within acceptable limits that do not override considerations of total

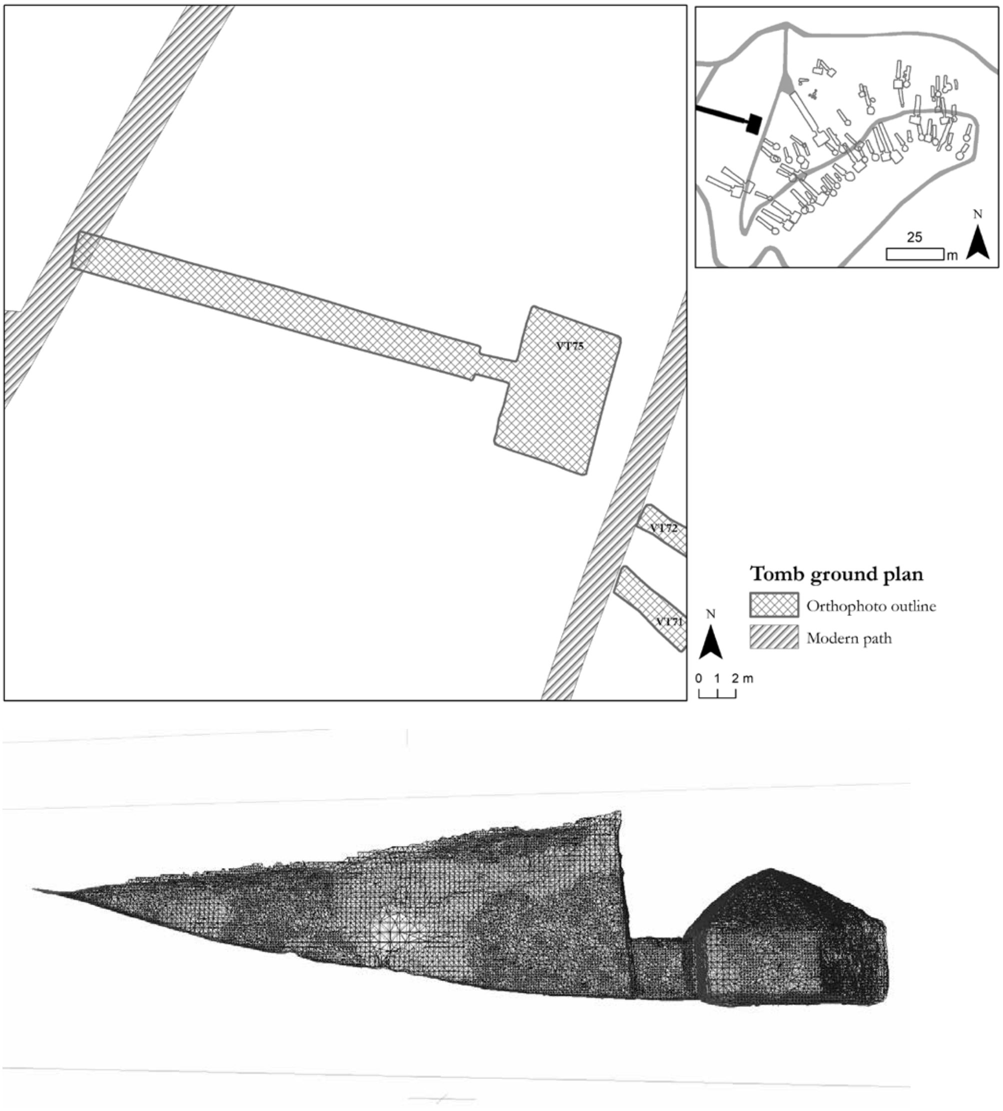


Figure 4.3.38. VT75 ground plan and wireframe model (northern cross-section).

volume (see Tables 4.1 and A1.3). Volume measurements from the photogrammetric model reflect 118 m^3 (*dromos*) and 139 m^3 (vault), totalling 257 m^3. Expected excavation costs are 2,313-3,084 ph or 62 days for 10 labourers, an investment over nine times the recognisable standard. Apart from VT4 (TRex 8.67), no other tomb at Voudeni approaches this scale of investment. Even without quantifying the volume or labour involved, VT75 feels grand enough to provoke awe from observers. Dampened perhaps from visiting the Treasury of Atreus at Mycenae in the year prior, our own enthusiasm upon entering VT75 for the first time bubbled over into typical expressions of amazement. That VT75 falls far short of the scale of investment at the Menidi *tholos* (TRex 22.27) was even more shocking, as the two tombs felt similarly imposing when standing within them.

Figure 4.3.39. VT77 entrance, facing southeast.

Voudeni Tomb 76

VT76 is a diminutive pit in the west group with a shallow hint of a *dromos* (Figures A3.82-A3.83). It has the familiar halo effect of topsoil cut back from the marl edge, and a vault with a rounded base. No other identifying features remain of the original form for the collapsed, uncovered tomb. The tomb's position above the vault of VT71 may have been limiting if VT76 was a later addition. In any case, it is difficult to imagine construction of one not taking into account the position of the other. Volume measurements show the weak signature of the *dromos* at only 0.88 m^3, leading into the remains of a shallow vault (1.5 m^3) for a total volume of only 2.38 m^3 (TRex 0.09), the second lowest recorded at Voudeni outside of the individual pits of the cluster modelled with VT33. Expected excavation costs are 22-29 ph or no more than a few hours for 10 labourers.

Voudeni Tomb 77

VT77 lies in the west group adjacent to the northeast of its nearest neighbour VT78 (Figures 4.3.39-40). From the surface, the tombs appear to be paired deliberately with similar *dromoi* on parallel west-northwest orientations. Their vaults overlap corners slightly, with a partial wall collapse upon entering VT77 in the right-front flank leading into the lower vault of VT78. The deep *dromos* of VT77 leads into a vault with rectangular base and pyramidal roof losing its shape to line fractures that create the Saturn effect of a partial dome, similar to those labelled as arched with grooved sidewall. Kolonas (2009b: 30) suggested, based on similar tombs, that the ceiling originally had a *hypotholion* since obscured by minor collapses. Five primary burials (all on the chamber floor and disturbed) and a scatter of other remains were found alongside "vases, beads of gold and glass, spindles, bronze pincers and a bronze knife", leading Kolonas (2009b: 30) to assign a date range of use from the LH IIIA1 to the Submycenaean period. A niche was cut into the upper portion of the trapezoidal façade but was found empty (Kolonas 2009b: 30). Volume measurements show 52 m^3 for the *dromos* and 44.4 m^3 for the vault, totalling

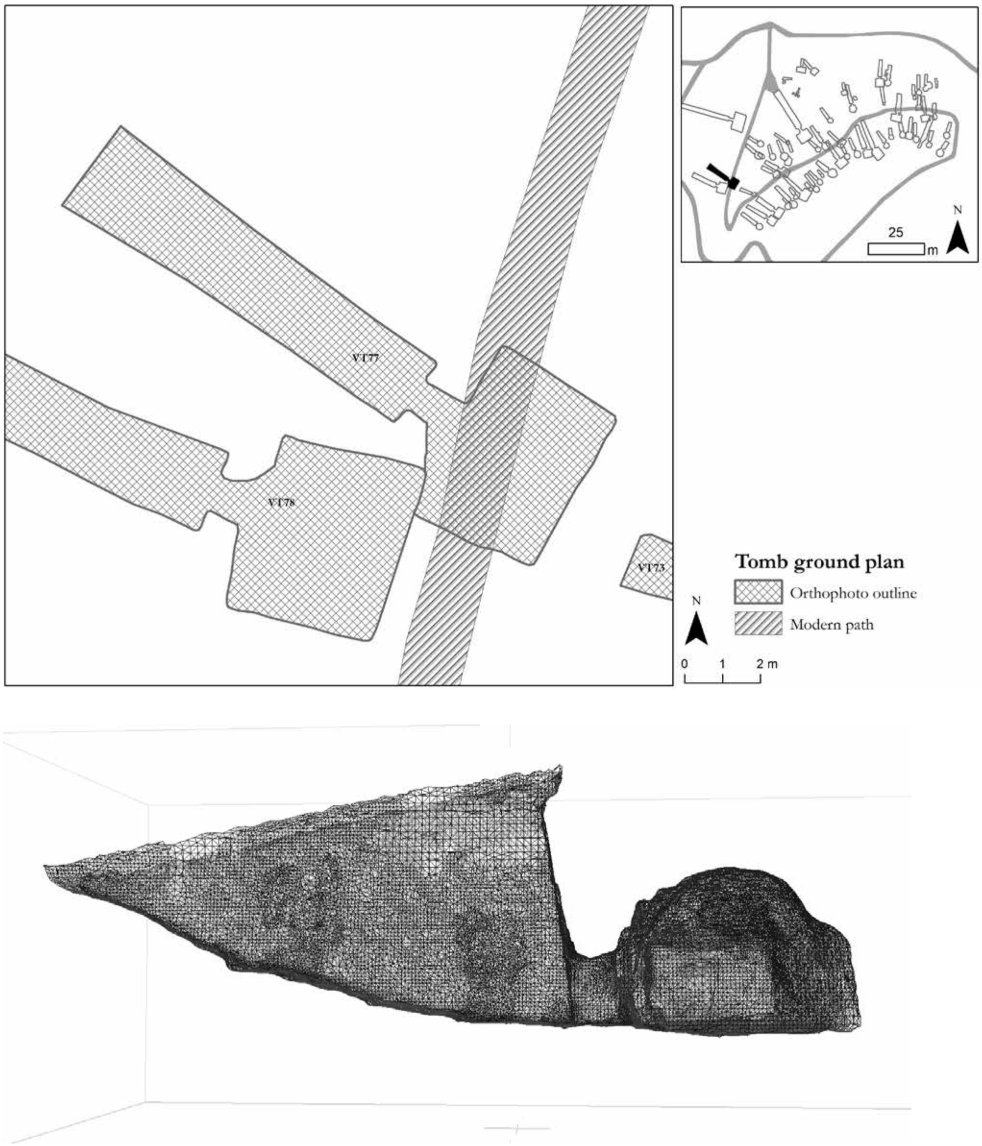


Figure 4.3.40. VT77 ground plan and wireframe model (north-eastern cross-section).

96.4 m³. Expected excavation costs range from 868-1157 ph or 24 days for 10 labourers, an exceptional investment nearly 3.5 times the standard.

Voudeni Tomb 78

VT78 is the lower right, larger twin of VT77 when facing the tomb openings (Figures 4.3.41, A3.84). Apart from a lower and larger vault that veers slightly north of the *dromos* orientation, VT78 shares many of the same characteristics with VT77. The final third of the *dromos* floor nearest the *stomion* steepens with a slippery and weathered surface. Someone has attempted to remedy this loss in traction with a few rotting wooden boards, but the damage from water infiltration was ongoing at the time of survey. The vault has a rectangular base and pyramidal

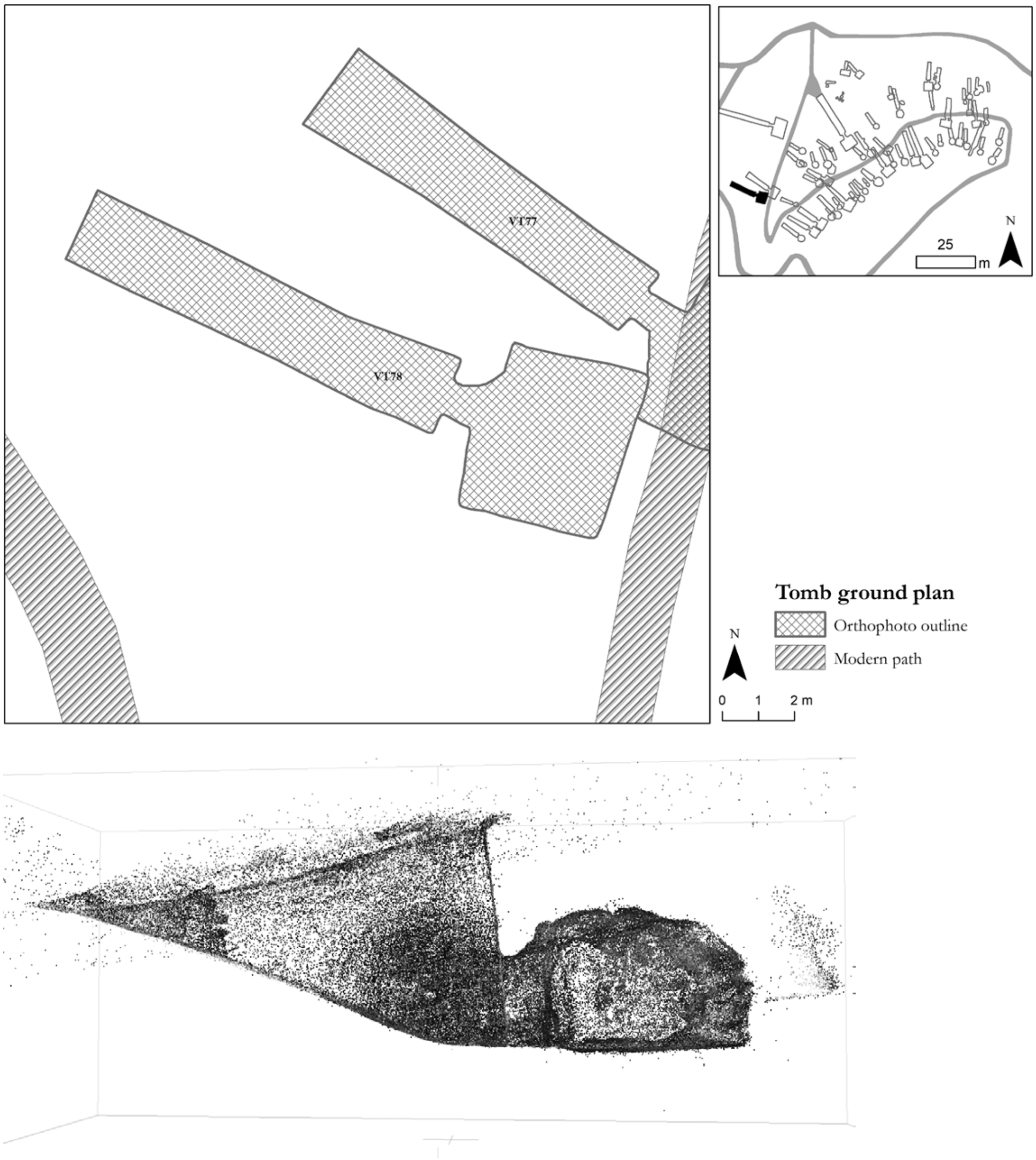


Figure 4.3.41. VT78 ground plan and sparse cloud model (northern cross-section).

roof leaning toward the *dromos*. Line fractures in the roof impart characteristics of arched and incline-vaulted shapes and may eventually alter the shape away from the pyramidal outline. A partial wall collapse leads into VT77 in the back-left flank of the vault as viewed from the *stomion*. Volume measurements for the *dromos* are nearly identical to that of VT77, at 51.4 m^3. The vault is larger at 54.6 m^3, creating a balanced volume across both features totalling 106 m^3. Expected excavation costs are 954-1272 ph or 26 days for 10 labourers, only two days more than VT77. Since simultaneous construction is almost certainly out of the question, the investment difference between the two tombs would likely go unremarked.

Voudeni Tomb (U2-U3)

See Appendix 2.

4.4. Summary

Overall, tomb modelling with a relative index of labour rates and photogrammetric measurements has shown potential for future rapid applications of architectural energetics (see also Chapter 3, section 3.4). By comparing similar tomb types with the tomb relative index (TRex), deviation from a recognisable standard in scale and shape highlights assertive practices by an influential few. For example, commissioners of the Menidi *tholos* made an unmistakably bold choice in building a tomb more than 22 times the scale of a standard chamber tomb and up to 71.5 times the cost (AA01, 27.75 m^3, 333 ph). The regional elite at the Mycenaean cemeteries of Voudeni and Portes, however, opted for more muted expressions in tomb scale, deviating by no more than 9.26 and 2.18 times larger than the AA01 standard, respectively. Undersized tombs (TRex < 0.75) at both sites echoed the designs of their exceptional neighbours (TRex > 1.5), allowing for cohesive expressions of mortuary tradition without straining the resources of less influential families.

Balancing those shared, broad-stroke characteristics, key differences appear in construction practices between Portes and Voudeni. Chamber tombs at Portes generally adhered to rounded, hive-like vaults, steep and narrow *dromoi* with restricted lengths (less than 9 m), and total volumes not more than twice the site median for intact chamber tombs (MedT$_P$ of 31.6 m^3). Chamber tombs at Voudeni, on the other hand, exhibited eight different vault shapes (Kolonas 2009b: 13; Figure 4.3.3, this volume), erratic *dromoi* lengths (from 1.2 m at VT76 to 23.4 m at VT75), and total volumes veering from the median AA01 standard by 0.18-9.26.

Chapter 5 will explore possible reasons behind these differences, including site layout and development factors briefly outlined here. Chamber tombs at Portes centred around earlier tumuli, clustering along a relatively flat ridge top inviting steeper entrance passages to obtain a stable depth for their rock-cut chambers. Further from this central cluster, chamber tombs took advantage of the slope for more gradual *dromoi*, nearly flat in some cases (PT11 and PT12). Similar to its tumuli influencing tomb location and *dromoi* shape, the Portes chamber tombs likewise may have drawn inspiration for their hive-like vault shape from the site's two earlier *tholoi*.

Without local tumuli and *tholoi* influencing the layout of its chamber tomb cemetery, the more expansive hillside at Voudeni hosted long, gradual *dromoi*, as well as those that dropped steeply where the slope flattened. Both house-like and hive-like vault shapes were built with no apparent clustering preference. The largest chamber tombs at Voudeni encouraged longer, wider entrance passages leading toward dramatic facades deeply set into the hillside, amplifying the sense of scale for those entering the open tombs. That scale was further enhanced for the largest tombs by greatly increasing the dimensions and cost of passages, thresholds, and burial chambers.

In broad terms of labour investment, some tomb builders at Voudeni either had wealthier commissions than those at Portes or had more freedom in deviating from an acceptable scale (see Chapter 5). At least 10 tombs at Voudeni exceeded the scale of the largest intact chamber

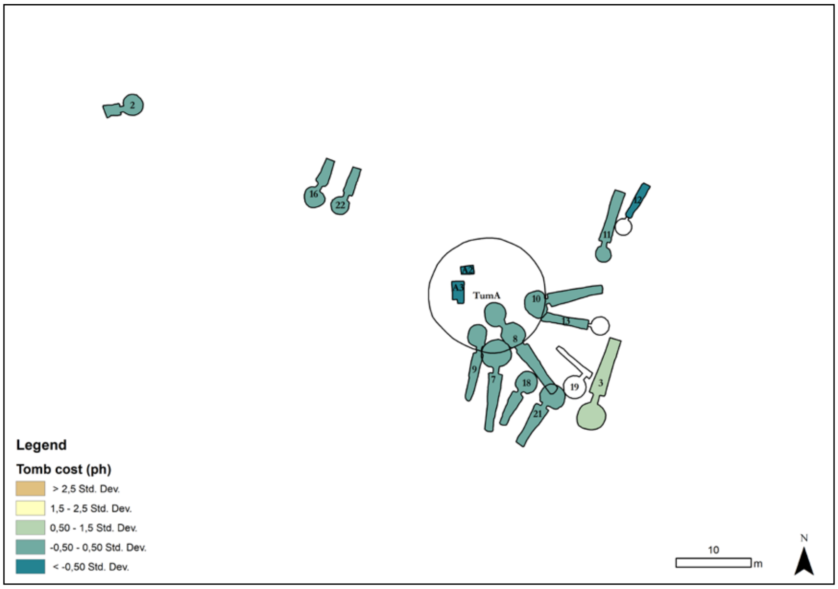


Figure 4.4.1. Map of Portes (main cluster) showing the distribution of tomb costs (ph) by standard deviation. Tombs without shading were not included due to incomplete modelling.

Figure 4.4.2. Map of Voudeni showing the distribution of tomb costs (ph) by standard deviation.

tomb at Portes (PT3) (see Tables 4.3 and A1.5). Two of these (VT4 and VT75) are more than four times larger. While intact chamber tombs at Portes rarely required more than two weeks for teams of 10 in expected excavation cost models, the largest chamber tombs at Voudeni could have needed up to two months (see Table 4.2 and A1.4). Where possible given the cramped working spaces, this likely manifested in larger labour teams, significantly dropping the estimated calendar time to completion, but the expected difference in investment still holds. Mapped examples show the locations of tombs alongside their relative costs (Figures 4.4.1 and 4.4.2). Combining cultural context with the theoretical framework outlined in previous chapters, the following chapter evaluates these tomb models in terms of their signalling and mnemonic potential for recurring designs and standards of scale.

5

Reminders

"Old age hath yet his honour and his toil;
Death closes all: but something ere the end,
Some work of noble note, may yet be done,
Not unbecoming men that strove with Gods."
Excerpt from Ulysses by Alfred, Lord Tennyson (1842)

Before death's veil no labour ends, and it may yet be carried forward by others to lengths unforeseen. I opened with a quote from the perspective of Telemachus mourning the lost glory from his absent father who lacked a tomb, and I close with one defiant reference to Odysseus two and a half millennia later. Since my catalogue of individual tombs and clusters narrows focus nearly to the exclusion of the surrounding reality (Chapter 4), it is important to conclude with a broader view. The tombs at Menidi, Portes, and Voudeni must operate, ironically, within a lived experience (*sensu* Alcock 2016: 5; Boyd 2002: 18-19; Dakouri-Hild 2016: 14-16). From the start (Section 1.1), I posed four sets of questions assessing how tombs fit in the lives of commissioners, builders, and witnesses, through their design (Q1), burden (Q2), memorial (Q3), and perception (Q4). Perception more or less attempts to summarise the others emically, and memorial is tenuously proxied by ethnographic and historical analogies.

Design and burden at least are measurable and mutually intelligible using architectural energetics, collective memory, and signalling (Sections 1.1 and 2.3.1). A tomb is unquestionably costlier, for instance, when hypothetical teams of 10 labourers spent a month (VT25, TRex 4.55) cutting the outline of one versus only a week for another (VT71, TRex 1.02). This is as clear to us as it would be to planners standing outside the *dromos* in 1400 BC. Blocking direct visual comparisons, the tripartite design of Mycenaean chamber tombs and *tholoi* rely on collective memory to replicate hidden chambers and thresholds (*stomia*). When opened, the exact size of comparable *stomia* may not have mattered, but crawling into one (VT6, Rex_sh 0.89) obviously differed from walking upright into another (VT4, Rex_sh 2.41) (for other embodied spatial analyses using Mycenaean tombs, see Papadimitriou 2016a, 2016b). Poorly lit burial chambers assaulted the senses when re-entered (Boyd 2002: 62-63, 2016: 63-64; Galanakis 2016a: 194; Hamilakis 2013: 131-132), amplifying the memory of the experience but weakening opportunities for visual learning from older vaults. Even so, four-sided vaults were a deliberate departure from rounded chambers (Kontorli-Papadopoulou 1987: 145-147), just as conglomerate masonry was a deliberate, costly choice for the largest *tholoi* at Mycenae (Wright 1987: 177-179). Whether a diminutive chamber tomb like VT3 – easily built by a pair of labourers in a few days – or an exceptional *tholos* like Menidi – demanding multi-yoke wagons hauling stone for weeks – investment opted for subordinate or superior signalling to rivals and peers. Signals can be cast as (1) cooperative, cohesive, and underwhelming, (2) pragmatic, contextual, and standard, or (3) competitive, assertive, and exceptional, repetitive terminology for a dealer's choice that amounts to the same deck of cards. In short, tombs either conveyed solidarity or were deliberately deviant.

