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The Lefkandi-Toumba Building as a Timber-Framed Structure

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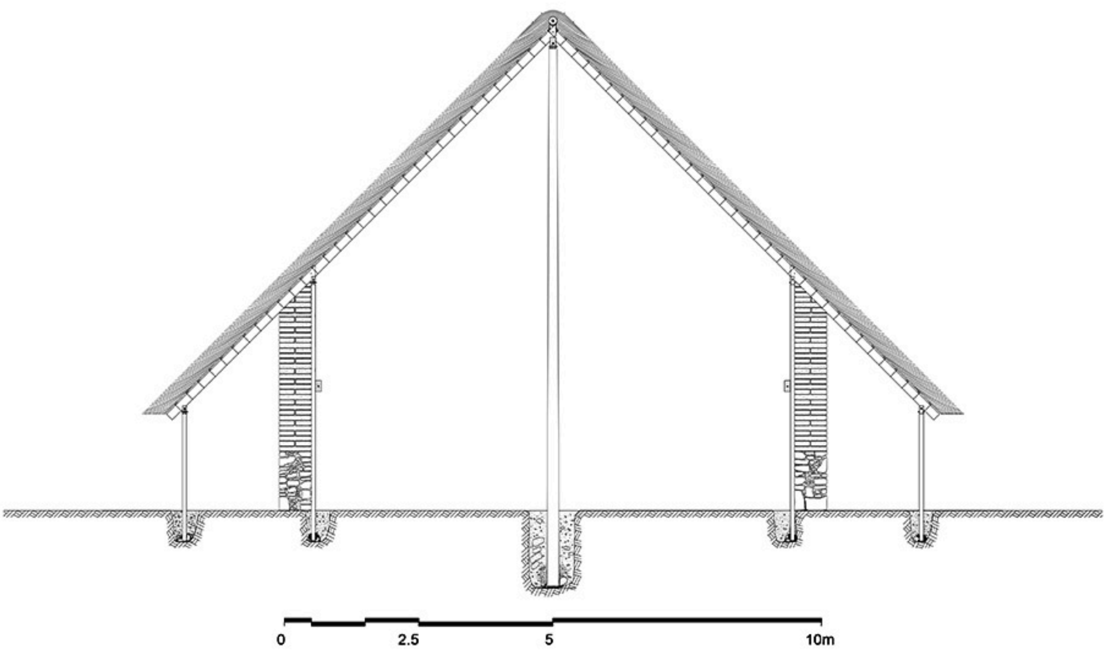

The article demonstrates that the building or megaron on the Toumba hill at Lefkandi (Euboea), dating from c.950 BC, was a timber-framed structure, in contrast to the common view of it as a building with loadbearing walls. This raises the possibility that the walls, perhaps even parts of the frame and the roof, were still under construction, rather than fully completed as previously assumed, when the building was buried under a mound. The reconstruction of the timber frame of the building, as well as an analysis of the manner of its production, give us valuable insights into ancient wooden architecture. Even more, a

structural analysis intended to test the integrity of the frame sheds light on the complex rationale behind the adoption of such designs as prototypes of later large-scale temples in Greece. Additionally, there is no evidence that the timber frame suffered any significant structural failure, but if such failure ever occurred, it would most likely be a partial uplift of the thatched roof due to high winds.

> “ As a timber-framed structure, the LK-T megaron provides us with valuable insights into ancient wooden architecture, including the craftsmanship and techniques of square timber-framed construction, as well as the complex of reasons behind the use of designs of this kind as prototypes for later large-scale temple architecture in Greece.

Introduction

This article deals with the truly exceptional building on the Toumba hill at Lefkandi (henceforth, LK-T building), on the island of Euboea, dating from c.950 BC (Popham, et al., 1993). Located on the summit of a low hill (altitude 17 m a.s.l.), about 270 m from the seacoast, the LK-T building stands out from its Early Iron Age contemporaries by its size, design, and sophisticated construction.

We offer a new perspective, differing from that of the excavators, suggesting that the LK-T building was a timber-framed structure, i.e. a structure where the walls served a non-loadbearing function, and the weight of the roof was carried entirely by posts, forming the main elements of a wooden framework. A new, detailed reconstruction of the timber frame of the building and its production stages is proposed, while the issue of the building's structural integrity is also addressed.

A brief description of the building

The LK-T building presents a megaron plan ending in an apse at its west end, with the entrance at the east end - an opening or 'secondary doorway' in the south wall (Popham, et al., 1993, pp. 5-6, 13, 43) is subject to interpretation (see *infra*). In its present state, following the damage it suffered in modern times (Popham, et al., 1993, pp. 1-3, 34), the building comprises, in succession, a shallow Porch, an East Room (ER), a Central Room (CR), two Square Rooms (SRs) - the North Room (NR) and South Room (SR) - on either side of a corridor (West Corridor), and an Apse Room (AR) (See Figure 1). Towards the middle of the building, in the CR, the rich double burial of a warrior accompanied by his female companion and four horses was found.

The walls consisted of a socle (c.1.15-1.30 m high) made of (mainly) coarse grey marble, in rubble masonry, surmounted by mudbricks of a light brown colour and a gritty texture up to a maximum height of four courses. The walls were preserved at markedly different heights, varying (in the places unaffected by modern damage) from c.0.50 m to c.1.60 m.

A prominent feature of the building, on which we will focus, is the large number of timber posts. These timber posts, after decaying, left clear imprints in the fill of the specially dug pits and, in some cases, their wood residue was preserved well above floor level. Thus, a series of posts of round cross-section (average diameter: 0.222 m)[1] were set on the long axis of the building (henceforth, centre posts) dividing it into two aisles. In addition, a double series of posts of rectangular cross-section (average width: 0.22 m; average thickness: 0.072 m) ran (a) all along the inner face of the exterior walls (henceforth, wall posts) and (b) parallel with but at some distance from the west, north and south walls of the building forming a veranda (henceforth, veranda posts). This veranda is a forerunner of the peristyle (or *pteron*, *peristasis*) of Greek temples and the earliest attested example. Finally, there is a series of post pits across the ER and another across the AR.

Including the veranda, the LK-T building would have measured 48.30 m x 13.80 m. Its reconstructed length - based on a geometrically generated triple-contour ellipse drawn for the ideal contours of the apse wall and its surrounding veranda, which are mostly missing - measures three and a half times its width throughout most of the building (except at the west end, where the building narrowed), as shown in Figure 2 with Inset A (the dimensions shown in Figure 2 and in the following figures are multiples or subdivisions of a foot of 0.30 m, a plausible local unit of length[2]). This is therefore the largest Early Iron Age building and the largest megaron known to us from ancient Greece. With its monumental size and megaron plan, as well as its surrounding posts in the veranda and its eastern orientation, the LK-T building is strongly reminiscent of later Greek temples.

A blocking wall runs across the façade of the building. Against the long walls, on the outside, there were ramps made predominantly of mudbricks of different colours and a soft texture, on a base of earth or pebbles. The interior of the building was filled mostly with earth, often containing mudbricks like those of the ramps, as well as stones, pebbles, remains of reeds or rushes, and other debris. Fill and ramps together formed a mound over the entire site.

The building has yielded a scarcity of finds and there is no evidence that it was ever occupied. In fact, there are signs that it was left incomplete, the most obvious being the following: an interrupted wall plastering- or floor laying operation within the SR (Popham, et al., 1993, pp. 24, 97-98); differences in the plaster coverage of some walls in the building's interior (areas of thick, finished plaster vs areas of patchy and thin, incomplete plastering) and complete absence of plaster from other walls (Popham, et al., 1993, pp. 6, 9-10, 13-14, 23, 25, 42, 97, pls 7, 8, 31b, 31c); clay floors covering only part of a room or being patchy, thin and poorly preserved, ill-defined or even totally absent (Popham, et al., 1993, pp. 12, 15-16, 22-25, 98, pl. 9); and lack of steps from what can safely be identified as a staircase in the north-east corner of the CR.[3]

In addition, there are signs of damage or disturbance to the building as well as some 'oddities': in the SR, the north wall presents a 'severe cant' in two opposite directions on either side of the doorway (Popham, et al., 1993, pp. 24, 98, pls 25a, 26, 31a, 37-West Section); in the NR, the part of the south wall to the west of the doorway is devoid of its inner face (Popham, et al., 1993, pp. 23, 98, pls 23, 24a, 26, 29d); patches of (decayed) reeds or rushes from the roof lying on the floor (and in the fill) of the building in several places (Popham, et al., 1993, pp. 18, 31, 99, pl. 12: level 4 and pl. 37-East Section); and a number of skewed or misaligned wall- and veranda posts in the eastern part of the building[4] (See Figure 1).

