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THE DOORWAYS OF THE KOUMASA THOLOI AS REGULATORS OF LIGHT AND DARKNESS. IMPLICATIONS OF SUMMER SOLSTICE ALIGNMENT OF THOLOS E.

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ABSTRACT

A hundred years after the original excavation in Koumasa, a correction of the orientations of the minoan tholoi was observed and documented in 2012. This north-east orientation can largely be understood as an adaptation to the local landscape, which is characterized by a hill directly to the east; a noteworthy fact for one of the largest ensembles of tholoi. The chosen orientation is clearly connected with receiving the direct morning sunlight in the summer months, as noted by the author for various dates throughout observations spanning a multiyear period. This light received through the narrow entrance reaches deep into the tholoi for a narrow timespan due to the rising mountain and the orientation. Most characteristic, however, is the exact orientation of Tholos E to the summer solstice sunrise, a phenomenon whose importance is enforced by the way its interior is lit on this occurrence, with the light reaching almost to the back of the tholos, a display noticeable today. A similar but less centered arrangement is seen for Tholos A. In this paper the measured data will be presented, as well as an interpretation framework for the significance of light in the tholoi as a driving force for this *ad hoc* implementation in Koumasa, backed by suggested sociological factors.

KEYWORDS: Aegean archaeology, Minoan tholoi, solar alignment, archaeology of the senses, landscape archaeology

1. INTRODUCTION

The tholoi of Koumasa have been in the centre of academic interest since their discovery in 1904, as the finds in combination with their relatively large size have played a role in understanding the mortuary landscape of the entire region and trying to decode social interactions therein (see e.g. Legarra Herrero 2014; Branigan 1970; 1993; Pelon 1976; Belli 1984). Attention was already drawn to them by Xanthoudides, as in his publication "The Vaulted Tombs of the Messara" they receive the largest chapter (Xanthoudides 1924, 3–50). The cartographic depiction of the three tholoi, however, have been proven to be inaccurate by modern excavations. A discrepancy was noted during the beginning of the modern campaign starting in 2012 by Diamantis Panagiotopoulos under the auspices of the Archaeological Society at Athens and the Institute for Classical Archaeology of the Heidelberg University. (Panagiotopoulos 2012, 208–210; Traunmüller 2011–12, Figures 1, 6.) The discrepancies are not only observed in the spatial relation of the tholoi to one another, but also in their respective orientation (see Figure 1 for an overview of the orientations and Table 1 for the measured orientation in relation to the first publication). Another difficulty for the interpretation of these short and sometimes vague statements arises from the fact that the diary of the excavation has been lost, as discussed by E. Georgoulaki (1990, 12), which affected other aspects of our knowledge of the Koumasa excavation. Interestingly, a preliminary handwritten text of Xanthoudides contains a much more accurate plan than the one published (Panagiotopoulos 2012, 210). However, the erroneous cartography of the Koumasa tombs in "The Vaulted tombs of Mesara" was accompanied by written description stating: "The doorway, as always in the Mesara tholoi, lies to the east" (Xanthoudides 1924, 4). Naturally, in future analyses that included Koumasa this mention was carried forward without further reflection in most subsequent entries before the current excavation, aided by the fact that the area was not easily accessible (e.g. Branigan 1970, 105; Pini 1968, 6). This raises the need to reconsider the plan of the tholoi, as shown.

The most obvious interpretation of their peculiarity may to be linked with the practical reason of catching the morning sunlight in the summer months, i.e., to allow the light to enter through the doorway deep into the tholos, a feat not possible for most months of the year, as the local landscape is characterized by the imposing Korakies hill to the east and north. Multi-year observations showed an architectural arrangement of the Koumasa tholoi in respect to the relatively scarce direct sunlight in their interior (given they were vaulted or semi-vaulted) a possible cause for the arrangement of Tholoi A and E with respect to the solstice sun. Most curious is the perfect orientation of Tholos E to the point of the summer solstice, being an exception in the corpus of the Minoan mortuary buildings. To further elaborate on the orientation, aspects of the built structures themselves and the specific agency of their design should be addressed.

2. ORIENTATIONS OF THE MINOAN THOLOI

From the beginning of scholarly interest in the Minoan tholoi, their general eastward orientation has been observed (e.g. Shaw 1973, 57; Branigan 1970, 104–5; Goodison 2001, 80). This is summarized in a list of 22 tholoi plans by Goodison (2019, Figures 3, 4). For the majority of the 23 tholoi measured by Goodison (2001, Pl. 19), a prevalent alignment pattern was found: Many of the tholoi opening orientations range within a month of the equinoxes, with exceptions, some of which indeed face the northeast. The observations and scope of these observations have been since refined via spatial analysis in Goodison 2019. Furthermore, out of thirty-five tombs measured by Goodwin in her unpublished thesis, twenty-nine show a general direction towards east or northeast. Of the tombs that were oriented towards the east, not all the measurements are precisely oriented towards 90°, but are grouped within 5° of the true eastern orientation, from 89° to 94° (Goodwin 1998, 89). Some, as is the case for Krasi A, face the summer solstice (Goodison 2018, 280-281). It is to be noted that even for the eastward oriented Tholoi, there are deviations, such as e.g. in Korakies, Kaloi Limenes II and Kephali (Branigan 1970, 105). Author's measurement of nine of the biggest tholoi show an eastern orientation with a tendency towards a slight tilting towards north-northeast.[1]

In the case of Koumasa, what seems worthy of attention is that each tholos within one of the most prominent tholoi concentrations presents a generally north-eastern orientation. Also of interest is the fact that the Koumasa ensemble contains the third and fifth biggest known tholoi in terms of diameter, while the others on top of the list are more confined to the general eastern orientation (Branigan 1970, Figure 3). Specifically, Platanos A and B are in the first two places, Kalathiana K in the fourth, and Agia Triada A

[1] Lentas 90°, Apesokari B 80°, Platanos B 70°, Platanos A 90°, Agia Triada 80°, Kamilari 75°, Koumasa A 68°, Koumasa B 54°, Koumasa E 67°.

in the sixth, which follow the norm of eastward orientation. It is noted that many of the above-mentioned exceptions are located in mountainous areas, possibly having different local horizons which change the observable sunrise. This fact makes many well-intended efforts towards the study of orientations based solely on compass readings less conclusive; the whole picture being provided by taking the local horizon into account (see also Goodison 2018, 282). A complete local horizon study of the tholoi is a desideratum, with an analytical effort in progress by Goodison (partially presented in 2018; 2019).

The three Koumasa tholoi fall under different orientation groups in Goodison's research. Without ignoring this categorization, this work approaches Koumasa as an *ad hoc* case focusing on the effects of the landscape on the choices of the builders. In this paper, the orientations of the Koumasa tholoi will be considered in respect to the local landscape characteristics.

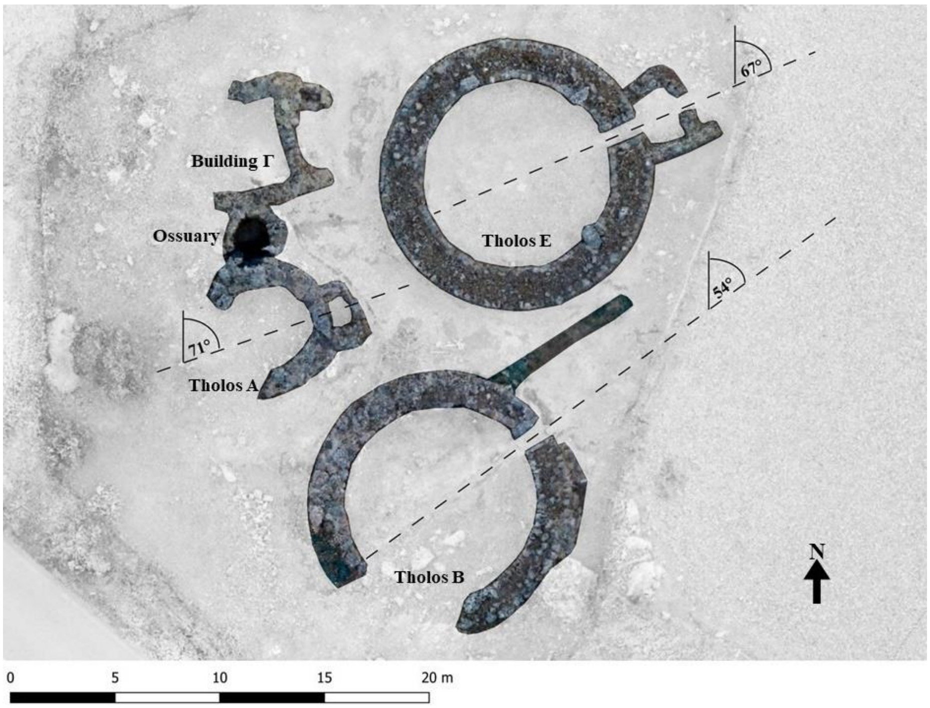

Figure 1. Orthophoto of the tholoi area. With the accentuated texture, the main buildings as named by Xanthoudides. The entrance axis of the three tholoi and their azimuth angle is given.[2]