As part of the SETinSTONE project, I sought to clarify communal burden concerning Mycenaean multi-use tomb construction, while others posed similar questions of fortifications, infrastructure, and subsistence (Boswinkel forthcoming; Brysbaert 2013, 2015a, 2015b, in progress-2020; Brysbaert et al. 2018; Timonen forthcoming). Isolated, none but the largest built tombs of Mycenae and Orchomenos would challenge the level of investment seen in the other categories (Cavanagh and Mee 1999; Harper 2016). Less influential sites like those under study here attempted similar conspicuous mortuary expressions within their means. Since most costly *tholoi* and large chamber tombs were built during the LH IIB-IIIA periods, however, their compounding costs could interfere with ongoing efforts elsewhere, amplifying the communal burden by diverting resources and depleting the available labour pool. Oxen teams needed for ploughing fields and hauling large stones would especially feel rising demand from concurrent tasks (Brysbaert 2013: 81-82; 2015b: 101-102). Individual tombs posed no threat unless an ill-timed investment overshot social constraints and exposed local readiness. Tomb commissioners risking noticeably higher scales of investment – greater than 1.5 times the standard (TRex > 1.5)– wagered communal support for familial or corporate legacy, a gamble that I have framed here as a dialectic of costly signalling and altruism.

Further to the risk of scale could be the group identity proclaimed by tomb shapes. Breaking with tradition to build a *tholos* in place of a tumulus, a chamber tomb in place of a *tholos*, or a house-type chamber in place of a hive-type chamber tomb was a risk in itself. Succeeding generations at Portes opted for many tomb forms in close proximity, anchoring the new within the memories and traditions of the old. Despite that generational will to adopt new styles, a conservative local bond seemed to encourage superpositioning and close repetition for the scale and shape of its chamber tombs. Voudeni by contrast built anew, focusing on chamber tombs and loosening restrictions as to which chamber shapes to follow. Individuals continued to experiment with architectural styles and flourishes, but the overall progression of form acknowledged an idealised shape for what a standard tomb should look like for each generation, carefully curated by collective memory and reproduced through mimetic design. Centuries of reuse down to the troubled LH IIIC period hint at the strength of those memories, as well as the apparent comfort found in a fading past.

5.1. Building legacy in the early LH

Group-planned and group-built, multi-use tombs reflect relationships forged elsewhere, in or on settlements and ships, forests and fields, highways and homes (e.g., Hope Simpson and Hagel 2006; Mason 2007; Timonen forthcoming; van den Berg 2018). The strength and variety of those relationships influenced tomb scale in a similar way to the prestigious offerings that passed between regional players (Voutsaki 1997: 39, 2001: 204). Larger tombs could invoke patronage as well as kinship, which even the least of multi-use tombs must have included in processions if not the passages and chambers (Boyd 2015a: 216, 2016: 65; Papadimitriou 2015: 104). MH III-LH I cemeteries and tumuli at least seem to be structured around kin groups (e.g., Papadimitriou 2016b: 339, 342). Whether LH II-III tomb commissioners and builders themselves were related by blood or business, recollection of construction deteriorated quickly into myth or oblivion (in the Mycenaean case, e.g., Brysbaert 2013: 86; Zangger 1994: 192; more generally on collective forgetting, e.g., Bindman 1999: 93; Forty 1999: 7-10). No known written media preserved Mycenaean eulogies or prayers, and the Homeric epics were not recorded for another 400 years (Palaima 2008: 346, 354-355). Centuries of tomb use anonymised all involved, to be reanimated and relabelled in reuse (e.g., Antonaccio 1994: 407; Cavanagh and Mee 1978: 35; Hamilakis 1998: 128; Paschalidis and McGeorge 2009: 81-84; on the general phenomenon of forgetting the dead, see Allard 2018: 117-118, 123, with references; Hallam and Hockey 2001). Atavistic memories, reversions to a vague ancestral world, have a long reach partly from the amplitude of the architectural signal – in the case of tombs, investing in future generations with the sunk costs of imagined past connections (Cavanagh 2008: 340; Dabney and Wright 1990: 52; Papadimitriou 2016b: 344; Voutsaki 1997: 38). Similar atavistic potential was found by Larsson (2010) in the 600-year upkeep of a ceremonial stave building in southern Sweden during the first millennium AD.

The underlying theories being well trodden (e.g., recent bibliographies on signalling in Conolly 2017; mnemonics in Lillios and Tsamis (eds) 2010; and architectural energetics in McCurdy and Abrams (eds) 2019), my contribution combines labour investment and architectural signal into a measurable index. The index is meant to resonate with builders, direct witnesses, and those who 'remember' second-hand through stories of the events or rediscovery of forgotten features. Investment has been expressed here through labour models, where energetics and signalling propose how tomb shapes and scales were perceived by those who used them. Thus the four research questions from Chapter 1 querying design, burden, memorial, and perception are repacked into that measurable index of relative cost and risk.

The labour models (Chapter 4), taken together as an index of relative investment or burden (Table 4.3), target two questions assessing perception risks for Mycenaean tomb commissioners. How big or different could a tomb be before witnesses felt alienated, and would a deviant tomb be perceived more readily as unfair (by inferiors), unbecoming (by superiors), or unfamiliar (by peers)–similar to comparisons of mortuary feasting (Borgna 2004: 263-264; Hamilakis 1998: 118, with references)? My over-simplified answer to these has been to classify tombs using a relative index (TRex, Tables 4.3 and A1.5). Tombs larger than 1.5 times the median standard (AA01) are exceptional, assertive or costly signals by local officials to promote factional authority. Tombs less than 0.75 times the standard are undersized, cohesive or group signals not meant to elevate users beyond others. Tombs between 0.75 and 1.5 times the standard are pragmatic and could be interpreted either way depending on the scale of nearby tombs. This arbitrary classification of scale appears flat without imagining each choice as a loaded decision made by real actors. Tomb builders coordinated with highly connected commissioners, either conservatively adhering to previous patterns or risking costlier designs. Commissioners of new tombs largely made that choice in the prosperous fifteenth and fourteenth centuries BC, when display secured the position of future generations with durable reminders of powerful ancestors who built grand spaces (Cavanagh and Mee 1998; Dabney and Wright 1990; Papadimitriou 2016b;

Voutsaki 1997, 2001; Wright 1987; for later examples in sixth/fifth century BC Thessaly see Stamatopoulou 2016). Claimants to tomb memories who opted for cheaper reuse did so during and after the thirteenth-/twelfth-century upheaval across the eastern Mediterranean, when building anew may have been less tolerable or desirable. Reuse of rock-cut tombs at least would be cheaper and still provide the backdrop of palpable authority over the past, something the more lavish LH IIIC burials – like those found in the large LH IIIA tombs VT4 and VT75 – highlighted *in extremis*. When and how tolerance for chamber tomb construction and reuse constricted adds to the lively conversation over the end of the Bronze Age (e.g., Bennet 2013: 11-13; Cline 2014; Jung 2010: 174-178; Murray 2017; see section 5.2).

Although no less a part of that changing world, local contexts might be less dramatic than the image of fiery destructions consuming palatial centres in the century prior to the final closing of tombs at Portes and Voudeni (cf. destruction layers at Achaean settlements from Aigion, Agia Kyriaki, Pagona, and Teichos Dymaion, e.g., Moschos 2009: 347; van den Berg 2018: 186-188). Late reuse here could speak equally to continuity in a shared past as it would to a contested future (Connerton 1989: 45; Papadimitriou 2016b: 340-344; on the contraction of the LH IIIC economy, see Murray 2017: 247). Relatively inexpensive labour requirements, particularly for standard tombs no larger than 40 m^3 (e.g., VT64, TRex 1.44, 480 ph), were not prohibitive to new investments on their own. Households of modest wealth could spare ten days for ten labourers to build a new tomb, unless dire circumstances of famine, disease, or war demanded complete attention elsewhere. Continued long-distance exchange during the LH IIIC period presents a compelling case for short-term resilience, enough to maintain the major Achaean cemeteries alongside eastern mainland holdouts like Tiryns and Perati (Moschos 2009; Murray 2017: 86-94; van den Berg 2018). Influential households, like those reusing VT4, VT75, and PT3, maintained lucrative Adriatic trade in metalwork (Moschos 2009; van den Berg 2018). Building new tombs would not have posed an economic risk for them, so perhaps it was socio-politically beneficial to reuse older tombs (e.g., Cavanagh and Mee 1978: 44; Papadimitriou 2016b: 344). If the old order was threatened or replaced during the early eleventh-century crises, new or newly assertive players would scramble to own public memory (e.g., Burford 1969: 84-88; Holtorf 1996: 127; Maran 2016: 153; Trigger 1990: 126-127). Claiming "ancestral narratives" in cemeteries legitimised early Mycenaean expansion up to the LH IIIA2 period (Papadimitriou 2016b: 342), strategies that could be extended to LH IIIC reclamation of collective tombs that amounted to four-century palimpsests of bones and offerings. In the case of tombs never used again, this was a final desperate effort.

More than just mnemonic continuity, those tombs reopened in the eleventh century held fifteenth-century architectural memories governing their original shape and scale – remembered blueprints for mimetic design. Practically, mimetic design applied collective memory and cooperative labour to replicate multi-use tombs consistently across regions and generations. Mimetic design determined *how* the tombs were shaped and remembered, but group (cohesive) and costly (assertive) signalling influenced *why* they were built following a certain scale. Both can be measured in evidence-based analyses, such as I have shown in creating the Tomb Relative Index (TRex) of measurements (shapes) and investments (scales). To my knowledge, this is the first time architectural energetics has been combined with collective memory to explore empirically how tombs were shaped and scaled as cohesive or assertive signals. Scales little more than double the regional standard (AA01, ca. 27.75 m^3) and conservative shapes mimicking the hive vaults of earlier *tholoi* prevailed at Portes. This championed a cohesive group message of solidarity, even for the LH IIIC VIPs of the PT3 Warrior Tomb (TRex 2.18). Voudeni, however, allowed up to six variant designs for burial chambers, including house-like vaults more than nine times the standard size. The largest tombs at Voudeni, VT4 (TRex 8.67) and VT75 (TRex 9.26), sent an assertive signal that dared to elevate an individual or family far above their peers. The signal risked a social backlash given its relative cost compared with other tombs, demanding a larger workforce, skilled planning, specialised elaborations, and more than a month of work – a checklist fulfilled to the utmost by the Treasury of Atreus (Cavanagh 2008: 337-338; Cavanagh and Mee 1999). This presumably happened months or years prior to the first death, an occasion that demanded attention and perhaps a reordering of local leadership. Unquestionably a costly signal, the LH IIIA2-B1 Menidi *tholos* (TRex 22.27) telegraphed the wealth and influence of its commissioners to their interregional partners, contacts evident in the diverse nonlocal and expensive assemblage sealed within its vault (e.g., Konsolaki-Yannopoulou 2015: 498; Lolling et al. 1880: 45-48; Stos-Gale and Gale 1982: 479; Stubbings 1947: 3-4; Thomas 1995: 354).

As shown, multi-use tomb styles developed over the course of generations, simplified in the Mycenaean case to MH III/LH I tumuli, LH I-II *tholoi*, and LH III chamber tombs (see Section 2.1). Portes notably built examples of each over six centuries of use and intermixed these with cist tombs and built chamber tombs (see Section 4.2). Only three other clusters (the destroyed Tumulus B and PTh1; PTh2 and D group; and the comparatively distant E and ST groups of built chamber tombs) seem to diverge from the massive Tumulus A and (destroyed) C grouping that attracted the site's largest chamber tombs and the largest recorded built chamber tomb (PC1) known from mainland Greece (see Chapter 4). Other chamber tombs scattered around the site seem more detached but were not always accessible to this survey, limiting claims on a definitive spatial layout. While overlap in usage inevitably occurred, construction of the slow developing tumuli-*tholoi*-chamber tomb legacy at Portes was staggered by generations and the initial construction acts themselves forgotten. That the inhabitants of Portes stubbornly continued to reuse the same cemetery space – even creatively incorporating subsequent tombs into their older counterparts and risking collapse by building too densely – indicates a strong sense of group identity with a conservative tethering to the past. Voudeni, by contrast, built its cemetery anew and almost entirely out of chamber tombs, with more flexibility in *concurrent* construction styles and scales from the LH IIIA onward. Finding an unused slope here was a feat unto itself.

Even as early as the 1970s, catalogue entries for Mycenaean tombs found in and around modern Patras (Tsoukaleika, Vrachneika, Aroe-Samakia, Ano Sychaina [possibly Voudeni; see Chapter 4], Achaea Clauss, Thea, Pavlokastron, Kallithea, Krini, and Gerokomeion) revealed how densely populated and wealthy the area between the Gulf of Patras and Mount Panachaicon was before the LH IIIB/C crises (Papadopoulos 1979: 26-28). Excavated to some extent by Kyparisses but since obscured by modern housing (Papadopoulos 1979: 26), several extensive Mycenaean cemeteries at Aroe and Samakia occupied the hills east of the sixth-century AD Patras castle and the ancient acropolis it destroyed. Although modern excavations have shown Voudeni and Achaea Clauss to be exceptional cemeteries, many of the hillslopes in the area also hosted Mycenaean chamber tombs, which if better preserved and reported could have rivalled the better-known sites (Table 1.1). The phenomenon extends along the southern upland ring surrounding the fertile valleys of lower western Achaea. The Chalandritsa/Katarraktis area in the Pharai region, for instance, is covered with localities for Mycenaean settlements and cemeteries with limited excavation between the 1920s and 1960s. Many of these spawn confusion over typical Greek redundancy in place-names (Aktypi 2017: 1-7; Kolonas 2009a; Papadopoulos 1979: 30-31), but the overall message of extensive Mycenaean activity is clear. For instance, seven Mycenaean chamber tombs were excavated in 1920 by Kyparisses at Rhodia-Bouga (Papadopoulos 1979: 31). There are two LH IIIA/B *tholoi* excavated in 1956 under the Ayios Athanasios entry (also "above Rhodia") which seem to correspond to Kolonas's (2009a: 14-17) introduction to Katarraktis, a locational reference itself for no fewer than five catalogue entries due to the nearby waterfalls and whitewater rapids (cataracts) (Papadopoulos 1979: 30-31). Alongside six recently excavated graves (three built cists, two slab cists, and one pit), Aktypi (2017: 5) mentions "the modern village *Rhodia* (formerly *Bouga*)" in relation to the paired *tholoi*, typically referred to simply as 'the Pharai tombs' for their rich finds now dated to the LH IIB-IIIA and displayed in the Patras Museum. Comparing these with the Portes *tholoi* would be a worthy endeavour for future research into that period, underpublished for Achaea in comparison with Messenia, Laconia, and the Argolid. My focus on the later LH III chamber tombs at Voudeni, Achaea Clauss, and Portes factors largely through ease of access and preservation, since dozens of similar cemeteries once dominated the landscape of western Achaea (Table 1.1). With a noticeable shift in burial practices to simple graves and *pithoi* burials during subsequent periods, Achaean sites are uniquely positioned to show how interests in chamber tomb cemeteries tapered after the LH IIIC period.

5.2. End-stage from LH IIIC Achaea

Isolated as it might be, a mnemonic framework attracts important questions as the curtain fell on the chamber tomb phenomenon at Portes and Voudeni by the turn of the first millennium BC. If the multi-use tombs of the Achaean cemeteries fulfilled their roles as mnemonic vaults for four centuries or more, what happened outside the cemeteries as they entered their final phase of use? What could derail such a long-lived and successful tradition? Contraction is the oversimplified but perhaps no less applicable short answer, stemming from generations of socioeconomic changes (e.g., Murray 2017: 247; Shelmerdine 2001: 375). No single rapid stroke erased multi-use tombs from the Greek mainland – smaller *tholoi* built from schist slabs continued to thrive northward in Early Iron Age Thessaly with 51 examples across 22 sites, the largest being 6.67 m in diameter at Kapakli (Georganas 2000: 53). However short-lived over the long term, several Achaean cemeteries persisted beyond the Mycenaean palatial collapses, even flourishing during the LH IIIC and Submycenaean periods. The following gives a snapshot of important finds from the region that contextualise those who created, witnessed, reused, and finally abandoned the tombs at Portes and Voudeni. A more thorough review can be found in recent literature for these and similar Achaean cemeteries (e.g., Aktypi 2017; Kolonas 1998; Moschos 2009; Paschalidis and McGeorge 2009; Paschalidis 2018; van den Berg 2018).

At the foreground of tombs built or reused late in the Mycenaean period are the social and economic upheavals that unravelled palatial influence and greatly affected larger settlements. Cavanagh and Mee (1978: 44) concluded that reuse of chamber tombs in the LH IIIC period had most to do with unrest and shifting populations after the collapse of the palaces. With notable exceptions like Perati, few wanted to invest in new chamber tomb construction when abandoned tombs were conveniently available where ties to the original family had faded. Even at Perati, new tombs were "on average smaller, more closely packed, less carefully cut and shorter-lived than the chamber tombs of the previous period" (Cavanagh and Mee 1978: 44). Tomb commissioners in the LH IIIC period had more pressing issues than achieving perfect architectural form.

Achaea was no exception. Excavations at the nearby settlements of Agia Kyriaki, Pagona, and Aigion reveal widespread destruction by fire and brief abandonment around the same time as a conflagration engulfed the fortified Teichos Dymaion 50 km to the west (Moschos 2009: 347; van den Berg 2018: 186-188). Destructions by fire here during the final EH, LH IIIB-C, and final LH IIIC periods were noted by Mastrokostas in excavations from 1962-1966, though the site seems to have continued as a fortified settlement until the Venetian period and even had a brief military outpost during the Second World War (Papadopoulos 1979: 24; van den Berg 2018: 186). The LH IIIB/C mainland crises had reached the Gulf of Patras but did not have the same terminal effect as they did on the palatial centres in the southern Peloponnese. The region's power continued measurably into the LH IIIC period, with imported objects of wealth like the Naue II longsword, 17 of which have been recovered in Achaea, appearing in warrior graves (Moschos 2009: 360; see extensive catalogue of objects from abroad recovered in western Achaea in van den Berg 2018: 440-484). New chamber tombs were rare, but the existing large cemeteries, like Voudeni and Portes, served the needs of the communities and newcomers displaced by events abroad (Moschos 2009: 348). Exceptional among the sites studied in Achaea, Voudeni experienced a secondary fluorescence in the Submycenaean period (Moschos 2009: 364) and was a major hub alongside Kallithea for LH IIIC Achaean-Adriatic contacts (van den Berg 2018: 309).

The later dates of use for the tombs in the Achaean cemeteries reinforce early understandings that Mycenaean traditions persisted longer in this region than elsewhere, prompting Papadopoulos (1991: 36) to refer to it as "one of the last strongholds of Mycenaean culture and civilization". Whether the region experienced a sudden influx of refugees fleeing catastrophes in the Argolid or gradual immigration over time is unclear, but no abrupt disruptions occurred until much later (Papadopoulos 1991: 35). Whatever the case politically for the maintenance of long-distance exchange, imported objects suggest that Achaean traders sustained or even expanded their networks for a short time before they permanently foundered by the turn of the first millennium BC (van den Berg 2018). Perhaps not coincidentally, decades of uncertainty manifested in grave goods with distinctly martial overtones, namely the weapons and armour of the LH IIIC Achaean warrior burials.

Fascination with warrior burials has persistently captured public imagination and attracted considerable attention from specialists. Examples can be found throughout the Aegean Bronze Age and Early Iron Age, relating more consistently with elite male status than the biographies of 'real warriors' (Georganas 2018: 189-191, with references; see also Alberti 2004; Preston 2004: 330-331). Martial or not, warrior tombs in Achaea do seem to abound. Of those yielding the iconic Naue II swords, two are known from the Achaea Clauss chamber tomb cemetery near Patras (Paschalidis and McGeorge 2009: 89), ca. 10-13 km over rough terrain south-southwest of Voudeni. These tombs were often equipped with a suite of other weapons and useful instruments, including bronze tweezers potentially deployed as part of a field medical kit meant to extract arrowheads (Arnott 1999: 501-503; Georganas 2018: 191; Paschalidis and McGeorge 2009: 93). Similar high-ranking warrior burials also appear during the LH IIIC period at Kallithea-Spenzes in Achaea (van den Berg 2018: 233-235) and at Palaiokastro in Arcadia (Papadopoulos and Kontorli-Papadopoulou 2001: 132-134). Since no definitive natural boundaries separate Achaea from Elis, it has been suggested to study these districts together alongside nearby north-western Arcadia and its similar cultural materials, forming a Late Mycenaean western koine (Papadopoulos and Kontorli-Papadopoulou 2001: 135). Well-furnished LH IIIC burials from Portes and Voudeni tend to coincide with the larger, more impressive tombs (e.g., PT3, VT4, and VT75), and though I have endeavoured to restrain my descriptions to avoid eclipsing smaller tombs, it is difficult to ignore the disparity in econometric and volumetric estimates (Tables 4.1 and 4.3). The late timing of reuse is intriguing. The tombs themselves were seldom new, and many were centuries old at the time of LH IIIC reuse (Table 4.4).

Secondary burials and reuse of tombs were common in Mycenaean Achaea and throughout the Aegean. Secondary burials of LH IIIA-B date equal the number of primary burials from LH IIIC (62 each, with 5 additional secondary burials from the later period) recorded at Achaea Clauss, with remains either swept to the side, interred in pits under the floor, or placed in an ossuary cut into the wall of a *dromos* (Paschalidis and McGeorge 2009: 81-84). The Messenian Tragana *tholos* tomb A contained a metre deep of funerary deposits with as many as thirty skulls and pottery styles ranging from the LH I to the Protogeometric period (Cavanagh and Mee 1978: 35). Twenty-five individuals were found among the layered LH IIIA-C remains of the Athenian Agora tomb J7:2 (VII). Investigations by Evans revealed 40 skulls and pottery ranging from the LM II-IIIC in the Royal Tomb at Isopata on Crete, prompting his assessment of the tomb's late use as an ossuary (Cavanagh and Mee 1978: 40).

In some cases, similar grave goods also reflect standardised practice in votive assemblages. The sealed tombs excavated at Achaea Clauss indicate that missing or damaged materials from within the tombs occurred during their Late Mycenaean usage, which could include a function as retrievable storage after "the dead were no longer revered or feared" (Paschalidis and McGeorge 2009: 84; cf. Gallou 2005: 18; Tsaliki 2008). As at Voudeni (Kolonas 2009b: 13), pottery found among the human remains at Achaea Clauss also showed consistency with vessel types (namely elaborately painted jars) appropriate for deposition in the tomb in that they mostly comprised closed shapes. Absent generally were vessels for bulk storage and transport, as well as those for serving food. Pouring and drinking vessels were common throughout LH southern Greece (e.g., Boyd 2015a: 211; Hamilakis 1998; Smith and Dabney 2014: 149), alongside stirrup jars and alabastra for perfumed oils and rarer effigy vessels interpreted as feeding bottles for young children or disabled adults (Paschalidis 2018: 401-402; Smith and Dabney 2014: 151; see below).

If the paucity of existing evidence gives any indication of frequency in antiquity, Mycenaean cremation was rare in Achaea as elsewhere. Although evidence from the late 1930s excavations at Achaea Clauss is missing apart from Papadopoulos (1979: 27) mentioning the excavation of twelve tombs here by Kyparisses, later excavations have provided a strong sample of mortuary practices. Of the 129 instances of bodily remains recorded in the 16 chamber tombs excavated from 1988 to 1992, only one cremation was found for a middle-aged male from Tomb N (Paschalidis 2018), dating alongside the LH IIIC primary and secondary burials (Paschalidis and McGeorge 2009: 79-84). Early in the Submycenaean period a cremation has been recorded for Voudeni, with two others at Kallithea: Spenzes and Kallithea: Laganidia, and two more in the Spaliareika warriors' tomb (Moschos 2009: 367).

