Logistics and Infrastructure in Support of Building BIG in the Late Bronze Age Argolid, Greece

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Introduction

This paper focuses on the Mycenaean Late Bronze Age (hereafter LBA) in the Argolid, Greece (figs. 1–2), where, in the 13th century BC, large-scale elite-sponsored building programmes accumulated in fortified citadels and massive stone-built or dug tombs and dams.[1] In past pre-industrial societies, when large-scale building projects took place, extensive manual labour was invested from the moment materials were scouted for, extracted, transported, employed, and subsequently maintained, and adapted. Since most pre-industrial societies also based themselves on subsistence economies, important decision-making and prioritising would have been a daily balancing act between building and agricultural work.[2] These decisions often impacted strongly on local land-use strategies at several socio-economic levels, and may have also resulted in circular economy strategies. Building BIG may have dominated such decision-making for most, if not everyone, involved. Many efforts must have come together, and needed careful planning, designing and executing.

Past literature indicates that several aspects of building big and its socio-political and technological consequences in the LBA Argolid have been ignored or only partially treated: the logistics and resources needed to transport oversized transport materials; the main research focus on Mycenae and its surroundings; and the lack of considering the topography in the *chaîne opératoire* of building in this landscape (details below). The paper, therefore, aims to redress some of these imbalances.

Brief Overview of Past Work

While Mycenaean monumental architecture has been studied in depth[3] a critical look at studies on the processes involved in large-scale building programmes in the LBA Argolid show that investigating the cost and logistics of transporting big building materials has been ignored or even deemed unnecessary,[4] because stones were considered to be extracted 'locally'. However, many architectural energetics studies worldwide illustrate that transport is not only labour-intensive even when materials were sourced nearby but that it also forms one of the highest cost factors in the entire building process.[5] Even when stones were locally extracted as at the Tiryns citadel where many had been extracted and brought up from the bedrock quarry on which it sits, these still had to be hauled up, without cranes, up to 10 m high and placed securely in 7 m thick walls (fig. 3).[6] Studies on over-land transport of building materials usually do not account for the

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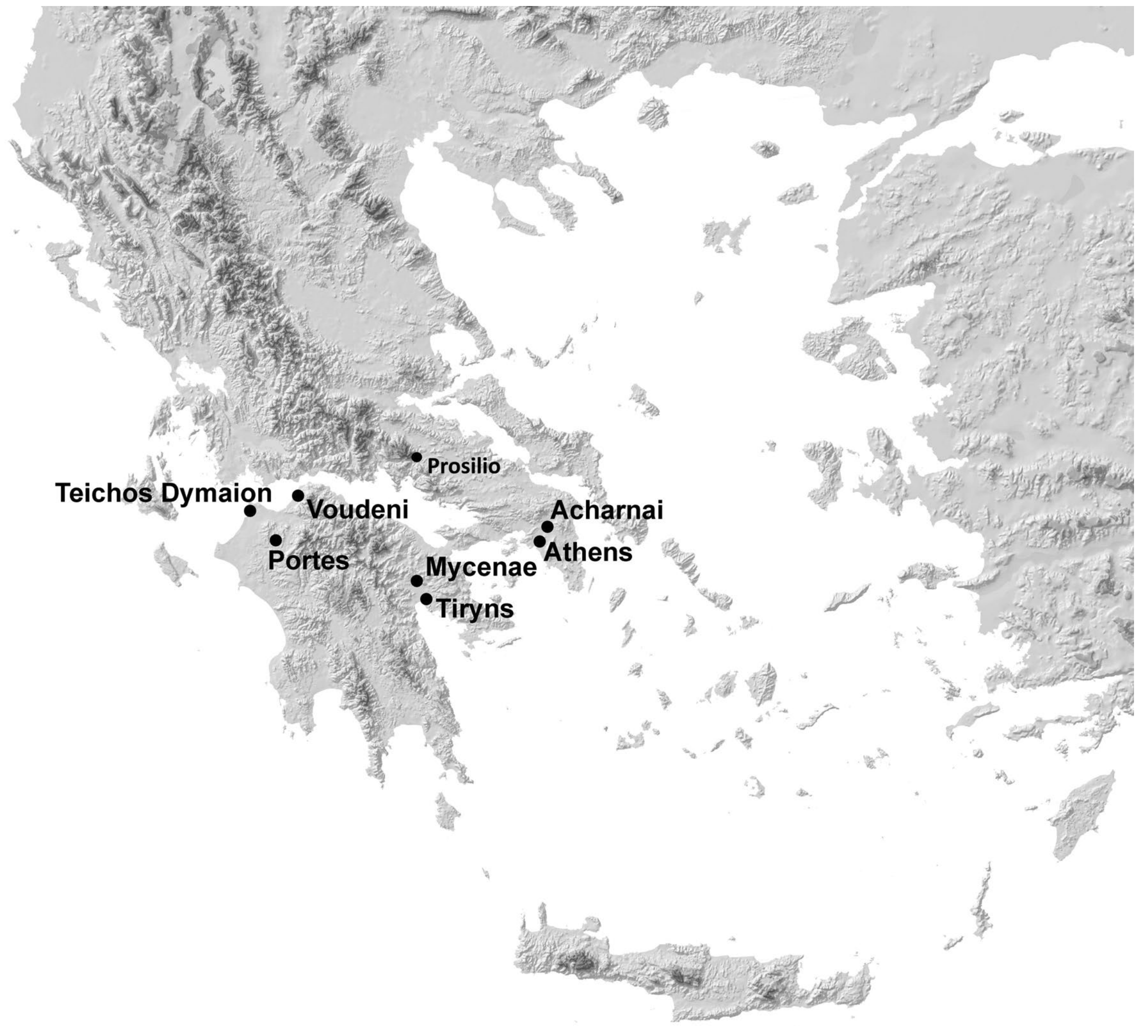