Table 1. Tholoi Orientations

Tholos	Orientation as per Xanthoudides	Measured Orientation	Discrepancy
A	90°	71°	19°
B	90°	54°	36°
E	90°	67°	23°

2.1 *Local landscape as regulator of light*

Within the last decades, a tendency has arisen to view the importance of space as socially constructed, and therefore the monuments within it as an effort to create a new landscape, an example being Tilley's examination of the landscape as a "spatial text" (Tilley 1993. For further discussion see Goodison 2019, 123–124). Within this context, the landscape and the monument can, in the words of Richards (1996, 206): "become fused and join in union to become a central point, an axis mundi." It is a correlation of location and cultural memory, as has been discussed by Assmann (2013; 1992, 59–66). Within this scope, to understand the orientations of the Koumasa tholoi, the relation to its landscape should be examined. Directly to their east, there is an adjacent elevated hill on which settlement activity is seen, a fact not observed opposing the entrance of some of the other bigger tholoi, such as Platanos, Aghia Triada or Apesokari. So it is the "spatial text" that is actually unique, not only the orientation. Keeping this in mind, there are two

[2] The orthophoto is based on a drone mapping of the entire Koumasa area, taken in 2022 with the permission of D. Panagiotopoulos. Photo edited further by the author.

possible reasons for the orientation of the Koumasa tholoi, one pertaining to the everyday coexistence of the worlds of the living and dead in the same place, and the other pertaining to performative aspects, indicating actions within the tomb. Both reasons have a symbolic level, while the inclination towards the sun also shows a practical one. Regarding the issue of contemporaneity, no direct evidence for an EM habitation of the hill exists, although it has not been excluded. At the very least, the new finds from both Tholos B (the only tholos of the area with undisturbed extensive context) and the Settlement show an overlap in the MM period, where Settlement building activity coincides with the last phases of the usage of Tholos B. Analytically, the late finds produced in Tholos B include a protopalatial seal (Panagiotopoulos 2014, 431), a small structure analogous to MM IA parallels (Panagiotopoulos 2013, 327), and pottery dated to MM IA in front of Tholos B and to MM II in the area between Tholoi B and E. Furthermore, as of yet unpublished ceramics from Tholos B include Barbotine and Kamares sherds. Regarding the Settlement, MM I-II pottery was produced in a settlement building (Panagiotopoulos 2013, 315; 2014, 426; 2014; Figure 2), whereas in the so-called Sanctuary – the area on the summit with optical view of the tholoi – protopalatial pottery also was found, some of which dated to MM II (Panagiotopoulos 2014, 428; 2019, 450; 2018, 488). This later coexistence influences only the perception of the tholoi for the early dwellers of the settlement.

As mentioned, in contrast to the other big tholoi, Koumasa has the landscape characteristic of the Korakies hill to its east. A true eastern tholos orientation would have resulted in direct observability by those accessing the hill or any dwellers there. In general, the width of the trilithon entrances of the Messara tholoi usually ranges from 0.70 m to about 1 m, and there are even narrower examples, such as Lebena IIa with 0,5 m and Kephali with 0,55 m (Branigan 1970, Appendix 1; Panagiotopoulos 2002, 11), although the function of Lebena IIa as a tholos tomb has been disputed by Alexiou and Warren (2004). As Branigan noted, the arrangement of the tholoi entrances, such as their small diameter and the unnecessarily massive slab doors – surely not the only option for closing the tombs – seem to indicate an alienation towards the dead (Branigan 1993, 121). For a summary of the slab stone blocking the trilithon entrance, or sometimes in later tombs'-built doorway entrance, (see also Branigan 1993, 58–59). If a typical eastward orientation of the Koumasa tholoi entrances were the case, this apparently aimed-for separation of the worlds of the living and the dead would have been blurred; then, even if closed with a slab, the doorways would have been in direct and likely uncomfortable line of sight of everyday life on the Korakies hill.

The other reason is that of maximising the amount of light accessing the interior. Since the following analysis will consider the direct illumination of the inside of the tholoi, a term that needs to be introduced is that of the 'window of visibility', defined as the range of horizon azimuths[3] visible from within an enclosed structure or chamber, in the case of the tholoi from their inner back side, i.e. from their interior wall on the axis of the entrance. The more abnormal the built circle of a tholos tomb is, the more difficulty there is in its determination, in contrast to other megalithic buildings, where this term is widely used, such as in the megaliths of western Europe including the megalithic dolmens on the Mondego, Portugal, where the window of visibility towards the horizon can be very precise (see Silva 2014, 27–32; Henty 2016, 8). In one third of the tholoi, the door cannot be exactly located, further complicating studies. In the case of Koumasa – where all tholoi show a clear doorway situation – the window of visibility is ca 4° for Tholoi E and B, being rather precise thanks to their relative size in comparison with the narrow entrance, whereas for Tholos A, which is smaller and more roughly made, the doorway is comparatively wider resulting in ca. 10°.

In order to speculate on the effect and impact of the sunrise on tholoi in general, the question of interior illumination should be addressed. Namely, in a fully vaulted or flat-roofed tholos, the sun's presence would create a dramatic duality of light beam and darkness within the structure. There is no certainty in the opinio communis regarding the way the upper part of the Minoan tholoi were built. A summation of the early argument discourse is presented in Branigan 1970, 28; 1988, 164. Branigan reasoned that although some of the Minoan tholos tombs could have been completely vaulted in stone, this does not apply to all and certainly not for the bigger ones. Rather after discussion of other theories, he seems to endorse the suggestion of Pendlebury of roofing with branches or wood, a suggestion which is backed with modern parallels. Finally, for the mechanics involved, the insight from a study on another type of tombs is deemed useful (Cavanagh and Laxton 1981 on the Mycenaean tholoi). However, the case for a closed

[3] Two values determine the positions on the dome (be it sky objects or points of the local mountains): (1) The altitude showing how high a point is, with its angle varying from 0° at the sea level horizon with the maximum being the zenith with 90°. (2) The azimuth, showing the angle distance from the north, where the value is 0°, true east being at 90°, south at 180°, and true west at 270°.

tholos has strong support, if for the largest tholoi not completely vaulted, at least covered by a flat roof. Based on the suggestion that the tomb was covered by a light, flat roof built of wood which could easily be removed when the tomb had to be fumigated. (Branigan 1970, 48-50). This solution opens the next issue of the need for internal support or not, argued by Hood, for which however there is no evidence.

Regardless of the exact method of building for their upper part, the resulting environment of the interior is one of rather claustrophobic atmosphere, even if the tholoi were accessed from above. If the doorway was actually used, as select torch marks suggest (see discussion below), the claustrophobic atmosphere is enhanced by the small entrance that enforces crawling as the only way inside the tholos. Indeed, this restricted entrance further augmented the seclusive nature of the inside of the tholos, but also blocked the area of the annex or the open area in front or near the entrance from the realm of the dead, experienced through darker surroundings, and the remains of the deceased (Miller Bonney 2016, 284). Further, the distinct smell contributed to the feeling of otherness inside the tholos, what has been called a heterotopic space, whose barrier with the exterior as a divide of the spaces of the living and dead is reinforced by the architectural arrangement which finally ensures the separation with a shut door. The term was used in reference to the performative area in front of the tholoi, used as per (Foucault 1986), here understood to be extended to the inside of the tholoi, where these performative acts extend, at least during new burials and related events (Hamilakis 2002, 128).