Interpretation of the building and its structure

The LK-T building has been identified by most of its excavators as a Heroön, a funerary building that would have been planned and initiated by (or erected in honour of) the warrior who was sumptuously and heroically buried in it, and therefore constructed, in imitation of a 'princely' residence, largely or entirely after the death of that individual (Popham, et al., 1982; 1993, pp. 49, 100). However, the Heroön hypothesis has been disputed, starting with Calligas, another excavator, in favour of an interpretation of the building as the residence of the 'warrior-king' (or *basileus*) who would have ultimately been buried in it.[5]

In Coucouzeli (1994), it was proposed that the LK-T building was an unfinished longhouse intended to be inhabited by a large, corporate kinship group, probably a clan, under the leadership of a powerful chief,[6] upon whose death the site would have been suddenly abandoned and buried under a mound. It was further proposed that in this setting, as a longhouse, the building had a CR likely designed to include twelve square rooms (SRs) or cabins placed in two rows antithetically on either side of a central corridor: ten more rooms of similar size to the two existing SRs can be reconstructed, the northern row ending at a sufficient distance from the staircase in the CR to provide access to a *sottoscala* (See Figure 3). These rooms would serve as the private, living apartments of the nuclear families (or *oikoi*) constituting the longhouse group. Finally, a mezzanine above the cabins would serve the storage needs of each family.[7] Although the reconstruction of two rows of cabins is not a prerequisite for identifying the building as a longhouse, it is recommended for two basic reasons: first, it addresses the unusual presence of the two SRs by making them part of the CR[8] and giving the building a neat tripartite division (front-central-back room), such as is familiar to us from other megara but is also characteristic of longhouses; and, second, it provides the additional cross walls that would be needed to brace the long exterior walls of the CR and prevent them from collapsing.[9] For these reasons, in what follows, the SRs will be considered as part of the CR. Finally, it was suggested that the LK-T building was a timber-framed structure (Coucouzeli, 1994, pp. 33-59), and this is the issue we will focus on here, with all the implications that it entails. We will put forward a new reconstruction of the LK-T building, as a timber-framed structure, differing significantly from previous reconstructions which presuppose the existence of loadbearing walls.

The excavators reconstructed the LK-T building assuming a *priori* that it was a structure where the walls, rather than the posts, supported the load of the roof, i.e. the walls had a structural character. Thus, the wall posts were interpreted as 'stabilisers' of the veranda posts (by connecting them to the wall via horizontal beams crossing the wall at about the height of the eaves) and of a timber plate placed on top of the walls to support the roof rafters. Therefore, according to the excavators, the wall posts served 'to connect all the main elements of the roofing system and also the walls' (Popham, et al., 1993, pp. 47-49, fig. 1, pl. 28).[10]

The excavators' reconstruction of the building as a structure with loadbearing walls has generally been taken for granted by other scholars, with some of them proposing different, equally questionable, reconstructions. Fageström's reconstruction of the building showing the wall- and veranda posts bending inwards and crossing at the ridge beam (Fageström, 1988, p. 60, fig. 46) is contradicted by the existing evidence. Herdt - who, incidentally, pointed out the LK-T building's similarity to European Neolithic longhouses - went even further. He asserted that 'there is no valid structural interpretation [for the wall- and veranda posts] as the wall is solid enough to fulfil any structural duties by itself', suggesting a reconstruction of the building whereby the veranda posts are detached from the building and instead form a fence surrounding it (Herdt, 2015; see also Wilson Jones and Herdt, 2022).[11, 12]

The a *priori* assumption of the existence of loadbearing walls in the LK-T building inevitably led the excavators to a series of hypotheses regarding the building, which are as follows.

Hypothesis 1:

The erection of the walls preceded that of the posts, the sequence being: construction of the walls, then setting up of the posts, and finally the installation of the roof.

Hypothesis 2:

The walls were built to their full height and 'the basic construction including the roofing had been completed'.

Hypothesis 3:

During the process of abandonment of the building, a large part of it must have been dismantled, to facilitate its filling and to form a low and regular mound or tumulus over it. Thus, the whole roof was removed; the upper parts of the mudbrick walls were dismantled for use in the ramps; the walls at the east and west ends of the building were dismantled to a greater extent, also affecting their stone socles; and the posts were partly or wholly removed (Popham, et al., 1993, pp. 29, 38, 44, 49, 52-55, 97-98, 100).

Our reconstruction of the LK-T building as a timber frame structure challenges the above-mentioned assumptions about the building's structural character, construction process, state of completion and abandonment process.

The LK-T Building as a Timber Frame Structure

One can safely identify the structural system used in the LK-T building as a frame construction or a skeleton system (as opposed to a mass construction or massive system, as it has hitherto been identified) and the building itself as a timber frame structure.[13] Timber frame construction was used in Greece from prehistoric times to the Archaic period, including in temple architecture.[14] The LK-T building is the earliest known Early Iron Age timber frame structure, which, as we will see, implies a high degree of sophistication at this early period.

The signs that the LK-T building was a timber frame structure are as follows. Firstly, the series of posts that ran along the inner faces of the exterior walls of the building is the most convincing indication that the walls had no structural function, i.e. the walls themselves were not loadbearing, and that the wall *posts* acted instead as loadbearing elements in a timber frame designed to support the weight of the roof. The wall posts of the LK-T building are indeed a clear example of *mesodmai* (*μεσόδμαι*), mentioned in Homer in close connection with the walls as being 'sprinkled with blood' during the slaying of the suitors in Odysseus' megaron (*Odyssey* 19, 37; 20, 354).[15]

Secondly, all the posts were related to each other by two kinds of alignment, which strongly suggest that there was a structural connection between them for the purpose of carrying the roof. Thus, if one leaves aside the west, curved end of the building, where the different geometry of the roof necessitated different roofing arrangements (*infra*), and focuses on the rest of the building, one notices that all the posts were carefully aligned with each other longitudinally, i.e. in the direction of the long axis of the building. The longitudinal alignment of the centre posts was an arrangement to carry the ridge beam or rather, given the great length of the building, the series of ridge beams of a gabled roof, i.e. a roof comprising two sloping surfaces on either side of a ridge and at least one flat, triangular end or 'gable' (Brunskill, 1992, p. 93, figs 2, 4, 60g, 69). The longitudinal alignment of the wall- and veranda posts implies that they carried at their top a series of 'plates' (also known as 'top plates' or 'wall plates') linking them together (longitudinal linkage) (See Figure 4[16]). Both the ridge beams and the plates would have tied the building in the longitudinal direction (Sobon and Schroeder, 1984, p. 23). At the same time, all posts were also generally aligned with each other transversely, i.e. perpendicularly to the longitudinal axis of the building, in a way such that there is (a) a one-to-one correspondence between the intervals of the wall posts and those of the veranda posts; and (b) a one-to-two correspondence between the intervals of the centre posts and those of the wall- and veranda posts. The intervals vary (see Popham, et al., 1993, table 3), with those of the wall- and veranda posts at the east part of the building averaging c.1.5 m (Popham, et al., 1993, pp. 27-28). A typical section across the timber frame involves a 3 meter[17] interval between centre posts C4-C5 which corresponded to two intervals of 1.5 m between the wall- and veranda posts on either side (See Figure 5). The general transversal alignment of all the posts, in conjunction with the large size of the intervals between the wall- and veranda posts, strongly suggests that all the posts participated in the carrying of the roof's 'principal' rafters (See Figure 6), with further, 'intermediate' or 'common' rafters placed in-between (See Figure 6: Insets A, B, C, D[18]). The actual way this was done is made apparent by the fact that the posts present a slight but consistent mutual staggering. The mutual staggering of the posts implies (a) the use of two separate rafters, one for each roof-span: an upper rafter (ridge to wall-post plate) and a lower rafter (wall-post plate to veranda-post plate); and (b) the use of *adjacent* rafters resting on the ridge beam and on the wall-post plates, over the wall posts (See Figures 6, 7). The use of two separate rafters, one for each roof-span, is to be expected, in view of the large spans occurring across the building (the horizontal span of the roof, between outer faces of plates over wall posts, is c.9.0 m - See Figure 7).

Thirdly, all the posts were firmly embedded in the ground, in pits carefully dug for this purpose.[19] The average (ascertained) depth (or depth of pit) for the wall- and veranda posts is 0.58 m, while the average (ascertained) depth for the centre posts is 1.44 m[20] (See Figure 7). This arrangement implies a structural function for the posts: earthfast posts act as pile foundations to anchor the timber frame to the ground and ensure its structural balance and resistance, primarily to lateral wind forces. It is the simpler arrangement for setting up the posts of a timber frame (compared to the technologically more advanced arrangement of setting the posts off the ground, which requires more complex structural solutions) and can be extremely effective when the posts are buried to the correct depths.[21]

Therefore, the posts of the LK-T building were the 'supporting elements' of a 'skeleton' system; they formed part of an 'active' frame, which concentrated the loads of the roof and transferred them to points in the ground.[22] As the main vertical components of the frame, these loadbearing, embedded posts were intended to play a crucial role in the overall strength and wind resistance of the timber structure. Consisting of either 'columns', i.e. timbers of a round cross-section (centre posts) or, in their majority, of 'squared timbers' (wall- and veranda posts), these posts imply a high-status building as they represent the best choices in timber frame architecture (as opposed to 'poles' or 'riven timbers').[23] It is important to note in this regard that the LK-T building predates by at least 250 years a temple which exhibits the same basic construction principle, the Archaic temple of Poseidon at Isthmia, using squared timbers embedded in the ground.[24] By contrast, the masonry walls of the building were merely the 'bounding elements' of the skeleton system; being non-loadbearing, they formed a permanent, protective envelope or cladding around the latter, isolating it from the atmospheric agents.[25]

It naturally follows from the above that when the plan of the building was executed, the timber framework would have preceded the walls (even if only by a few hours). Therefore, the walls must have been constructed mainly from the outside, being erected in close proximity to the wall posts' line in most of the preserved part of the building (with a few exceptions at the west end). Thus, the timber frame would have been built quickly, with the roof following closely, thereby also ensuring the necessary waterproofing for the construction of various inner features. Then, slowly, the frame would have been closed all around with the walls. Evidence that the walls were added after the timber posts were in place is provided (a) by the fact that several post pits ran partly under the walls; (b) by the fact that the wall plaster was only applied between the posts; (c) by a case where the wall plaster (and one expects the wall too, which no longer exists) was put in place in function of the wall post (N5) rather than the other way around; and (d) by the fact that at least one wall post (N9) and probably another (N8) were hidden behind internal transverse walls (See Figure 1), implying that the latter were constructed later.[26] Previous delineation on the ground of the posts' positions, like that of the walls, is suggested (a) by the fact that in the northern half of the AR, the wall posts are largely symmetrical to those in the southern half, while the remaining wall posts as well as the veranda posts and the wall itself follow the outline of the triple-contour ellipse drawn for them (See Figure 2: Inset B); and (b) by the setting of the wall posts N7, N8, S7, and S8 closely on either side of the partition wall between CR-ER (See Figure 1). This arrangement also raises the question of the relative irregularity of the posts' intervals, which we will try to answer after examining the structure of the roof.