Fig. 1: Map of Greece indicating the sites where team members of SETinSTONE carry out fieldwork.

labour and organisation that may have gone into establishing the *infrastructure network itself,* while separate studies on road systems do exist for the Argolid.[7] Admittedly, when regular-size materials need transport, such as brick loads, soil, or collected fieldstones, existing land-routes and paths may have sufficed in most cases.

Equally problematic is that most road systems surrounding Mycenae have been studied in detail, but their connections to other places (Tiryns, Midea, Mastos and beyond) far less so.[8] Lavery worked intensively on outlining the entire network of Mycenaean routes in the 1990s.[9] Until his death in 2004, he both visualised these in maps but also explored their archaeological remains in comparison to the work B. Steffen had carried out much earlier.[10] The Mycenaean Atlas Project, however, was much larger in scope and mapped the site's nearby stone, clay and other resource extraction points,

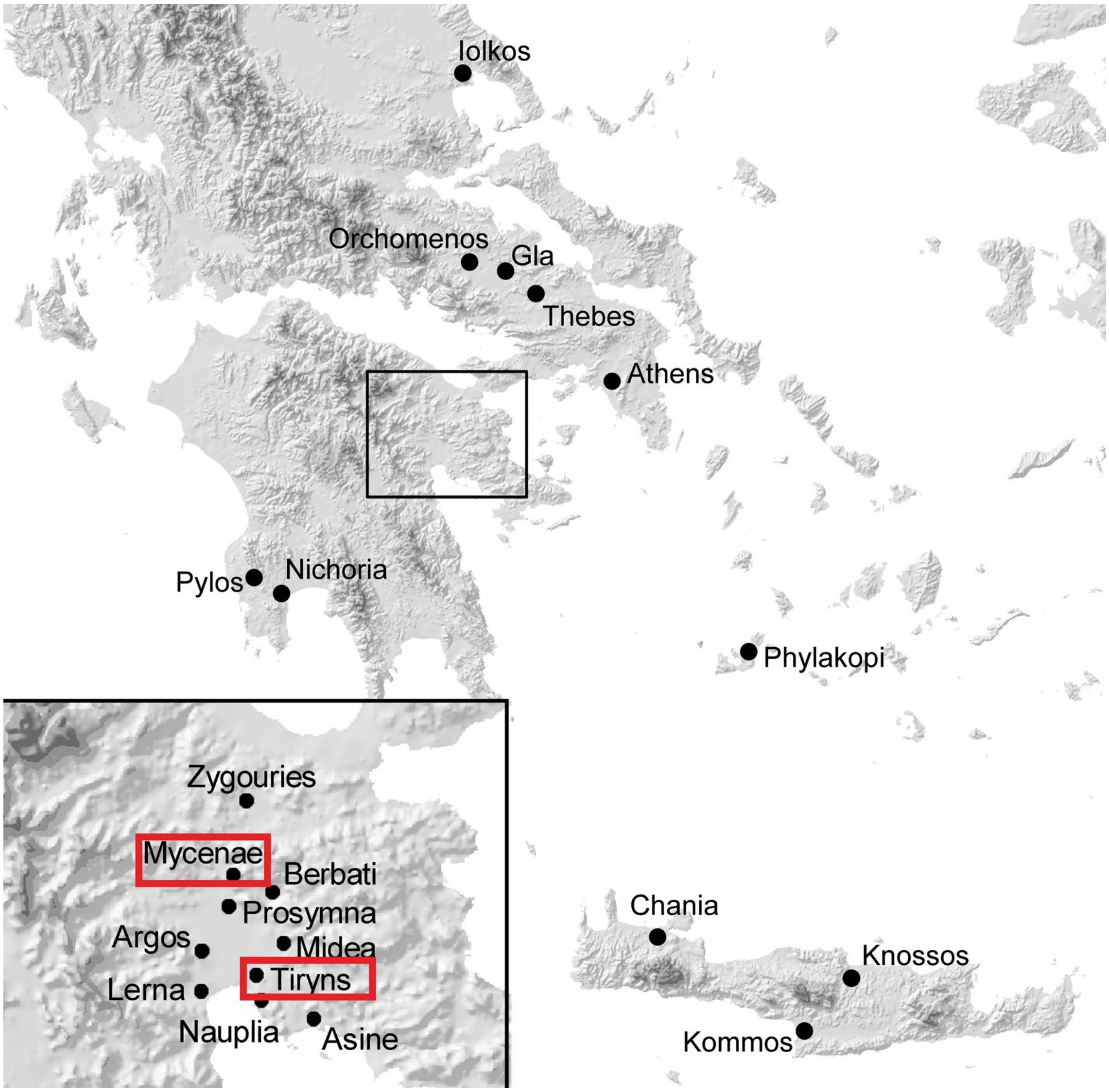

Fig. 2: Map of the Argolid with the important sites around the Argive Plain of relevance to the study/project.

its roads, and the multiple cemeteries in and around Mycenae.[11] As is also the case for the Mycenaean Atlas Project maps, most of the road studies carried out in and around Mycenae, Steffen's 1884 work (fig. 4) is still the followed standard reference.

Finally, the local east Argolid topography in which transport-routes need to be negotiated from extraction point to construction site, is not often taken into the discussion. This is no surprise, given that most traditional maps of the region are published in 2D format despite the sometimes detailed contour lines given. The exception to this, although visually 2D while representing 3D, are the maps generated by the ArchAtlas project at Sheffield University (fig. 5).[12] While a varied topography may not