In addition to robust regional traditions, materials and influence from overseas showed an enduring web of contacts in LH IIIC Achaea, an extensive network analysis for which has been completed by van den Berg (2018). The Balkans, Italy, and Crete are particularly well represented. Tomb H at Achaea Clauss contained a “fenestrated razor” with the closest known parallels at Scoglio del Tonno and Peschiera del Garda (Paschalidis and McGeorge 2009: 85; van den Berg 2018: 203-204). A bronze knife from the Achaea Clauss Warrior 2 burial also conformed to the Peschiera type known from that site near Verona in northern Italy (Paschalidis and McGeorge 2009: 92; van den Berg 2018: 223, 235-236). Two other Peschiera daggers in the region are known from Teichos Dymaion and Voudeni (van den Berg 2018: 253). Stirrup jars with typical Minoan qualities appeared in Tomb A at Achaea Clauss and Tomb 2 at Spaliareika-Loussika (Paschalidis and McGeorge 2009: 87). PT7 at Portes yielded another stirrup jar, and several Minoan vessels appeared at Voudeni. Both Voudeni and Portes also harboured two-handled alabastra (Moschos 2009: 373-374).

Other archetypal funerary deposits known from LH IIIC Achaea included duck-vases or bird *askoi* accompanying child burials, such as PM 12185 from Tomb Δ at Achaea Clauss and its twin found during earlier excavations and thought to be from the same artist (Paschalidis and McGeorge 2009: 96-100). One ‘feeding bottle’ was reinterpreted as an “invalid cup” due to its recovery alongside an adult male burial (Paschalidis 2018: 401-402). Similar feeding bottles and bird vessels have been recorded at Ayia Sotira (Nemea), Prosymna, Perati, and Kallithea-Rampantania (Paschalidis and McGeorge 2009: 100; Smith and Dabney 2014: 151). Clay whorls and bobbins found with the adult female Burial ΣT of Tomb 3 and the sickle attached to the waist of the adult male Burial Z of Tomb B indicate the importance of weavers and farmers interred at Achaea Clauss. Iconic, attention-grabbing grave assemblages were not the exclusive legacy of warriors from the Late Mycenaean period.

Difficult under heavy reuse, contextual clarity concerning chronology of construction and use from associated finds would save labour studies of tombs from being incomplete and monochromatic. Ideally, tombs constructed concurrently would be compared in the absence of noise from tombs constructed decades or centuries before or after. Although used for 75-150 years, comparatively short-lived sites like the six excavated LH IIIA1-B2 chamber tombs at Ayia Sotira near Tsoungiza would be especially fruitful for future labour analyses (Smith and Dabney 2014: 145-146). One defence remains for comparing all tombs wholesale, in that each data point tracks a discrete episode of construction. One tomb should not, unless under extraordinary circumstances, have avoided completion for more than a few months. Each was purpose-built, and dragging construction into a multi-generation affair would be absurd under common scenarios. A scatter plot of tombs constructed, irrespective of their chronological appearance, is still worth examining for the outline of events it portrays. Painting the full picture, however, requires the chroma of context and chronology unmasked from the confusion of reuse.

5.3. Interpreting tomb scale and sameness

Some perspective is necessary to avoid overshooting the evidence if taken out of context. As my primary proxy, tomb building represented only a small fraction of Mycenaean economies. Far more effort was expended in erecting walls (Boswinkel forthcoming; Harper 2016; Loader 1998), building and maintaining domestic and public spaces (Burford 1969; Pakkanen 2013; Walsh 1980), and creating portable crafts and commodities consumed locally or distributed for far-flung trade (e.g., Berg 2004: 74; Broodbank 2013: 415; Murray

2017: 248-250; Voutsaki 1997: 42, 2001: 197; for named examples in the tablets see the late Pylian *po-ku-ta* craftsmen likely exempted from military service, Nakassis 2010: 273). With an estimated cost over a century of building at 240-290 talents – roughly 75% of the yearly internal revenue of Athens – the sanctuary of Asklepios at Epidauros was financed through donations ranging from the pocket change of individual contributors to more than 1,200-*drachmae* gifts provided by the communities of Epidauros and Hermione (Burford 1969: 84-85). Militarism, if as popular as iconographic depictions and warrior burials would suggest, also incurred much higher costs than any tomb could boast. Maintaining troops in the field or ships at sea would cost more in a season than building their barracks and shipsheds at home, a relative cost no less applicable for fifteenth-century Pylos as for fifth-century Athens (Nakassis 2010: 270-274; Pakkanen 2013: 72-74). At roughly 4 talents per year and 100 workers per season–"a minimum expenditure of 1.2 million man-days or 200 talents", enough to support "100 triremes out at sea for a month or somewhat more"–fifth-century Athens could easily build 300 shipsheds at Piraeus in 50 years and still afford the 30 talents per year for the 500-talent Parthenon (Pakkanen 2013: 72).

Although a debatable proportion of local economies, few more widespread manifestations of cooperative preindustrial labour can be found than earthmoving (see Chapter 3). If earthmoving acts as a reliable index of relative socioeconomic strength, then multi-use tombs must convey some sense of local and regional capabilities. Local manufacture is key for the tombs to meaningfully relate to their corresponding settlements. Fortunately, outside help would likely be too infrequent for skewing results with standard chamber tombs that did not depend on instruction like complex *tholoi* (Cavanagh and Laxton 1981: 132). Labour at least would be a local expense, even if the ideas were sourced from abroad. In the case of the Mycenaean *tholos* at Kolophon in Ionia (western Anatolia), "local builders working outside the mainstream of the tholos-building tradition" deviated from the typical shape with a wider entrance compared with its chamber diameter (Bridges 1974: 266). While some interregional coincidences open the door for travelling talent, as Papadopoulos (1987: 139) mused over Aetolian tomb similarity with the Kiperi-Pargas *tholos* in Epirus, it is far more likely for common chamber tombs to have sought their builders nearby. Rumour of similar tombs on the Peloponnese likely influenced construction of the Menidi *tholos* and Portes *tholoi*, but the labour behind their demanding stonework was undoubtedly as locally sourced as the stones.

Capability to build is only part of the equation. It is the hard cap hardly reached, as willingness to build is more easily exhausted and quickly changeable. The two find equilibrium in standards of scale to which most tombs gravitate. Standards of scale – e.g., constraints on overly ostentatious building – show a collective wish to adhere to forms internalised by social and ritual principles (e.g., on standardisation see Berg 2004; Eerkens and Bettinger 2001; Rice 1991; on collective mimetic design with funerary iconography, see below, e.g., Küchler 1999; Rowlands 1993). It is argued here that those standards hold the majority of LH III chamber tombs at Voudeni and Portes on the near side of the spectrum from sameness to exceptionalism. The spectrum here relies on the square symmetrical matrix created for tomb dimensions (see Figures 3.2-3.4), colour-coded to highlight patterns in a similar manner to Bourgeois and Kroon (2017: 10).

Exceptionalism has often underwritten the motivations of a powerful few. For Mycenae especially, unrivalled power and complexity oversaw the resurgent LH III monumental construction program giving rise to the Lion Gate and expanded circuit wall, a refurbished

Grave Circle A, and the final three massive *tholoi* (Genii, Clytemnestra, and Atreus) (Wright 1987: 177). Big tombs were built for those of wealth and (not always royal) importance, a truism with which many have intersected from various roads (Cavanagh and Mee 1998: 56; Dickinson 1977: 63; Mee and Cavanaugh 1984; Trigger 1990: 127). Sameness, however, telegraphs something more than any single personality or small group of personalities can project, a tenacious ideal rooted into the collective memory of many. Tombs calling back to a standard united communities, muting assertive elaborations that alienated public opinion.

Establishing a baseline of sameness and what it could mean to a given community, chamber tomb similarities and deliberate departures implicate which side of the spectrum maintained the upper hand for those constructing chamber tombs at Voudeni and Portes. What becomes immediately apparent from systematic measurements (Chapter 4), despite the two occupying the same region (ca. 90 km from one another) and touting a similar level in the Western Mycenaean koine surmounted by a regional power in the Dyme and Pharai regions of western coastal Achaea, Voudeni and Portes did not share a proprietary sense of appropriate tomb scale. Simply put, the Portes chamber tombs adhered more closely to an ideal of reserved scale, to say nothing of their universal beehive shape. To be sure, the site had experimented with other tomb styles in the centuries prior to the construction of its first chamber tomb, which likely coincided with or followed closely upon the later use of its *tholoi* (see Section 4.2). It also superimposed much smaller built cist graves on Tumulus A and PTh2, roughly concurrently with the construction of chamber tombs from the LH IIIA/B periods. Once chamber tombs had effectively replaced the earlier multi-use tumuli and *tholoi*, however, their shape and scale actively sought a group identity as rigid as their connection to an already ancient cemetery. Surrounding and intersecting tumuli and *tholoi* whose builders were by that time anonymised into an ancestral collective, the later Portes chamber tombs kept a cohesive tradition alive by embracing the ruins of inexorable change. Voudeni, on the other hand, showcased a freedom in form and scale that gave rise to tombs 10 times the median size for the site and more than 200 times the size of a typical pit grave (see below). The chambers also reflected at least eight shapes from house to beehive (see Figure 4.3.3). To some extent, lopsided scales and experimental shapes expressed unconcern with the risks of ostentation. If they did not, then few architectural excesses could do so within the limits that chamber tombs offered. It would be surprising indeed to recover houses two orders of magnitude apart in scale in close proximity, but domestic structures tap into different metrics of functional use, tolerable costs, and visibility (Chapter 2).

Perspective is critical in determining where tomb scale pushed social limits. The smallest tombs could be informative here. Despite sharing some core mortuary functions, pit graves operated differently than their chamber tomb counterparts. Reuse, multiple inhumations, and spectacle, common to chamber tomb construction and function, were not priorities for pit graves. Individuals and immediate use were the more logical focus, though not necessarily applicable in every sense. Excavation of a pit grave could hardly occupy more than a pair of labourers for a few hours, whereas most chamber tombs would demand a team of five or more for several days. Beyond those affected by loss – intensely variable in the anthropological literature on death (Robben (ed.) 2018)–construction and use of a pit grave would go comparatively unremarked by daily life in the settlement a kilometre away. Reduced visibility accompanies reduced investment here, but the circumstance of loss would not cheapen the impact to close family and friends.

Reduced economic investment in smaller tombs may obscure an outsized emotional impact, such as the loss of a child (cf. Allard 2018: 117). In association with nearby chamber tombs, shallow pit graves such as the VT33 cluster have been linked to child burials elsewhere. Seven pit graves with tell-tale funerary deposits but no human remains were recorded for the LH IIIC Perati cemetery in Attica, and four of these had skeuomorphic *dromoi* (Gallou-Minopetrou 2015: 58; Iakovides 1969). It is intriguing that the cluster of open pit graves at Voudeni occurs close to the smallest excavated chamber tomb on site (VT3), also suspected of a connection to juvenile burial.

Large chamber tombs (PT3) that are not excessively scaled (e.g., VT4 and VT75) climb above the practicality and sobriety of standard tombs, yet fall below the risky message of exceptional tombs. PT3 made a statement with its scale, but it was a muted one relative to what might have been achieved (see VT4 and VT75). The projected cost of PTh2 proves that tomb builders at Portes, at least at one point in time, could complete labour-intensive projects that were far more expensive than PT3. It was not for lack of ability that the premier chamber tomb for the site was capped at a modest size. The commissioners of PT3 may have simply wanted to limit extravagance or excessive deviation from the standard. Whether this served in some capacity to enhance or preserve group cohesion is a compelling thought. For Portes, doubling the median may have been seen as extravagant enough.

Even accounting for a plodding pace of work, most multi-use tombs at Portes and Voudeni required minimal time and resources easily managed by extended families and close contacts. Wider networks at one's disposal, while not strictly needed, could further ameliorate the short-term effects of loss. This we know from labour costs typically falling in the four- to six-day range for teams of ten (Chapter 4). Why should that pattern appear? Perhaps it was a target that aligned with group ideals for tomb investment, whereas much larger tombs made an assertive, costly signal from an influential family or individual (Chapter 2). New tomb construction would not likely await death, interfering with the period of mourning and activities away from the tomb. Whether these culminated in a crescendo of eschatological significance punctuated by the tomb's readying, such as re-plastering – or re-opening in subsequent usage – is worth considering. For the LH IIIA2 Prosilio tomb 2 near Orchomenos, Galanakis (personal communication 2019) noted second coatings of clay over the bench within the burial chamber. This surface was only exposed prior to and immediately following the death of the tomb's lone individual, marking anticipatory tomb construction far in advance of an important individual's death. At least two prepared floors of lime plaster were noted in the chamber of Tomb 4 at Ayia Sotira in the Nemea Valley, only visible in the microstratigraphy due to poor preservation (Karkanas et al. 2012: 2731; Smith and Dabney 2014: 148). These were prepared for successive burials and secondary burials – with 8 or 9 individuals placed in different orientations across the floor, or in the case of the older layer, within pits – from the LH IIIA2-B. Two of the burials were judged to be men in their late 30s, with a third in a separate pit identified as "a young woman aged between 16 and 17 years old" (Smith and Dabney 2014: 148). Burials in modern Greece are typically completed within 48 hours following death (Ann Brysbaert, personal communication 2019), a reactionary process accounting for heat and religious imposition. Similar purity taboos surrounding decay and pollution from deviant behaviour, like the Greek mythos for miasma, are common for warm climates – protection against a maddening inevitability that eases with anonymisation of remains over time (Douglas 1966: 176-179; see below). Mycenaean secondary treatment of remains being frequently attested (e.g., Boyd 2015a; Gallou 2005;

Moutafi and Voutsaki 2015; Papadimitriou 2011), contact with the sights and smells of decay would have been unavoidable.

The timing of Mycenaean burials, assumed to be rapid in most cases, would not likely be delayed to allow for the assembly of people or materials appropriate to the memorial of the deceased (cf. Boyd 2016: 61). If the labour models ring true, rarely less than three day/night cycles marked the progress of tomb construction prior to the first interment. Labourers might have required a week or more just to hollow the tomb, which would not account for time to apply finishing touches like the painted entrance seen with VT75 (Kolonas 2009b: 27-28; other examples see below and Demakopoulou 1990: 115; Gallou 2005: 68-69; Sgouritsa 2011: 737-739). For subsequent use, re-opening the tombs could occur as needed following death, requiring less than two days in all but exceptional cases (Table 4.2). Loose fill blocking *dromoi* could be shifted at three times the pace of cutting the rock anew (Chapter 3 § Placement). Exceptionally large tombs like VT4, VT75, and the Menidi *tholos*, may have required more than a week to reopen when fully closed, leaving the possibility for an open display long before the death of the next in line for the family vault. Tolerance would be low for delaying re-opening or hurrying proceedings, as mourners already experienced a heightened sense of passing time for a potentially disorienting loss. In processing the "perpetual absence" of the deceased, grief is not far from rage (Flaherty and Throop 2018: 165-166). Shorter and longer schedules would break continuity, not lightly done for significant life events keenly felt, and remembered, by all.

No matter the timetable of construction, building the tombs echoed the socio-economic standing of the deceased, whose vacant role was purged from memory and replaced within expected limits (e.g., Allard 2018: 118; Battaglia 1990: 196; Hamilakis 1998: 117-118). Building tombs, like 'testimonial memory' in history or revered war memorials, invited direct comparison testing the limits of public expectation and opinion (King 1999: 148, 152; Ricoeur 2004: 21; Rowlands 1999: 129). Limitations on excess acknowledged the risks of alienating others with a garish monument that upstaged neighbouring tombs, sending a message of factional competition evident in mortuary display (Hamilakis 1998: 123-126; Voutsaki 1995: 62; 1997: 44, 2001: 204), as well as tomb type and placement (Boyd 2016: 64-65; Fitzsimons 2014: 91-94; Galanakis 2016b: 162; Papadimitriou 2016b). More influential individuals and sites had a greater allowance, a more forgiving scale for excess among locals as the message was understood to be cast further afield across space and time (e.g., the "far shining" *tumulus* McGowan 2016: 163-164, citing Homer *Od*. 24.80-84; see also Schnapp-Gourbeillon 2016: 206-207). Placed in full view of important routes between sites, monumental *tholoi* with decorated facades and overlying tumuli signalled to much more than local traffic (Galanakis 2011: 226; Mason 2007: 47-48; Wilkie 1987: 128-129). For instance, travellers from Pylos to Pherai (Kalamata) passed Nichoria's largest and best-equipped *tholos* (Wilkie 1987: 128-129). Similarly, the *tholoi* of Mycenae, particularly the later Clytemnestra and Atreus, conveyed a symbolic message of power to a larger territorial audience than the restricted spheres occupied by the Shaft Graves (Mason 2007: 49; Wright 1987: 176). The crowded LH IIA scene of six contemporary *tholoi*, however, further corroborates the suspicion that *tholoi* did not house rulers alone but the heads of powerful lineages (Darque 1987; Mee and Cavanagh 1984).

When opened, VT4 and VT75 signalled a momentous change in the regional political economy. Someone with unmistakable influence was clearly lost when each was built (Kolonas 2009b: 17, 29), and, arguably, each time they were reopened. Closed, however, and the tombs all but disappeared like any other. Only the outline of the *dromoi* or an occasional chamber collapse opening a visible hole would prevent superimposition in the absence of markers (Papadopoulos 1979: 52; tomb collapses may have contributed to the Troubes site name in the Chalandritsa-Katarraktis area of western Achaea, Aktypi 2017: 1). The proximity of tombs like VT67 and VT68 show that avoidance was not always successful, and in the case of multiple burial traditions at Portes, superimposition was actively sought. Chamber tombs here continued a long tradition of intersecting earlier tomb types, engaging with an already distant past and reinventing it as needed in collective memory. Although their locations were apparent enough for builders to avoid them if they wished, chamber tombs did not share the visibility impact of marquee *tholoi* with displayed facades or tumuli "forever calling for attention" (Alcock 2016: 6). Even the mighty Atreus and Clytemnestra *tholoi* diminished under filled *dromoi*, though there are some indications that this was avoided with open *dromoi* for an indeterminate period (Mylonas 1966: 124-125; Wright 1987: 182-183). Chamber tombs relied more on construction and memory than a persistent visual reminder to carry forward their messages to the living.

More than concern over standing out, tomb builders actively mimicked previous examples using "mimetic technique"–Plato's *tekhnē eikastikē* explained by Ricoeur (2004: 11) as reproducing a copy (*eikōn*) with dimensions and colours through pattern recognition. Cummings (2003: 39) proposed a similar mechanism, "archetypal memories", for the local reproduction of styles in early Neolithic stone monuments in western Britain. Modelling tombs closely upon the dimensions of previous generations – the knowledge of which would be stronger among those with access to tomb interiors through close ties – restrains architectural choices with familial bonds and memorial traditions, providing a space for contested individual and collective memories to coexist (King 1999: 165; Küchler 1999: 55; Rowlands 1993: 146; 1999: 129, 139-141). Collective memory pushes for continuity – only when dreaming does individual memory take precedence in fragmentary and incoherent form (Halbwachs 1992: 42). Individuals recall memories of the past in limited bursts, never capable of lingering indefinitely in a world that effectively no longer exists. They do so from a present that is the only real foundation for that recall (Halbwachs 1992: 51). Personal, recent, and distant memories all seem to strengthen from conversations with others, even anticipated conversations that never take place. Problems with chronological recall are sidestepped by focusing on memories that resonate in a particular group, responding to questions and aiding one another (Connerton 1989: 36-37). These associative memories are recalled by individuals specifically for group interests, such that families, organisations, or communities can use and retain information pertinent to their shared past (Halbwachs 1992: 52). In effect, exchanges with memory are compartmentalised. This is how I envision Mycenaean funerary construction: collective memories guide behaviour on how to engage community and sustain mimetic technique. For builders, collective recall informs construction, both the process and the final product in its shape and scale.

Collective recall is key in adhering to a standard of scale and shape, as the tombs practically disappear under backfill until their next use, concealing what lies within similar to tumuli (Alcock 2016: 6). Despite being closed most of the time – though displayed before and immediately following death, sometimes with painted or plastered surfaces (e.g., Asine, Deiras, Kokla, Mycenae, Prosymna, Tiryns, and Thebes, Demakopoulou 1990: 113, 115; Voudeni Tomb 75, Kolonas 2009b: 27-28; Prosilio tomb 2, Yannis Galanakis, personal communication 2019; Tomb 4 at Ayia Sotira in Nemea, Karkanas et al. 2012: 2731; Smith and Dabney 2014: 148) –

dromoi invited reuse and sustained memory of individual chamber tombs. By contrast, the dolmens of Neolithic northern Europe lacked passages and were sealed with megalithic blocks set within mounds (Sherratt 1990: 161). Even so, offerings continued as the earlier tombs acted as focal points for lineages and rituals (Sherratt 1990: 151).

Rowlands (1993) made an effective case for how a buried tomb could be reproduced from memory. Combining Kopytoff's (1986) model for discussing object biographies as the embedded stewardship of memory in material form as well as Gombrich's (1979) link to "a template held in the collective mind", Rowlands (1993: 144) explained the recurrence of recognisable and durable architectural forms like Classical Greek columns in American public buildings. Through recalling enduring motifs, continuity of form lends weight to newer memorials and navigates taboos on charged depictions where reverence is expected (King 1999: 152-155; Rowlands 1999: 139-141), just as calendar repetition of performative acts deliberately claims continuity with the past (Connerton 1989: 45). Deviations draw reproach (Rowlands 1999: 129), but conservative repetition is also devalued. Originality is elevated, ironically, by some redundancy in form. As Rowlands (1993: 146) phrased it, "However false or fictional it might be, the illusion of singularity, authenticity, uniqueness, and originality of culture rests on the redundant condition of a reified signifier."

Builders at Portes especially cultivated a strong sense of architectural tradition when constructing new chamber tombs, weaving them in and around older tumuli and built chamber tombs. Tombs clustered closely, demanding considerable care in construction to avoid collapsing earlier tombs if not borrowing from them intentionally (as in PT3 partially dismantling the built chamber tomb PC1). Tombs 7, 8, and 9 at Portes spared so little room between them that excavators were able to interlink chambers and *dromoi* with small portals. The result is reminiscent of a macabre playpen. With all passages open, one can simply drop from the main chamber of tomb 8 into the lower chamber of 7 and climb further into the *dromos* of tomb 9. As stated previously (Chapter 4), the setup seems more a convenience of access during excavation than an intentional feature of the original tombs that had no need for rapid access via an awkward drop from an adjacent ledge.

Small room for error invited irreversible mistakes, and the many collapsed ceilings of chambers at Portes and Voudeni attest to the vagaries of preservation, particularly among the shallower tombs. The builders must have been aware of these risks, but some calculus led them to proceed. Expediency is tempting but seems unsatisfactory on its own. Deeper, larger, and more stable tombs did not come with prohibitively high costs, leastways not in terms of labour alone. The cost may have aligned more with avoiding an inflation of status, which could have been construed as off-colour or fraudulent. Worse than a *faux pas* would be attracting the attention of more powerful families. There are many familiar sayings in Western traditions that advocate humility, and the Greek myth of Icarus sharply frames the antiquity of that concern in the region.