As already mentioned, in most of the building, except at the west end, the roof would have been gabled. More particularly, the 'prop-and-ridgepole' (or 'column-and-ridgepole') roof construction[27] would have been used, with the ridge beams and the plates tying the building in the longitudinal direction, i.e. providing longitudinal linkage to the axial and side posts, respectively (See Figure 7).

In principle, given the use of embedded posts acting like pile foundations (*supra*), the longitudinal linkage would have been sufficient for the carrying of this type of roof. Indeed, the longitudinal linkage would have rendered the use of transversal linkage in the form of a series of cross-bracing crossbeams essentially redundant.[28] Besides, the use of such crossbeams would also have required their attachment to the centre posts; in this instance, however, lashings would not have been as effective; alternatively, if carved joints[29] were used, these would have weakened the centre posts - since cutting a joint inevitably introduces a weakness - and would have created a load.[30] In fact, the evidence suggests that the use of such a series of crossbeams is unlikely, since in no case is it possible to include all three interior posts arranged transversely (i.e. a centre post and two wall posts on either side) in an imaginary line with a thickness equal to 0.22 m, i.e. that of a potential crossbeam[31] attached to a centre post and sitting, along the rafters, on the plates.[32, 33]

There are, however, three areas where crossbeams would have been necessary and, at the same time, sufficient to brace the entire structure.[34] The first two areas are those of the partition walls between ER-CR and CR-AR, where the intermediate (ridge-supporting) centre post had to be banned due to the presence of a doorway and replaced by a 'king post', i.e. a shorter vertical post supporting the ridge at a higher level, namely within the roof space, and standing upon the midpoint of a crossbeam (See Figure 4: 'king posts' K1 and K2). The crossbeams in these areas would have been carried at either end by the plates above the wall posts (See Figures 8, 9). The squared timber jambs of the doors in the partition walls between ER-CR and CR-AR could have extended to the underside of the crossbeams reconstructed in these areas, since in frame construction, openings such as windows and doors are commonly incorporated into the entire structure, being useful for filling-in the frame with materials.[35]

The third area, which would have required a crossbeam, is immediately adjacent to the centre post C1: the crossbeam placed here and resting, like the others, on the wall plates would have supported, in conjunction with the crossbeam in the area of the partition wall between ER-CR and the wooden studs of a partition across the middle of the ER (See Figure 4), the floor joists and floorboards of a loft extending above the ER and the Porch; this loft would have been accessed via the staircase located in the north-east corner of the CR.[36] The three crossbeams could have been connected by diagonal struts or 'braces' to the wall posts on either side (See Figures 4, 8, 9),[37] thereby providing important diagonal bracing to the timber frame.[38] Additional bracing would have been provided by the floor joists and floorboards of the loft above the ER and the Porch (See Figure A3:4b; Appendix 4: II, Figure A4:3), as well as by a 'ledge' attached to the wall posts at mid-height, on which the first landing of the staircase and the roof joists of the cabins in the CR could have rested (See Figures 7, 8, 9).[39, 40]

Having established the use of a combination of centre posts and king posts for the support of the ridge beam(s), we can now reconstruct the intervals between the timber uprights on the long axis of the building as shown in Figure 10. This figure shows that the division of the building's interior into three main spaces (front-central-rear) separated by partition walls that included doorways, according to our reconstruction, played an important role in determining both the intervals between the ridge-supporting posts on the long axis of the building (and, by extension, their corresponding intervals between the wall- and veranda posts) and the intervals between the last centre post (C12) and the two wall- and veranda posts on the long axis of the building. Thus, a symmetry would have been created in the timber frame between its front and rear parts (both equal to 11.156 m) on either side of its central part (equal to 25.987 m) and, within each of these parts, the axial intervals would have been determined according to structural and other needs. The figure also shows that the intervals between the ridge-supporting axial posts would have been measured from edge to edge of post rather than from centre to centre of post.

We are therefore now able to address the question of the relative irregularity in the spacing of all the posts. Four main factors appear to have contributed to this: (a) the clear intention to 'break' the sequence of centre posts' intervals in the areas of the partition walls between ER-CR and CR-AR, and to treat each room separately in terms of post spacing; b) the placement of wall posts next to the partition walls, either on each side or on one side of them (these are, respectively, posts N7-8, S7-8 and posts N26, S26), probably due to the need to connect the crossbeams supporting king posts K1 and K2 with them; (c) the need for all the posts to be staggered mutually to accommodate pairs of adjacent 'principal' rafters; and (d) the actual procedure that was possibly followed during the setting of the wall- and veranda posts. If the site had originally been marked out in some fashion with these intervals (e.g. by using cords marked with a powdered pigment) and the workmen were instructed to dig their post pit and place their post 'next to the mark', it is obvious that a variety of relationships between the post pits and the marks could have resulted (See Figure 5).

The rafters and the structural horizontal elements used in the roof (ridge-beams, plates, and crossbeams) are best reconstructed as squared timbers, with a rectangular cross-section, like the wall- and veranda posts (See Figure 7), rather than as poles. For if time and effort were not spared in squaring the timbers of the wall- and veranda posts, as well as those of the doorjambs, it would be natural to also want to shape these wooden members of the roof in a similar manner. This is especially true if these roof members were also intended to be exposed and visible from the interior of the building (cf. the timber-framed buildings characteristic of 12th-18th century northern and central Europe[41]), as is likely.[42] Indeed, a homogeneous timber-frame structure with a profusion of squared members would have given a more luxurious appearance to this prestigious building, and with this a feeling of pride to its sponsor and owner. This brings to mind the contribution of the beams (*δοκοί*) of fir alongside the high columns (*κίονες*) and the *mesodmai*, which are described as 'beautiful' (*καλαί*) - all of which appear glowing and inhabited by a god - to the marvellous and Olympian appearance of the palace of Odysseus, and the feeling of admiration and pride they aroused in his son, Telemachus (Homer, *Odyssey* 19, 35-43). Moreover, squared timbers imply the use of carved joints, which are a stronger type of connection compared to the lashings commonly used in pole-frames[43] as carved joints transfer the load through the frame and help to tie the whole structure together. Carved joints, thus, make the structure more rigid against loads (including the wind load and the outward thrust of the roof) and facilitate the joining together and final assembly of the squared timbers of the frame and the roof. Although carved joints require greater labour in their production, these strengths make them worthwhile.[44] This presupposes, of course, that such joints were well executed in the LK-T building, especially since the timber frame would not have been pre-assembled on the ground (see *infra*), unlike, for example, the construction of British box-frame buildings.[45]

A variety of carved joints would have been used to interlock the squared timbers of the LK-T building with each other.[46] Since no iron nails were found in the building (Popham, et al., 1993, p. 48), the joints would have been held in place with wooden pegs or wooden nails (dowels), such as those used by Odysseus for mortising the timbers of his ship (Homer, *Odyssey* 5, 248). The action of the joints may have been supplemented by wooden wedges. Wooden pegs or nails are the natural thing that a carpenter uses to give resistance to a squared-timber frame and prevent movement; they are indeed very strong, capable of forming extremely tight joints, and much more effective than iron nails, which are also likely to corrode quickly (Mercer, 1951, pp. 257-160; Hodge, 1960, p. 98; Forrester, 1975, p. 24; Harris, 1979, p.13; Brown, 1986, p. 38; Brunskill, 1994, pp. 37-38; Zwerger, 2015, pp. 68, 104, 122-123, 253).