Fig. 3: West side of Tiryns citadel: bedrock quarry lines following natural layering sloping up north.

have impacted normal-size loads transport too much, moving multi-tonne blocks, over 1 or 100 km, may have changed such picture drastically.

To address these shortcomings, this paper presents the first findings collected when we traced the Mycenaean roads and paths in the Argolid, mentioned in the publications above. I focused specifically on those around Mycenae, and between Mycenae and Tiryns, in order to assess their suitability for the transport of multi-tonne blocks of conglomerate since the transport question of differently-sourced heavy blocks to the Tiryns citadel was the starting point.[13] The conglomerate blocks that were used in various places in the Tiryns citadel likely came from Mycenae.[14] The volume and mass of these specific blocks has been calculated and an estimated transport system suggested.[15] However, the roads themselves were not studied in detail, and the distance of c. 20 km known from modern local routes in the area was taken as a point of departure. The local topography with slope gradient differences was not integrated – even though such considerations (i.e. friction) had been mentioned earlier[16] – because the entire actual past route was not known. Transport by means of oxen and wagons seemed logical and was calculated on the basis of data in earlier studies.[17] It was further assumed that the wagons would be able to hold these blocks, and the weight of the wagons themselves was not calculated either.[18] Beyond the transport issue but (in)directly linked to it, this paper also presents potential connections between roads and other landscape modifications, such as specific monumental tombs. Finally, it looks at the potential of combined road usage laid out in this already strongly modified Bronze Age landscape.