Within this atmosphere, dragging the body through – pushing and pulling and further making room for the deposition – must have overwhelmed all senses. In this context, the light used was a crucial element of seeing, but also of setting the tone for the experience of the inner tomb.[4] The physical proximity to these elements and restriction of the small space would have amplified the sense of a transcendental locale. Ultimately, the senses can be viewed as part of the archaeological understanding of a site; (for further elaboration see Hamilakis 2011, 216–217; 2014).

A major factor in this is the achronic quality of time inside the tombs, further stressing the separation from the outside and the contemporary time. Or rather one of peculiar time, as the visitor was perhaps aware of the previous generations that he came in contact with, aided with a view of pottery and other artifacts, whose use he must have understood but whose style – in some cases centuries old – must have been perceived as archaic, adding to the feel of otherness (Miller Bonney 2016, 285; Hamilakis 2002, 128). Expanding on Branigan's suggested fear of the dead, regarding the tholoi, a certain fear of the dark can be postulated. For some times every year though, providing the annexes were not high enough or not yet built (see discussion in Part 5), the morning sun illuminates the interior, providing a much more soothing effect and forming an event which is a link to the world's time. Especially if it is an annual occurrence, on these occasions, for the visitor the achronic flavour of time within the tholos interior seems to bend under the physical light and align to the annual rhythm of the worlds' time – the time of the living.

The small door soon proves too low to allow for the rapidly rising sun to penetrate the tomb; the sun must still be low for the light to enter through the trilithon. Due to this low altitude, a ray of sunlight at the moment of its appearance would cause stark shadows and break the darkness by shedding light on the tholos floor, thus increasing the illuminance but also keeping the rest of the tomb in relative darkness, causing a dramatic contrast.

Evidence for use of fire is seen in some tholoi, such as marks of torches in Lebena II and torch remains at Kamilari I (Branigan 1970, 92-93; Branigan 1988, 166) and even lamps have been found in at least seven tombs which – especially a richly decorated and pedestaled example from Koumasa Tholos E – alludes to a ceremonial use (Branigan 1970, 84). However, as Papadopoulos showed in his case study at Archanes, the illumination of lamps is not only inferior, but also the shadow casting does not alleviate the claustrophobic effect. Hamilakis mentioned that one of the aims of "archaeology of the senses" is to tackle issues related to sensory experiences that research had considered as rather ephemeral and immaterial (Hamilakis 2011, 209). I consider the interaction with sunlight also part of this field, in terms of its perceived heat and light, and – pertaining to the subject matter of this paper – also its mental impact upon its appearance, beyond the pure practical reason of seeing inside the tholos, for which torches suffice.

The dawn shining on the interior space containing the bodies of the relatives and ancestors, as Goodison put it, must have been impressive (Goodison 2001, 80). Furthermore, it reaching the centre of the tholoi would be possible only weeks around the chosen date and only for some minutes, especially for tholoi with a small window of visibility. This illumination is not

[4] For Tholos C at Archanes, the illumination with natural and artificial light was studied with the help of 3D modelling. In this study, the question of maximum number of attendants was calculated at 8 people for the tholos of ca 5 m diameter. It also emphasised the difference that sunlight would make (Papadopoulos 2010, 62–66). The case of Archanes, being much later than the time period concerned here, is used only for its example for illumination.

perceived as a passive one – as that of lamps and torches that can have been used, as the case of Lebena II– but as active. At the moment when the ray of light directly enters from the door, it splits the darkness of the interior, raising the luminance eightfold compared to the times when only indirect light might enter.[5] Where the ray of light strikes the interior directly, the luminance value will be up to 400 lux, while the rest of the interior will have 70 lux (Papadopoulos 2010, 63. For reference, a 100 W lighting bulb emits 170 lux). The perceived impact is that of the outside connecting to the inside through this sunbeam, or for those already in the inside of the tholos it arouses the association that the outside figuratively dares invade the world of the dead.

Researchers such as Branigan have handled theories for choosing orientations with caution, especially those relating to afterlife beliefs for the dead. These argumentations can be seen as having anachronistic elements or efforts to draw parallels with Egyptian or modern mortuary beliefs. Thus, after addressing such theories, Branigan is right to conclude that "tradition rather than religious necessity demanded that the entrance be on the east" (Branigan 1970, 105). However, the beginning of this tradition is not further elaborated on. As it has obvious benefits, illumination is a reason that can arise independently of any exterior influences or various belief systems.

What should be considered is that this stark illumination of the interior may serve as a spark of courage and hope for those who have gathered there prior to the sunrise trying or who may even be about to enter the tomb at that time. The implication is that a vital visit to the interior, born out of necessity as part of the funerary processes of the tholoi (Branigan 1993, 80) was to be done during the time of maximum illumination; this may pertain to secondary depositions or acts of cleaning the interior. The annual repetition of an act imbues it with a performative character, as it becomes associated with specific seasons within the agricultural circle. This act – or "form" in the words of Assmann – can evolve from ephemeral memory and become codified in tradition or rather become entangled with the cultural memory of a society (Assmann 1992, 56; 64). Making sure the interior gets illuminated by choosing the right orientation should not be perceived acriticly as strictly religious in nature, but the practicality should also be considered, as a choreographed act that crystalises in tradition, and acts as a "mnemonic device". The memory function is examined by Assmann within three categories: That of material objects, action, and texts (Assmann 2006, 69). In the case of the memory aspect of the use of the tholoi, the only known of these parameters is the first. The proposed yearly ritual, bound and related to the sun's appearance pertains to the second stage of this division. The achronic time (or heterochronic, following Foucault's arrangement as presented in Foucault 1986, 26; Hamilakis 2002, 128) of the tholos interior is bent so that it synchronises with that of the tropical year, the oscillating beat of the yearly cycle that denotes life, thus bringing the heterochrony of the tomb in sync with the world's time, at least momentarily.

This more specific need cannot be ascertained for most of the other tholoi that have an open eastern horizon with no shortage of light. But for the Koumasa tholoi, the main proposed reason for their chosen orientation is, at least in the earliest example of Tholos A, increasing the gathering of light around the short time window when this is possible, as will be elaborated on in Part 4. This arrangement – mostly punctuated by the arrangement of Tholos E – seems to have evolved beyond this need to architecturally encapsulate a performative annual dance with the sun, bringing another level to Branigan's expression, "Dancing with Death".

Before continuing to the subject matter, it is necessary to discuss aspects of archaeoastronomical research.

3. A CRITIQUE OF ARCHAEOASTRONOMICAL PRACTICES

Regarding the assumed orientations to specific astronomical events, there has been a lot of interest within the Aegean Bronze Age in general and the Minoan tholoi in particular. This can be seen in discussions of decorations (MacGillivray 2012; Banou 2008; 2015), seal depictions (Rethemniotakis 2016; Kyriakidis 2005), and also in the choice of architectural orientations. Buildings that have been considered include tholoi, peak sanctuaries and palaces (see Goodison 2001; Davis et al. 2016; Goodwin 1998; Blomberg 2000). From the beginning of Aegean archaeology, analogies with contemporary cultures or even the later Greek culture were sought to explore the beliefs and practices within the Aegean pertaining to the sky. Such works normally consider similar motifs in Crete and Egypt and build upon them (Such examples include: Marinatos 2009, MacGillivray 2012, and Banou 2015 where Egyptian influences are assumed and particularly transmission of aspects and meaning of symbols, iconography and architecture.) Further, mentions from the archaic Greek literature are considered, that are assumed to be remnants of an older tradition going back to the Bronze Age. Elements of this is seen

[5] Calculations based on the 3D Modell for Archanes Tholos C (Papadopoulos 2010, figs. 69, 70). Of course, the exact numbers will vary for each case, as the inner diameter and door opening determine the luminance and illuminance factors.

in the floating objects of Rethemniotakis 2016, Kyriakidis 2005 and involve a methodological mainframe for approaching depicted motives in the seals and sealings of the Middle and Late Bronze Age, and see them as bearers of astronomical meaning based on classical Greek traditions. Although this way of thinking can prove fruitful in specific contexts, often these links are taken for granted resulting in methodologically weak arguments. This trend is a result of the absence of direct references from the Aegean cultures themselves, and it is especially noticeable for archaeoastronomical analyses where argumentations based on cultural parallels are sought to Middle East, Egypt and with the European megalithic traditions is assumed, sometimes without careful examination of the local characteristics of such traditions or working within a solid methodological approach. (Goodison 2020, 170–171). Especially the later prehistoric period within Europe, and particularly around the Atlantic coast, marks the widespread construction of large, evidently communal, structures where tangible connections with the sky have been identified, such as the sun at the summer or winter solstice and bright stars around the ecliptic (Ruggles 2010, 28). In seeking parallels, sometimes the methodological error, as Goodison put it, of a direct "translation" of a phenomenon known from the Atlantic coast to the Aegean occurs.