Let us now proceed to the reconstruction of the roof cover. As already mentioned (*supra*, Introduction), patches of reeds or rushes were found on the floor in various parts of the building. This clearly implies that the cover of the roof was thatched, and therefore lightweight, as is the case with many timber-framed buildings.[47] The use of reeds or rushes, more specifically, as thatching material is another indication that this is a high standard building. Indeed, compared to straw, (water) reed is the most durable, finest, and highly prized of all thatching materials. Reed thatch is waterproof and resilient thanks to the water-repellent qualities of the reed, a waxy organic material, and can last 60 to 100 years; it also creates a beautiful, thin, close-cropped, and neat roof with sharp edges (unlike straw thatch, which must be renewed after about 15 years, creates a thicker and more rounded roof and gives the impression of having been heaped), and has high thermal insulation properties (West, 1971, pp. 112-113; Brown, 1986, pp. 110-111; *The Thatcher's Craft*, pp. 1-2, 47, 123; Hall, 1988, pp. 3-4). Often, (water) reed is mixed with rushes and this mixture (known as 'mixed reed') is preferred for its greater durability, as well as for its tapering and its distinctive appearance (*The Thatcher's Craft*, 123). For these reasons, the (water) reed and rushes mixture could also have been used in the LK-T building. A reed thatch coat does not need to be more than 300 mm, a standard thickness, which has also been adopted for the reconstruction of our building (See Figure 7). When laid to 300mm thickness, reed can weigh around 40 kg/m2 when dry and up to 50 kg/m2 when wet, being the heaviest thatching material (*The Thatcher's Craft*, p. 214; Hall, 1988, pp. 10, 44). The bundles of reeds, c.1.5-2 m long, would have been stitched (with string or fibre, less likely with wire) to horizontal battens.[48] These battens would have been attached by means of lashings on the 'principal' and 'common' rafters (See Figure 7)[49] for the purpose of adequately fixing the thatch and providing a closer framework for the safe work of the thatcher (*The Thatcher's Craft*, p. 214; Hall, 1988, p. 10). The apex of the thatched roof may be reconstructed with a capping of straw or sedge (which, unlike reed, are materials flexible enough to bend without breaking) that would have run the full length of the ridge of the gable roof and been fastened to a roll of reeds placed at the intersection of the rafters to maintain the steep pitch of the last two layers of reeds (*The Thatcher's Craft*, pp. 168, 173-187; Hall, 1988, p. 31) (See Figure 7).[50]

As regards the pitch of the gabled roof, a thatched roof must be steeply pitched to ensure maximum water runoff with minimum penetration into the thatch coat and thus avoid the rapid decay of the latter (Hall, 1988, p. 9). The pitches of thatched roofs in northern European timber-framed buildings are between 45° and (in areas with heavy snow) 60°, and especially those of reed thatched roofs between 45° and about 50°.[51] Since the question of the roof pitch is at the same time the question of the respective heights of the different posts supporting the roof and, here, also of the veranda (the latter being restrictive and not favouring very high pitches), one can assume the minimum required pitch of 45° for the reed thatched, gabled roof of the LK-T building, with the veranda roof built as an extension of the main roof. In that case, a height for the veranda posts (to the underside of their plates) equal to 1.80 m, gives: a minimum height of roof (to the lowest point of the veranda rafters) equal to 1.69 m, which is reasonable; a total height of 9.30 m for the building (up to the apex of its thatched roof); a height of 9.0 m for the timber frame (up to the top of the rafters' crossing on the ridge beam), which is equal to its width (and the internal width of the building);[52] the heights of 8.79 m, 8.58 m, 3.67 m, and 4.20 m, respectively, for the ridge beam (to its top), the centre posts, the walls, and the wall posts (to the underside of their plates) (See Figure 7); and a height of 4.275 m from the floor to the underside of the crossbeams, two of which would have supported the floor joists of the loft (*supra*) (See Figure 8). Interestingly, 4.275 m is also the height of the second landing of the staircase that would have given access to the loft over the ER and the Porch, according to our reconstruction (See Figure 8),[53] thus making likely the reconstruction of the loft at a height of 4.76 m from the floor.[54]

The gabled roof, with its pattern of antithetical pairs of adjacent rafters set perpendicularly on the ridge beam, would have continued to the last centre post, C12 (See Figure 6). However, to the west of line Z-Z′, its pitches would have been gradually modified due to the progressive narrowing of the building for the formation of the apse, as can be seen in Figure 9 showing a cross-section in the area around the partition wall between CR-AR, and in Figure 11 showing a cross-section in the area around C12, where we further observe that, in this zone, the pitch of the main roof would have also been different from that of the veranda roof.

Figure 11 also depicts, in the centre, part of the different roofing arrangement that had to be adopted to cover the west half of the AR and the surrounding veranda. In this area, beyond C12, a hipped roof would have been used (See Figure 12),[55] with a pitch of 47.2° and with the veranda roof built as an extension of the roof over the west half of the AR. The hipped roof would have been supported by a special, 'triptych'-like structure made of the centrally located (but not ridge-supporting) post C11 and of posts T1-T3 and T4-T7 forming two almost symmetrical, L-shaped arrangements on either side of C11 (See Figure 6: Inset A).[56] All these posts would have been crowned by plates: a horizontal plate over posts T2, T3, C11, T4 and T5 (See also Figure 11); two cranked plates respectively over posts T1-T2 and T5-T6; and perhaps also another horizontal plate over posts T1 and T6 for the bracing of the 'triptych'[57] (not shown on Figure 6). On the plates of the 'triptych' would have rested the upper ends of the interior rafters of the hipped roof in a fan-shaped arrangement with their lower ends resting on the plates above the wall posts; the latter would also have received the rafters of the veranda roof (See Figure 6: Inset A and Figure 12). The plates for the wall- and veranda posts in the apsidal part of the building would probably be curved (rather than straight) timbers.[58, 59] Adopting a hipped roof over the (west end of the) apse would have been yet another method - besides embedding the posts and adding verandas acting as aisles (*supra*) - used by the LK-T carpenters to ensure the structural balance of the building, since this type of roof offers the advantage of resisting high winds.[60]

The east facade of the building would have had a gable, as clearly suggested by the axial post in the middle of this short side (Audouze and Büchsenschütz, 1992, p. 59). The presence of a loft above the ER and the Porch[61] would have required the gabled end to be closed (with materials such as planks or thatch), perhaps with a door-like opening, such as that shown, for instance, by the terracotta house model from the Heraion at Argos.[62] Under the gable, the entrance to the building would have been monumental (reconstructed width: 5.175 m[63] - see Figure 3) and framed by a substantial wooden lintel and doorjambs presumably made of squared timbers, like those which left their traces in the rest of the building.

We shall now examine how the timber frame and the roof that it supported might have been produced.

The Production of the Timber Frame and Roof

The production of the timber frame and roof of the LK-T building must have involved carpenters of a high standard. Like in the case of the timber-framed buildings in medieval northern Europe, the LK-T carpenters would have been the master builders on the site; indeed, the ancient Greek word for 'carpenter', *τέκτων*, is closely related to the idea of woodworking and building (Singer, et al., 1956, p. 233; Liddell and Scott, 1996, s.v. τέκτων; Kakaras, 2013, pp. 118-119; cf. the Japanese *daiku* - Zwerger, 2015, p. 58). This connection is already found in Homer, where the carpenters, *τέκτονες*, are at the same time furniture makers (*Odyssey* 19.56), builders of boats (*Iliad* 5.59; 13.390; 15.411; *Odyssey* 5.250; 9.126) and builders of houses (*Iliad* 6.313-316, referring to the palace of Paris in Troy, built by the best carpenters; *Odyssey* 17.384 and 21.43, referring to the carpenter as a builder using wood, *τέκτονα δούρων*,[64] and as a builder of the threshold, door jambs and doors of a doorway, respectively).

The LK-T carpenters or *τέκτονες* would have had crucial decisions to make pertaining to: the different depths required for the embedment of the centre posts and the wall- and veranda posts; the shape, dimensions and proportions of the timber frame members and the joints that interlocked them to each other; the orientation of the wall- and veranda posts; and the height and pitch of the roof. These decisions would have been necessary to ensure the overall structural equilibrium and strength of the timber frame to resist the action of the roof load,[65] the wind forces, but also the earthquakes, to which Euboea is particularly prone.[66]

The use of 'squared' timbers for the majority of the posts (i.e. the wall- and veranda posts) of the LK- T building, probably also for other elements of the frame and for the roof as reasonably reconstructed above, implies a laborious process of conversion of tree trunks and fairly advanced carpentry skills.[67] It also implies a technological level such as to include the manufacture of rather complex tools or equipment suitable for working the wood with precision. Indeed, unlike pole-frame buildings, which exploit the natural qualities of trees with minimal conversion and only require tied connections between poles, without the use (or with minimal use) of tools, a squared timber frame building like the one at LK-T would normally have required, as already mentioned, carved joints for the interlocking of the timbers. These carved joints would have been made before they were put in place and should have been carefully shaped and tight-fitting. The specific shape and fit of the carved joints, too, would have been vital parts of producing a rigid and long-lasting frame, since in square timber framing 'the critical thing is to get the joints right'.[68] Special tools and jointing techniques, and by extension skilful carpenters, were essential to this effect. Given, however, the irregularities in the dimensions and spacing of the posts, one does not expect at LK-T the very high level of 'prefabrication' and precision exhibited, for instance, by the traditional box-frame buildings in Britain, whose various frames were pre-assembled on the ground.[69, 70]

For a carpenter to acquire knowledge of his craft and accumulate empirical experience in producing a solid and lasting timber frame by means of precisely executed and tight-fitting carved joints, one to two generations are needed (Zwerger, 2015, pp. 61, 65, 105). One therefore expects that by the time of the construction of the LK-T building, c.950 BC, the knowledge and skills of building carpentry had been handed down and accumulated over a few decades. Additionally, with the parallel development of iron technology and thus the production of accurate, steel-like tools and more precise wood joints, the construction skills would have also undergone constant refinement, adaptation and experimentation, though presumably with smaller-scale timber-frame structures.[71]

The realisation of the proposed timber frame and roof for the LK-T building would have involved the following stages, typical of traditional timber frame construction (Mercer, 1951, *passim*; Oliver, 1997, pp. 286-287), each one of which characterised by the use of specific tools.[72]

Stage 1. Preparation

First, the trees, most likely conifers (with cypress being the best candidate),[73] would have been felled and made into logs by sawing off their branches using a felling axe (cf. *οἳ δ' ἴσαν ὑλοτόμους πελέκεας ἐν χερσὶν ἔχοντες/And they went forth bearing in their hands axes for the cutting of wood* - Homer, *Iliad* 23, 114; cf. the *πέλεκυς* used by Odysseus when felling trees for the construction his 'raft' or ship - Homer, *Odyssey* 5, 234-244). The felling would have taken place in spring for the 'round' logs (used for the centre posts) whose bark had to be stripped, but in autumn and winter for the 'squared' timbers (used for the remaining framing and roof members).[74] Once transported to the site, the logs would have been converted into round timbers by being debarked using a felling axe and into square timbers by being cut to the required lengths using saws.