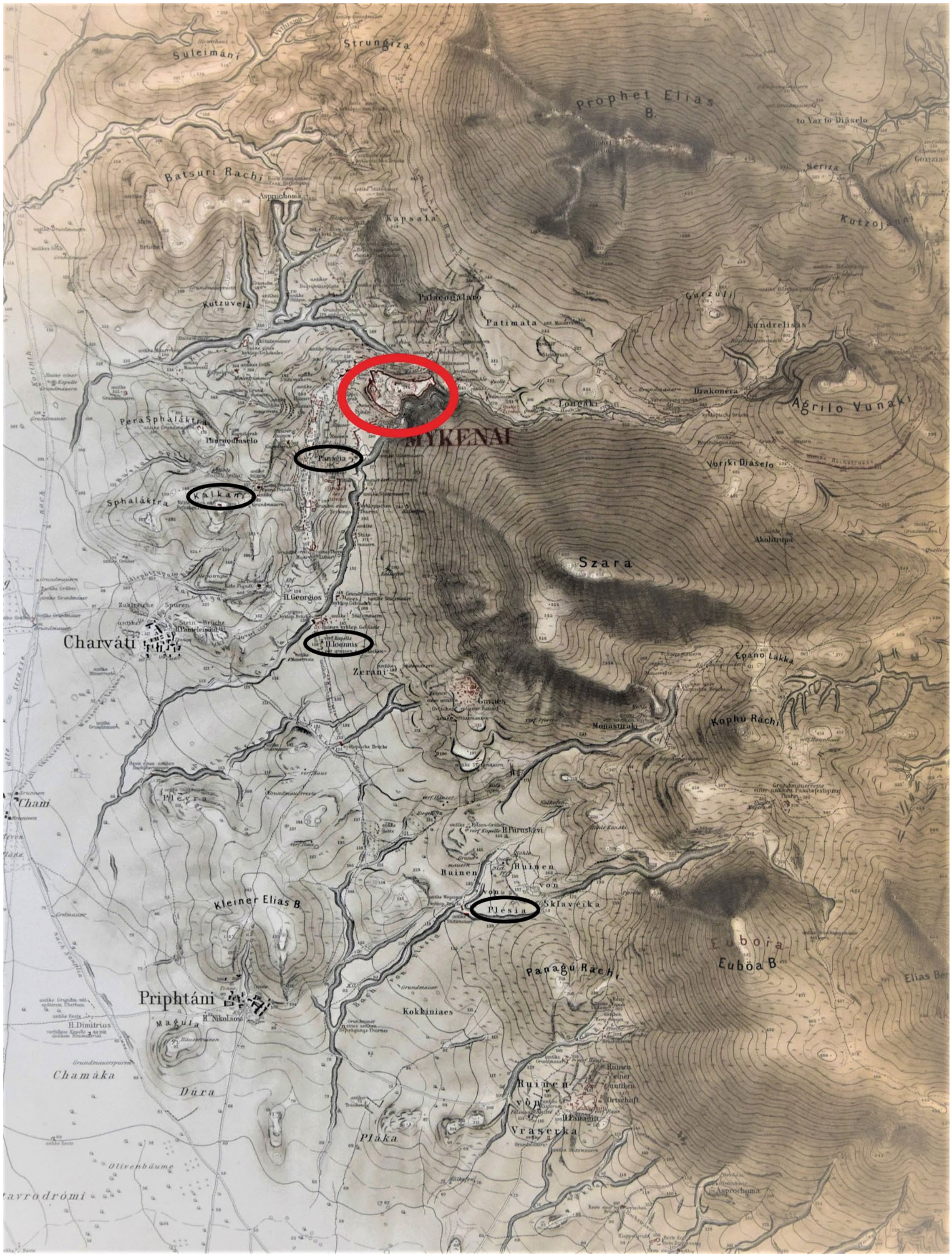

Fig. 4: Map of Mycenae and surroundings, indicating Mycenae citadel (red), Panagia, Kalkani, Plesia and Agios Ioannis (black).