But even when solely studying the architecture, a sceptical reception of suggested astronomical alignments was seen in the archaeological community, partially due to the phenomenon of "alignment hunting", in which researchers not necessarily familiar with the field were extracting results based on a weak or non-existent methodological mainframe, often only based on maps without consideration of the ground experience, or the other archaeological aspects of the monuments. (These points were also raised in Goodison 2020, 172.) Often such efforts were made by astronomy enthusiasts with no prior experience in related academic discourse. Unfortunately, this would lead to generic claims that at times have no archaeological basis. Regarding the tholoi for example, sometimes a predominance towards summer or winter solstice is suggested, especially in works interested in astronomical orientations (Chapin et al. 2014, 149), a fact that is not the case, as discussed above. Sometimes, guided by enthusiasm, an entire scope of a building or decorative programme was in a monosemantic manner suggested to be of only astronomical concern, which alienated archaeologists even more. On the positive side Goodison argues that gradually there is a tendency for a carefull methodological approach (2020, 172). One misconception however is that the term 'astronomical arrangement' implies tentative sky observance, when in fact the everyday experience of the sky is often linked with matters of handling light and heat, mainly from the sun.

4. THE LOCAL HORIZON AND THE ANNUAL DANCE OF LIGHT AND DARKNESS

Regarding the human interest in the sky, there is plenty of anthropological evidence from various places remote from one another in space and time to allow for such a suggestion (Ruggles and Cotte 2010; Wilson 1997). This pananthropic aspect could be seen first and foremost as a major sensory experience caused by the sun and the moon, and thereafter the sky dome itself. In this approach, humans are understood to have conceptualized the sky elements; they attached meaning to celestial objects, regardless of the place or time they lived in. This is the view also expressed by Iwaniszewski (2011, 30) when he wrote that the "sky is an aspect of the physical universe which is universally perceived by all humans, although comprehended and structured in different ways". So even the simple act of directing houses to the north to avoid the sun's direct light is a case of endeavour falling within astronomical architecture. In the same vein, approaching the sky elements can be seen within fields such as the "archaeology of the senses", as discussed by Hamilakis (2011; 2014) and their mental impact. The sky is not an abstract thing remote from human activities, but rather one of the main elements of nature that surrounds man, next to the sea and the mountains (Brown 2013, 8). On a second level, humans link those objects with other aspects of their everyday life, either social or religious. This falls within a correlation that exists between man and his environment with its landmarks, be they man-made or natural (Silva 2014, 4).

The movement of people in space facilitated the contact with the environment around it and relates to the memory of past activities in it, what has been called a "memory space" (Glaraki 2016, 84; Assmann 1992, 38; 56–65), pertaining to the lived-in space and its transformation towards a memory space, referred to also as Mnemotop (Assmann 1992, 59). And thus, the landmarks, either constructed or existing natural ones such as mountains, helped the activation of memory and the repetition of the actions of a society, forming a continuity in space and time (Tilley 1994, 27). The environment is not merely an external entity, rather it has its own agency and actively produces meaning through a long-term entanglement with people (Ingold 2000, 189). An environment is signified by the human presence, not the opposite way: a presence that is physical, but also active (Heidegger 1953, 79).

Investigations of structure orientations should be seen as an extension of this perception: the daily practices such as ritual and ceremonial acts or even just habitation and moving in space constituted a means of everyday entanglement with the environment through which the world is actively perceived (Ingold 2000, 190; Bourdieu 2013, 73–82). Amongst the issues of a 'lab analysis' or an in situ-analysis that fails to study the surrounding environment is that the various alignment readings could lead to false results (Brown 2013, 6). Regarding stellar objects, cardinal points as seen from a bird's eye view are not sufficient to determine orientations of interest, as the local horizon can alter them significantly. An example for this may be found in the orientations of the Armenoi tombs, which although not relevant for the discussion of prepalatial Crete, pose the same methodological issue and were analytically recorded by Papathanassiou and his team. Here, however, the perceived skyline is influenced by the altitude of the mountain peak of Vrysinas to the east, which by being above 8 degrees is in a significant range of the eastern local horizon. This makes the point of the equinox sunrise to be at an azimuth of 95,7º instead of 90º (Papathanassiou et al, 1992, 45–47). Therefore, the movement away from the narrow focus of astronomical issues that takes place only within the study rooms to experiences in a real place within a landscape has been the first step to understanding the place itself, allowing for a comprehension of the landscape closer to that of the ancient builders, and therefore allowing less anachronistic interpretations.

5. TOPOGRAPHY OF THE KOUMASA THOLOI AND THE LOCAL HORIZON

The area of the tholoi lies around the point with a latitude of 34.983304, or 34° 58′ 59.89″ in degrees and a longitude of 25.012994 or 25° 0' 46.7784 in degrees.[6] The three tholoi are in close proximity,[7] so that the surrounding landscape is very similar for all three locations, meaning that the local horizon is almost the same. Small deviations are observed to the east, as the result of the nearby Korakies hill, whose slope begins rising directly eastwards of the Tholoi up to the two summits of the hill, around which the proto- and neopalatial settlement of Koumasa is located, with the so-called area of the Sanctuary at the northern summit (see Figure 2).

The hill's distance impacts the local horizon, as it expands for approximately 160 m from a point between the three tholoi (as measured from the point marked with an 'x' in Figure 2) up to the top of the hill on the northern summit, while the height difference to the two summits is approximately 45 m, with a maximum of 50 m at the very top of the hill, depending on the height of the buildings found in the so-called Sanctuary area. Viewed from the area of the tholoi, the hill appears to have an altitude of 16º to 17º at the peaks and generally more than 14º for an azimuthal arc of 40° due east, corresponding with the two peaks of the Korakies hill, as presented in Figure 3).[8]

Given the axis of their respective doorways, the azimuthal orientation of Tholos E is 67° and that of Tholos B 54°. The more irregular shape of Tholos A in combination with its ratio of large door opening to radius does not allow for a precise direction of the central axis, nor an exact definition of its visibility window, but an approximation would set the orientation at 71°, thus being 4° south of Tholos E.

As the analysis will focus on Tholos E, in order to demonstrate the precision of the solstice alignment, some more details are relevant: The elevation of the centre is at 380,9 m above sea level with an inner diameter of 9,25 m, although it should be pointed out that the inner shape is not a precise circle, which leads to a slight uncertainty.[9] The wall is about 2 m thick (Xanthoudides mentioned 1,9-2,1 m.). Its doorway can be measured today as around 0,85 m wide on the inside and 0,9 m wide on the outside, with a surviving height reaching up to 1,25 m on the inside and 1,35 m on the outside. However, the original height was 1 m, as mentioned by Xanthoudides noting that his other measurements seem close to accurate. At least in the upper row around the entrance, a partial reconstruction appears to have been made. This can be verified from an archive photo, submitted in 1909 to the German Archeological Institute of Athens (Archive num-

[6] The coordinates of latitude and longitude (34.98330, 25.01302) in WGS 84/ EPSG:4322 are measured from a point (point 'x' in Figure 2) between the three tholoi, in front of the entrance of Tholos A. Given that the distance of the centres of Tholoi B and E to this point is almost 10 m, one point can be assumed to represent the area.