Beyond elevated difficulty in construction, proximity of tombs may suggest closer relationships among those that commissioned them but not on the strength of location alone. Conducted in the same style and executed to a similar scale, however, clustered tombs with a higher degree of sameness raise the possibility of family or factional ties. At Voudeni, two or three such groups appear based on the dissimilarity matrix of their dimensions and their locations relative to one another (see Figures 3.2-3.4, 4.3.1). Potential pairs with adjacent tombs (VT53/54, VT71/72, and VT77/78) can be spotted from the site maps, but remarkably similar distant pairs like VT29 and VT62 would go unremarked

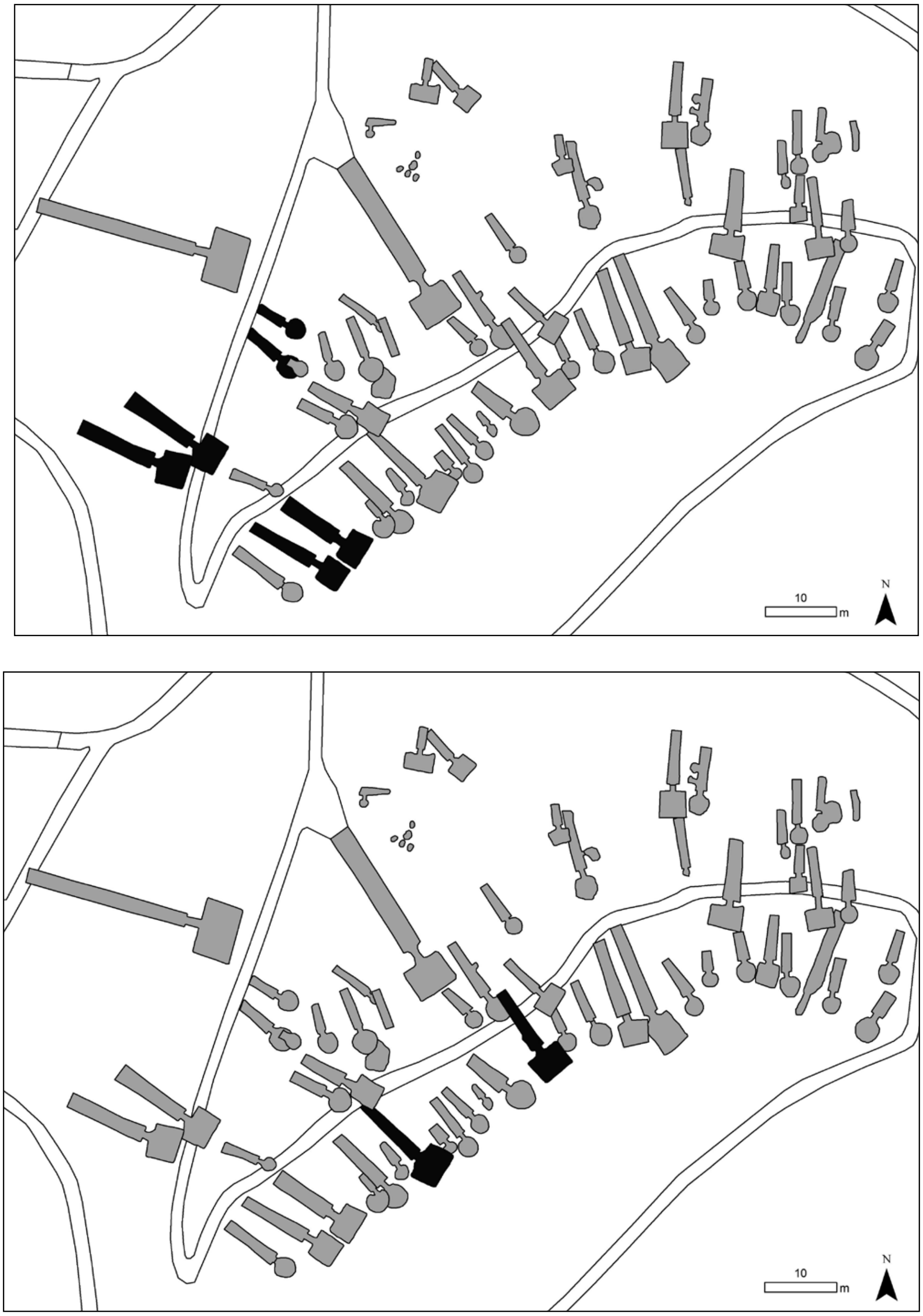


Figure 5.1. Paired clusters of tombs showing strong correlation from mimetic design and location.

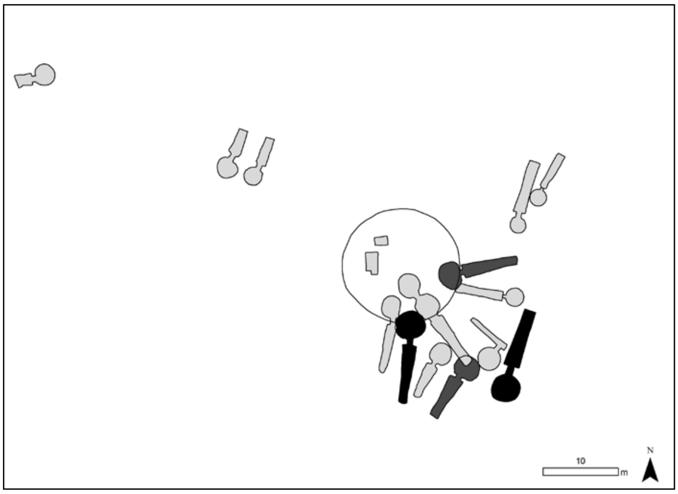


Figure 5.2. Incidental clusters of tombs showing strong correlation in design but weak correlation in orientation and location at Portes (left) and Voudeni (below).

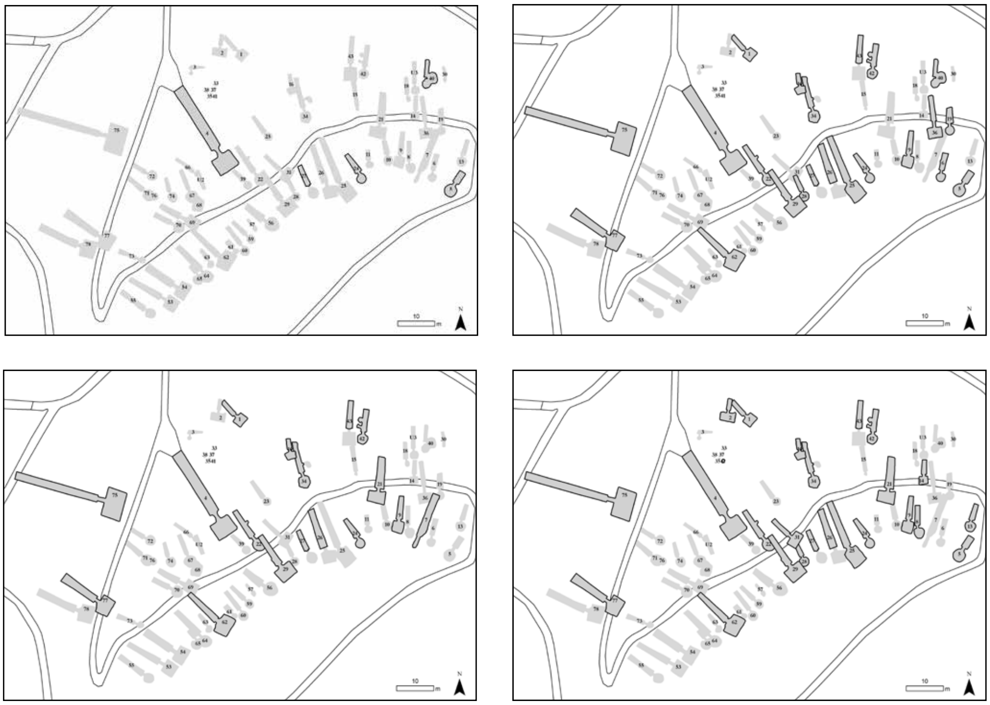
without the matrix (Figure 5.1). Other apparent mimetic clusters would almost certainly be incidental: VT72 closely resembles VT6/8 in shape and scale, for instance, but its location and orientation distance it from the pair (Figure 5.2). What the matrix does not account for, the diverging traditions of house-like and hive-like vaults, also nullifies some apparent clusters, particularly those forming around the conservatively scaled VT1 (Figure 5.3). Corroboration from finds and remains might support this idea of clustering (Figure 5.4; see also Table 4.4), but only if reuse was not so thorough as to erase initial construction.

Figure 5.3. False clusters of tombs showing strong correlation in scale but weak correlation in shape and location.

Part of the intent behind construction following a certain scale, big or small, may still be depicted through relative investment. Measurable intent lies in a signalling approach to labour costs. I labelled tombs more than 1.5 times the standard as exceptional, assertive signals by wealthy families to claim a share of local leadership during the LH IIB/IIIA fluorescence of Mycenaean sites in Achaea (for mapped examples at Portes and Voudeni, see Figure 5.5). This not only includes obviously extravagant examples like PTh2, PT3, VT4, and VT75, but the more subtle confidence suggested by the construction of PT7 and VT56. Smaller tombs, including those near the standard size like PT9 and VT71, attempted to append group membership for less influential families without risking backlash from rivals and peers. Subsequent reuse of tombs, including the lavish LH IIIC warrior burials, made similar statements with the added weight of an anonymous past, yet without most of the expense required by new construction (Table 4.2). More expensive by far would be the accumulation of the imported wealth on display here (e.g., Kolonas 2009a, 2009b; Moschos 2000, 2009; van den Berg 2018).

5.4. Labouring toward forgetting

From here, tomb labour must part from events singular to regional timescales and join a discussion relevant to the human condition, namely that of memory. Doubtless the bustle of construction around the Menidi *tholos* and monumental chamber tombs like PT3, VT4, and VT75 impressed their intended audiences with architectural achievement and collective potential. The impression certainly endured through encouraging reuse of the tombs or mimicry in new constructions, but it might be more efficacious to follow



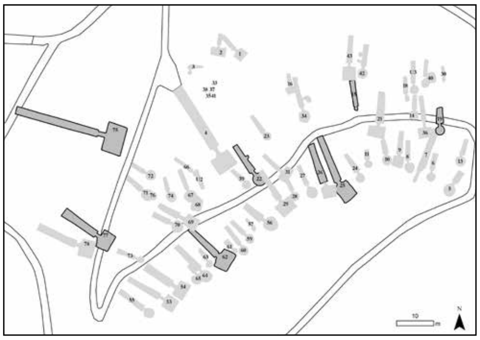


Figure 5.4. Tomb clusters through time using provisional chronology. In reading order: LH IIB, LH IIIA, LH IIIB, LH IIIC, Submycenaean.

the much longer-lasting and wider-reaching spectacle of rumour and memory. Both never quite allow labour's role a peaceful rest, so long as some vestige of glory remains for Ozymandian feats. Retracing memory's evolution back to architectural inspiration follows a circuitous, context-dependent route but generally has a similar destination in commissioner/community prestige and posterity. The subject recurs often in studies of monumentality. Santillo Frizell (1997-1998: 103) connected Mycenae's largest tombs to their "main value" in prestige. Others have argued that monuments primarily claimed a past or stabilised a present in transition (e.g., Glatz and Plourde 2011; Renfrew 1973). Holtorf (1996: 121, citing Assmann 1992: 71) prioritised monument roles in projecting into the future, placing posterity in primary focus as others have done (Bretschneider 2007: 4; Speer 1985; Trigger 1990; see Chapter 2, this volume). Commemorative projections blur as memories change, each ignited by reminders coded into mortuary architecture. For that staccato reinvention I have chosen the simple phrase *grave reminders.* Grave reminders quickly supersede or misplace purpose, prestige, and posterity in humanity's vain search

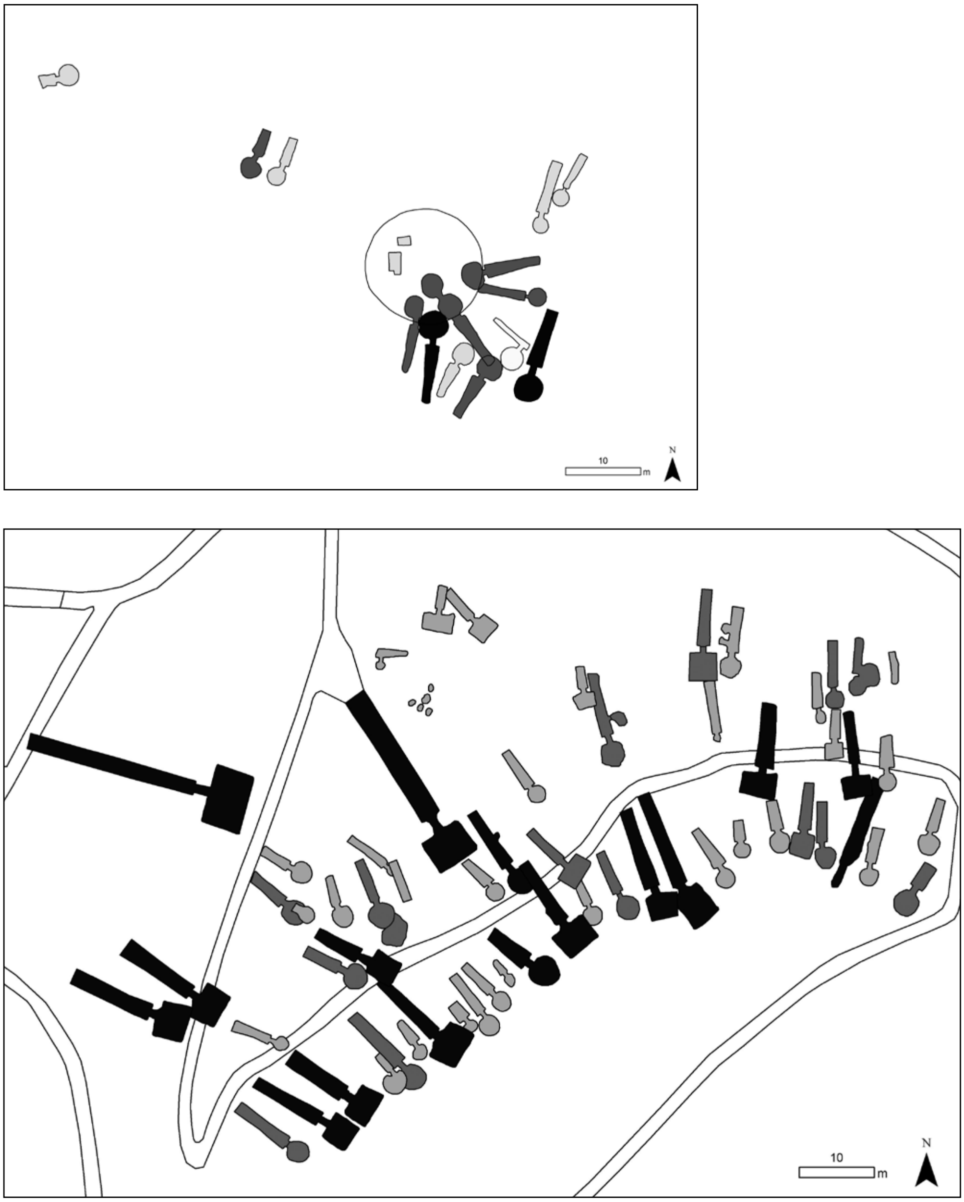


Figure 5.5. Tomb scale/signalling classes at Portes (top) and Voudeni (bottom): undersized/cohesive (light grey), standard/pragmatic (grey), and exceptional/assertive (black).

for a durable record of existence. Perhaps more unsettling for those concerned over legacy, derivative lessons from ruined architecture, like Percy Shelley's Ozymandias, will almost certainly outpace the scope of its original intent.

Memory and memorials share global similarities despite diverse cultural manifestations (e.g., Lillios and Tsamis (eds) 2010; Hamilakis 2013; Henry and Kelp (eds) 2016; Peterson 2013; Williams 2006). Where monuments serve as mnemonic devices, cultural transmission through memory is seen as a more rigid process than societies where memory replaces and recreates destroyed objects (Rowlands 1993: 141). Less rigid transfers of memory in material can be found in Maussian terms of object sacrifice and gift exchange, where memories of objects-in-action drive future behaviour rather than commemorate the past (Mauss 1966 [1925]; Rowlands 1993: 147). Destroyed objects especially are said to be "held in the social memory" where actions can parallel beliefs in the process of death (Rowlands 1993: 148). The mnemonic role is no less effective here, and there is little if any information lost after destruction (Jones 2007: 114-118; 2010). Performance is more significant than the material object in creating and sustaining memory. With their antecedents being stripped by money flung from funeral attendants who discarded them into the jungle to rot, some elaborately incised Malangan funerary sculptures were reproduced consistently after more than a century (Küchler 1999; Rowlands 1993: 148-149). Schieffelin (1985: 707) also emphasised performance rather than recognition as the semiotic vector for symbolism (Argenti 1999: 23; see also Connerton 1989; Forty 1999:2).

Contrary to their image of permanence, the durability of chamber tombs has been contested, and rightly so given the many collapses commonly recorded at Mycenaean cemeteries. Cavanagh and Mee (1978: 42) were bleak about the survivability of most chamber tomb ceilings, noting the mixture of roof collapses even among layers of use (see also Smith and Dabney 2014). Faulty architecture would not halt operations so long as the cemeteries served community needs. Destruction of tombs could also stem from deliberate acts of forgetting through superimposition or intentional abandonment. The *tholos* at Voidokoilia was sunk into a MH I tumulus built over an EH II settlement, staking claim to a rich past as Galanakis (2011: 220) saw it. Positioning *tholoi* near MBA tumuli likewise may have accelerated forgetting by replacing, rather than commemorating, the earlier monuments (Galanakis 2011: 222). The builders of the two LH IIB Portes *tholoi* avoided the prominently placed MH III/LH I tumuli A and C, instead preferring association with Tumulus B (PTh1) or a marginal slope (PTh2). That the site's largest LH IIIA chamber tombs returned to the A/C cluster of tumuli and built chamber tombs, even dismantling them in some cases, could reflect a generational divide in the layout of the aging cemetery. Abandoned tombs with a gap longer than three generations between uses were assumed to be co-opted by another family or one distantly tied to the previous users (Cavanagh and Mee 1978: 32). The point here lies with material longevity being less crucial than the survival of the tombs in collective memory, even if some connections must have been made anew. Dispelling the notion of architectural permanence also brings us closer to perceptive connections with somatic experience, the foremost being decay (as anyone on the north side of middle age can attest).

Architectural metaphors for the human body offer stark imagery of decay. For the Oku *ndavos*, "once built, the house is left to fall into decay, never to be repaired again. As the king grows old in his palace, so too the house will fold in upon itself and crumble into the ground" (Argenti 1999: 27). Drawing a parallel to the sempiternity of medieval European kingship, in which a king's natural body dies but the body politic endures, Argenti (1999: 27) noted the euphemisms veiling an Oku 'lost' king. Natural decay is expected; institutional decay is unacceptable. Invoking that anonymisation process under other terms, ethnographies – from the Merina tombs of Madagascar to Melanesian exchange – have elevated ephemeral objects, performance, and the ancestral collective in social memory's crusade to absorb and forget individuals (Williams 2003: 6-7 with references). Water, darkness, and dirt have the same erasing effect, an anonymising by homogeneity and immersion (Douglas 1966: 161). Thus, closing tombs darkens and finalises what lies within, allowing it to be forgotten until the next death cycle. In a similar vein, Fowler (2003: 53) saw parallels between the decaying mortuary structures of Neolithic Britain and the rotting bodies left inside, a pungent image that demands covering to control attention and mask offensive reminders with dirt's "creative formlessness" (Douglas 1966: 161). Transposing this directly on Mycenaean elites and mortuary rites might be reckless, but it would be equally wilful not to see some glimmer in the decay of chamber tombs and the anonymisation of ancestral remains in secondary funerary practices (Boyd 2015a; Moutafi and Voutsaki 2015; Papadimitriou 2011). At Routsi *tholos* 2, for instance, Boyd (2015a: 213-214) speculated whether the tomb's collapse was deliberate to seal its contents and prevent reuse. Elsewhere, collapsed chamber tombs either failed to deter reuse as new floor layers or prompted construction of side chambers to avoid previous burials (e.g., Cavanagh and Mee 1978: 42; Smith and Dabney 2014: 151). In the case of Tomb 6 at Ayia Sotira (Nemea), builders repeatedly repaired collapses with rubble masonry, the final episode of which stemmed from tunnelling through the roof of the *stomion* rather than unblocking the entrance (Smith and Dabney 2014: 152-153). I wonder if, of the many roof collapses seen at Portes and Voudeni, not a few resulted from deliberate negligence, if not orchestrated sabotage (from a design flaw like too-shallow construction, since demolition of rock-cut architecture seems unnecessarily risky). Their proficiency in construction elsewhere certainly casts doubt on ignorance as a principal factor.

Fortunately, grave reminders do not rely on markers or direct recollections of events and can arise entirely from social transmission, hearsay, or personal suppositions, so long as they tether to a concrete experience via some degree of separation. If that is difficult to accept, celebrations of birth are routine reminders of events we cannot possibly recollect without help, or in Telemachus's anxiety over coming of age without a father, "Who, on his own, has ever really known who gave him life?" (Homer *Od.* 1.250-251). Fabricated or not, reignited memory in grave reminders derives from and surpasses material durability in extending the life and influence of memorials. Idling in the background, such memories seldom roar to life without a kick-start from a recent death or material reminders of an older one. Initial frames of reference from reminders of Mycenaean funerals should take into account the rarity of the event itself, particularly where archaeological enthusiasm may have forgotten it.

Voudeni makes for the perfect example here. It was indeed a massive and long-lived cemetery, and its estimated 150 (ca. 78 excavated) multi-use tombs could have accommodated over 3,000 individual remains with heavy reuse, as suggested by tombs showing MNI counts from 2 to 27 individuals (Kolonas 1998; Moutafi 2015: 537). Stretched over 350 years, however, the rate of reuse shows roughly 8-9 burials per year, or one every 45 days. The purpose here is not to suggest the actual rate of use for the cemetery, which surely varied with demographics and the fortunes of nearby communities. It is rather to dampen the notion of rampant mortality and tomb obsession in lives obviously lived outside of cemeteries. It also shifts the tombs away from active space and into their more accustomed niche of memory.

Fixations of Agatha Christie novels and modern mass media notwithstanding, inescapable death does not generally insert itself into daily thought, much less experience (Flaherty and Throop 2018: 162). Even where mortality rates elevate risk, passive awareness suffices until the unthinkable occurs, whereupon specific coping mechanisms promote individual and collective resilience (e.g., Barbarin 1993; Maček

2018; Utsey et al. 2007; Zakour 2012). For instance, Sarajevans converted 1990s wartime disillusionment into a popular joke about an old man in a rocking chair teasing snipers (Maček 2018: 244). Community attention to recent losses may last for weeks or more as the missing links are renegotiated, depending on the circumstances of death (i.e., sudden or expected) and importance of the person or close affected groups (e.g., family, economic or political contacts). Individuals, however, are more susceptible to traumatic loss and may take years to recover if at all (Zakour 2012: 98).

Less so do the comparatively short-term preparations surrounding death preoccupy the aggrieved for long, outlasted by far by the emotional and practical impacts of loss. From my own labour estimates throughout Chapter 4, standard chamber tomb construction of seven days seems nontrivial compared to the few hours needed for a simple pit grave. However, those 7 days versus 15,000 days lived (perhaps the last 7,000 were integral to the community) by a hypothetical 41-year-old Mycenaean official would be on the verge of imperceptible for those left behind. The loss itself and reminders thereof are more keenly felt than the expense of tomb construction. Thus, the practical cost of multi-use tomb construction might be trivial, and the even cheaper cost of reuse especially so, but the psychological and social rewards of memorialisation are not.