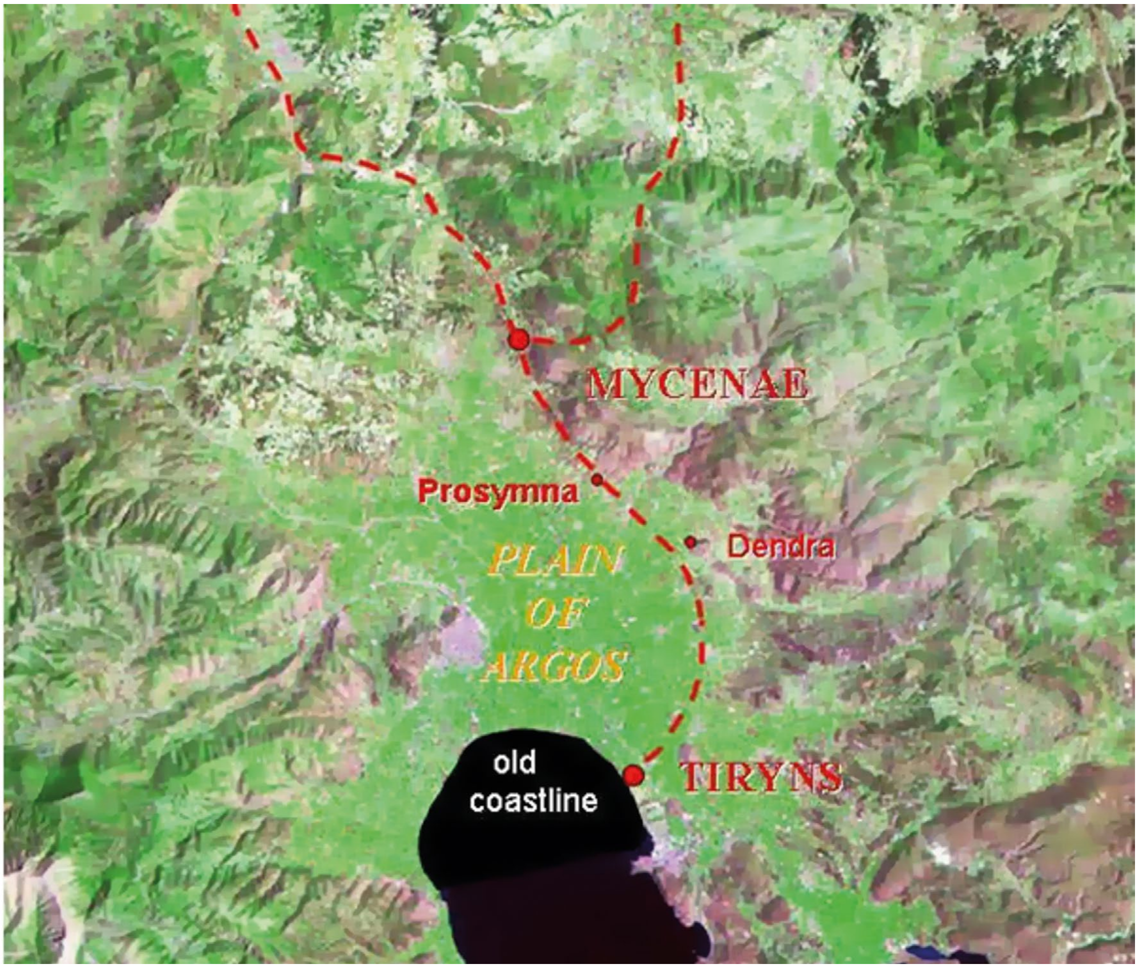

Fig. 5: 3D representation of the Argive plain, based on satellite imagery.

From Mycenae to Tiryns

The building materials for the Tiryns citadel came from a wide range of places: from the actual rock outcrop itself to minimum 15 km away, and, considering that half of the quarry sources are not yet identified, perhaps even from further afield.[19] Tiryns is known to be the only Argive citadel where *red* building stones are employed,[20] not only in the fortification walls, several doorways and gates, but now also identified at the Tiryns Tholos tomb, dated to the 15th century BC (LH IIB).[21] The geologists determined that the red stone originated from Aria near Nafplio and from the hill near Profitis Ilias, but it was unclear which Profitis Ilias.[22] Several walks (2014–2015) clarified outcrops of this red stone in several locations south, east and north of Tiryns. Since we now also noted red stone embedded in the Tholos, the Profitis Ilias outcrop, which sits just above it, seems the most logical one, but loose massive boulders seen in the quarried area of Agios Georgios makes it a possible additional candidate.[23]

While either distance was maximum 1 km to the citadel and the terrain was flat, moving red stone blocks of 4–6 tonnes would still have needed solid and wide road surfaces, perhaps aided by either sledges pulled on top of rollers or sleepers, or oxen yokes pulling sturdy wooden wagons at a rate of 1 oxen yoke per tonne of material, plus an oxen guard per yoke.

The conglomerate blocks employed at Tiryns during its largest remodelling phase ca. 1250–1200 BC, weighed between ca. 1.6 and 10 tonnes.[24] Some were identical in shape and size as those used at Mycenae. These were not the earliest conglomerate blocks found in monuments nearby. The carved and polished lintel block of the Prosymna tholos and several early tholoi at Mycenae witness this.[25] While both the Prosymna and the early Mycenaean tholoi sit in conglomerate-rich areas, some level of local transport was required. Which roads and means were used for the earlier tomb lintels, and were the same or other ones employed for the transport of conglomerate from Mycenae to Tiryns? The Mycenaean road systems, such as the M-highways,[26] are dated up to three centuries later than the construction of these early tholoi. Lavery gave many of the highways an LH IIIB date based on construction techniques used.[27] Only highway M1, excavated by Mylonas, was dated by two sherds to possibly LH IIIA2 or IIIB1. This date would be in line with the period when the Berbati valley was exploited as agricultural land by Mycenae, but Lavery considered these sherds as fill of that fortified road.[28] Several questions then arise: were these highways ever used for such heavy transport, or were they designed mainly for pack animals and chariots,[29] or for military defence and territorial control?[30] And even if enough road surface along their entire trajectory to transport the blocks are traceable, do they have, over their entire length, (1) a sufficient width to let the needed Heavy Transport Vehicle (HTV) pass, irrespective of its type and how it was powered, and (2) were the slope gradients realistic for the animals to allow such transport? (3) Are these roads sufficiently solid and 'weatherproof' to avoid subsidence and mud pools in which the transport system might get stuck?