For the conversion of the logs to squared timbers, the logs would have been marked with lines along their length using a cord covered in powdered pigment, such as chalk or ruddle (red ochre) (Singer, et al., 1956, fig. 352; Bayford, 2001, p. 13), and then sawn through and through along the marked lines, following the method of 'plain sawing'. In this method, the log is 'slabbed', i.e. cut out into 'slabs' or 'deals'. The various dimensions or 'scantlings' (i.e. widths and thicknesses) of the rectangular wall- and veranda posts[75] would have been produced by slabbing logs from average-sized trees (c.27.5-37.0 cm in diameter), a single log being able to produce either four 'deals' (of which two pairs with the same scantlings) or three 'deals' (of which one pair with the same scantlings) (See Figure 13). 'Plain sawing' is the fastest and easiest method of cutting timber, but also an essential method for the economic conversion of tree trunks, since one trunk can produce a number of sizeable timbers of a rectangular cross-section with the least amount of waste;[76] however, the outer 'slabs' (the 'slabs' near the top or bottom of the end surface or 'end grain') of plainsawn logs are prone to warping (cupping) and only the centre slabs (the 'slabs' from the middle of the log's end grain) 'will remain perfectly flat' or will show minimal distortion.[77] Since the vast majority of the (surviving) squared posts at LK-T appear to have been straight (at least in their parts within the post pits) and have dimensions such as to suggest that they come from the central part of the logs shown on Figure 13, it is reasonable to assume that the carpenters were well aware of this fact. The refined method of plain sawing would also have been used for the boards forming the treads of the staircase and the floors of the loft and the mezzanine (cf. Ulrich, 2007, p. 236, fig. 11.16). The LK-T carpenters would therefore have benefited from (or ushered in?) a major advance in construction technology by converting whole logs into squared timbers based on the principle of 'slabbing', thus skilfully optimising the potential of the wood as building material. The sawing would have been done by two sawyers using a 'cross-cut saw' (or 'two-handed saw')[78] or a large 'frame saw' operated over a saw-pit (Singer, et al., 1956, fig. 357; Meiggs, 1982, fig. 14d) with one man pushing and the other pulling, in an up-and-down movement.

The sawn 'slabs' would have been squared at their ends using a square and an axe or adze, then 'dressed' (trimmed) using a broad axe, and subsequently smoothed and given a clean finish using an adze (cf. the first stage of the construction by Odysseus of his ship: *πελέκκησεν δ᾽ ἄρα χαλκῷ, ξέσσε δ᾽ ἐπισταμένως καὶ ἐπὶ στάθμην ἴθυνεν/[he] trimmed them with the axe; then he cunningly smoothed them all and made them straight to the line* - Homer, *Odyssey* 5, 244-5; cf. *πέλεκυν μέγαν ἠὲ σκέπαρνον/a great axe or an adze* - Homer, *Odyssey* 9, 391).

After the conversion of the logs to round and squared timbers, all timbers should, in principle, have been neatly stacked on a raised, well-drained surface in the open and allowed to air-dry, in order to evaporate as much of their moisture content as possible (seasoning)[79] during the cold winter months.[80] This air-drying process would ensure that, at the onset of the dry season, the wood would have been at its strongest (Oliver, 1997, p. 903).

Stage 2. Setting out

This stage would have involved preparing the timbers for assembly by setting out the appropriate lengths and joints for them whilst they lay on the ground, including perhaps the numbering of both timbers and joints. The equipment needed for this would have been a series of measuring tools: a scribing tool, a ruler (a one-foot ruler marked with subdivisions in palms and fingers), a plumb line, a level (such as an A-frame level, with plumb bob), various types of squares (for angles), callipers or 'dividers', and a pair of compasses.

Stage 3. Joint-carving

The joints for interlocking the timbers would have been carved using mainly a chisel, in combination with a wooden mallet, and occasionally also a very small bow-saw. For the necessary holes through the joints to accommodate the wooden pegs or wooden nails, boring bits or augers would have been used (cf. the *τέρετρα* that Odysseus used for his ship and with which *he bored all the pieces [of timber] and fitted them to one another, and with pegs and morticings* (*γόμφοισιν ... και ἁρμονίῃσιν*) *did he hammer it together* - Homer, *Odyssey* 5, 246-8) or perhaps even a more complex type of tool, a drill activated by a bow ('bow drill'). Alternatively, for boring deep holes in heavy timbers, a more powerful version of the bow drill would have been used, activated by a strap ('strap drill') (cf. the *τρύπανον 'spinning with the thong (ἱμάντι*)' mentioned in Homer, *Odyssey* 9, 385-6).

After the cutting of the timbers into the required shapes and boring the holes for the carved joints, all the timbers, especially the posts intended to be embedded in the ground, would have had to be treated with a preservative,[81, 82] to prevent them from being attacked by xylophagous (i.e. wood-eating) insects and to delay the process of fungal decay (i.e. rot) over time.[83] After the preservative treatment, these were then left to thoroughly dry.

Stage 4. Assembly

For the assembly of the timber frame, in addition to ropes, special scaffolding, forked timbers,[84] levers or crowbars may have been used, in combination with a plumb line, a level, and various squares for the accurate positioning of the timbers against each other; the last three tools would also have been used to position the roof timbers. Wooden mallets would have been used to secure the wooden pegs, nails and wedges when assembling the carved joints.

Stage 5. Roof pitch and cover

The proposed 45° pitch for the roof could have been calculated using a square equipped with such an angle.[85] The covering of the roof with thatch would have completed the whole procedure; the laying of reed thatch would have involved tools such as wooden leggetts and mallets, hammers, reeding-needles, hooks and various cutting tools (*The Thatcher's Craft*, pp. 205-209).

Implications for the State of Completion of the Building

The identification of the LK-T building as a timber-framed structure and the theoretical precedence of the timber frame over the walls for the carrying of the roof during the construction process imply that it is no longer necessary to assume that, at the time of the decision to abandon the site, 'the basic construction including the roofing had been completed' (with walls already built to their full height and all posts and the whole roof installed) (*supra*, Introduction). Nor is it necessary to assume that the building was subsequently largely dismantled, including part of the stone socles of the walls at the east and west ends, so as to leave a low and regular mound or tumulus over the entire site (*supra*, Introduction). This is especially true since no large quantities of stone or mudbricks such as those preserved on the stone socle of the walls were found anywhere on the site, either in the building and its fill or in the ramps (Popham, et al., 1993, pp. 6, 13, 23, 30) and the mound does not appear to have had a regular shape.[86]

The possibility therefore arises that the differences in the preserved heights of the walls, when not due to stone-robbing or mechanical damage, reflect the state of completion (or incompleteness) of the walls. The construction of the walls could have reached different stages in different parts of the building, with their mudbrick superstructure still largely unfinished, whether its upper part was intended to be made of the same type of gritty, brown mudbricks as those preserved on the walls or of the smooth mudbricks of various colours, which formed the main body of the ramps.[87]

Thus, it is possible that in the CR: the partition wall between CR-ER had its stone socle still under construction;[88] the part of the south wall to the west of the so-called 'secondary doorway' (*supra*, Introduction) had its stone socle already built but not yet its mudbrick superstructure; other walls (i.e. the north wall, the part of the south wall to the east of the 'secondary doorway', and the north wall of the SR) had already received a mudbrick capping of 2-4 courses, up to a height of c.1.30-c.1.60 m; the superstructure of the staircase and its wooden treads had not yet been built;[89] and more transverse walls were to be constructed within the CR, which would also have provided the indispensable bracing to the long exterior walls of this room (*supra*, Introduction). If these walls were in the form of a double series of SRs (as reconstructed in Figure 3), then (a) the 'secondary doorway' in the south wall of the CR would be located almost exactly in the middle of the south series and could therefore be a temporary opening serving a practical purpose during construction work (such as providing natural light to this very large hall apparently already covered with a roof and/or facilitating the circulation and transport of materials inside it[90]) and (b) a possible mezzanine above the double row of SRs (see Introduction), forming part of the framework, had yet to be built.

At the west end of the building, it is possible that at least the south section of the wall in the AR had not reached any great height, since the south ramp appears to stop short of the apse, at a row of stones which aligns with the east wall of the AR and which may therefore have been intended to mark its western end (Popham, et al., 1993, p. 54). In this region, it is even possible that the timber frame and the roof were under construction: the absence of imprints or remains of wood in the pits relating to the wall- and veranda posts (except for N27, S27, VS27 and VS28) as well as to the posts of the 'triptych'-like structure, which is unlikely to be due to modern damage (Popham, et al., 1993, p. 34), together with the absence of any thatch remains in the AR (Popham, et al., 1993, p. 97), may in fact indicate an unfinished state of construction. Likewise, the absence of impressions or wood remains relating to the posts across the middle of the ER could indicate that the partition wall here and, by extension, the loft it would support above the ER and the Porch[91] had not yet been constructed.