[7] Namely, the distance between the centres of Tholoi E and B is ca. 16,9 m; the distance between the centre of Tholos B and the entrance of Tholos A is ca. 10,5 m, and the distance between the centre of Tholos E and the entrance of Tholos A is ca. 11,7 m.

[8] These observations are based on measurements done with total station combined with a 3D model of the site produced with a drone and georeferenced in a GIS programme. The angles were also separately measured with the clinometer.

[9] Xanthoudides mentioned 9,8 m (Xanthoudides 1924, 33). The reason is that, as seen in image 1 the exterior circle is more precise than the interior. The interior has a slight oval or egg shape seen from above with the thinnest part of the wall being to the north-west. Therefore, two lines can be defined: The line that passes exactly through the middle of the doorway and divides the outer circle, and another line that divides the inner area. These two lines diverge by a distance of less than 50 cm when they reach the western wall, and from both, the solstice sunrise can be observed. The line that divides the inner circle is the one taken into account.

ber: D-DAI-ATH-Kreta 154), where the trilithon entrance of Tholos E – now lost – is still visible. On this photo, (graciously provided to the author by the DAI-Athens to study) some stones are recognizable today, from which it can be determined that the level excavated was a little deeper, almost 20cm, than today's level. The reconstruction seems to try to increase the height of the entrance, given that the upper lintels are gone. As per the source of reconstructions, it is not very clear as discussed in Traunmüller 2011–12. Lebesi very briefly mentioned some work being carried out at the cemetery, with actions of "strengthening and rebuilding of the three protominoan tombs" (see Lebesi 1984, 316). In the era of the first excavations, the doorway itself, measuring 1,3 m in length, was covered by two lintels; this can be attested to by Xanthoudides' original plan and the 1909 photo mentioned above. In Xanthoudides (1924, pl. 61) the two lintel stones as well as the anteroom is depicted.

Figure 2. Orthophoto of the Koumasa slope, with 2m isometric lines. The two peaks are marked with a cross and the 'x' between the tholoi marks the observation point for measurements and from which the panorama of Figure 3 was observed.[10]

5.1 Methodology

The following angles of altitude and azimuth, as well as the other angle and distances were measured in two ways. The first was based on measurements on site, initially done with a clinometer and then refined using total station measurements of points in the tholoi area and on the visible skyline, combined with an orthophoto and a DEM model for Koumasa produced by drone, so that distances and height measurements could be obtained (see Figures 2 and 3). The second method was the astronomical one, using the database of the *American navy website*, the *sunearth tools*, and the opensource programme *Stellarium*, which yield the sun's coordinates for a specific date, time, and place.[11] It was observed that on a variety of days, the calculated solar position in an altitude and azimuth defined by the horizon fit perfectly to the measurements on site. The final step was the verification, which was done by witnessing the sunrises at various times of the year from the three tholoi, including the equinox and the summer solstice, that verified the predictions of time that was given by the astronomical tools.

[10] The orthophoto and the isoletric lines are based on a 3D model of the area produced by a drone mapping of Koumasa, taken in 2022 with the permission of D. Panagiotopoulos. The editing in GIS was done by the author.

[11] (Available online <https://aa.usno.navy.mil/data/docs/AltAz.php>; <sunearthtools.com>; <Stellarium.org> accessed September 2022).

5.2 *Observed Sunrises and Illumination of the Koumasa Tholoi through the Entrance and the Summer Solstice Orientation*

The association with the sun is not arbitrarily guaranteed based on a general eastern orientation; the sunrise point oscillates between the maxima of the solstices. The sun's appearance is further regulated based on the mountains, which define the local horizon, as shown in Figure 3. This image is based on a panorama taken from a point between the tholoi, located on the back side of Tholos E, in front of Tholos A and north of Tholos B. (see the 'x' mark in Figure 2). The analysis can be considered similar in the whole tholoi area, where only the decimal points change.[12] Figures 2 and 3 indicate the dynamic mountain relief of the region, as well as the liminal point of Koumasa between valley and mountain. The section presented in Figure 3 extends over an azimuthal arc of 40° to 150°, denoting the apparent sunrise of the sun throughout the year.

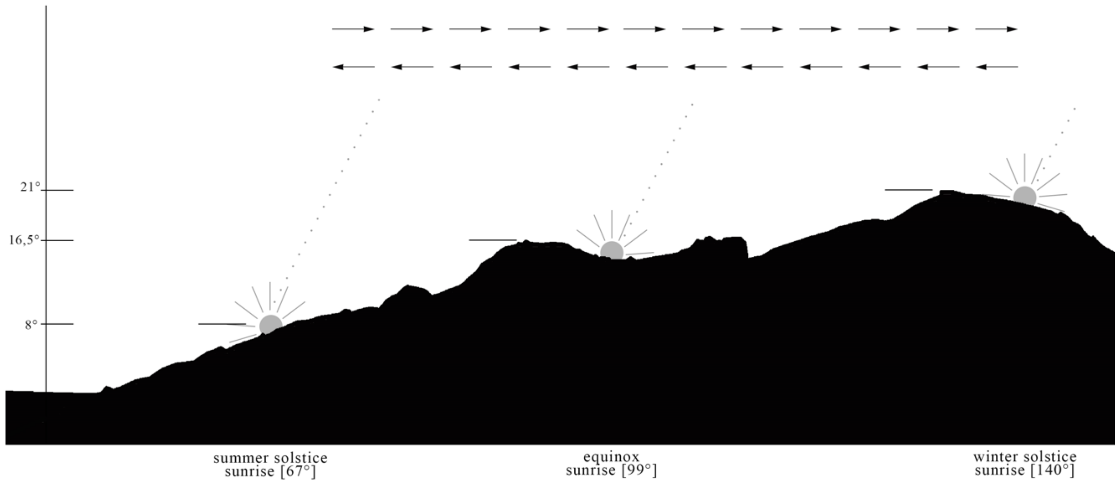

Figure 3. Koumasa´s tholoi skyline. The shift of the point of sunrise over the hill of Koumasa and the Asterousia throughout the year for an azimuthal arc 40° to 150°, as seen from a panorama taken from the Tholoi area (from the point marked with 'x' in Figure 2). For the three key sun positions, the altitude (vertical axis) and azimuth (horizontal axis) is given.

As the winter arrives (in Figure 3 indicated by the arrows pointing towards the right), the sunrise occurs further to the south reaching its maximum southern extent at the winter solstice. As the sun in its daily apparent movement follows the ecliptic – therefore not rising vertically – an obstacle on the horizon will cause the sun to appear shifted to the south in comparison to its rise on the level horizon with zero altitude (see dotted lines above the sun discs in Figure 3). Thus, the apparent sunrise, i.e. the appearance of the sun behind the local horizon is further pushed to the south and to a higher altitude due to the ever-rising Asterousia mountain range.

At the winter solstice the sunrise given on the horizon level around the area of Koumasa is at 119° of azimuth. As the hill reaches 20° of altitude, the sun is calculated to reach that altitude and thus appear behind the mountains at 140° degrees of azimuth (Figure 3, right).

In the following months, the point of sunrise then shifts towards the north (Figure 3, arrows pointing left), until it reaches near true east at the equinox point, which is the same for spring and autumn (late March, late September), where a median orientation from a level plane would be expected. At Koumasa, the equinox point is at 89° on the horizon level, while appearing behind the hill at 99°, almost exactly between the two Koumasa Settlement peaks (Figures 4a, 4b). This sunrise point forms an angle of more than 30° azimuthally with the entrances of the tholoi. So, although the sun enters at the equinox, this beam is acentral, since all three doorways are clearly otherwise oriented. The result is that the light shines only on the part directly in front of the entrance and towards its north, and part of the beam just hits the northern side of the corridor. This point is illustrated in Figure 4b, where the sun can be seen through the door of Tholos A, but only at a steep angle and only very near the entrance. The depth of light reached

[12] The back of Tholos E is at an elevation of 380,8 m. The distance to the highest point of the Sanctuary hill is 160 m, at 428 m in height, corresponding to an altitude angle of 16,5°, as noted in the figure.

within the Tholos decreases the higher the altitude of the light source is. The equinox sunrise point has ca. 14° of altitude, which would lighten only the area in front of the doorway of the tholos; additionally, the light beam would enter sideways, remaining in front of the door (Figure 4b).[13]

Figure 4. The equinox sunrise, seen from Tholos B (4a, left) and from the inside of Tholos A (4b, right). Photos taken on September 20th 2018, 8:20 am

Around two months before and after the summer solstice (end of April and of August respectively), the sunrise point reaches the southern edge of the hill (point of 16,5° in Figure 3), as seen on a photo taken at the beginning of September. The sunrise points are identical for the dates, symmetrical to the solstice day. Thus, two months before and after a solstice, the sun will rise from the same point.) from which point onwards – as the dates come closer to the summer solstice – the sunrise point will have a lower altitude, following the slope of the hill. August 2nd (Figures 5a, 5b) shows a sunrise that allows for sun within the tholoi, although still not through the centres of Tholoi B and E, although it does so for Tholos A, which has a wider visibility window.