Mycenae is surrounded by at least four so-called highways, M1 to M4, several secondary roads, m1 to m7, and plenty of smaller paths.[31] Fig. 4 indicates the important sites mentioned below. Highway M4, of concern to transport conglomerate multi-tonne blocks from Mycenae to Tiryns, was known to run from Mycenae over the Chavos ravine and descending into the valley near Prosymna, located ca. 4 km SE of Mycenae and near the later Argive Heraion. There it split off in the direction of Tiryns following the contour level at ca. 100 masl (fig. 6). In walking this road from its start by the modern car park at Mycenae citadel,[32] it descends along possibly two lines: (1) either following the modern road, along the Atreus Treasury and the cemetery at the 3rd km, then crossing the Chavos ravine near the church of Agios Ioannis at the Agios Giorgios bridge, or (2) on the other side of the Chavos ravine from the start, to the same bridge. If, however, this conglomerate came from the better quality material outcrops at Mycenae village[33] or even the Kalkani ridge further west, additional road surface

Fig. 6: Map indicating the citadel of Mycenae, the Argive Heraion and the Citadel of Tiryns with the likely trajectories between the locations: M4 between Mycenae and Argive Heraion (green), and its possible continuation options to Tiryns (light blue).

from there to the Agios Giorgios bridge needs to be calculated. From the latter bridge, the M4 went south, likely through the modern village of Monastiraki, where it may have linked up with a relatively wide and flat agricultural dirt road, still in use today. However, outside the village, once the road passed the chapel of Zoodohou Pigis, it had to cut into gentle upward slopes, towards the direction of Prosymna, while following the landscape contours. In the section from the Chavos ravine onwards, Lavery noted that nine bridges were needed until the Heraion was reached, in order to negotiate the topography. We found remains of several, at least two near Mycenae itself, while others were likely destroyed during modern modifications of the landscape (for example at the Plesia ravine junction, which, however, is not located along the M4). Interestingly, the M4 also passes within less than 20 m from the Prosymna Tholos tomb near the later Argive Heraion, located further to the south. This tholos tomb has been dated roughly between 1600–1400 BC and features a well-worked conglomerate lintel block.[34] Conglomerate lintel blocks are also known from the contemporary Mycenaean tholoi but this is perhaps no surprise considering that these are located within or near the conglomerate outcrops of the village of Mycenae, and the Kalkani and Panagia ridges. In contrast, the Tiryns tholos does not feature any conglomerate at all. Once Prosymna and the location of the later Argive Heraion were reached, Lavery saw visible tracks of the M4 continuing south to Tiryns. While there were no large road gradient problems with a steady walking height between 110–135 masl from the Agios Giorgos bridge to the Argive Heraion, we could not identify Lavery's visible tracks present after that point. Instead, we decided to follow all possible modern routes, that were as flat and as direct as possible, leading to the Tiryns citadel (fig. 1.6). Currently, the most likely candidate is difficult to determine[35] but one runs very close to the Profitis Ilias red outcrop with its tholos, and could have linked up to the local route between the Tiryns tholos and citadel.

The M4 did not preserve any trace of its original construction and surface, likely due to long-term usage afterwards: plenty of it is still in use as a dirt road. This leaves the dating of this road hard to solve, but not entirely. Let us not forget that Tiryns may have been the harbour and subordinate of Mycenae by 1400 BC and that wide and solid roads would have been fully functioning by then to transport cargoes from Tiryns to Mycenae. The entire trajectory that we traced from Mycenae to Tiryns was wide enough, i.e. ca. 3–5 m, for an oxen yoke with a multi-tonne load to pass. It also had accessible road gradients for HTVs in both directions: up-slope is harder work but safer than down-slope for draught animals attached to multi-tonne cargoes.