This leads into the question of whether a threshold can be found where practical costs reclaim a nontrivial element of collective labour potential. Perhaps a population undergoing exceptional demographic crises of war, famine, or pestilence would take greater note of frequent funerals. It might if that frequency did not also have its limits in terms of response. Too many fallen may trigger responses to collective trauma rather than individual loss, where it is more likely that normal operations would defer to necessity in multiple or commingled mass burial, as with the ca. 150 buried at Kerameikos in the 430-426 BC Athenian epidemic (Papagrigorakis et al. 2008: 162-166). While lessons here need be sought no further than twentieth-century atrocities (e.g., Kontsevaia 2013; Maček 2018), their antecedents extend as far back as the Early Neolithic in Central Europe with documented massacres at Talheim, Asparn/Schletz, and Schöneck-Kilianstädten (Meyer et al. 2015; Teschler-Nicola 2012; Wahl and Trautmann 2012). Mass burials at Nichoria and Thebes show precedent for the Greek Bronze Age (Arnott 1996; Vika 2009; see Chapter 2, this volume), and it would take no great leap to imagine similar scenarios playing out under the martial fascinations evident in LH IIIC Achaean warrior burials (see above).

Under harsh but not exceptional circumstances – where collective trauma is absent or more diffuse – several thousand residents in the LBA communities on the Gulf of Patras may have buried dozens from locally important families in a rough season of violence or disease. As the labour index indicates (Table 4.2), space to bury the less-influential dead would be exhausted long before cost became prohibitive – interring 20 bodies all at once in each of the 89 surveyed chamber tombs from Portes and Voudeni would demand ca. 109,000 ph (roughly a working calendar year, 218 five-hour days, for 100 labourers) in cumulative reopening costs, compared with ca. 33,000 ph in initial construction costs (a little more than two months for the same group). Neither scenario is likely in the short term, yet it still leaves thousands of common deaths to be disposed elsewhere. Unless secondary treatment or other vagaries of taphonomy have erased the evidence with remarkable efficiency, clearly not all victims warranted use of a chamber tomb. Neither would a community majority turn out *en masse* for any but the most extraordinary funeral, leaving the average death comparatively unremarked.

This is not to say the dead were not celebrated, as indeed evidence remains of goodbyes ranging from a reflective offering to a wild party. A final offering of an LH IIIB2 drinking vessel seemed to mark the last use of Tomb 4 at Ayia Sotira, one of several examples from the site of parting gifts, which included an LH IIIB amphoriskos placed near a slab-covered pit in the deliberately cleared Tomb 3, an LH IIIB jug in the *stomion* of Tomb 5, and an LH IIIB1 stirrup jar set above older burials in Tomb 6 (Smith and Dabney 2014: 149-153). Menidi, on the other hand, held an apparent feast in or near its cavernous *dromos* (Borgna 2004: 263-264), closer to the vivid image envisioned by Hamilakis (1998: 128) as a drunk, possibly high, dancing crowd for extravagant Minoan and Mycenaean funerals.

Death looms large in Mycenaean archaeology, partly from its festive allure and partly from taphonomic serendipity. Funerary evidence is the best remaining proxy for daily activity, supporting continued fervour in Mycenaean mortuary studies (Cavanagh 2008: 327-328). Quite simply, cemeteries and their more fortunate unpilfered graves dominate the literature and the landscape, justifying the seldom necessary variant term of deathscape. Dense and rich Mycenae, for instance, generated more than 250 chamber tombs across 27 cemeteries (Boyd 2016: 68, citing Shelton 2003), and likewise disposed of some poorer and younger dead in other, less visible ways. Near Tiryns, another palatial power of note in the Argolid, 50 chamber tombs arranged in three clusters were excavated in 1927 along the eastern slope of Profitis Ilias, whose opposite slope housed the looted remains of two large *tholoi* (Papademetriou 2001: 67-71). Not to be outdone by rock-cut counterparts, particularly in Messenia where *tholoi* were indisputably preferred (Dickinson 1977: 63), over 200 LBA *tholoi* have been recorded across much of Greece and the Aegean (Galanakis 2011: 223).

Greater numbers of reported tombs do not always guarantee availability of information. Magnification on their contents nullifies some advantage gained by lengthier catalogues of sites and features, particularly where ritual prescription in the past prompted wholesale removal of tomb contents. Selective bone removal on MBA Crete was taken to the extreme for the fifteen *tholoi* discussed by Xanthoudides (1924) in *The Vaulted Tombs of Mesara*, who recorded only eight skulls for what Branigan (1987: 48) estimated as “at the very least a thousand burials”. Tomb 3 at Ayia Sotira (Nemea) was thoroughly cleared, leaving only fragments of an LH IIIA2 conical rhyton in *dromos* fill, two adult teeth in a slab-covered *dromos* pit, and an LH IIIB amphoriskos deliberately placed at the edge of an empty slab-covered pit in the chamber (Smith and Dabney 2014: 152). Earlier burials at Portes and Voudeni were certainly swept to the side or removed to secondary pits in *dromoi* or side chambers to accommodate newer additions, but the extent of removal away from the tomb would be difficult to track (Moutafi 2015).

Avoiding total loss, looking beyond tomb contents recalls that purpose is imprinted on the architecture itself. The operation of multi-use tombs was very much a forward-looking family affair with the weight of antiquity, being collective in construction, maintenance, and use; meaningful in deliberate shapes and elaborations, and enduring in physical and symbolic longevity (Cavanagh 2008: 336-340). Tombs, like houses, extend beyond container to fulfil roles of “creating and perpetuating social relationships” (Sherratt 1990: 164). Like most monuments, they recall a symbolic past and provide anchor points for the future. That the largest and most elaborate tombs anchored and transferred a hereditary elite identity has been strongly attested (Dabney and Wright 1990: 50; Santillo Frizell 1997-1998: 103). The smaller more rural tombs, however, applied to a shared human condition, one not always rooted in the late emphasis on ancestor worship and its deliberate manipulation (Dabney and Wright 1990: 52; Gallou and Georgiadis 2006: 126; Stamatopoulou 2016: 182).

Two centuries of archaeology may have inflated the resulting deathscape away from the ground-level Mycenaean experience but not from the wider human one. Deathscapes form part of a phenomenon well attested by anthropology, art, and literature: humanity's strident attempt to capture some element of permanence in the face of inevitable impermanence (e.g., Hallam and Hockey 2001: 25 and associated bibliography). As Hallam and Hockey (2001) observed, the key factor is not death but memory. Every action following loss thus claims a mnemonic function. Even mundane items can take on transformative meaning to trigger memories in defiance of catastrophe, as Kurt Schwitters' collages of street rubbish invoked a world broken by the First World War (Hallam and Hockey 2001: 12). Memorials in durable materials are not without their rules (e.g., King 1999: 148, 152-155; Rowlands 1993: 146; 1999: 139-140). The Lion Mound Memorial commemorated the Battle of Waterloo but did so via destruction of the battlefield, with construction levelling the surrounding fields to create the 41 m tall mound and prompting the Duke of Wellington to call it "a hideous thing" (Morgan 2008: 23). A similar proposal to commemorate the Second World War with a bulldozer-built tumulus never materialised (McGowan 2016: 164). Statuary war memorials typically depict soldiers without aggression or violence, electing for defensive or watchful postures if combat is shown at all. Bayonets were removed from the Bradford City War Memorial after an outcry from moralists who objected to the violent imagery (King 1999: 152-155). The image of the 'good soldier' in statuary did not hold up when literary accounts came forward (King 1999: 152), particularly Remarque's (1929) flawed characters and Jünger's (2004 [1920]) visceral eyewitness viewpoint. Tombs are another form of commemorative architecture, a powerful, purpose-driven form of mnemonic investment. They return families and communities to daily routine, where upended lives can move forward absent mortality's cloud.

The vaults of *tholoi* and chamber tombs functioned as repositories for atavistic memories *(sensu* Larsson 2010: 180), invented and autochthonous, to be opened and re-lived during secondary treatment or new primary burials, heterochthonous experiences with unknowable death (Flaherty and Throop 2018). In this my use of the term *vault* when referring to the burial chamber has been deliberate, as it alludes to the tomb's role as memory bank, safeguarding the revered past irrespective of how fabricated it might be. In this sense, I am less focused on another popular role of the tomb as performative stage (see Dakouri-Hild and Boyd 2016), wherein much activity takes place just outside the tomb on the meaning-loaded threshold (Dakouri-Hild 2016: 20; Gallou 2005: 67) or in processions around the cemetery (Boyd 2016: 64-65; Gallou and Georgiadis 2006: 140). Since I argue elsewhere against the visual impact of closed chamber tombs (see Chapter 2), it is important to reiterate here that mnemonic purpose permeates construction irrespective of continued use or visibility. Similar arguments have already surfaced in Greek mortuary studies, particularly where mid-first millennium traditions intersect with tumuli (e.g., McGowan 2016; Stamatopoulou 2016). Galanakis (2011: 220) applied landscape associations rather than visual prominence in reconstructing mnemonic landscapes with tumuli, since MBA and early LBA tumuli in the broken Greek landscape are not as visually striking as those on the open steppe (Alcock 2016). With their maximum observed heights of 5 m and diameters of up to 30 m, mountainous terrain simply eclipses their visual fields. Even cleared as it has been for the modern archaeological park, the Voudeni cemetery is not easily spotted from a distance (see Figure 1.10). Its view toward the gulf is impressive (see Figure 4.3.2), but like all ground-level or subterranean architecture in broken terrain, the cemetery melts into the background maze of ravines and hillslopes.

Mnemonic roles, like grave reminders, merely add to the repertoire of Mycenaean multi-use tombs. In addition to tomb-specific reuse and secondary treatments, those mnemonic roles were playing out on a grander scale already in the early LH, shaping sitewide architectural and socio-political trajectories at Mycenae. Here, older tombs and cemeteries served in the systematic veneration of ancestors for the benefit of living actors, as affirmed by Gallou (2005: 13) in anchoring a Mycenaean cult of the dead on the reorganisation of Grave Circle A in the LH IIIB period. At a time of sweeping architectural projects, Grave Circle A avoided subsequent overtopping construction, gained its own wall, and was placed within the circuit wall and near the cult centre (Gallou and Georgiadis 2006: 127). Grave Circle B was not accorded the same concessions, as evident in the intrusion by the Tomb of Clytemnestra (Button 2007: 89; Gallou 2005: 17). Despite their different roles, however, both grave circles were thrust back into public memory by non-random acts of construction, just as builders at LH III Tiryns and Pylos negotiated new construction by demolishing or preserving ruins (Maran 2016: 161-162; Nelson 2007: 150-151). Proximity may function similarly as an (unexpected) grave reminder in the case of densely clustered chamber tombs. Several cases at Voudeni and Portes have been shown where wall collapses have merged burial chambers built with too little intervening space, such as VT40/44, VT67/68, and PT7/8 (see Chapter 4).

5.5. Concluding summary

I initially asked what considerations affected tomb shape, scale, siting, and reuse (Q1). Correspondence analyses of photogrammetric measurements and labour costs suggest pragmatic strategies appropriate to local resources and social constraints. Large LH IIIA chamber tombs (e.g., PT3, VT4, VT75) declared factional strength for a regional audience, similar to MH III/LH I tumuli (PTumA-C) and LH II *tholoi* (PTh1-2) built by preceding generations. By siting its largest chamber tombs on tumuli and a massive early LH I-II built chamber tomb (PC1), Portes grounded its evolving mortuary traditions in a mythical past. Diverging LH IIB/IIIA traditions could reflect competition with those reusing the site's LH IIB *tholoi* or superimposing LH IIIA-B cist and built cist tombs there rather than alongside their peers on the dense Tumulus A/C cluster. The changing landscape across six centuries of use no doubt fostered mercurial fortunes and rivalries, but new multi-use tomb construction at the site settled on *tholoi*-like, hive-type chamber tombs of a muted scale no greater than twice the site median (or roughly triple the AA01 standard) from the LH IIIA onward. Voudeni, on the other hand, built its cemetery anew and almost entirely out of chamber tombs, loosening restrictions on the shape and scale they could assume with at least eight apparent vault shapes and scales from less than a fifth to more than nine times the median.

Further to this I asked if construction and reopening costs burdened the commissioner(s) while creating a memorable experience for the builders and witnesses (Q2). Of the tombs accessed here, only the Menidi *tholos* presented a cost sizeable enough to challenge local resources, while still falling far short of enormously costly projects like the LH IIIA/B mega-*tholoi* and fortifications of major citadels. Future publications by the SETinSTONE research group may illuminate the relative technical challenge of these marquee endeavours (Boswinkel forthcoming; Brysbaert in progress-2020; Timonen forthcoming). For most LH IIIA chamber tombs, construction costs were unlikely to strain local resources. Late reuse during the contracting LH IIIC period further allowed lineages to claim powerful ancestry with reduced construction costs, freeing resources to invest in far more expensive grave goods like those found in 'warrior burials'.

For my third set of questions, I asked if tomb architecture reflected the memory of the deceased or if their remains and assembled offerings were more informative for those remembering them (Q3). Ideally, tomb architecture would combine with contents to write eulogies insofar as we can discern them three millennia later. Reuse and looting has hindered progress, but snapshots are still possible where access limitations do not defer querying available data. Unsurprisingly, tomb architecture does reflect the standing of the deceased and their close supporters, pulled from and assessed by a local audience. Grave goods, particularly nonlocal and expensive items, point to connections made further afield. Whether the deceased also came originally from afar would be an intriguing line of research for variable mobility through the long Mycenaean era.

For my final question, I asked how builders perceived tomb construction, its costs and rewards (Q4). Comparatively low costs of construction and reuse did not evidently prohibit building excessively scaled tombs on technological or economic grounds. Social rather than economic constraints encouraged compliance with a recognisable standard, limiting overly ostentatious tomb building away from major citadels. Collective memories held a 'blueprint' for tombs to follow, allowing mimetic design to replicate the tripartite shapes familiar to builders and witnesses. By electing to build larger, more elaborate tombs, commissioners risked family and factional reputations in a costly signalling gamble to secure legacy. Builders and supporters sacrificed time and resources on the legacies of others, deferring benefits of association with grand projects and wielding the powerful court of public opinion for a garish misstep.

The main takeaways from this study began as largely methodological but leave openings into bolder statements on Mycenaean mortuary practices. Relating the hosting tombs to their human remains and grave offerings, for instance, is a daunting task awaiting further study. Combining the architectural data here with the work of Moutafi (2015) and Kolonas (1998) would be especially fruitful for Voudeni, as would inter-site comparisons using the work of van den Berg (2018) and recent publications from Aigion, Achaea Clauss, and Chalandritsa-Agios Vasileios (Aktypi 2017; Papadopoulos and Papadopoulou-Chrysikopoulou 2017; Paschalidis 2018). As I hope to have shown, comparative labour – as a simplified but lengthy catalogue application of architectural energetics – enhances econometric research through compiling labour rates and casting a wider net for case studies. Visualisations and tabular data depicting labour ranges with many case studies are more informative than the exhaustive treatment of single cases with single rates.

Adding case studies for energetics at a faster pace than traditional reliance on plan drawings, digital modelling of tombs promises greater preservation and efficiency in relevant measurements for architectural features. It also enables statistical analyses that capture patterns not easily demonstrated with conviction in qualitative descriptions. Multidimensional scaling, for instance, helped to illuminate the spectrum of sameness and exceptionalism in tomb scale (Figures 3.2-3.4; Tables 4.1-4.3 and A1.3-A1.5). This suggested the inter-site duality for a conservative Portes – interweaving rigidly designed chamber tombs in a dense, centuries-old cemetery of tumuli, *tholoi*, cist and built chamber tombs – and cosmopolitan Voudeni, flexibly building chamber tombs with different shapes and radically variable scales on a blank slope. The relative index of tombs also showed intra-site clustering that may indicate family groups and traditions (Figures 5.1-5.4). Groups of three and more clustered solely on a shared sense of scale and shape. Interpretive gains are only tempered with the prospect of combining that insight with osteological and portable finds data, an eventuality that must await further research and publication of these important sites. Architecturally at least, multi-use tombs seem to express much more about Mycenaean community than the individuals interred therein.

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Appendix 1

Labour rates

Context		Material		Tool			Rate		
ID	**Stamina**	**kg/m^3**	**Type**	**Cutting Surface**	**Handle Length**	**Description**	**ph/m^3**	**m^3/ph**	**kg/ph**
9d	conditioned	2711	marble	metal	unsp	19th C. masonry kit	125.00	0.008	21.7
9f	conditioned	2711	marble	metal	unsp	16th C. masonry kit	90.00	0.011	30.1
14c	average	2500	limestone	stone, copper alloy	unsp	ancient Egyptian kit	50.00	0.020	50.0
14b	maximum	2500	limestone	stone, copper alloy	unsp	ancient Egyptian kit	30.30	0.033	82.5
6c	supervised	1786	chalk	bone	short	antler pick	13.57	0.074	131.6
13b	average	1500	tuff	unsp (stone?)	unsp (short?)	unspecified	12.20	0.082	123.0
14a	average	2500	limestone	iron	unsp	modern	11.24	0.089	222.5
6g	average	1600	turf	steel	long	modern	11.11	0.090	144.0
6d	unsupervised	1786	chalk	bone	short	antler pick	10.15	0.099	175.9
15h	average	2000	clay	unsp	unsp	unspecified	10.00	0.100	200.0
1a	average	1580	silt loam	stone	short	chert hoe	8.85	0.113	178.5
6i	average	1700	turf and soil	steel	long	modern	8.33	0.120	204.0
6h	average	1600	turf	steel	long	modern	7.69	0.130	221.0
6e	average	1786	chalk	bone	short	antler pick	7.14	0.140	250.0
2a	average	1795	chalk	bone	short	antler pick	7.04	0.142	254.9
1b	average	1580	silt loam	stone	short	chert hoe	6.67	0.150	237.0
1c	conditioned	1580	silt loam	stone	short	chert hoe	5.85	0.171	270.2
6j	average	1700	turf and soil	steel	long	modern	5.56	0.180	306.0
3a	conditioned	1400	unspecified	unsp (steel?)	unsp (long?)	unspecified	5.26	0.190	266.0
1d	average	1580	silt loam	stone	short	chert hoe	5.24	0.191	301.8
1e	conditioned	1580	silt loam	stone	short	chert hoe	4.90	0.204	322.3
4a	conditioned	1400	unspecified	unsp	unsp	unspecified	4.44	0.225	315.0
8c	conditioned	1500	tuff	wood	long	hardwood post	4.35	0.230	345.0
2b	maximum	1795	chalk	bone	short	antler pick	4.26	0.235	421.8
1f	conditioned	1580	silt loam	stone	short	chert hoe	4.00	0.250	395.0
2c	maximum	1795	chalk	bone	short	antler pick	3.92	0.255	457.7

Table A1.1a. Extraction rates (continued overleaf).

Context		Material		Tool			Rate		
ID	Stamina	kg/m^3	Type	Cutting Surface	Handle Length	Description	ph/m^3	m^3/ph	kg/ph
5a	average	1580	silt loam	stone	short	chert hoe	3.45	0.290	458.2
3b	conditioned	1400	unspecified	unsp (wood?)	unsp (long?)	unspecified	3.03	0.330	462.0
6a	average	1795	chalk	bone	short	antler pick	3.03	0.330	592.4
1g	conditioned	1580	silt loam	stone	short	chert hoe	2.72	0.367	579.9
1h	conditioned	1580	silt loam	stone	short	chert hoe	2.71	0.369	583.0
6b	maximum	1795	chalk	bone	short	antler pick	2.67	0.375	673.1
6f	average	1786	chalk	steel	long	modern pick/shovel	2.38	0.420	750.0
7a	conditioned	1400	unspecified	steel	variable	pre-modern industrial	2.12	0.471	659.4
8a	conditioned	1300	sandy loam	wood	long	digging stick	1.92	0.520	676.0
9a	conditioned	1800	clay	steel	variable	pre-modern industrial	1.81	0.554	996.5
9b	conditioned	1800	clay	steel	variable	pre-modern industrial	1.72	0.583	1049.4
5b	conditioned	1800	clay	steel	variable	modern	1.67	0.600	1080.0
8d	conditioned	1500	tuff	iron	short	crowbar	1.49	0.670	1005.0
7b	conditioned	1400	unspecified	steel	variable	pre-modern industrial	1.42	0.706	988.4
5d	average	700	wood	stone	short	stone handaxe	0.70	1.429	1000.0
8b	conditioned	1300	sandy loam	steel	long	modern	0.69	1.440	1872.0
5c	conditioned	1280	loam	steel	variable	modern	0.50	2.000	2560.0
10a	conditioned	1600	turf	steel	long	modern	0.50	2.000	3200.0

Table A1.1a. (continued).

Context		Material		Travel			Load	Portage	Rate		
ID	Stamina	kg/m^3	Type	To source (km)	Round trips per hour	Speed (km/h)	kg	Method	ph/m^3	m^3/ph	kg/ph
12a	conditioned	2711	marble	35.40	0.02	1.2	500	drawn, single yoke (ox)	271.10	0.004	10.0
9i-a	conditioned	2000	unsp	10.00	0.25	5.0	55	pack, donkey	145.45	0.007	13.8
9i-b	conditioned	2000	unsp	5.00	0.50	5.0	55	pack, donkey	72.73	0.014	27.5
9j-a	conditioned	2000	unsp	10.00	0.25	5.0	120	pack, mule	66.67	0.015	30.0
9l-a	conditioned	2000	unsp	10.00	0.08	1.7	400	drawn, single yoke (ox)	59.88	0.017	33.4
9k	maximum	2000	unsp	10.00	0.25	5.0	135	pack, mule	59.26	0.017	33.8
9m	maximum	2000	unsp	10.00	0.08	1.7	640	drawn, single yoke (ox)	37.43	0.027	53.4
9j-b	conditioned	2000	unsp	5.00	0.50	5.0	120	pack, mule	33.33	0.030	60.0
11a	conditioned	2000	unsp	0.55	3.00	3.3	22	basketing (unsp)	30.30	0.033	66.0
8j	conditioned	1500	tuff	1.00	2.20	4.4	23	tumpline	30.00	0.033	50.0
9l-b	conditioned	2000	unsp	5.00	0.17	1.7	400	drawn, single yoke (ox)	29.94	0.033	66.8

Table A1.1b. Transportation rates.

Context		Material		Travel			Load	Portage	Rate		
ID	Stamina	kg/m^3	Type	To source (km)	Round trips per hour	Speed (km/h)	kg	Method	ph/m^3	m^3/ph	kg/ph
9h	conditioned	2000	unsp	1.00	2.50	5.0	50	basketing (unsp)	16.00	0.063	125.0
8h	conditioned	1500	tuff	0.50	4.00	4.0	25	tumpline	15.00	0.067	100.0
8i	conditioned	1500	tuff	0.75	3.00	4.5	34	tumpline	14.51	0.069	103.4
8g	conditioned	1500	tuff	0.25	6.80	3.4	28	head balanced	7.89	0.127	190.0
9c	conditioned	1800	clay	0.25	5.00	2.5	50	basketing (unsp)	7.69	0.130	234.0
5e	average	600	wood	1.00	1.70	3.4	100	team (6) shoulder carry	3.50	0.286	171.4
8f	conditioned	1310	sandy loam	0.10	23.20	4.6	20	handheld container	2.86	0.350	458.5
8e	conditioned	1310	sandy loam	0.05	41.20	4.1	20	handheld container	1.59	0.630	825.3

Table A1.1b. (continued).