Figure 5. Sunrise on August 2nd from Tholos B (5.a, left) and Tholos E (5.b, right). Photos taken on August 2nd 2019, 7:20 am.

On the summer solstice, the azimuthal movement of the sun's rising point reaches its northern extreme (Figure 3., left). The rate of change slows down, meaning the observers would see the sunrise point remaining, as the etymology of solstice suggests, still for some day; if no modern need for accuracy is needed, almost an entire week.

5.2.1 Summer solstice

For a flat horizon, the solstice sunrise at Koumasa happens at 61° of azimuth around 6:05 am local time. However, the hill blocks the sun's appearance with 8,1° of altitude, which makes the apparent sunrise to seem shifted to the south from 61° to 67°. The sunrise

[13] The distance to the point of sunrise at the equinoxes is 147 m, at 417 m in height with an altitude of ca. 14,0°. Basic trigonometry (right triangle) for Tholos E with 1 m door height and a declination of 14° yields 4 m length for the beam of light. Given that the thickness of the wall at the entrance is 1,3 m, this results in the light reaching less than 2,7 metres inside the tholos, less than one third of the interior diameter, and with the light beam tilted to the north, so a significant width of the beam just hits the inner side of the corridor and the wall in front of the entrance.

would reach Tholos A first, then Tholos E and finally B in a span of ten minutes before 7:00 am, as observed in the images below.

Tholos A:

On the summer solstice, the sun rises near the northern edge of the entrance, i.e., its left side as seen from the interior. This arrangement makes use of most of the sun's illumination, as the sunrise point will be visible from the interior for the largest amount of time (Figures 6a, 6b). For comparison, see Figure 4b and also Goodison 2001, Plate 18. Of course, it should be noted that building Tholos E, which seems to have occurred at a later period (see discussion in Part 5) would block this view.

Figure 6: Solstice sunrise from Tholos A, as seen through the doorway from the back of the tholos (6a, right) and directly behind the doorway (6b, left). Photo taken on June 21st 2022, 7:00 am.

Tholos B:

The doorway of Tholos B has been subject to reconstruction, which is obvious when compared with the Xanthoudides photos; Lebesi only very briefly mentioned some work being carried out at the cemetery in order to strengthen and secure the walls (1984, 316). The height of the lintel has however been deemed trustworthy (Traunmüller 2011–12, Figures 4, 5; 64, 65). The solstice sunlight enters at an angle, aligning with the southern side of the door, forming an angle towards the entrance axis of the tholos of 10° on a line that reaches the back of the tholos at 1,5 m from its central back point, as can be seen from the plan (Figure 1). No precise orientation to the solstice can be assumed, however the interior illumination is sufficient and covers more than half of its diameter, a fact that is only true for few weeks around summer the solstice (Figures 7a, 7b).

Figure 7. Summer solstice sunrise from Tholos B entering at an angle of 10 o. Photo 7a from the back of the inside the tomb, Photo 7b from the outside with the photographer's shadow emphasizing the beam. Photos taken on June 21st 2022, 6:59 am.

As for the assumed reason for the tilt, it could be proposed that the entrance of Tholos B is tilted to the north far enough to avoids the hill while still catching enough of a morning sunrise, albeit only near the solstice. So the timespan for the entrance into the tholos is narrowed around this date, as in August 2nd for example, the sun beam enters, but a minimal distance just near the entrance. It should be noted that even at minimum height, the rather long annex of Tholos B would from the moment of its erection further hinder the sun at its lower angles. The annexes of Tholoi B and E have been re-evaluated in the course of the current excavation, as the plan of Xanthoudides has proven inaccurate (Panagiotopoulos 2016, 556).

Tholos E:

For Tholos E, there is a clear orientation towards the solstice sunrise (Figures 8, 9a, 9b). What is of note is that the sunbeam reaches deeply towards the interior wall centrally at the moment of sunrise (Figure 9b). This must have been by design, as it only lasts a couple of minutes, and the likelihood of this occurring by chance is low. The gathered data was crosschecked with *Stellarium*, *American navy website*, and *sunearthtools.com*, namely that at 6:55 am, the sun has an altitude of 8° and an azimuth of 67°. These three numbers correspond with the photos taken from that location on the solstice and also with the data gathered from measurements on the landscape.

Figure 8. Summer solstice sunrise as seen from behind Tholos E, on the doorway axis (June 21st, 2022). Photo taken on June 21st, 6:51 am.

Figure 9. Summer solstice sunrise from inside of Tholos E on the doorway axis (9.a, 9.b top: from two positions along the entrance axis, in the first third of the Tholos depth), and sunbeam entering Tholos E on its central axis (9.c, 9.d). Photos taken 6:55 – 7:00 am.

The point on the hill in the direction of the Tholos E axis on which the solstice sun rises was found and measured at 318843.849, 3873056.158, 412.514, at a distance of ca. 220 m from the tholos. Seen from Tholos E, whose height is also known, the angle of that point is calculated at 8,1° in height.[14]

The doorway reaches 1,25 m in height on its outer side and 1,35 m on the interior. However, a part of this can be assumed to be later reconstruction. Based on the report of Xanthoudides and a photo of Tholos E taken in the year 1909 while the cover was still there, the height of the doorway from its outer side measured 1 m to 1,2 m from the bedrock. The distance from the part of the interior wall facing the entrance to the inner side of the doorway (i.e., the inner diameter) is 9,25 m. To determine the depth the light reaches, one has to consider the distance of the farthest side of the interior to the outer side of the door which is 10,55 m. Assuming the conservative estimation for the height of the doorway at 1 m, based on simple trigonometry, the sun beam appearing at an angle of 8° reaches a depth of ca. 7 m into Tholos E at the moment of sunrise, or ca. 3,5 m from the back wall. In Figure 9d, the beam seems to reach even deeper, but this should be attributed to the reconstructed row of stones discussed above. So, the sun beam covers at least two thirds of the inner diameter of the tholos, from which point the sun beam starts retreating and tilting slightly to the north. This distance can be also seen in Figure 10, where the photographer's shadow represents the height of the doorway.

If one takes the illumination alongside the central axis as sufficient and considers the uniqueness of the phenomenon being once a year, it is interesting to see what length of time the phenomenon spans (for the role of torches and lamps, see above). The centre of Tholos E lies at a distance of 6,11 m to the outer entrance of the doorway, and measured from there, the vertical angle to the sunrise point is, as mentioned above, 8.1°. For a lintel height of 1 m, the vertical angle from the centre of the tholos upwards is 10°, meaning that the sunrise occurs approximately 2° lower than the lintel. For a depth corresponding to that of a third of the inner diameter, the vertical angle of the opening is 13°, i.e., 5° higher than the mountain line where the sunrise occurs (see Figure 9a). The sun moves the equivalent of its own diameter – close to half a degree – every two minutes, so that 2° will be covered in 8 minutes, and 5° in 20 minutes.

So in summary, the entire phenomenon has a duration of around twenty minutes, and occurs within of couple of days around the solstice. This very narrow window of usage time, both in the calendar year and within the day suggests a less practical or frequent function, but perhaps one that serves to initiate or coincide with a maintenance activity, possibly imbued with ritualistic meaning and corresponding activity given the yearly repetition.