Finally, the weatherproofness of the M4 was considered of importance if it was used during all seasons. Even though there are good reasons to believe that the heavy stone transport likely did not take place in months with heavy rains, this road quality is difficult to assess, considering the state of its preservation. However, if we can extrapolate the known information from the well-preserved and well-investigated M1, the Mycenaeans certainly knew how to make weather-proof roads and bridges. According to Mylonas, the foundations of the M1 consisted of a fill of stones and earth whose depth varied according to the slope gradient. On top, a layer of earth with small stones with a diameter of ca. 25 cm was deposited. That supported the pavement of well-packed earth with pebbles and sand and continued over bridges and culverts that, with additional help of under-surface drain channels, very efficiently diverted water run-offs from the hill slope into the valley below.[36] We could verify this in our exploration of the M1 and a similar layering of materials was also noted on top of and near the Arkadiko bridge. This multi-layered composition, together with a useable road width, allowed a steady trot,

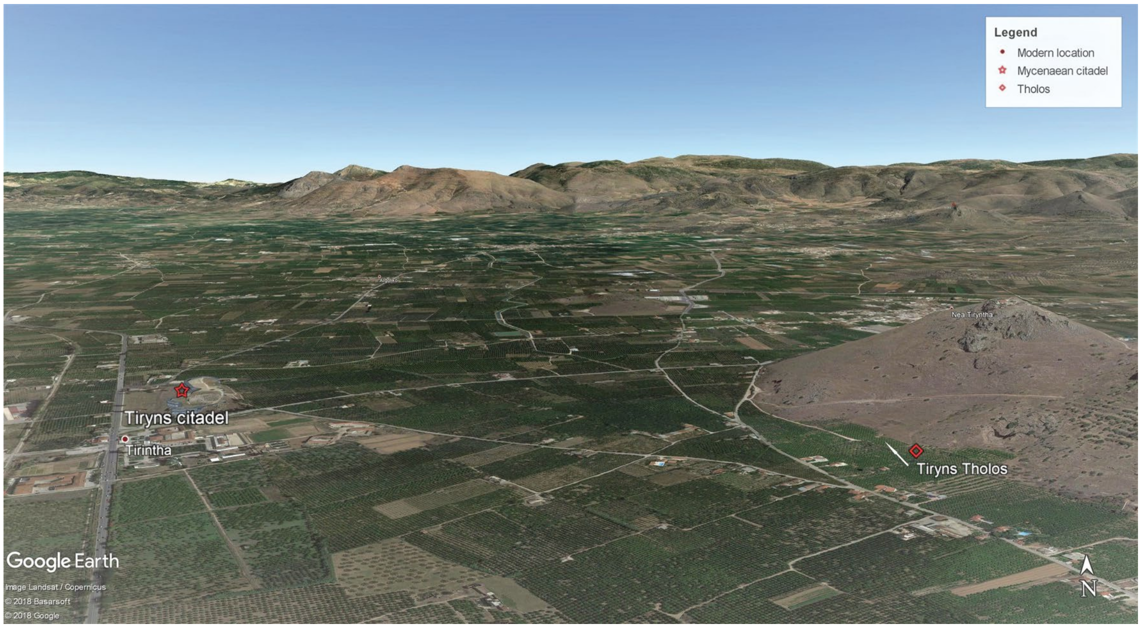

Fig. 7: Tiryns citadel (Left) and tholoi (Right) 3D view of their intervisibility, bridging about 1 km.

rather than high speed, for horses and chariots on these roads under the condition that the flat and even surface was maintained and repairs conducted[37]. In contrast to such light transport, I suggest that oxen too would have been able to use these and would have been protected from getting stuck during sudden or seasonal rains. However, the M4 had far less of its length cut out in such relatively steep slopes as the M1 does and perhaps the former never had to be built up using multiple layers and such an intricate drainage system.

Conclusions

This paper discussed specific aspects of the infrastructure of and its impact on moving large blocks from Mycenae to Tiryns from a practical viewpoint, its cost calculation will be discussed in a subsequent paper.[38] While maps and photographs remain restricted to illustrate walking, 3D images give a better impression of the negotiated topography and of the intervisibility between places which may have been of significance in choosing a trajectory, also beyond its purely practical usage (figs. 7. 8).

The first results from tracing published Mycenaean roads and paths, specifically those between Mycenae and Tiryns, seem to suggest that the M4 was suitable enough over its entire length for the transport of multi-tonne blocks of conglomerate. The road was wide enough and the road gradient did not vary largely along most of the route,[39] allowing both draught animals and human resources to work in relative comfort.

Fig. 8: 3D view of the route between Mycenae (Left) to the Argive Heraion (Right) along M4.

Certain efforts may have gone into improving existing roads to allow HTVs and without any calculations yet to offer, these logistics and its infrastructure impacted many human and animal resources. These road constructions also impacted on the surroundings, some are still in use as roads today and thus changed the landscape for ever. Where they cut into the slopes, they needed regular maintenance to remain usable and farmers who knew how to cut terraces to extend their subsistence levels were certainly useful labour and knowledgeable on such matters. Therefore, without taking the topography into account we would be unable to understand how it must have dictated the initial road survey to find the best route (albeit perhaps not the shortest), and the efforts and logistics undertaken, prior to building other monuments nearby or further afield.