Context		Material		Process	Tool	Rate		
ID	Stamina	kg/m^3	Type	Description	Description	ph/m^3	m^3/ph	kg/ph
14d	average	2750	granite	percussion shaping granite (blocks)	stone and alloy	2777.78	0.00036	1.0
14f	average	2750	granite	channelling granite (obelisks)	ancient Egyptian kit	1923.08	0.00052	1.4
14e	average	2750	granite	percussion shaping granite (blocks)	stone and alloy	1785.71	0.00056	1.5
15a	average	2700	stone	sawing hard stones (*pierres dures*)	metal alloy	1000.00	0.00100	2.7
9g	conditioned	2711	marble	shaping marble (blocks)	16th C. masonry kit	180.00	0.00556	15.1
15j	conditioned	2500	stone	channelling *poros* and sandstone	stone and alloy	101.00	0.00990	24.8
13a	conditioned	1500	tuff	dressing porous volcanic masonry	unspecified	90.91	0.01100	16.5
9e	conditioned	2711	marble	shaping marble (blocks)	19th C. masonry kit	75.00	0.01333	36.1
15c	average	2700	stone	percussion shaping stone (blocks)	stone and alloy	61.73	0.01620	43.7
15b	average	2960	gypsum	sawing gypsum slabs (*dalles gypse*)	metal alloy	24.39	0.04100	121.4
15d	average	2000	brick	brick wall construction	stone and alloy	9.52	0.10500	210.0
15f	average	2000	brick	mixing bricks	stone and alloy	7.60	0.13150	263.0
4b	conditioned	1730	mudbrick	digging, mixing, and shaping bricks	ca. 2100-1600 BC kit	6.67	0.15000	259.5
15i	average	2700	rubble	rough manufacture (masonry)	stone and alloy	6.17	0.16200	437.4
15e	average	2100	mortar	mixing mortar	stone and alloy	4.35	0.23000	483.0
15g	average	2000	brick	moulding bricks	stone and alloy	3.03	0.33000	660.0
5f	average	700	wood	setting post upright (palisade)	stone hoe/handaxe	2.00	0.50000	350.0

Table A1.1c. Manufacturing and finishing rates.

ID	Reference	Method	Material Description	Tool Description	Original Rate
1a	Milner et al. 2010:109	experimental	compact silt to clay loam, variable moisture and occasional rocks	Mill Creek chert hoe replica, hafted on short wooden handle with rawhide, scooping assisted by white-tailed deer scapula and excavator's hands	0,202 m^3 in 1,78 hr
1b					0,609 m3 in 4,05 hr
1c					0,171 m^3 in 1,00 hr
1d					0,131 m^3 in 0,68 hr
1e					0,085 m^3 in 0,42 hr
1f					0,250 m^3 in 1,00 hr
1g					0,367 m^3 in 1,00 hr
1h					0,369 m^3 in 1,00 hr
2a	Ashbee and Jewell 1998:491	experimental	chalk	antler pick, scapula shovel, woven basket	5 cwt/m-h, 1 cwt = 1 ft^3
2b					8,3 cwt/m-h, 1 cwt = 1 ft^3, assisted basketing not counted
2c	Ashbee and Jewell 1998:491, citing Pitt Rivers 1875	experimental	chalk	antler pick	9 cwt/m-h, 1 cwt = 1 ft^3
3a	Squatriti 2002:41, citing Vulpe 1957	ethnographic	unspecified	unspecified	1,5 m^3 in 8 hr
3b	Squatriti 2002:31, citing Hofmann 1965 and the Royal Frankish Annals	historical	unspecified	unspecified	750,000 m^3, 6,000 workers, 55 days
4a	Ristvet 2007:199, citing tablet M.288 in Charpin 1993:196	historical	unspecified	unspecified	2.25 m^3/m-d
4b	Ristvet 2007:200, citing Robson 1999	historical	Old Babylonian period mudbrick wall	unspecified	1.5 m^3/m-d, 2.55 litres of barley/m-d
5a	Hammerstedt 2005:46	experimental	root-penetrated, compact silty loam	Mill Creek chert hoe replica, metal bucket	0,29 m^3 in 1 hr
5b	Hammerstedt 2005:50, citing ECAFE 1957	ethnographic	dry hard clay	modern hand tools	0,334 p-d per m^3
5c			common soil		0,1 p-d per m^3
5d	Hammerstedt 2005:59	experimental	tree cutting (30cm diameter)	stone tools	0.7 ph/tree, t=exp(-1.766058) d^1.622969 where t is time and d is diameter in cm
5e	Hammerstedt 2005:63-64		post transport		25 min. to carry post 1 km (teams of 4 to 6)
5f			post setting		30 min. to set post (teams of 4 to 6)
6a	Coles 1973:74, citing Pitt Rivers 1875	experimental	chalk	antler pick	1 m^3 in 1,5 hr for 2 men
6b					9 m^3 in 12 hr for 2 men
6c	Coles 1973:73, citing Jewell 1963	experimental	chalk	red deer antler picks, ox and horse scapulae, wicker baskets	1543 ph, including 388 ph among 4 supervisors for 113.75 m^3 (203,125 kg). Rate with supervision (0.0737 m^3/ph or 131.61 kg/ph), without supervision (0.0985 m^3/ph or 175.89 kg/ph)
6d					
6e					
6f				modern steel picks, shovels and buckets	750 kg/ph (50 kg = 0.028 m^3)
6g	Coles 1973:81, citing Hobley 1967	experimental	turf	modern metal tools	4.5 – 6.5 turfs (32 – 34 kg/turf)/m-h, 144 – 221 kg/m-h, prison labour
6h					
6i			turf and soil		840 – 1200 ph for 7600 turfs (243,200 – 258,400 kg), turf cutting and total cost for Lunt fort (190,000 turfs, 6.46 million kg), plus 40 – 46 m^3 earth fill
6j					

Table A1.2. Supplement for context IDs (continued on following pages).

ID	Reference	Method	Material Description	Tool Description	Original Rate
7a	Bachrach 2005:270, citing Bachrach 1993:65-72	ethnographic	unspecified	19th century hand tools	400,000 m^3 in 850,000 m-h
7b	Bachrach 2005:270, citing Bachrach 1993:65-72	ethnographic	unspecified	19th century hand tools	600,000 m^3 in 850,000 m-h
8a	Erasmus 1965:285-287	experimental	Las Bocas sandy soil	digging stick	2.6 m^3/m-d, m-d = 5 hr
8b				modern shovel	7,2 m^3/m-d, m-d = 5 hr
8c			tuff (porous rock from consolidated volcanic ash)	hardwood post	1700 kg per 5-hour man day, 1500 kg per m^3
8d				iron crowbar	5 tons of rock over an area of 30 sq. m in 5 hours
8e			Las Bocas sandy soil	5-gallon container	carrying soil 50 m, average load 0.02 m^3 (20 kg)
8f					carrying soil 100 m, average load 0.02 m^3 (20 kg)
8g			tuff (porous rock from consolidated volcanic ash)	head balanced	carrying rock 250 m, average load 28 kg, 6.8 trips per hour
8h				tumpline	carrying rock 500 m, average load 25 kg, 4 trips per hour
8i				tumpline	carrying rock 750 m, average load 34 kg, 3 trips per hour
8j				tumpline	carrying rock 1 km, average load 23 kg, 2.2 trips per hour
9a	DeLaine 1997:116-118, citing Pegoretti 1865	historical	clay for brickmaking	19th century hand tools	93 m^3 in 14 m-d
9b					49 m^3 in 7 m-d
9c			loading and carrying clay		1.58 m^3/m-d, 50 kg load averaged from Roman 2-modius basket (0.026 m^3) and 19th C. builder's basket (0.03 m^3)
9d	DeLaine 1997:121, citing Pegoretti 1865 and Klapisch-Zuber 1969		marble quarrying	metal tools	4 days for one mason and two assistants, or 12 md per m^3
9e			squaring of marble block		7.5 days for one stonecutter
9f			Carrara quarrying		3 md per carrata (1/3 m^3)
9g			Carrara squaring + quarrying		9 md per carrata (1/3 m^3)
9h	DeLaine 1997:98,107-108	historical	human portage average	basketing, likely using tumplines	50 kg at 5 km/h
9i			pack transport (donkey)	small donkey (unsp)	55 kg at 5 km/h
9j			pack transport (mule)	large mule (low range)	120 kg at 5 km/h
9k			pack transport (mule)	large mule (high range)	135 kg at 5 km/h
9l			drawn transport (ox)	single yoke oxcart (low range)	400 kg at 1.67 km/h
9m			drawn transport (ox)	single yoke oxcart (high range)	640 kg at 1.67 km/h
10a	Geddes 2004, citing Souness 1985	ethnographic	cutting turf for roofing	metal tools	200 turfs per md, 1000 turfs needed for roof with average surface area of 100 sq. m, 20 m^3/pd
11a	Aaberg and Bonsignore 1975:47,50-57	ethnographic	earthmoving with local soils	basketing, likely using tumplines	22 kg (0.011 m^3) loads, 10-minute walk of 600 yards

Table A1.2. (continued).

ID	Reference	Method	Material Description	Tool Description	Original Rate
12a	Burford 1969:189	historical	Pentelic marble to Eleusis	ox-drawn cart/wagon, single yoke	500 kg load limit, 22-mile trip in 2.5 to 3 days
13a	Abrams and McCurdy 2019:6-13, citing Abrams 1994	experimental	dressing volcanic tuff blocks	unspecified (stone tools?)	0.086 m^3/p-d (8-hour workday)
13b			quarrying tuff (Honduras)		0.41 m^3/p-d (5-hour workday)
14a	de Haan 2009:3, citing Lehner 1997:207	experimental	quarrying limestone blocks	iron tools (NOVA experiment)	0.089 m^3/man-hour
14b				stone and copper alloy tools (estimated)	0.033 m^3/man-hour
14c					0.02 m^3/man-hour, base case
14d			quarrying granite blocks	stone tools	1800 cm^3 in five hours, or 0.00036 m^3/man-hour
14e	de Haan 2009:3, citing Engelbach 1923:48				563 cm^3 in one hour, or 0.00056 m^3/man-hour
14f	de Haan 2009:3, citing Arnold 1991:40 and Goyon et al. 2004:164-166	historical	channelling granite obelisk		0.00052 m^3/man-hour, estimated from Hatshepsut obelisk (7-month completion) and unfinished Aswan obelisk
15a	Devolder 2013:43	compilation	sawing hard stone	(hammer)stone and metal alloy tools	0.001 m^2 per p-h
15b			sawing gypsum slabs		0.041 m^2 per p-h
15c			shaping stone blocks by direct or indirect percussion		0.0162 m^3 per p-h
15d			brick wall construction		0.105 m^3 per p-h
15e			mixing of mortar		0.23 m^3 per p-h
15f			mixing bricks		0.1315 m^3 per p-h
15g			moulding bricks		0.33 m^3 per p-h
15h			clay for brickmaking		0.1 m^3 per p-h
15i			rough rubble masonry manufacture		0.162 m^3 per p-h
15j			channelling cut stones		1 m^3 per 101 p-h

Table A1.2. (continued).

Tomb	Total (m³)	Dromos (m³)	Vault (m³)	Dro_L (m)	Dro_W (m)	Dro_H (m)	Sto_L (m)	Sto_W (m)	Sto_H (m)	Vault_L (m)	Vault_W (m)	Vault_H (m)
Menidi	618.00	349.00	269.00	27.00	2.90	6.74	2.74	1.70	3.02	8.25	8.35	8.81
Prosilio_T2	276.80	122.00	154.80	20.00	2.20	5.55	2.40	1.35	2.40	7.10	5.84	3.50
VT75	257.00	118.00	139.00	23.40	1.88	6.60	1.99	1.17	2.13	5.08	7.60	4.57
VT04	240.70	165.00	75.70	19.20	2.65	5.63	2.22	1.20	2.41	4.58	5.78	3.55
PTA	166.88		166.88									
VT25	126.30	52.00	74.30	13.20	1.98	4.29	1.13	0.98	1.84	4.79	3.90	4.09
VT78	106.00	51.40	54.60	11.90	2.17	5.47	1.27	0.94	2.06	3.80	4.58	3.23
VT77	96.40	52.00	44.40	11.00	1.89	4.88	1.26	0.91	1.33	3.56	4.71	3.27
VT62	94.90	32.30	62.60	10.60	1.84	3.48	0.82	0.94	2.15	3.74	5.18	3.17
VT29	82.10	31.00	51.10	9.73	1.77	3.93	0.85	0.93	2.09	3.66	4.70	3.29
VT54	81.40	46.80	34.60	9.43	2.19	5.09	1.56	0.99	1.59	3.15	4.55	2.87
VT21	74.90	35.00	39.90	8.63	2.44	3.43	1.00	0.93	2.35	2.99	4.58	2.93
VT53	65.50	38.10	27.40	10.90	1.91	4.34	1.38	0.86	1.17	3.57	3.71	2.79
PT03	60.50	38.10	22.40	8.87	2.01	4.74	1.23	0.78	1.28	3.44	3.58	2.81
VT69	51.20	19.10	32.10	6.52	1.94	3.34	1.75	1.11	1.16	3.86	3.32	3.45
VT56	47.80	25.80	22.00	6.77	2.29	3.56	0.91	0.97	1.68	3.76	3.85	2.92
VT07	47.03	43.10	3.93	12.40	1.47	3.47				3.21	1.11	1.14
VT36	45.00	17.20	27.80	7.26	1.33	3.15	1.64	0.76	1.16	2.83	3.81	2.53
PT07	44.80	24.80	20.00	8.48	1.79	3.90	0.98	0.77	1.36	3.61	3.94	2.48
VT22	42.60	23.80	18.80	8.62	1.68	4.50	1.09	0.85	1.29	3.37	3.36	2.91
VT64	40.00	25.80	14.20	9.23	2.06	2.85	1.00	0.76	0.97	3.25	3.27	2.41
VT26_Dro.	38.80	38.80		11.50	2.02	4.03						
PT16	35.62	3.22	32.40	3.79	1.51	1.18	0.68	0.83	0.87	2.33	2.55	1.11
VT31	35.20	14.40	20.80	6.24	1.32	4.05	0.86	0.76	1.56	2.67	4.04	2.62
VT34	32.90	19.00	13.90	8.83	1.57	3.16	1.15	0.77	1.14	3.16	3.09	2.33
PT10	32.80	20.30	12.50	8.04	1.80	3.69	0.49	0.71	0.95	2.77	3.47	2.32
PT08	32.00	18.40	13.60	8.15	1.82	3.73	0.61	1.17	1.51	2.97	2.95	2.17
PT21	31.60	17.90	13.70	6.74	1.88	4.14	0.44	0.67	1.15	2.92	3.35	2.16
VT71	28.30	15.50	12.80	6.06	1.64	3.64	0.61	0.78	1.33	3.18	3.15	2.70
AA01	27.75	13.50	14.25	6.00	1.50	3.00	1.00	0.75	1.00	3.00	3.00	2.50
PT09	27.50	17.40	10.10	7.11	1.34	3.37	0.93	0.61	0.88	2.85	2.35	2.36
VT09	27.30	12.90	14.40	6.52	1.68	2.71	0.57	0.80	1.01	3.01	2.96	2.40
PTh2	26.10		26.10	*Partial vault volume only								
VT70	25.30	11.40	13.90	5.33	1.65	2.89	1.06	0.90	1.15	2.95	3.31	2.45
VT68	25.15	4.55	20.60	3.23	1.86	1.03				3.09	3.63	2.81
VT55_Dro.	23.10	23.10		8.45	1.75	3.89						
VT67	22.06	9.06	13.00	6.35	1.17	2.04	0.69	0.79	1.00	3.46	3.59	2.41

Table A1.3. Supplement to Table 4.1 (Summary of tomb dimensions ranked by total volume) (continued overleaf).

Tomb	Total (m^3)	Dromos (m^3)	Vault (m^3)	Dro_L (m)	Dro_W (m)	Dro_H (m)	Sto_L (m)	Sto_W (m)	Sto_H (m)	Vault_L (m)	Vault_W (m)	Vault_H (m)
VT08	21.90	12.20	9.70	5.53	1.44	2.84	0.69	0.62	0.86	2.79	2.73	1.79
VT44	21.66	7.30	14.36	5.00	1.08	2.85				2.79	2.71	2.82
VT05	21.16	7.06	14.10	3.62	1.89	1.83	1.14	0.89	1.47	3.03	3.25	1.94
VT01	20.63	6.83	13.80	4.71	1.30	2.33	0.89	0.59	1.06	2.47	2.94	2.05
Dro_PT13	19.40	19.40		6.42	1.22	4.12						
PT18	18.95	10.60	8.35	5.31	1.39	3.21	0.47	0.50	1.01	2.77	2.73	1.82
VT60	18.90	12.00	6.90	6.42	1.34	2.61	0.67	0.53	0.61	2.69	2.62	1.96
VT42	18.70	11.00	7.70	6.36	1.45	2.11	1.11	0.58	1.14	2.48	2.66	1.71
PT02	18.56	3.86	14.70	2.26	1.09	1.75	1.03	0.71	1.52	2.58	2.34	1.55
VT13	18.29	4.49	13.80	4.66	1.55	1.55	0.77	0.85	1.05	2.65	2.84	1.98
VT43_Dro.	18.20	18.20		7.92	1.68	3.13						
VT24	17.83	11.10	6.73	5.86	1.76	2.04	0.75	0.70	0.86	2.38	2.46	1.60
VT02	17.42	4.32	13.10	3.39	1.05	2.36	0.82	0.62	1.13	2.20	4.04	1.83
VT19	17.30	10.80	6.50	4.53	1.94	2.10	0.78	0.62	1.03	2.27	2.35	1.57
VT72	17.11	8.56	8.55	4.87	1.39	2.92	0.74	0.67	0.98	2.63	2.71	2.21
VT06	16.98	9.44	7.54	4.87	1.53	2.24	0.84	0.68	0.89	2.16	2.51	1.76
PT11	16.33	11.60	4.73	7.31	1.49	2.26	0.78	0.64	0.96	1.97	1.95	1.82
VT59	15.72	7.13	8.59	5.10	1.33	1.72				2.45	2.28	1.42
VT14	15.31	6.65	8.66	4.05	1.38	1.99	0.58	0.75	1.37	1.99	2.34	1.94
VT28	13.49	7.00	6.49	5.33	1.18	2.21	0.46	0.49	0.86	2.39	2.65	1.96
VT40	13.24	7.30	5.94	5.00	1.08	2.85				2.21	2.19	1.91
VT27_Dro.	13.10	13.10		6.66	1.43	3.24						
VT15_Dro.	13.02	12.30	0.72	7.30	1.15	3.06						
VTU3_Dro.	12.40	12.40		6.21	1.45	3.37						
PT22	12.03	4.86	7.17	4.02	1.19	1.94	0.58	0.59	0.91	2.25	2.27	1.96
VT16	11.14	5.59	5.55	3.34	1.21	2.37	0.51	0.65	0.89	1.96	2.82	1.36
VT73	10.88	7.49	3.39	5.34	1.24	2.82	0.77	0.59	1.14	1.76	1.90	1.62
VT74	10.55	2.20	8.35	4.19	1.25	1.06	0.76	0.96	1.14	2.67	2.67	1.58
VT65	10.38	1.39	8.99	2.83	0.92	0.78	0.83	0.63	0.85	2.31	3.24	0.92
PT08_In	10.00		10.00							3.02	2.96	2.09
VT18_Dro.	8.86	8.86		4.96	1.48	2.65						
VT66	6.58	4.92	1.66	5.99	1.15	1.85	0.54	0.50	0.75	1.45	1.49	1.28
PTE1	5.98		5.98									
VT11	5.85	2.05	3.80	2.92	1.10	0.95	0.71	0.58	0.71	1.71	2.03	1.32
VTU2_Dro.	5.73	5.73		5.51	1.07	1.77						
VT63	5.31	1.96	3.35	3.57	1.47	0.66				1.76	1.72	0.95
VT03	4.88	4.02	0.86	4.32	1.65	1.48	0.57	0.47	0.84	1.00	1.18	0.92
PTA1	4.57		4.57									
VT61_U1	4.49	2.46	2.03	3.03	1.51	0.58				1.36	1.56	0.92

Table A1.3. (continued).

Tomb	Total (m^3)	Dromos (m^3)	Vault (m^3)	Dro_L (m)	Dro_W (m)	Dro_H (m)	Sto_L (m)	Sto_W (m)	Sto_H (m)	Vault_L (m)	Vault_W (m)	Vault_H (m)
Dro_PT12	4.37	4.37		5.13	0.78	2.07						
VT33	3.48		3.48									
VT57	2.57	1.41	1.16	2.16	0.88	0.49	0.47	0.80	0.56	1.60	1.23	0.65
PTST1	2.49		2.49									
VT76	2.38	0.88	1.50	1.20	1.01	0.36				1.97	1.87	0.44
VT30_Dro.	2.15	2.15		4.46	1.08	0.78						
PTA3	1.55		1.55									
PTA2	1.22		1.22									
PTE2	1.22		1.22									
PTST2	1.11		1.11									
PTE1A	0.76		0.76									
PTA4/A6	0.03		0.03									
PTA5(A8)	0.02		0.02									

Table A1.3. (continued).

Tomb	Low rate (ph)	High rate (ph)	5-hr days	Reopen rate (ph)	(Reopen) 5-hr days	Reopened x 5 (ph)	Reopened x 10 (ph)	Reopened x 20 (ph)	Closing (ph)	(Closing) 5-hr days
Menidi	5562	7416	149	1396	28	6980	13960	27920	698	14
VT75	2313	3084	62	472	10	2360	4720	9440	236	5
VT04	2167	2889	58	660	14	3300	6600	13200	330	7
PTA	1502	2003	41	0	0	0	0	0	0	0
VT25	1137	1516	31	208	5	1040	2080	4160	104	3
VT78	954	1272	26	206	5	1028	2056	4112	103	3
VT77	868	1157	24	208	5	1040	2080	4160	104	3
VT62	855	1139	23	130	3	646	1292	2584	65	2
VT29	739	986	20	124	3	620	1240	2480	62	2
VT54	733	977	20	188	4	936	1872	3744	94	2
VT21	675	899	18	140	3	700	1400	2800	70	2
VT53	590	786	16	153	4	762	1524	3048	77	2
PT03	545	726	15	153	4	762	1524	3048	77	2
VT69	461	615	13	77	2	382	764	1528	39	1
VT56	431	574	12	104	3	516	1032	2064	52	2
VT07	424	565	12	173	4	862	1724	3448	87	2
VT36	405	540	11	69	2	344	688	1376	35	1
PT07	404	538	11	100	2	496	992	1984	50	1
VT22	384	512	11	96	2	476	952	1904	48	1
VT64	360	480	10	104	3	516	1032	2064	52	2

Table A1.4. Supplement to Table 4.2 (Estimated costs for labour teams of 10 ranked by ph) (continued overleaf).

Tomb	Low rate (ph)	High rate (ph)	5-hr days	Reopen rate (ph)	(Reopen) 5-hr days	Reopened x 5 (ph)	Reopened x 10 (ph)	Reopened x 20 (ph)	Closing (ph)	(Closing) 5-hr days
VT26_Dro.	350	466	10	156	4	776	1552	3104	78	2
PT16	321	428	9	13	1	65	129	258	7	1
VT31	317	423	9	58	2	288	576	1152	29	1
VT34	297	395	8	76	2	380	760	1520	38	1
PT10	296	394	8	82	2	406	812	1624	41	1
PT08	288	384	8	74	2	368	736	1472	37	1
PT21	285	380	8	72	2	358	716	1432	36	1
VT71	255	340	7	62	2	310	620	1240	31	1
AA01	250	333	7	54	2	270	540	1080	27	1
PT09	248	330	7	70	2	348	696	1392	35	1
VT09	246	328	7	52	2	258	516	1032	26	1
Part_PTh2	235	314	7	0	0	0	0	0	0	0
VT70	228	304	7	46	1	228	456	912	23	1
VT68	227	302	7	19	1	91	182	364	10	1
VT55_Dro.	208	278	6	93	2	462	924	1848	47	1
VT67	199	265	6	37	1	182	363	725	19	1
VT08	198	263	6	49	1	244	488	976	25	1
VT44	195	260	6	30	1	146	292	584	15	1
VT05	191	254	6	29	1	142	283	565	15	1
VT01	186	248	5	28	1	137	274	547	14	1
Dro_PT13	175	233	5	78	2	388	776	1552	39	1
PT18	171	228	5	43	1	212	424	848	22	1
VT60	171	227	5	48	1	240	480	960	24	1
VT42	169	225	5	44	1	220	440	880	22	1
PT02	168	223	5	16	1	78	155	309	8	1
VT13	165	220	5	18	1	90	180	360	9	1
VT43_Dro.	164	219	5	73	2	364	728	1456	37	1
VT24	161	214	5	45	1	222	444	888	23	1
VT02	157	210	5	18	1	87	173	346	9	1
VT19	156	208	5	44	1	216	432	864	22	1
VT72	154	206	5	35	1	172	343	685	18	1
VT06	153	204	5	38	1	189	378	756	19	1
PT11	147	196	4	47	1	232	464	928	24	1
VT59	142	189	4	29	1	143	286	571	15	1
VT14	138	184	4	27	1	133	266	532	14	1

Table A1.4. (continued).