Furthermore, what is seen from the entrance can be understood from Figure 10a, which was taken by the author while kneeling. Today, the anteroom at the doorway axis seems absent, but it existed at the time of Xanthoudides. A height of 1,15 m is mentioned (Xanthoudides 1924, 33), which would not prohibit the light (Figure 10b). Unlike the contemporary situation, the height of the anteroom seemed equal on all

[14] Analytically its distance, height difference and angle to the three points on the axis are:
From the back of the tholos its distance is 225,73 m while being 30,414 m higher. Therefore, its angle is 7.973°. From the interior side of the entrance its distance is 216,51 m, being 31,621 m higher and therefore at an angle of 8.309°. From the centre of Tholos E, its distance is 221,08 m, being 31,615 m higher, therefore at an angle of 8.138°.

sides, as seen by the photo of 1909 discussed above, but also in the plan (Xanthoudides 1924, Plate 61). While an originally greater height cannot be entirely disregarded, the comparatively thin walls do not make it seem very likely. Additionally, the anteroom was likely a later addition, as discussed below.

Figure 10. The interior of Tholos E as seen from the entrance of the tholos from a kneeling position, 3 minutes after local sunrise (10a, left) and from the far side of the anteroom, in a photo taken 5 minutes after sunrise (10b, right).

The enclosure of the anteroom may be assumed to function as a second blockade after the door slab, resembling the arrangement in Porti with two slabs, as Branigan has emphasised. Given the close proximity of Porti to Koumasa, cultural similarities – likewise shown by the material evidence as seen in figurines of man and bull from these tholoi – are not to be discarded (Xanthoudides 1924, Plates II and VII; Branigan 1993, 122). Furthermore, if at the entrance axis the anteroom was originally lower, as today's image suggests – which shows a clear dip in height facing the tholos entrance, though the wall continues unbroken by an entrance of its own.

The calculations above were empirically verified in situ, as the images show. Based on these observations, a purposeful alignment of Tholos E to the summer solstice can be assumed.

6. EVALUATION OF THE SOLSTICE ORIENTATIONS

The apparent solstice direction for is one of the orientations to a solstice occurrence, which include Krasi A for the summer solstice and Archanes E for the winter solstice (Goodison 2018, 280-283), with Tholos E showing a noteworthy precisiton in the alignment. The approximate similarity in the orientation of Tholos A and to a lesser degree of Tholos B also calls for interpretation of the Koumasa tholoi as a group. This evaluation has to proceed with care. In fact, Ruggles has warned against selecting one astronomically aligned site from a coherent group while ignoring the rest.[15] While heeding this advice, the situation in Tholos E seems to be an *ad hoc* phenomenon based on the local topography. This aligns with the general usage of the other tholoi, but takes into account specific circumstances. For example, the solstice alignment does not coincide with a landscape feature, as in Krasi A (Goodison 2018, Figure 1.d). Similarly, Koumasa A has a window of visibility difficult to define, but nevertheless seems to only marginally point towards the Koumasa hill, the local landmark. The typology of the tholoi based on their orientations towards landscape features or sunrise phenomena as analysed by Goodison is a very promising tool, which should be complemented by analyses specific to each location, which is the goal of this paper regarding Koumasa.

Here, the chronology of the tholoi seems to be crucial in understanding these discrepancies and the gradual developments in the Koumasa tholoi area. Tholos E and B are considered later than A, based on the finds and the architecture of the tholoi. This postulation is endorsed by Legarra Herrero (2014, 43; 187–188; Figure 25) and is confirmed by the current excavation, with an EM I dating for Tholos A, and EM II for Tholoi E and B (Panagiotopoulos 2016, 562-63). As mentioned by Legarra Herrero (2014, 43), there is no material evidence earlier than Early Minoan (EM) IIA, with Tholos A and B possibly dated to this period, and Tholos E constructed later, being in use from

[15] The case of the Drombeg stone circle in Ireland is given as a counter example for an assumed solstice orientation. Its solstitial alignment was assumed by Ruggles to be unintentional based on the fact that its alignment is unique among 50 similar Irish axial-stone circles. Ruggles 2015, 373–388; Ruggles 1999, 100. The monument, originally consisting of 17 stones, offers a variety of possible lines, of which some have more potential of falling on an alignment by chance. This is however not the case in the tholoi.

EM III through Middle Minoan (MM) II, as can be attested to with more certainty (Legarra Herrero 2014, 187–88; Figs.18; 25.) The ongoing excavation showed that Tholos A as well as the adjacent Ossuary are characterised by EM II finds, while Tholos B and E produce finds from the later periods (Panagiotopoulos 2013; 2014; 2016; 2018). This argument for the chronological succession is strengthened by the more canonical stone arrangement visible for tholoi B and E. Tholos A aligns very well with the concept of receiving the maximum amount of light through its doorway, as the solstice sun arises from the edge of the door and is visible from there for dates of more than one month before and after the solstice.

Tholos E's alignment does not offer the maximum days for illumination of the interior through the summer, instead keeping the duration of visible sunlight restricted to only a very limited time. Designing the building in a manner that allows the summer solstice sunlight to enter centrally from the doorway comes at the expense of the amount of overall sun-lit days inside the tholos, as the sun's path does not cross the entirety of the doorway's opening or window of visibility, which is the case in Tholos A. As the establishment of a tradition is assumed, a special meaning could have been given to the solstice itself.

It is the most probable explanation that the arrangement and indeed the erection of Tholos E emphasizes the solstice event, as a possible date when the annual occurrences inside Tholos E would have taken place. Keeping in mind the extreme tilt of Tholos B, the assumption that the maximisation of sunlight days in the tholoi was a priority cannot be assumed to have been the purpose for those later tholoi, whereas a more pragmatic design for assuring light inside was implemented in the likely earlier Tholos A. Tholos E shows more refined architecture both in the execution of the building itself and its orientation. In that sense, it seeks to replace Tholos A, which is emphasized by the fact that Tholos E would have blocked Tholos A's solstice sunrise.

Regarding the indications of alignments, there have been some suggestions. For example, Goodison has provided proof for orientation of sunrises occurring at periods of September and April, and Goodwin suggested an orientation of the Minoan tholoi to the moon's maxima, which would partially fit for Tholos B. The most analytical ongoing study is that of Goodison and Guarita, aspects of which can be seen in Goodison 2018; 2019.

While surveying the Minoan tholoi as a collective phenomenon may show specific tendencies for the EM cultural preferences, as already discussed above, not every location needs necessarily be viewed in accordance with the whole corpus of tholoi. As discussed above, taking into consideration the role of the specific landscape characteristics and evaluating the choice of orientation as an *ad hoc* phenomenon – as in this case presented for Koumasa – might in some cases prove more fruitful or at the least enrich the discussion. This does not invalidate the search for choices made for the majority of other tholoi, as Goodison's work indicates.

Coming now to the architectural implications, Dowd spoke of manipulation of light as an architectural element in ancient cultures (Dowd 2020, 194). This statement can hardly ring truer than in the case of the Tholos E design. An alignment alone is not enough to indicate if there was a certain target. In the case of Koumasa, as an exception within other significant tholoi, the assumed need for light is a factor that would enforce the tilt towards the northeast.

Beside the discussion of whether any particular event was targeted, the role of the surrounding topography in combination with the need for light should be acknowledged. Seen from this point of view, the solstice orientation of Tholos E, contrary to our modern academic tendencies, becomes secondary, even an afterthought within the bigger picture. Orienting monumental buildings towards points of significance could be seen as part of the involvement of man with his wild surroundings, an act that is part of a dialectic relation, which constructed part of the prehistoric self (Hodder and Meskell 2011, 250–51).

Another aspect to be kept in mind is that decisions do not have to be monosemantic. It is true that, as has been discussed in chapter 1, often tholoi have a slight north-eastern orientation, for which the light factor may be assumed to be important. The Koumasa paradigm is faced with yet another parameter that might explain the extreme north-eastern tilt, which as demonstrated for Tholos B was even more north than the solstice. As the rising hill directly faces the tholoi, an alternative eastern orientation of the entrance would force an optical encounter with the realm of death on dwellers of the hill slope, which as discussed above would be faced with fear. Koumasa is the only one of the big tholoi ensembles that faces an elevated area directly opposite their eastern side, which was inhabited at least in their later usage phases, as discussed in Part 1. his possibility would explain the need for the entrance of Tholos B, which is the southernmost of the tholoi to be much more pivoted towards the north, as to avoid optical connection to the door. Tholos E does not require such extreme tilt, since it is marginally more northern than the peak of the hill.