The M4 was likely employed for a variety of activities,[39] ranging from transporting goods back and forth between Tiryns (harbour and citadel) and Mycenae (citadel), patrolling along this important artery if/when needed, bringing heavy conglomerate blocks from near Mycenae to Tiryns, visiting important tholoi, and perhaps even holding races with chariots. Moreover, stops could be made along the route at significant places: at the Prosymna tholos and the Tiryns tholos, perhaps even at Zoodohou Pigis for water. Walking away from Mycenae, while remaining visible for a long time, also entails crossing other landmarks. Once Mycenae was out of view, the Larissa at Argos loomed on the horizon in a southwest direction at the height of the Prosymna tholos, and, further on, the main landmark is the Profitis Ilias hill to the south, below which lies the Tiryns tholos, marking the anticipation of arrival.

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Notes

[1] Simpson – Hagel 2006; also Maran 2010.

[2] Brysbaert 2013; 2017.

[3] E.g. Wright 1978; Küpper 1996; Loader 1998.

[4] E.g. Fitzsimons 2011.

[5] Crucial work by Burford 1969; Delaine 1997; Russell 2013; Brysbaert 2015b; half of the papers in Brysbaert et al. 2018.

[6] Brysbaert 2015b with references.

[7] Jansen 2002; Simpson – Hagel 2006 for overview; useful on road functions: Lavery 1990; 1995. See now also Brysbaert et al. 2020.

[8] Jansen 2002, map 1.

[9] Lavery 1990; 1995, 226–227, maps 1–2.

[10] Steffen 1884.

[11] Iakovidis et al. 2003.

[12] Sherratt 2004.

[13] Only partially dealt with in Brysbaert 2015a.

[14] Müller 1930; Wright 1978; Küpper 1996; Maran 2006; but see Varti-Matarangas et al. 2002, and for some critique to the latter paper, Brysbaert 2015a.

[15] Brysbaert 2015a.

[16] Brysbaert 2013.

[17] Burford 1969; DeLaine 1997 among others.

[18] But see Boswinkel 2021. Omitting the wagon weight is not necessarily a problem: for later periods, the later Greek and Roman epigraphic and literary sources can be used to calculate costs of effective (net) loads, e.g. related to the volume of the stone carried. This means that there is no compulsion in these cost calculations to take into account the wagon mass. However, multi-tonne blocks may have needed

heavier transport platforms. Equally, in later periods, iron axles were able to hold larger masses but iron technology was not yet available in the LBA. Boswinkel 2021 suggests wooden axles.
[19] See Varti-Matarangas et al. 2002; for Tiryns with comments, see Brysbaert 2015a, table 1; for Mycenae, see Brysbaert, in press, for stones seemingly brought in from beyond Corinth.
[20] Already in Müller 1930.
[21] See Brysbaert et al. forthcoming.
[22] Varti-Matarangas et al. 2002.
[23] Brysbaert 2018, fig. 3.
[24] Brysbaert 2015a, table 3.
[25] Wace et al. 1921-1923; on dates, see Fitzsimons 2011, 93.
[26] Lavery 1990; 1995; Jansen 2002; Simpson – Hagel 2006.
[27] Lavery 1995 ; but see now Brysbaert et al. 2020 for a complete review on all dates for the M-highways.
[28] Simpson – Hagel 2006, 149, 156 for a summary.
[29] Crouwel 1981; Simpson – Hagel 2006.
[30] E.g. Simpson – Hagel 2006, 156.
[31] Lavery 1995, maps 1–2.
[32] Where conglomerate quarries are located all the way to the ridge above the Atreus tomb.
[33] Cavanagh – Mee 1999, 95–96 mention two qualitative types of conglomerate.
[34] Wace 1921–1923.
[35] Least Cost Path Analysis is currently being carried out; Brysbaert, in press; Brysbaert et al. 2020.
[36] Mylonas 1966.
[37] Hope-Simpson – Hagel 2006.
[38] Brysbaert, in press.
[39] The initial descent from Mycenae is rather steep, but over the whole route, the height difference between Mycenae and Argive Heraion is only ca. 35 m over a distance of 4–5 km, resulting in a negligible average slope.
[39] Also suggested by Jansen 2002.

Image Credits

Figs. 1– 2: Anavasis Editions/H. Birk; modified by A. Brysbaert. – Fig. 3: A. Brysbaert. – Fig. 4: Steffen 1884, modified by A. Brysbaert. – Fig. 5: ©Sherratt 2004. – Figs. 6–8: ©Google Earth 2018; modified by A. Brysbaert – E. Vikatou.

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