Tomb	Low rate (ph)	High rate (ph)	5-hr days	Reopen rate (ph)	(Reopen) 5-hr days	Reopened x 5 (ph)	Reopened x 10 (ph)	Reopened x 20 (ph)	Closing (ph)	(Closing) 5-hr days
VT28	122	162	4	28	1	140	280	560	14	1
VT40	120	159	4	30	1	146	292	584	15	1
VT15_ Dro.	118	157	4	50	1	246	492	984	25	1
VT27_ Dro.	118	158	4	53	2	262	524	1048	27	1
VTU3_ Dro.	112	149	3	50	1	248	496	992	25	1
PT22	109	145	3	20	1	98	195	389	10	1
VT16	101	134	3	23	1	112	224	448	12	1
VT73	98	131	3	30	1	150	300	600	15	1
VT74	95	127	3	9	1	44	88	176	5	1
VT65	94	125	3	6	1	28	56	112	3	1
PT08_In	90	120	3	0	0	0	0	0	0	0
VT18_ Dro.	80	107	3	36	1	178	355	709	18	1
VT66	60	79	2	20	1	99	197	394	10	1
PTE1	54	72	2							
VT11	53	71	2	9	1	41	82	164	5	1
VTU2_ Dro.	52	69	2	23	1	115	230	459	12	1
VT63	48	64	2	8	1	40	79	157	4	1
VT03	44	59	2	17	1	81	161	322	9	1
PTA1	42	55	2							
VT61_U1	41	54	2	10	1	50	99	197	5	1
Dro_PT12	40	53	2	18	1	88	175	350	9	1
VT33	32	42	1	0	0	0	0	0	0	0
VT57	24	31	1	6	1	29	57	113	3	1
PTST1	23	30	1	0	0	0	0	0	0	0
VT76	22	29	1	4	1	18	36	71	2	1
VT30_ Dro.	20	26	1	9	1	43	86	172	5	1
PTA3	14	19	1							
PTA2	11	15	1							
PTE2	11	15	1							
PTST2	10	14	1							
PTE1A	7	10	1							
PTA4/A6	1	1	1							
PTA5(A8)	1	1	1							

Table A1.4. (continued).

Tomb	TREX	RexD	RexV	Rex_ dl	Rex_ dw	Rex_ dh	Rex_ sl	Rex_ sw	Rex_ sh	Rex_ vl	Rex_ vw	Rex_ vh
Menidi	22.27	25.85	18.88	4.50	1.93	2.25	2.74	2.27	3.02	2.75	2.78	3.52
Prosilio_T2	9.97	9.04	10.86	3.33	1.47	1.85	2.40	1.80	2.40	2.37	1.95	1.40
VT75	9.26	8.74	9.75	3.90	1.25	2.20	1.99	1.56	2.13	1.69	2.53	1.83
VT04	8.67	12.22	5.31	3.20	1.77	1.88	2.22	1.60	2.41	1.53	1.93	1.42
VT25	4.55	3.85	5.21	2.20	1.32	1.43	1.13	1.31	1.84	1.60	1.30	1.64
VT78	3.82	3.81	3.83	1.98	1.45	1.82	1.27	1.25	2.06	1.27	1.53	1.29
VT77	3.47	3.85	3.12	1.83	1.26	1.63	1.26	1.21	1.33	1.19	1.57	1.31
VT62	3.42	2.39	4.39	1.77	1.23	1.16	0.82	1.25	2.15	1.25	1.73	1.27
VT29	2.96	2.30	3.59	1.62	1.18	1.31	0.85	1.24	2.09	1.22	1.57	1.32
VT54	2.93	3.47	2.43	1.57	1.46	1.70	1.56	1.32	1.59	1.05	1.52	1.15
VT21	2.70	2.59	2.80	1.44	1.63	1.14	1.00	1.23	2.35	1.00	1.53	1.17
VT53	2.36	2.82	1.92	1.82	1.27	1.45	1.38	1.15	1.17	1.19	1.24	1.12
PT03	2.18	2.82	1.57	1.48	1.34	1.58	1.23	1.04	1.28	1.15	1.19	1.12
VT69	1.85	1.41	2.25	1.09	1.29	1.11	1.75	1.48	1.16	1.29	1.11	1.38
VT56	1.72	1.91	1.54	1.13	1.53	1.19	0.91	1.29	1.68	1.25	1.28	1.17
VT07	1.69	3.19	0.28	2.07	0.98	1.16				1.07	0.37	0.46
VT36	1.62	1.27	1.95	1.21	0.89	1.05	1.64	1.01	1.16	0.94	1.27	1.01
PT07	1.61	1.84	1.40	1.41	1.19	1.30	0.98	1.02	1.36	1.20	1.31	0.99
VT22	1.54	1.76	1.32	1.44	1.12	1.50	1.09	1.13	1.29	1.12	1.12	1.16
VT64	1.44	1.91	1.00	1.54	1.37	0.95	1.00	1.02	0.97	1.08	1.09	0.96
VT26_Dro.	1.40	2.87	0.00	1.92	1.35	1.34						
PT16	1.28	0.24	2.27	0.63	1.01	0.39	0.68	1.10	0.87	0.78	0.85	0.44
VT31	1.27	1.07	1.46	1.04	0.88	1.35	0.86	1.01	1.56	0.89	1.35	1.05
VT34	1.19	1.41	0.98	1.47	1.05	1.05	1.15	1.02	1.14	1.05	1.03	0.93
PT10	1.18	1.50	0.88	1.34	1.20	1.23	0.49	0.94	0.95	0.92	1.16	0.93
PT08	1.15	1.36	0.95	1.36	1.21	1.24	0.61	1.56	1.51	0.99	0.98	0.87
PT21	1.14	1.33	0.96	1.12	1.25	1.38	0.44	0.90	1.15	0.97	1.12	0.86
VT71	1.02	1.15	0.90	1.01	1.09	1.21	0.61	1.04	1.33	1.06	1.05	1.08
AA01	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
PT09	0.99	1.29	0.71	1.19	0.89	1.12	0.93	0.81	0.88	0.95	0.78	0.94
VT09	0.98	0.96	1.01	1.09	1.12	0.90	0.57	1.06	1.01	1.00	0.99	0.96
VT70	0.91	0.84	0.98	0.89	1.10	0.96	1.06	1.21	1.15	0.98	1.10	0.98
VT68	0.91	0.34	1.45	0.54	1.24	0.34				1.03	1.21	1.12
VT55_Dro.	0.83	1.71	0.00	1.41	1.17	1.30						
VT67	0.79	0.67	0.91	1.06	0.78	0.68	0.69	1.05	1.00	1.15	1.20	0.96
VT08	0.79	0.90	0.68	0.92	0.96	0.95	0.69	0.82	0.86	0.93	0.91	0.72
VT44	0.78	0.54	1.01	0.83	0.72	0.95				0.93	0.90	1.13
VT05	0.76	0.52	0.99	0.60	1.26	0.61	1.14	1.19	1.47	1.01	1.08	0.78
VT01	0.74	0.51	0.97	0.79	0.87	0.78	0.89	0.79	1.06	0.82	0.98	0.82

Table A1.5. Supplement to Table 4.3 (Tomb Relative Index ranked by TRex).

Tomb	TREX	RexD	RexV	Rex_dl	Rex_dw	Rex_dh	Rex_sl	Rex_sw	Rex_sh	Rex_vl	Rex_vw	Rex_vh
Dro_PT13	0.70	1.44	0.00	1.07	0.81	1.37						
PT18	0.68	0.79	0.59	0.89	0.93	1.07	0.47	0.66	1.01	0.92	0.91	0.73
VT60	0.68	0.89	0.48	1.07	0.89	0.87	0.67	0.71	0.61	0.90	0.87	0.78
VT42	0.67	0.81	0.54	1.06	0.97	0.70	1.11	0.77	1.14	0.83	0.89	0.68
PT02	0.67	0.29	1.03	0.38	0.73	0.58	1.03	0.95	1.52	0.86	0.78	0.62
VT13	0.66	0.33	0.97	0.78	1.03	0.52	0.77	1.13	1.05	0.88	0.95	0.79
VT43_Dro.	0.66	1.35	0.00	1.32	1.12	1.04						
VT24	0.64	0.82	0.47	0.98	1.17	0.68	0.75	0.94	0.86	0.79	0.82	0.64
VT02	0.63	0.32	0.92	0.57	0.70	0.79	0.82	0.83	1.13	0.73	1.35	0.73
VT19	0.62	0.80	0.46	0.76	1.29	0.70	0.78	0.83	1.03	0.76	0.78	0.63
VT72	0.62	0.63	0.60	0.81	0.93	0.97	0.74	0.89	0.98	0.88	0.90	0.88
VT06	0.61	0.70	0.53	0.81	1.02	0.75	0.84	0.90	0.89	0.72	0.84	0.70
PT11	0.59	0.86	0.33	1.22	0.99	0.75	0.78	0.85	0.96	0.66	0.65	0.73
VT59	0.57	0.53	0.60	0.85	0.89	0.57				0.82	0.76	0.57
VT14	0.55	0.49	0.61	0.68	0.92	0.66	0.58	0.99	1.37	0.66	0.78	0.78
VT28	0.49	0.52	0.46	0.89	0.79	0.74	0.46	0.66	0.86	0.80	0.88	0.78
VT40	0.48	0.54	0.42	0.83	0.72	0.95				0.74	0.73	0.76
VT27_Dro.	0.47	0.97	0.00	1.11	0.95	1.08						
VT15_Dro.	0.47	0.91	0.05	1.22	0.77	1.02						
VTU3_Dro.	0.45	0.92	0.00	1.04	0.97	1.12						
PT22	0.43	0.36	0.50	0.67	0.79	0.65	0.58	0.79	0.91	0.75	0.76	0.78
VT16	0.40	0.41	0.39	0.56	0.81	0.79	0.51	0.87	0.89	0.65	0.94	0.54
VT73	0.39	0.55	0.24	0.89	0.83	0.94	0.77	0.78	1.14	0.59	0.63	0.65
VT74	0.38	0.16	0.59	0.70	0.83	0.35	0.76	1.28	1.14	0.89	0.89	0.63
VT65	0.37	0.10	0.63	0.47	0.61	0.26	0.83	0.85	0.85	0.77	1.08	0.37
PT08_In	0.36	0.00	0.70	0.00	0.00	0.00				1.01	0.99	0.84
VT18_Dro.	0.32	0.66	0.00	0.83	0.99	0.88						
VT66	0.24	0.36	0.12	1.00	0.77	0.62	0.54	0.66	0.75	0.48	0.50	0.51
VT11	0.21	0.15	0.27	0.49	0.73	0.32	0.71	0.77	0.71	0.57	0.68	0.53
VTU2_Dro.	0.21	0.42	0.00	0.92	0.71	0.59						
VT63	0.19	0.15	0.24	0.60	0.98	0.22				0.59	0.57	0.38
VT03	0.18	0.30	0.06	0.72	1.10	0.49	0.57	0.63	0.84	0.33	0.39	0.37
VT61_U1	0.16	0.18	0.14	0.51	1.01	0.19				0.45	0.52	0.37
Dro_PT12	0.16	0.32	0.00	0.86	0.52	0.69						
VT33	0.13	0.00	0.24									
VT57	0.09	0.10	0.08	0.36	0.59	0.16	0.47	1.07	0.56	0.53	0.41	0.26
VT76	0.09	0.07	0.11	0.20	0.67	0.12				0.66	0.62	0.18
VT30_Dro.	0.08	0.16	0.00	0.74	0.72	0.26						

Table A1.5. (continued).

Appendix 2

Other tombs

Portes Chamber Tomb 1

Along the eastern edge of the saddle bridging the hill and south-eastern ridge that hosts the majority of tombs at the cemetery, PT1 is mapped upslope and adjacent to the south of the roof of PT2. With no easy access from PT2 or our network of fixed points, PT1 was omitted from this study. According to one of the park's information placards (Kolonas et al. 2002: 1), PT1 is the smallest chamber tomb at the cemetery and was likely meant for a child. No remains were recovered here, but its proximity to the LHIIIA-C PT2, PT24, and PT27 suggests a close association with these.

Portes Chamber Tomb 2

The model for PT2 included 294 photos and 12 photopoint markers, many of which were linked with the failed model of PT24/27.

Portes Chamber Tombs 4-6

PT4, PT5, and PT6 are the easternmost of the mapped tombs at the cemetery. Lying outside the path and railing along the steep eastward slope leading into the valley more than 30 m below, the tombs were not safely accessible with equipment and are thus not included within this study.

Portes Chamber Tomb 17

PT17 forms the eastern edge of the 'bat cave cluster' (PT17/25/26/29) adjacent to the southwest of PT9. A small opening connects the collapsing tombs with the partially excavated *dromos* of PT9. A stone marker placed above the façade to mark the tomb's position is mentioned for three of the tombs in this cluster (PT17, 25, and 26), though it is not clear whether this refers to three separate markers or one with multiple associations due to the proximity of the tombs (Kolonas et al. 2002: 2). Due to the cluster's location on the steep slope southwest of Tumulus A and its apparent poor state of preservation, PT17 was not included within this study.

Portes Chamber Tombs 19 and 20

PT19 and PT20 lie on the south-eastern perimeter of the central cluster radiating from Tumulus A, separating it from the differently oriented PT3 directly to their southeast. Sheer-sided *dromoi* with no apparent ease of access automatically ruled out their inclusion within this study. The signposted map-scaling limits our knowledge of how these tombs actually appear relative to others that were included. PT21, for instance, opens into a secondary, higher vault with an original entrance into the side (rather than in-line) of a separate *dromos*. Unmapped and unlabelled, PT21's higher neighbouring vault may open into the PT19 *dromos*.

Portes Chamber Tomb 24

PT24 was part of the failed model with its immediate neighbours PT27 and PT2. Although the latter functioned in its own separate model, the small concave depressions left by PT24 and PT27 were discarded as meaningful candidates for photogrammetric modelling after initial attempts failed to align the tombs with one another and the adjacent trail.

Portes Chamber Tombs 25-29

These tombs were not included within this study for various reasons. PT25, PT26, and PT29 form part of the 'bat cave cluster' of unstable tombs along the western edge of the Tumulus A central group. Due to their placement on the slope and generally poor preservation state, the tombs were omitted from study. PT27 was included within the failed model of PT24 as the second in a pair of concave depressions in the hillside adjacent to the trail, and PT28 was not immediately identifiable, being unlabelled and unmapped.

Portes Tumuli B and C groups

The remaining tombs on site, largely associated with the poorly preserved *tholos* PTh1, Tumulus B, and Tumulus C, were omitted from this study. This includes the built chamber and cist graves from the B (B1-4) and C groups (C1-3), Tumulus B (not mapped but likely in the vicinity of B group), and the destroyed PTh1. Notably, tomb C1 is the largest recorded built chamber tomb in mainland Greece and is mapped above the approximate position of the PT3 chamber (Kolonas et al. 2002: 5). The latter, otherwise known as the Warrior Tomb and dated to the LH IIIC period, could have targeted this area as exceptional due to the presence of the early LH I/II period tomb C1, which preceded it by several centuries and was largely deconstructed for its useful stone.

Voudeni Tomb 1

The VT1 model included 485 photos and 15 photopoint markers and boasted one of the lowest error margins at under 3 mm.

Voudeni Tomb 2

With a maximum error of just under a centimetre, alignment of the VT2 model involved 405 photos and 15 photopoint markers.

Voudeni Tomb 3

VT3 was modelled with 306 photos and 8 photopoint markers with no more than a centimetre of error.

Voudeni Tomb 4

VT4 was modelled with 791 photos and 11 photopoint markers and, despite its size, maintained a maximum error margin under a centimetre.

Voudeni Tomb 5

VT5 was modelled with 657 photos and 9 photopoint markers with an average error of under 3 mm.

Voudeni Tomb 6

A total of 412 photos and 8 photopoint markers were needed to complete the model.

Voudeni Tomb 7

VT7 was modelled using 329 photos and 15 photopoint markers.

Voudeni Tomb 8

VT8 was modelled with 349 photos and 7 photopoint markers with an average error of under 5 mm.

Voudeni Tomb 9

A total of 447 photos and 15 photopoint markers captured the model with an average error of roughly a centimetre after revision of problematic photopoints.

Voudeni Tomb 12

VT12 is one of the few missing and unlabelled tombs not able to be paired with a likely candidate tomb surveyed here. As such, it is not included within this study.

Voudeni Tomb 13

Modelling of VT13 involved 432 photos and 9 photopoint markers with an average error of just over 5 mm.

Voudeni Tomb 14

The tomb was modelled with 478 photos and 7 photopoint markers maintaining an average error around 1 cm.

Voudeni Tomb 15

Modelling of the tomb comprised 465 photos and 9 photopoint markers with an average error of 1.1 cm.

Voudeni Tombs 17-20

VT17 and VT20 were unable to be located or convincingly linked to unlabelled tombs surveyed herein. Models for VT18 and VT19, both in the NE group, failed to render fully. VT18 has a steep *dromos* leading to a vault with circular base, vaulted roof, and ceiling cragged with partial fissure collapses. Modelling of the *dromos* succeeded and yielded 8.86 m^3. The model of the vault inexplicably failed despite repeated attempts to realign. VT18 was recorded with 355 photos and 10 photopoint markers with an average error under 6 mm. Excavation of the *dromos* alone would require 80-107 ph or 3 days for 10 labourers.

Modelling of VT19 (312 photos, 10 photopoint markers, average error less than 2 mm), partially failed due to the overpass of the walkway that cuts across the top of the deep *dromos* directly above the facade of the *stomion*, confusing Photoscan with an alternating open and closed *dromos* at the surface. A rough size can be estimated at 10.8 m^3 for the VT19 *dromos*. When added to the vault (6.5 m^3), VT19's volume (17.3 m^3) is comparable to that of VT24. The VT19 vault shows a circular base, vaulted roof, and partial ceiling collapse that would otherwise add 1.5 m^3 to its volume. Since the walkway overpass complicates the model of the *dromos*, the labour model for VT19 should be taken with an extra measure of caution. Accepting those limitations, excavation costs for VT19 are 156-208 ph or 5 days for 10 labourers.

Voudeni Tomb 21

Modelling of VT21 comprised 597 photos and 10 photopoint markers with an average error of under 8 mm.

Voudeni Tomb 22

A total of 619 photos and 10 photopoint markers produced an average error of under 7 mm.

Voudeni Tomb 23

Also in the central group near VT4 and VT22, VT23 failed to render fully in Photoscan. The tomb has a standard *dromos* and a circular chamber with an inclining vaulted (conical and *tholos*-like) roof. Reference points failed to reconstruct the *dromos*, leaving only a free-floating vault without secure dimensions. The stored dataset for reattempted models includes 480 photos and 9 photopoint markers.

Voudeni Tomb 24

The model comprised 404 photos and 8 photopoint markers with an average error of 4 mm.

Voudeni Tomb 25

The VT25 model comprised 532 photos and 8 photopoint markers with an average error of under 4 mm.

Voudeni Tomb 26

The model comprised 439 photos and 9 photopoint markers with an average error of 5 mm.

Voudeni Tomb 27

Its model comprised 600 photos and 9 photopoint markers with an average error of 1 cm.

Voudeni Tomb 28

The model comprised 633 photos and 10 photopoint markers with an average error of 5 mm.

Voudeni Tomb 29

The VT29 model comprised 488 photos and 10 photopoint markers with an average error of just over 3 mm.

Voudeni Tomb 30

VT30 represents a collapsed or unfinished tomb with only a *dromos* to model in its current form. The tomb lies at the far north-eastern corner of the lawn maintained for the cemetery. An overhanging branch from a nearby mature tree prompted additional steps in cropping the model, which relied upon 158 photos and 5 photopoint markers with an average error of 8 cm. Although not especially useful as a comparative in its current state, the VT30 *dromos* measures only 2.15 m^3, the second smallest recorded on site after VT11 (2.05 m^3). Expected excavation costs would range around 20-26 ph or no more than 2 days for 4 labourers.

Voudeni Tomb 31

Modelling of VT31 comprised 643 photos and 10 photopoint markers with an average error of 1 cm.

Voudeni Tomb 32

VT32 marks the entrance to what appears to be a collapsed *dromos*. The tomb lies to the northeast of VT31 in the central group below the modern path. Since the tomb is unfinished or unexcavated, it was omitted from this study.

Voudeni Tomb 34

Modelling of VT34 comprised 760 photos and 10 photopoint markers with an average error under 8 mm.

Voudeni Tomb 36

Modelling VT36 comprised 647 photos and 10 photopoint markers with an average error under 3 mm.

Voudeni Tomb 39

VT39 lies directly above the wood-frame awning covering VT4 in the central group downslope of the modern path. With a steep *dromos* and no secure tie-off, the tomb was omitted from this study.

Voudeni Tomb 40 and 44

Modelling of VT40 and VT44 comprised 705 photos and 9 photopoint markers with an average error under 3 mm.

Voudeni Tomb 42

Modelling of VT42 comprised 731 photos and 8 photopoint markers with an average error of 4 mm, though error was among the lowest seen pre-optimisation of the camera locations.

Voudeni Tomb 43

In the northeast group immediately west of VT42, VT43 has a multi-slope *dromos* and vault with a four-sided base. The *stomion* shows a low rectangular shape tapering at the top, trending toward a trapezoidal shape. Lighting differential between the sunny *dromos* and dark vault caused a failure of the vault point cloud. Separating the parts may prove successful in future 'chunking' and combining of the model. The dataset for VT43 comprised 624 photos and 9 photopoint markers with an average error under 10 mm. The *dromos* model succeeded and yielded a volume of 18.2 m^3, approaching the total volume of VT42. Expected excavation costs for the *dromos* alone would range from 164-219 ph or 5 days for 10 labourers. Tombs with comparable *dromoi* include VT34 and VT36. Assuming the vault of VT43 lies between the range of their vaults (13.9-27.8 m^3), estimated total investment for VT43 would rise another 3-6 days for 10 labourers.

Voudeni Tombs 45-52

VT45-52 cluster in the southernmost part of the cemetery. These were unable to be accessed and are not included within this study. As mapped, many appear to be buried beneath the slope around the modern paths near VT55.

Voudeni Tomb 53

Modelling for VT53 comprised 533 photos and 10 photopoint markers with an average error under 4 mm.

Voudeni Tomb 54

Modelling for VT54 comprised 715 photos and 10 photopoint markers with an average error under 10 mm.

Voudeni Tomb 55

The dataset for reattempted models for VT55 comprises 407 photos and 10 photopoint markers with an average error of 11 mm.

Voudeni Tomb 56

With a low pre-optimised error for camera locations, modelling for VT56 comprised 443 photos and 9 photopoint markers with an average, post-optimised error under 5 mm.

Voudeni Tomb 57

Modelling for VT57 comprised 131 photos and 7 photopoint markers with an average error under 8 mm.

Voudeni Tomb 58

VT58 is unlisted on site maps and could not be conclusively identified with one of the unnumbered tombs surveyed herein. It is likely in the southern portion of the cemetery and could be buried or misidentified.