The Structural Integrity of the Timber Frame

We conducted a forensic engineering analysis[92] to assess the structural integrity of the timber frame of the LK- T building, as reconstructed above and as shown in the idealised cross-section in Figure 7. Timber frames are lightweight structures; thus, our primary hypothesis in the analysis is that wind poses the greatest threat to structural stability. However, other potential damage mechanisms are also considered, including those related to earthquake and gravity buckling of the centre posts. The natural hazards are characterised by the wind speed and the earthquake ground acceleration that correspond to a 2% chance of occurrence in any given year (a standard method for assessing hazard intensity in engineering).

A timber frame construction allows it to withstand both vertical (gravity) and lateral loads resulting from wind or earthquake forces. Gravity loads primarily stem from the weight of the roofing material (thatch), transferred from the battens through the rafters and ridge beam to the posts, which could lead to post buckling. Wind can exert both downward and upward pressures on the roof, necessitating its ability to withstand both. The downward pressures due to winds perpendicular to the longitudinal axis of the building are transferred as a horizontal load on the top of the posts, making them susceptible to bending failure or overturning due to soil failure. Similar horizontal effects occur during earthquakes, where inertial forces are largely induced by the weight of the thatch. In this sense, the wall- and veranda posts were intentionally designed to have a plank- like shape and be oriented so as to be parallel to the long axis of the building in order to act as 'spades' and thus maximise resistance to soil failure rather than being perpendicular to the building's long axis to resist snapping due to lateral loads. Therefore, the veranda, a precursor of the peristyle of Greek temples, was a fundamental component of this large-scale timber-frame structure and did not simply serve to increase the size of the LK-T building and invest it with what Vitruvius called *auctoritas* (i.e. grandeur, imposing effect) or to protect against rain and sun.[93]

Although there is no definitive evidence of significant structural failure or deformation of the timber frame, we identified wind uplift as the most probable damage mechanism. Negative wind pressures could have uplifted the thatch, the roof, or the entire frame, with the former being significantly more likely. The traces of thatch found on the building's floor could be indicative of partial uplift, with the remaining thatch, found in the fill of the building, having possibly been dismantled during the filling operations. Another failure scenario involves the frame overturning due to horizontal forces, whether from wind or earthquake, with wind being the more likely cause. Our conservative analysis suggests that such a scenario would be possible given the intensity of the wind hazard considered. However, we did not account for horizontal load transfer elements, such as diagonal bracing. Moreover, if such a scenario occurred, significant structural damage would likely be evident, which is not the case. Other frame-damaging mechanisms, such as centre post buckling or rafter breakage, appear less likely.

Finally, had the exterior walls been fully erected, they would have increased the structure's stiffness and overall resistance to lateral wind forces, even if in such an event the wall posts merely leaned against them. In the event of an earthquake, the stone socle of the walls, composed of unreinforced masonry, would be prone to high inertial forces, potentially explaining the damage observed, unless the latter is to be attributed to the filling operations of the building or modern bulldozing over this area. In this regard, it is crucial to consider the possibility that earthquakes, in a seismic hazard zone such as Euboea, could have occurred during the building's lifespan or after its abandonment.

Conclusions

The LK-T building was a timber-framed structure, rather than a building with loadbearing walls, as had been considered until now. This raises the possibility that the walls, perhaps even parts of the frame and roof (such as a partition wall and a superincumbent loft in the ER, a likely mezzanine in the CR, as well as the frame and roof at the west end of the building), were still under construction, rather than fully completed as previously assumed, when the decision was made to abandon the site.

As a timber-framed structure, the LK-T megaron provides us with valuable insights into ancient wooden architecture, including the craftsmanship and techniques of square timber-framed construction, as well as the complex of reasons behind the use of designs of this kind as prototypes for later large-scale temple architecture in Greece. Our analysis has shown that the production and installation of the wooden frame must have involved high-level carpenters. The use of 'squared' timbers implies quite advanced carpentry skills and tools capable of yielding precision-made carved joints. In addition, the earthfast posts served as pile foundations, anchoring the frame to the ground and increasing its resistance to lateral wind loads, the wall- and veranda posts playing an important role in this regard through their exceptional shape and orientation. The veranda posts, especially, precursors of the peristyle of the Greek temple, would have contributed greatly to the overall strength of the framework. The end-result would be a well-executed, sophisticated, and solid frame for this high-standard building. There is no evidence that the timber frame has suffered any significant structural failure, but if such failure ever occurred, it could be due to high winds acting upon the roof, most likely causing a partial uplift of the thatch.

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1 For the dimensions of the posts, see Coucouzeli, et al., 2024, Appendix 3, Table A3:1.

2 See Coucouzeli, et al., 2024, Appendix 3: I, II.

3 Cf. Popham, et al., 1993, p. 98; see Coucouzeli, et al., 2024, Appendix 4: I.

4 Posts N3, S3, VS4, VS5, VS8, VS9 and VS11 are skewed; post N4 is misaligned, being located c.0.2 m from the wall (Popham, et al., 1993, pp. 28, 39, table 2, pl. 38).

5 Calligas, 1984-1985; 1988; Fageström, 1988, pp. 59-60, 129; Whitley, 1991, pp. 185-186; Crielaard and Driessen, 1994; Mazarakis-Ainian, 1997, p. 55; 2006, p. 191; 2012, pp. 78-79; Coucouzeli, 1994; 1999; 2004.

6 Depending on the status of its leader, a longhouse can start at a length of 10.50 m and reach great lengths, such as c.60 m (Neolithic and Bronze Age Europe - see Coucouzeli, et al., 2024, Appendix 1: B.2.1), 75-120 m (North America) or even attain lengths of 180-660 m thereby constituting a 'hamlet' or even an entire village (Northwest Coast of North America, Borneo) (Coucouzeli, 1994, pp. 319, 329-330, 332, 335, 340); this is in reply to Mazarakis-Ainian, 2006, pp. 190-191.

7 See Coucouzeli, et al., 2024, Appendix 4: I, III, Figs A4:1, A4:2, A4:4.

8 This is also suggested by the fact that the partition wall between the two SRs and the AR is 0.60 m thick, as are the partition walls between Porch-ER and ER-CR, unlike the eastern walls of the NR and SR, which are only 0.50 m thick.

9 J. Moreira, pers. comm. A similar point is made by Herdt (2015, p. 207).

10 In an earlier publication, one of the excavators expressed the view that, in contrast with lightly built, wattle-and-daub walls, which need wall posts 'to provide rigidity and stability to the walls', '[stone and mudbrick

walls] do not need wall posts to ensure their own stability and/or to help carry the roof load and at Lefkandi in particular, where the walls of the Toumba building were c.0.60m thick and had a substantial stone socle, posts only c.0.008m thick can hardly have given much additional support', concluding that the firmly embedded wall posts at LK-T had the function of anchoring the (timbers of the) light-weight, thatched roof directly to the ground, so as to resist the lateral and upward forces exercised by the wind, by being attached to a timber plate running on top of the (loadbearing) walls (for the support of the rafters) (Coulton, 1988, pp. 59-63). However, such a view is based on what might be called a wall-centric or 'toichocentric' perspective, which considers the walls as the determining structural factor (for other examples of this kind of perspective, see Coucouzeli, et al., 2024, Appendix 1: B.2.2, notes 24, 36, 37, 40, 42, 44; Drerup, 1969, pp. 108-109), and the two types of walls mentioned and contrasted with each other are actually both part of timber frame buildings (see Coucouzeli, et al., 2024, Appendix 1: passim).

11 We address Herdt's argument in Coucouzeli, et al., 2024, Appendix 2: II and Appendix 5: III.b.

12 Crielaard and Driessen (1994, pp. 255-256 n. 24, 267) raised the possibility of the existence of a timber framework in the LK-T building, while nevertheless adhering to the excavators' view of the role of the wall posts as 'stabilizers' of the veranda posts via horizontal beams passing through the mudbrick walls.

13 On what is a timber-framed structure, see Coucouzeli, et al., 2024, Appendix 1.

14 See Coucouzeli, et al., 2024, Appendix 1: B.2.2.

15 See Drerup (1969, p. 109), who identifies the mesodmai as 'eingelassenen Wallpfosten'.

16 Since this and the following figures of the reconstruction of the building have been drawn in Auto-CAD, it is necessary to allow for irregularities and imperfections in the actual appearance of the building. All figures in the article were drawn by Alexandra Coucouzeli.

17 Popham, et al., 1993, table 3: Interval between C4-C5, measured from centre to centre of post imprint = 3.02 m.

18 See also Coucouzeli, et al., 2024, Appendix 3: III.

19 The care with which this was done has been remarked upon by the excavators as constituting a 'striking feature' of the building (Popham, et al., 1993, p. 58).