From the archaeological point of view, the local horizon is sometimes neglected when evaluating the orientations, such as nearby slopes and hills, as discussed above.

In utilizing this methodology other factors must be considered, such as the possible presence of trees and buildings, in case the apparent horizon is near the site from which the observations are made. In the case of the Koumasa tholoi, the point of solstice is far enough, so any trees or a small-scale erosion would not have altered the observable point of sunrise. Furthermore, no pottery or structures were found there. As for the anterooms, categorised as vestibules in Koumasa, it is unclear whether their walls may have blocked the path of the sunlight, as their original height is unknown. Even in this case, they may have been built after the tholoi had already been in use for some time, as is often the case for tombs erected in EM II-III and thus would not be relevant to the purpose of the original construction (for annexes in this period see Legarra Herrero 2014, 41-51). In the case of Tholos E, the height of the anteroom is given by Xanthoudides as 1,15 m, without specifying variations (Xanthoudides 1924, 33). If this was the original height, with less than 20 cm higher than the lintel of the entrance, and more than a 1m away, it would not have blocked the morning light, based on the calculations above, even if its date coincides with that of the tholos. Finally, regarding the impact of the annex on the doorway, it should once more be mentioned that the usage of the doors of the tholoi is not undisputed, as the case of Krasi B shows, whose doorway was blocked by stones essential for the support of the structures, indicating it was not used (Platon 1959, 387), which in turn enforces the argumentations of accessing through the roof. In this case the entrances could have only a symbolic role (Goodison 2018, 283) and being blocked by an annex is not crucial. However, Tholos E, whose design allows illumination to the back of the tholos on the solstice, allows for the suggestion of a purposeful implementation, which can in turn also strengthen the case that in this instance, the annex would not have interfered with the solstice sun.

6.1 Method of determination and an overview of the change in obliquity

In evaluating the alignment of an ancient building towards a particular rise of a sky object above the horizon – such as the sun at the solstice – some more points need to be addressed. It would have required the determination of which day the phenomenon occurs and then making an alignment, i.e., drawing a line towards that phenomenon. Both of these tasks are considered to have been easy for ancient civilizations in the case of the apparent sun's sunrise point movements. For the solstice, the observer will notice a couple of days where there is no apparent change (Lehoux 2007, 88–89).

As for the modern determination of the azimuth point of the summer solstice sunrise at a particular site in the past, the various astronomical cycles of the earth have to be taken into account. Of those, it is the obliquity of the ecliptic that affects the rising and setting positions of sun, moon, and planets. Whereas the procession of the equinoxes relates to the star positions and is not considered for an astronomical ephemeris (timetable) of planets, the moon and the sun (Ruggles 2005, 319). The azimuth point at sea level is given by $\cos(A) = \sin(\varepsilon)/\cos(\varphi)$, where φ stands for the latitude of the site, and ε is the obliquity of the ecliptic (i.e., the tilt of the earth's axis).

Obliquity, defined as the angle between the equatorial plane and the ecliptic, is not stable but varies through time. Although its variations have been more extreme in past geological eras, it is fairly constant since the period of 41ka that coincides with the late Palaeolithic up to modern times, with fluctuations limited to the range of two or three degrees.[16]

Calculations of past values of the obliquity of the earth can be based on the polynomial equation of Laskar, who provides a method that produces the parameters of the polynomial (Laskar 1986, 68. See also Laskar et al 1993; Laskar et al 2011). Further processing of this data yields a result for the obliquity of about 24° in 3000 BCE, 23,9° in 2000 BCE, and 23,865° in 1450 BCE being close but not identical to today's value of 23,45°. Calculation for 1450 BCE by Davis using Laskar's Formula (see Chapin et al. 2014, 149). The data from 3000 and 2000 BCE are based on (Ruggles 2015, Table 31.3). The table was produced based on (Lascar 1986). For more recent the algorithmic calculations of past obliquity ranges see Lascar polynomial see Lascar et al 2011. It is worth mentioning that this method has been utilized for finding the solstice on the horizon as viewed from other Aegean monuments, such as the Vapheio Tholos in Greece (Chapin et al. 2014, 149. See also Laskar 1986).

Based on these calculations, in the tropical zones around 2500 BCE, which coincides with the beginning of the tholos tradition the sun rose and set 0,5° further north at the June solstice, a distance which is approximately equal to its own diameter (Ruggles 2015, 473–482; Goodison 2001, 79–80). In temperate zones, the corresponding azimuth difference is somewhat greater. Ruggles argues the difference is important

[16] In the range of 21,5°–24,5° (Williams 1993) or 22,2°–24,4° (Berger 1976, 133). In fact, for most of earth's history, the obliquity has been more than 50°, falling under 30° only in the last 500 Ma. (Williams 1993, 31–32). See also Laskar eta al. 2004. As for the effects of the obliquity and its impact on the precession, tidal periods and other phaenomena, see: Olsen, P. E., and D. V. Kent. 1996. "Milankovitch climate forcing in the tropics of Pangaea during the Late Triassic." Palaeogeography, Palaeoclimatology, Palaeoecology 122:1–26.

when assessing putative solar, and particularly solstitial alignments at later prehistoric monuments (Ruggles 2015, 473–482). However, Crete is not that far from this zone in comparison to northern Europe for which Ruggles argues, leading for variations not observable with the naked eye. The need for more precise accuracy can be argued to be a modern tendency, without including the element of the error margin that the ancient builders had, especially for differences not noted with bare eye observation (see Brown 2013, 6; Silva, 2014, 27). The above means that the sunrise point would have been about 0,5° to the north (left in reference to the observer in the images above) as seen for example from Tholos E, making the alignment even more precise, since the orientation when the sun has fully risen above the horizon would have coincided exactly with its middle.

The opening of the Tholos E doorway seen from the back of the round interior measures 4°. Of this opening, the sunrise point – taking into account the small discrepancy of where the exact centre is – falls within a margin of ca 1°, which is more than the change of the sunrise point due to the obliquity shift since the erection of the tholoi. Seen empirically from the middle of the tholos, where the opening is perceived as 8o wide, the centrality of the solstice sunrise is prevalent, and so is the interior illumination of the tholos, with the light beam dividing the inner circular surface in two and reaching deep towards the back, before the light beam slowly decreases in length as the sun rises further, but continues illuminating the interior.

7. CONCLUSIONS

The rather unusual orientation of the Koumasa Tholoi seems dictated by the stark elevation to their direct east, leading to the development of *ad hoc* needs and solutions regarding the management of light, be it symbolic or practical. The typology of the tholoi based on their orientations towards sunrise phenomena as developed by Goodison are taken into consideration. Within the scope of this paper, the Koumasa tholoi were approached as an *ad hoc* case focusing on the effects of the landscape on the choices of the builders; it is therefore to be seen as complementary to broader analyses of the tholoi question.

Building the tholoi to face northeast not only allows for the summer sun access through their low entrance, but also removes the entrance from a direct view of the hillside, an aspect especially relevant to Tholos B. Activity on the hill during the time of building is not yet backed by evidence at this point, but habitation there is proven to be contemporary with at least the last phase of the usage of the Tholoi area. Accepting the earlier dating for Tholos A, a development and an establishment of tradition can be seen. It is so oriented to ensure maximum daylight sun, expressed in the alignment with respect to the solstice sun which is made to enter from the edge of the entrance. In Tholos E, an orchestration of the summer solstice sunrise by careful architectonical arrangement is seen, so that it may be viewed centrally, putting an emphasis on the phenomenon itself, rather than general light management. In this aspect, the astronomical associations suggested here are seen as a product of the long use of the tholoi that gradually transformed.

The uniqueness of this ensemble in Koumasa – all the more noticeable as it constitutes one of the major tholoi locations – and the need for its arrangement was approached within the framework of landscape archaeology and archaeology of the senses, stressing the sociological factors and the research linked with the mortuary archaeological research for the Messara tholoi.

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