Voudeni Tomb 59

Modelling for VT59 comprised 293 photos and 11 photopoint markers with an average error of 7 mm.

Voudeni Tomb 60

Modelling for VT60 comprised 354 photos and 9 photopoint markers with an average error under 15 mm.

Voudeni Tomb 61 (U1)

Modelling for VT61 (U1) comprised 168 photos and 10 photopoint markers with an average error under 17 mm.

Voudeni Tomb 62

Modelling for VT62 comprised 492 photos and 9 photopoint markers with an average error under 6 mm.

Voudeni Tomb 63

Modelling for VT63 comprised 244 photos and 8 photopoint markers with an average error under 4 mm. Pre-optimisation of camera locations the average error remained under 6 mm, and the point cloud showed remarkable fidelity for the myriad of features surrounding the tomb, including the tile roof of the protective awning for VT62.

Voudeni Tomb 64

Modelling for VT64 comprised 408 photos and 8 photopoint markers with an average error of 5 mm.

Voudeni Tomb 65

Modelling for VT65 comprised 213 photos and 10 photopoint markers with an average error under 5 mm.

Voudeni Tomb 66

Modelling for VT66 comprised 386 photos and 10 photopoint markers with an average error under 10 mm.

Voudeni Tombs 67 and 68

Modelling for VT67 and VT68 comprised 848 photos and 10 photopoint markers with an average error under 8 mm.

Voudeni Tomb 69

Modelling for VT69 comprised 445 photos and 9 photopoint markers with an average error under 7 mm.

Voudeni Tomb 70

Modelling for VT70 comprised 483 photos and 10 photopoint markers with an average error under 7 mm.

Voudeni Tomb 71

Modelling for VT71 comprised 813 photos and 9 photopoint markers with an average error of 3 mm. Pre-optimisation error reflected a low 5 mm average.

Voudeni Tomb 72

Modelling for VT72 comprised 814 photos and 9 photopoint markers with an average error under 6 mm.

Voudeni Tomb 73

Modelling for VT73 comprised 338 photos and 10 photopoint markers with an average error under 8 mm.

Voudeni Tomb 74

Modelling for VT74 comprised 398 photos and 10 photopoint markers with an average error under 4 mm. Pre-optimisation, two photopoints were removed to correct an initial error of over a metre.

Voudeni Tomb 75

Modelling for VT75 comprised 1828 photos and 15 photopoint markers with an average error under 7 mm.

Voudeni Tomb 76

Modelling for VT76 comprised 130 photos and 8 photopoint markers with an average error under 4 mm.

Voudeni Tomb 77

Modelling for VT77 comprised 686 photos and 10 photopoint markers with an average error of 3 mm.

Voudeni Tomb 78

Modelling for VT78 comprised 647 photos and 11 photopoint markers with an average error of 5 mm.

Voudeni Tomb (U2)

VT U2 is an unlabelled tomb that could not be conclusively identified with a missing mapped tomb in the west group. The proximity of VT66 and VT67 to the unlabelled VT U2 *dromos* may have contributed to some confusion between the diagrammatic map and the tomb plaques (Kolonas 2009b: 14, Figure 10). Only the *dromos* remains here, accompanying an unfinished or unexcavated vault and closed *stomion*. Some stone rubble signifies the latter, but much of the material marking the interior edge of the *dromos* matches the marl or earth fill of its walls. Construction or excavation of the vault may have been aborted due to the proximity of a collapsed adjacent tomb to the right below the modern path. In the description of VT68, Kolonas (2009b: 26) suggests that its damaged vault intersected with two neighbouring tombs to its northwest (VT67) and northeast. This could indicate the vault of VT U2. Modelling for VT U2 comprised 162 photos and 8 photopoint markers with an average error under 5 mm. Volume and labour estimates exclusively reflect the *dromos*, the only open feature remaining here. At 5.73 m^3, expected excavation costs are 52-69 ph or 2 days for 10 labourers.

Voudeni Tomb (U3)

VT U3 is the third and final unlabelled tomb that could not be linked to a missing mapped one in the northeast group. VT41 is listed here on the diagrammatic map (Kolonas 2009b: 14, Figure 10), but the tomb plaque for 41 at the cemetery lies in the pit cluster associated with VT33. Again, only the *dromos* remains for VT U3, leading to an unfinished or unexcavated collapsed vault. Where the *stomion* should lie, a sinkhole-like undulation could signify collapse. Construction or excavation may have been abandoned due to overlying *dromoi* directly upslope. In profile, the *dromos* does not maintain a consistent wedge shape as many others do, with the floor arcing downward gradually before becoming steep midway through and redirecting back to a gradual slope. Modelling for VT U3 comprised 274 photos and 8 photopoint markers with an average error of 3 mm. The *dromos* has a volume of 12.4 m^3 (RexD 0.92), near the expected standard for *dromoi* volume, with expected excavation costs of 112-149 ph or no more than 3 days for 10 labourers. With a completed vault of comparable size, it is easy to imagine VT U3 in a similar size class to VT8 and VT9.

Appendix 3

Digital collection of excess tomb models

Data related to the project, including more than 40,000 photos organised by site and tomb name, will be made available from September 2021 with Data Archiving and Networked Services (DANS), an institute of the Royal Netherlands Academy of Arts and Sciences (KNAW). This can be accessed through (https://easy.dans.knaw.nl/ui/datasets/id/easy-dataset:182792) or the persistent identifier (https://doi.org/10.17026/dans-zyb-y9cy). Further information on how to navigate the dataset can be found in the data explanation file. Figures removed from the original manuscript can be found under the following file names:

A3.1.F4.2.6.	PT2 entrance with PT1 visible as a small depression in the upper right corner near the protective awning, facing east.
A3.2.F4.2.8.	PT3 Warrior Tomb entrance, facing southwest.
A3.3.F4.2.11.	Remnant stone walling from Tomb C1 above the PT3 vault, facing northeast.
A3.4.F4.2.12.	C group of built chamber tombs and former Tumulus C near PT3, facing east.
A3.5.F4.2.13.	PT7 entrance, facing north. The entrance to PT18 is visible on the upper right edge of the frame.
A3.6.F4.2.17.	PT9 entrance, facing north.
A3.7.F4.2.19.	PT10 entrance, facing west.
A3.8.F4.2.21.	PT11 (right) and PT12 entrances, facing south.
A3.9.F4.2.22.	PT11 and PT12 ground plan and sparse cloud model (western cross-section).
A3.10.F4.2.23.	PT13 sparse cloud plan and dense cloud model (northern cross-section). See drawn ground plan for PT10 (Figure 4.2.13).
A3.11.F4.2.24.	PT16 entrance, facing south-southwest.
A3.12.F4.2.25.	PT16 ground plan and wireframe model (eastern cross-section).
A3.13.F4.2.26.	PT18 entrance, facing north-northeast.
A3.14.F4.2.28.	PT21 entrance, facing northeast.
A3.15.F4.2.30.	PT22 entrance, facing south.
A3.16.F4.3.4.	VT1 entrance, facing southeast.
A3.17.F4.3.6.	VT2 entrance (right), facing south.
A3.18.F4.3.8.	VT3 entrance, facing southwest.
A3.19.F4.3.10.	VT4 entrance, facing southeast.

A3.62.F4.3.74.	VT60 entrance, facing southeast.
A3.63.F4.3.76.	VT61 (U1) entrance, facing southeast.
A3.64.F4.3.77.	VT61 (U1) ground plan and wireframe model (north-eastern cross-section).
A3.65.F4.3.78.	VT62 entrance, facing southeast.
A3.66.F4.3.80.	VT63 entrance, facing southeast.
A3.67.F4.3.81.	VT63 ground plan and sparse cloud model (north-eastern cross-section), showing the shallow anomaly above (southeast of) the chamber.
A3.68.F4.3.84.	VT65 entrance, facing southeast.
A3.69.F4.3.85.	VT65 ground plan and wireframe model (north-eastern cross-section).
A3.70.F4.3.86.	VT66 entrance, facing southeast.
A3.71.F4.3.89.	VT68 entrance, facing southeast.
A3.72.F4.3.90.	VT67/68 ground plans and sparse cloud model (eastern cross-section), showing the relative location of each chamber (VT68 partially rendered due to access difficulty).
A3.73.F4.3.91.	VT69 entrance, facing east-southeast.
A3.74.F4.3.93.	VT70 entrance, facing east-southeast.
A3.75.F4.3.95.	VT71 entrance, facing east-southeast.
A3.76.F4.3.97.	VT72 entrance, facing east-southeast.
A3.77.F4.3.99.	VT73 entrance, facing east-southeast.
A3.78.F4.3.100.	VT73 ground plan and wireframe model (northern cross-section).
A3.79.F4.3.101.	VT74 entrance, facing south.
A3.80.F4.3.102.	VT74 ground plan and wireframe model (eastern cross-section).
A3.81.F4.3.103.	VT75 entrance, facing east-southeast.
A3.82.F4.3.105.	VT76 entrance, facing southeast.
A3.83.F4.3.106.	VT76 ground plan and wireframe model (north-eastern cross-section).
A3.84.F4.3.109.	VT78 entrance, facing east-southeast.

English summary

Unskilled labour and earthmoving have been treated secondarily to skilled labour, craft specialisation, and masonry in considerations of Aegean prehistory, especially where monumental stone architecture and elaborate material culture eclipse their mundane counterparts. I address this alongside a cross-cultural issue in labour studies: the absence – recently rectified (Abrams and McCurdy 2019: 6-13; Turner 2018: 198-199; Appendix 1, this volume)–of a comparative reference on task rates for common preindustrial construction activities. Progressing through the architectural energetics approach initially outlined by Abrams (1984; 1989; 1994) and advanced by scores of new research (e.g., Brysbaert et al. (eds) 2018; McCurdy and Abrams (eds) 2019), I remodel 'comparative labour' in the same spirit, agreeing that it can only ever be "a work in progress" (Abrams and McCurdy 2019: 17). This partly comprises a compilation of preindustrial labour rates based on multidisciplinary timed observations for procurement, transport, and construction using analogous methods. I then test the reference system in the context of the Late Bronze Age (LBA) Aegean through case studies of 94 multi-use tombs in Attica and Achaea (ca. 1600-1000 BC). Tomb measurements derive primarily from photogrammetric models obtained during fieldwork at the Menidi *tholos* (2016) and Achaean cemeteries of Portes and Voudeni (2017).

Rather than apply the traditional energetics perspective as a proxy for power and demography, I examine correlations in tomb shape, scale, and collective memory to contextualise labour ranges built from field measurements and comparative labour rates. This is designed to gauge the compounding stress on local populations at generational timescales, appropriate for the appearance and reuse of monumental tomb types in southern Greece during the LBA. The results of the study warn against minimalist labour costs using limited task rates for construction activities, which, when replaced by other acceptable rates, can substantially alter cost estimates and their dependent interpretations. While more manageable than early generalisations on the excess of monumental construction, the potential labour ranges for conspicuous mortuary behaviour indicate a greater impact on daily life in the LBA than a minimalist energetics approach would suggest. Site-based correlations of shape and scale also reveal that tomb builders followed set templates, possibly curated by collective memories of construction and reuse, which either discouraged deviation or encouraged experimentation. These correspondence analyses of dimensions reflect mimetic design with tomb construction, persistent 'mental blueprints' that influenced tomb shape, scale, and reuse for centuries.

Facilitating these analyses through a tomb relative index (TRex), I created the fictional chamber tomb AA01 based on 492 original measurements from reasonably intact tombs. By comparing each multi-use tomb to that median standard (TRex 1.0, total excavated volume of 27.75 m^3 and excavation costs of 333 ph), successful tomb models are classified as undersized/cohesive (TRex < 0.75), standard/pragmatic (TRex 0.75-1.5), or exceptional/assertive (TRex > 1.5) signals to regional peers. Patterns in shape and scale reveal preferences for LH III Achaean chamber tomb construction ranging from conservative adherence at Portes to cosmopolitan innovation at Voudeni. Meanwhile, the Menidi *tholos* in Attica may have challenged the *combined* cost of all 60 modelled tombs at Voudeni and nearly tripled those modelled at Portes. For a tomb more than 22 times the standard size and up to 71.5 times the standard cost, Menidi telegraphed renown far beyond a local audience. The fact that Menidi falls well short of the investment seen with the largest known *tholoi* at Mycenae and Orchomenos shows a tremendous wealth disparity underlying elite Mycenaean mortuary behaviour at its peak, to say nothing of the gap relative to simple graves.

That this behaviour may have surpassed community tolerance is intriguing for future research into the troubled final centuries of the second millennium BC, especially given the resilience of multi-use tombs in western Greece. Reuse of the largest chamber tombs at Portes (PT3) and Voudeni (VT4 and VT75) outlasted the collapses of major palatial centres. In some cases, elaborate burials continued here multiple generations after the destruction or severe contraction of settlements to the south and east (Kolonas 2009a, 2009b; Moschos 2000; Papadopoulos and Kontorli-Papadopoulou 2001). Although the cause(s) of these changes have yet to be resolved, the persistence of elite mortuary behaviour and international trade in western Greece present a strong case for a westward pivot (Georganas 2000; Moschos 2009; Papadopoulos 1995; van den Berg 2018), at least on the surface. It could also be that targeted reuse of centuries-old tombs cleverly masked opportunistic appropriation. Reusing tombs was much cheaper than building anew, and continuity over several centuries allowed conveniently anonymous connections to a shared, malleable past.

Nederlandse samenvatting

Ongeschoolde arbeid en het verplaatsen van grond worden gezien als tweederangs ten opzichte van geschoolde arbeid, ambacht specialisatie, en het bouwen in steen, in de Egeïsche prehistorie. Dit is met name het geval wanneer monumentale stenen architectuur en een uitgebreide materiële cultuur hun alledaagse tegenhangers overschaduwen. Ik bespreek dit naast een intercultureel probleem in arbeidskosten studies: de afwezigheid – recentelijk gerectificeerd (Abrams and McCurdy 2019: 6-13; Turner 2018: 198-199; Appendix 1, this volume) – van een vergelijkingsreferentie van tarieven (in persoon uren) voor veelvoorkomende pre-industriële bouwactiviteiten. Doorlopend door de *architectural energetics* methode, oorspronkelijk uitgewerkt door Abrams (1984; 1989; 1994) en vervolgens door tal van onderzoeken verder uitgebreid (bv., Brysbaert et al. (eds) 2018; McCurdy en Abrams (eds) 2019), vorm ik het vergelijken van werkzaamheden om in dezelfde geest en ben ik het eens met de uitspraak dat het 'werk in uitvoering' blijft (Abrams and McCurdy 2019: 17). Dit omvat gedeeltelijk een compilatie van de tarieven van verschillende pre-industriële activiteiten als transport en constructie, gebruikmakend van analoge middelen, gebaseerd op multidisciplinaire observaties die getimed werden. Vervolgens test ik dit referentiesysteem in de context van de Late Bronstijd in het Egeïsche gebied aan de hand van 94 tombes die meerdere keren zijn (her)gebruikt, in Attika en Achaea (ca. 1600-1000 v. Chr.). De afmetingen van de tombes zijn voornamelijk vergaard door middel van fotogrammetrie modellen tijdens veldwerk bij de Menidi *tholos* (2016) en de begraafplaatsen Portes en Voudeni in Achaea (2017).

In plaats van de traditionele aanpak van *architectural energetics* als proxy voor macht en bevolkingsomvang, bestudeer ik de correlaties tussen de vorm en schaal van de tombes alsmede het collectieve geheugen om de arbeidskosten te contextualiseren, gebaseerd op metingen uit het veld en vergelijkbare tarieven voor werkzaamheden. Dit is bedoeld om de mogelijke stress op de lokale bevolking te meten op een grotere tijdschaal, welke aansluit bij de opkomst en het hergebruik van monumentale begravingen in zuid Griekenland tijdens de Late Bronstijd. Het resultaat van deze studie kan gezien worden als een waarschuwing tegen de aanname van minimalistische arbeidskosten, omdat het gebruik van andere, hogere, maar tevens geaccepteerde, tarieven, tot substantiële veranderingen kan leiden in de kostraming en de daaruit voortvloeiende interpretaties. Hoewel de geraamde kosten meevallen ten opzichte van eerdere generalisaties over monumentale bouwwerken, de impact van de kosten is wel groter op het alledaagse leven in de Late Bronstijd dan een minimalistische aanpak zou suggereren. De vergelijking van de vorm en grootte van de tombes op de sites laat zien dat de bouwers sjablonen volgden, allicht onderhouden door de collectieve herinneringen aan het bouwen en het hergebruik van de tombes. Deze collectieve herinneringen ontmoedigde afwijking van de sjablonen of bemoedigde experimenteren. Deze vergelijkingsanalyses van de afmetingen laten zien dat men elkaar nabootst in het bouwproces en dat de gebruikte sjablonen de vorm, schaal en het hergebruik van de tombes eeuwenlang heeft beïnvloed.

Deze analyse leidde tot een relatieve tombe index (TRex), die ik heb gebruikt om een fictionele tombe AA01 te creëren, gebaseerd op 492 originele metingen van min of meer intacte tombes. Door de hergebruikte tombes te vergelijken met de mediaan (TRex 1.0, totaal afgegraven volume van 27.75 m^3, met graafkosten van 333 pu), kunnen succesvolle tombes geclassificeerd worden als een beneden gemiddeld (TRex < 0.75), standaard (TRex 0.75-1.5), of uitzonderlijk (TRex > 1.5), signaal naar gelijkwaardige personen uit de regio. De patronen die te zien zijn in de vorm en schaal van de tombes, laten zien dat de voorkeur in de Late Bronstijd in Achaea conservatief is in Portes, maar zeer innovatief in Voudeni. Echter, de kosten van de Menidi *tholos* in Attika, zijn vergelijkbaar met alle 60 onderzochte tombes van Voudeni gezamenlijk en is bijna drie keer zo hoog als de gezamenlijke kosten van de onderzochte tombes van Portes. De Menidi tombe is ruim 22 keer zo groot als de standaard grootte en ruim 71.5 keer zo duur als de standaard kosten en genoot daarmee aanzien ver buiten de lokale omgeving. Het feit dat Menidi nog niets is in termen van investering ten opzichte van de grootste *tholoi* bij Mycene en Orchomenos, laat zien dat er een enorme discrepantie bestaat in rijkdom die samenhangt met de elitaire Myceense begravingsnorm op zijn hoogtepunt. Om nog maar te zwijgen over het gat met de relatieve simpele begravingen.

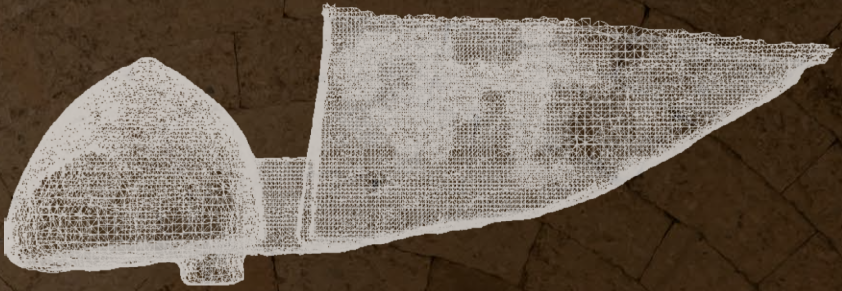
Of dit gedrag de lokale draagkracht van gemeenschappen heeft overtroffen is een interessante vraag voor toekomstig onderzoek naar de onrustige laatste eeuwen van het tweede millennium voor Christus, met name gezien de veerkracht van hergebruikte tombes in west Griekenland. Het hergebruik van de grootste kamer-tombes in Portes (PT3) en Voudeni (VT4 en VT75) overleefde de ineenstorting van de grote centra met paleizen. In sommige gevallen werden uitgebreide begravingen nog meerdere generaties lang voortgezet na de vernietiging, of de substantiële inkrimping, van de gemeenschappen in het zuiden en oosten (Kolonas 2009a, 2009b; Moschos 2000; Papadopoulos and Kontorli-Papadopoulou 2001). Hoewel de oorzaak of oorzaken van deze veranderingen nog niet zijn vastgesteld, laat het voortduren van de elite begravingen en de internationale handel in west Griekenland, een draai naar het westen zien (Georganas 2000; Moschos 2009; Papadopoulos 1995; van den Berg 2018), althans, aan het oppervlak. Het zou ook kunnen dat het hergebruik van eeuwenoude tombes een slim gemaskeerde, opportunistische toe-eigening is. Het hergebruiken van tombes is veel goedkoper dan nieuwe bouwen en continuïteit gedurende meerdere eeuwen zou een handige, anonieme verbinding met een gezamenlijk en vormbaar verleden mogelijk maken.

Curriculum Vitae

Daniel Turner was born in 1987 in Jacksonville, Alabama, as the second son of a nurse and an industrial parts distributor. Graduating salutatorian from Jacksonville High School in 2006, he began studying aerospace engineering at the University of Alabama before gravitating to a major in Anthropology and minor in History. Upon completing his BA *summa cum laude* in 2010, he received the C. Earle Smith, Jr Memorial Award in Anthropology and matriculated to St Catharine's College, Cambridge, for an MPhil in Archaeological Research (2011-2012). His studies during this time were greatly aided by the University of Alabama Presidential Scholarship, McWane Undergraduate Research Fellowship, and Cambridge Overseas Trust.

In the late 2000s, Daniel took part in three field projects with the University of Alabama (Glass Site, MS; Pride Place, AL; and Graveline Bayou, MS) and one with Purdue University (Zeugma, Turkey), sparking a list that grew to more than 60 by 2017. The majority of these field opportunities arrived due to his assignment as Field Director with Panamerican Consultants, Inc. (2012-2015). In 2015 he resurrected the Tuscaloosa Chapter of the Alabama Archaeological Society, which continues to thrive in the capable hands of the region's academic, professional, and avocational archaeologists.

In 2016 Daniel began his PhD within the SETinSTONE project at the Faculty of Archaeology at Leiden University, where he served on the Editorial Board of *INTERSECTION: Innovative approaches by Junior Archaeological Researchers* and assisted teaching for undergraduate and graduate courses (2017-2019). He continued with the project as a postdoctoral researcher in January 2020. From July 2020, he will begin a funded postdoctoral project for the Anchoring Innovation research agenda within OIKOS, The Netherlands National Research School in Classical Studies. That project, "Anchoring mimetic design as a building guide during the Aegean Bronze Age", will apply similar themes from his PhD research on Late Bronze Age tombs to Early Bronze Age fortifications.



GRAVE REMINDERS

From ca. 1600 – 1000 BC, builders across southern Greece crafted thousands of rock-cut chamber tombs similar to earlier and contemporary 'beehive' tholos tombs. Both tomb styles were designed with multiple uses in mind, filling with the remains of funerals forgotten over generations of reuse. In rare cases, the tombs were used once or seemingly not at all, cleaned thoroughly or sealed and abandoned entirely. Rather than focus on the missing or muddled record of funeral and post-funeral activities, this book re-examines Mycenaean tomb architecture and the decisions that guided it.

From minimalistic to monumental, builders designed tombs with forethought to how commissioners and witnesses would react and remember them. Patterns suggest that memories of what tombs should look like heavily influenced new construction toward recurring shapes and appropriate scales. The wider debates over cost from 'architectural energetics' and perception in Aegean mortuary behaviour are thus revisited. Both can find common purpose in labour measured through a relative index and collective memory – how labourers and patrons saw their work. That metric for comparison lies within a median standard: in this instance, tombs expressed in terms of correlative shape and simple labour investment of the earth and rock moved to create them. This was accomplished here through photogrammetric modelling of 94 multi-use tombs in Achaea and Attica, verifying a cost-effective alternative for local authorities warding off information loss through site destruction from looting and earthquakes. Since most labour models suggest the tombs were not burdensome, commissioners held extravagant building in check by weighing the social risks and rewards of standing out from the crowd.

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