20 See Coucouzeli, et al., 2024, Appendix 3, Table A3:1.

21 See Coucouzeli, et al., 2024, Appendix 1: A.2; Appendix 5: II.b; infra, Section IV.

22 See Coucouzeli, et al., 2024, Appendix 1: A.2.

23 See Coucouzeli, et al., 2024, Appendix 1: A.2; infra, Section II.

24 See Coucouzeli, et al., 2024, Appendix 1: B.2.2.3.

25 See Coucouzeli, et al., 2024, Appendix 1: A.2.

26 Post pits running partly under the walls: S7, S9, S10, S11, S12, N8, N9, N13, N26, S24, S26; to these may be added Pit 1, which probably lay partly under the anta of the east wall of the NR (Popham, et al., 1993, p. 22, pl. 23) and which must have been intended to receive a post with a structural function, such as to hold a beam carrying the joists of a mezzanine over the NR (See Figure 1; see also Coucouzeli, et al., 2024, Appendix 4: III, Fig. A4:4). Cf. Fageström, 1988, p. 60; Crielaard and Driessen, 1994, pp. 255 n. 24, 267. Cf. also the relative position of walls and posts in the Burnt House at Sitagroi and in the so-called 'Daphnephoreion' at Eretria, both of which were timber-framed buildings (See Coucouzeli, et al., 2024, Appendix 1: B.2.2.3). The excavators' explanation of some of the post pits running partly under the walls of the LK-T building as being due to the difficulty of cutting a perfectly vertical face for such pits, because of the friable nature of the conglomerate in which they were dug (Popham, et al., 1993, p. 39), is not convincing.

27 See Coucouzeli, et al., 2024, Appendix 1: A.2.

28 See Coucouzeli, et al., 2024, Appendix 1: A.2, B.2.1-Danubian Neolithic houses.

29 The excavators expressed uncertainty as to whether lashings or carved joints had been used to join the timbers in the LK-T building (Popham, et al., 1993, pp. 48-49). They interpreted the mutual staggering of the centre posts and wall posts as being due to the possible lashing of crossbeams to the centre posts (Popham, et al., 1993, p. 49) but reconstructed the building with a series of crossbeams attached to the centre posts by means of deep, carved joints (Popham, et al., 1993, p. 47, fig. 1, pl. 28).

30 C. R. Calladine, pers. comm.; M. De Jong, pers. comm.

31 See Coucouzeli, et al., 2024, Appendix 3: III.

32 Cf. Coucouzeli, et al., 2024, Appendix 1: B.2.1-Danubian Neolithic houses.

33 Therefore, no truss-roof system was used here. This is not surprising, since in timber-framed buildings, this elaborate system is used in connection with posts standing off the ground and necessitates the perfect alignment of opposite posts (for the carrying of the truss) (see Coucouzeli, et al., 2024, Appendix 1: A.2, B.1.IV), which is not the case at LK-T. The truss system appeared much later in the Greek world, where it was used in buildings with masonry walls and 'when the width to be spanned without intermediate supports exceeded 11 meters' (see Ulrich 2007, 138 ff. with further references).

34 I. Kavrakov, pers. comm.

35 See Coucouzeli, et al., 2024, Appendix 1: A.2.

36 See Coucouzeli, et al., 2024, Appendix 4: II, Fig. A4:3.

37 See also Coucouzeli, et al., 2024, Appendix 3: III.

38 No diagonal bracing appears to have existed between the wall posts, judging from the inner face of the south wall in the CR, which was well preserved and reached a height of 1.30 m, with a thick plaster adhering to it (Popham, et al., 1993, p. 14, pl. 31b).

39 See also Coucouzeli, et al., 2024, Appendix 3: III, Fig. A3:4c; Appendix 4: III, Figs A4:1b, A4:2, A4:4.

40 On the various types of bracing, see Coucouzeli, et al., 2024, Appendix 1: A.2.

41 See Coucouzeli, et al., 2024, Appendix 1, B.1.IV.

42 J. Moreira, pers. comm.

43 See Coucouzeli, et al., 2024, Appendix 1: A.2, B.2.1; see also e.g. Lotay 2015, 36.

44 †A. Baggs, pers. comm.; J. Moreira, pers. comm.

45 See Coucouzeli, et al., 2024, Appendix 1: B.1.IV.

46 See Coucouzeli, et al., 2024, Appendix 3: IV.

47 See Coucouzeli, et al., 2024, Appendix 1: B.1, B.2.

48 For the stitching of thatch with string, fibre or wire, see Hall 1988, 11, 21, 25; the alternatives of screwing and nailing (Hall, 1988, pp. 11, 21-3) are excluded here. For the stitching of thatch to battens, see The Thatcher's Craft, pp. 132-139; Hall, 1988, pp. 10-11, 21, 28-29.

49 See also Coucouzeli, et al., 2024, Appendix 3: IV.

50 This is the most common and easiest version of capping, such as that of the timber-framed thatched buildings of Northern Europe (see Coucouzeli, et al., 2024, Appendix 1: B.2.1) or that depicted by the house models from Samos (Schattner, 1990, figs 35, 36, 37, 38, pls 19:3-4, 20:1-3, 21:1-3), as opposed to the twisted grass capping illustrated by the house model from Perachora (Schattner, 1990, fig. 8). For the roll, cf. also the restoration of a Bronze Age house at Százhalombatta (Hungary) (Jerem, et al., 2010, fig. 33).

51 Glendenning, 1948, pp. 3-4; Roofing, 2-8: 3, table I; Clifton-Taylor, 1962, pp. 280-290, especially 284; The Thatcher's Craft, p. 220. Cf. early Greek clay models of thatched houses: two of these models, from Perachora (Schattner, 1990, pp. 37-38, fig. 10) and Samos (Schattner, 1990, pp. 76-78, fig. 36), show a pitch of 45°; others (Schattner, 1990, figs 2.3, 4, 8, 35, 37, 38, 41) show pitches between 50° and 70°.

52 Cf. the longhouses of the Iroquois and Huron (North America), which were as high as they were wide (Coucouzeli, 1994, pp. 320-321).

53 See also Coucouzeli, et al., 2024, Appendix 4: I, II, Fig. A4:2.

54 See also Coucouzeli, et al., 2024, Appendix 4: II.

55 For hipped roofs, see Coucouzeli, et al., 2024, Appendix 1: Fig. A1:6a; Brunskill, 1992, p.93, figs 34e, 60a, 125; for a combination of gabled and hipped roof, as in LK- T, compare also the ancient Greek house models from Ithaca, Perachora and Samos (Schattner, 1990, pp. 28-31, fig. 4; pp. 33-35, fig. 6, pl. 4; pp. 74-76, figs 34, 35, pl. 19: 3-4; pp. 76-78, fig. 36, pl. 20:2-3).

56 Contra Popham, et al., 1993, p. 50, where this alignment of posts is identified as a light partition wall (Popham, et al., 1993, p. 50). The 'triptych' posts T1-T6 are associated with Pits 20, 20A, 24, 26, 31 and 32 (Popham, et al., 1993, pl. 23), which according to the excavators 'may have held the posts of a light partition' (Popham, et al., 1993, pp. 44, 50). With the identification of a 'triptych' structure in the apse, C11 can no longer be considered as the last (ridge-supporting) centre post (as assumed by the excavators) and this role is now taken up by another post, C12, which would have been embedded in Pit 25; the latter contained traces of ashes (Popham, et al., 1993, p. 25, table 4, pl. 23), which were presumably remains of wood.

57 J. Moreira, pers. comm.

58 J. Moreira, pers. comm.

59 The shallow depths of the pits of the 'triptych' posts and those of the wall- and veranda posts in this area, i.e. 0.23 to 0.30 m compared to the usual 0.50 m in the rest of the building (Popham, et al., 1993, p. 25, table 2), if not due to the artificial terracing of the lower ground in this part of the site or to damage caused by bad weather or bulldozing (Popham, et al., 1993, p. 36) or simply to the fact that the post pits were still being dug, may be another clue to the existence of a hipped roof in this area - cf. the Danubian LBK Neolithic longhouses, about which it has been argued that the weaker anchorage of the posts at one end could be linked to the fact that they would have been subjected to a weaker vertical thrust due to a hipped roof (see Coucouzeli, et al., 2024, Appendix 1: B.2.1).

60 See Coucouzeli, et al., 2024, Appendix 1: A.2, Fig. A1:6ab; Appendix 5: II.b and Discussion.

61 See Coucouzeli, et al., 2024, Appendix 4: II.

62 See Coucouzeli, et al., 2024, Appendix 1: B.2.2.3, Fig. A1:21.

63 Popham, et al., 1993, p. 43: 'nearly 5 m wide'. Cf. the 5.50 m wide entrance of the Hekatompedon II on Samos (see Coucouzeli, et al., 2024, Appendix 1: B.2.2.3); the 4.92 m wide, monumental door of the Parthenon (Meiggs, 1982, p.198); the 3.66 m wide, two-leaved doorway of the megaron in the Mycenaean palace at Pylos (Meiggs, 1982, p.103); the 3.50 m wide doorway of the 'Daphnephoreion' at Eretria (see Coucouzeli, et al., 2024, Appendix 1: B.2.2.3); and the wide entrance of the house model from the Heraion at Argos (see Coucouzeli, et al., 2024, Appendix 1: B.2.2.3, Fig. A1:21).

64 δούρων: gen. pl. of δόρυ, stem, tree, plank or beam (Liddell and Scott 1996, s.v. δόρυ). In Iliad 12.36, the δούρατα πύργων are the beams of the towers in Troy, while in Iliad 24.448-51, the δοῦρα are clearly the posts in Achilles' thatched hut, rather than the beams of the roof, since the latter is described thereafter.

65 The imposed load of the roof exposed the earthfast posts to deflection but also to the danger of sinking into the ground (Zwerger, 2015, pp. 62, 79, 105).

66 See Coucouzeli, et al., 2024, Appendix 5: III.

67 See Coucouzeli, et al., 2024, Appendix 1: A.2.

68 On the different jointing requirements of pole-framed and timber-framed constructions, see Zwerger, 2015, pp. 112, 116-120. On the requirement of carefully shaped and fitted joints for a solid and long-lasting timber-framed structure, see Brunskill, 1994, pp. 36-37; Oliver, 1997, p. 281; Zwerger, 2015, pp. 61-62, 79.

69 See Coucouzeli, et al., 2024, Appendix 1: B.1.IV.

70 Cf. Hansen, 1971, p. 69, who argues that the irregular spacing and relative positioning of posts set in pits (rather than upon footings of stone) in early timber-frame buildings in Britain precludes prefabrication and very precise jointing together of the timbers, unlike, for instance, in later box-framed buildings (see Coucouzeli, et al., 2024, Appendix 1: B.1.IV).

71 Snodgrass, 1971, pp. 228 ff. On the role of iron technology in the continuous development of new tools and the creation of increasingly refined and specialized wood joints, such as all the joints known to us today from square-timber framed buildings, see Acland,1972, pp. 12-14; Zwerger, 2015, pp. 122, 128.

72 For the various tools cited below, all of which are documented in the ancient Mediterranean and some of which (such as saws, axes, adzes, and chisels) are already attested in Greece by the tenth century BC, see: Flinders Petrie, 1917, pp. 5-22, 39-40, 42; Mercer, 1951, passim; Blegen, 1952, p. 289 nos. 6-7; Singer, et al., 1954, pp. 189-190, 481, 618-620, 687-689; 1956, pp. 228-231, 243, 389-392; Brock, 1957, pp. 137-138, 202; Orlandos, 1959-60, pp. 131-44; 1966, pp. 29-45; Deshayes, 1960, pp. 46-50, 79-80, 98-100, 105-109, 361-362, 394-395; Pleiner, 1969, p. 15; Snodgrass, 1971, pp. 233, 249-250; Hansen, 1971, p. 186; Harris, 1980, p. 5; West, 1971, p. 20; Forrester, 1975, pp. 25-27; Harris 1979, pp. 17, 19; Gaitzsch, 1980, passim; Meiggs, 1982, pp. 346-349; Brown, 1986, pp. 31-33; Brunskill, 1994, pp. 30-33; Oliver, 1997, pp. 255-257, 281, 286-287; Hijmans, 2003, pp. 126-127; Ulrich, 2007, pp. 16-57; Kostoglou, 2008, pp. 44-47; Kakaras, 2013, pp. 119-129; Zwerger, 2015, pp. 26, 53, 68, 71, 120-122, 125, 127; Blackwell, 2020 with further references. For evidence of EIA tools at the site of Toumba at Lefkandi, see Popham, et al., 1993, p. 31 n. 1 (marks of adze from the LK-T burial) and Popham, et al., 1979, p. 256; Popham and Lemos, 1996, p. 201 (axes/adzes from the Toumba cemetery).

73 See Coucouzeli, et al., 2024, Appendix 2: I.

74 See Coucouzeli, et al., 2024, Appendix 2: I.

75 See Coucouzeli, et al., 2024, Appendix 3, Table A3:1 and supra.

76 As opposed to 'quarter sawing' or 'rift sawing', which, even though they produce more stable timber, are more time-consuming, generate a higher amount of waste, and are used for specific purposes (furniture making, string instruments, etc.). See Singer, et al., 1956, pp. 389-390, 392; Fletcher and Spokes, 1964, p.177; Forrester, 1975, p. 69; Harris, 1979, p. 17; Oliver, 1997, pp. 255-256; Zwerger, 2015, p. 128; Bayford, 2001, p. 14; Ulrich, 2007, p. 236, fig. 11.16; Wood Handbook, p. 3-14.

77 Bayford, 2001, p. 14; Wood Handbook, p.4-5, fig. 4-3. This is because in the outer 'slabs' the growth rings, as seen on the log's end surface or 'end grain', lay tangentially to the width of the timber, whereas in the central 'slabs' the growth rings lay more and more perpendicularly to the width of the timber in a radial (i.e. pith-to-bark or centre-to-edge) direction; in the former case, the rings will expand or contract more, since wood shrinks (swells) most in the direction of the annual growth rings, i.e. tangentially, and about half as much across the rings, i.e. radially (Wood Handbook, p. 4-5, fig. 4-3), causing a significant amount of warping (cupping). In general, wood cut from the heart of the tree is more stable against warping**.**

78 For the use of the crosscut saw to produce planks, see Hodge, 1960, p. 96.

79 Air-drying (seasoning) is essential to prevent decay and stain, as well as swelling and shrinking and, by extension, warping, splitting and checking (i.e. lengthwise separation) of the wood and thus increase its strength properties (Wood Handbook, pp. 13-5, 13-6, 14-6, 15-16, 17-7). Ideally, timbers should be dried to the equilibrium moisture content (EMC) that the material will reach when in service, i.e. the moisture content at which the wood is neither gaining nor losing moisture and is therefore dimensionally stable. (Wood is dimensionally stable when its moisture content is greater than its fibre saturation point, MCfs. Below MCfs, wood changes dimension as it gains moisture (swells), i.e. absorbs water from the surrounding air in response to a rise in humidity until reaching EMC or loses moisture (shrinks) in response to dry air until reaching EMC; this shrinking and swelling can result in dimensional changes.) This ideal is possible with pieces of wood less than 0.076 m thick - and it is interesting to note that the average thickness of the wall- and veranda posts in the LK-T building is 0.072 m - but, in general, it is rarely practical to obtain fully dried timbers (Wood Handbook, pp. 4-2, 4-3, 4-5, 10-15, 13-3, 16-7).

80 This is because during the cold winter months, the cooler temperatures and low air humidity allow for a very slow drying rate, thereby minimising the infestation by insects and the development of fungal growth, mould, and stains, and helping to avoid dimensional changes, as opposed to humid and warm periods with little air movement, which can cause volume increases (swelling) and promote the growth of fungi and colour stains, and periods of dry and hot winds, which can cause volume losses (shrinking), splitting and checking, thereby degrading the quality of the wood (Wood Handbook, p. 13-6).

81 Wood Handbook, p. 15-18, advising that 'All cutting and boring of holes should be done prior to preservative treatment'.

82 Pitch, which came from conifers, primarily from pines (Theophrastus, HP 9.2.5; Pliny, NH 16.16-19; Meiggs, 1982, pp. 468-470; Kakaras, 2013, p. 118), was an important wood preservative used in ancient times on roof timbers, doors, and timbers exposed to the weather (Meiggs, 1982, pp. 439-440, 453, 463, 467-468). Other wood preservatives used in antiquity were cedar oil and amurca, the sediment of olive oil, the former more difficult to obtain, being an exotic product, the latter easily available, but mentioned by Cato (De Re Rustica, 98.2) only in connection with furniture (Ulrich, 2007, p. 261).

83 H. B. Voulgarides, pers. comm. The embedded posts, if not treated with a preservative, would have absorbed water, even if well- seasoned (Ulrich, 2007, p. 261).

84 Cf. the ways of erecting posts or positioning beams in Papua New Guinea (Coudart, 1998, fig. 47).

85 One such square survives from Roman times (Ulrich, 2007, fig. 3.47).

86 Although at its east end, the mound may have ended in a curve, judging by the arched arrangement of the tombs in front of the building, belonging to the Toumba cemetery (Popham, et al., 1982, fig. 2; 1993, pp. 9, 55) - its shape at the west end is unknown due to modern damage (Popham, et al., 1993, p. 55) - in a north-south direction, the mound was higher on the building's north side (judging by the surviving portion of the exterior wall in Trial A and the height of its adjoining ramp; maximum preserved height: c.1.60 m) than on the south side (maximum preserved height: 1.30 m) (Touchais, 1982, figs 110, 111; Popham, et al., 1993, pp. 6, 13, 53, pls 4, 6, 37). Moreover, on the south side, the exterior wall was higher to the east of the so-called 'secondary doorway' (supra, Introduction) than to the west of it (Popham, et al., 1993, p. 13, pl. 4a) and the same is expected for the corresponding parts of its adjoining ramp. Cf. the tumulus covering the EH II apsidal building and the mass burial it contained in the plot adjacent to the Archaeological Museum of Thebes, and which does not appear to have been designed to have a regular shape - the fill of disintegrated, collapsed mudbricks from the building's walls that formed part of this mound has maximum heights of 1.33 m, 1.42 m and 1.75 m, respectively, at the west end (apse), at the central part and at the east end of the building - but rather to simply 'seal' the site (Aravantinos, 1997, p. 358; 1998, p. 326; Aravantinos and Psaraki, 2012, figs 2, 3).

87 The mudbricks of pure clay and different colours characteristic of the ramps may have been originally intended for use in the upper part of the mudbrick superstructure of the walls (to create decorative patterns) (cf. Popham, et al., 1993, pp. 55, 57). In favour of this hypothesis could also be the fact that there were piles of mudbricks in the ramps (Popham, et al., 1993, p. 29, pl. 37), as if they had been stacked there in anticipation of being placed in the walls. In terms of volume, the mudbricks used in the ramps appear to have largely sufficed for the upper part of the superstructure of the walls, both those that survive and those reconstructed in the present study.

88 It is unlikely that the partition wall between CR-ER had been dismantled, because it is for the most part lower in height (c.0.48 to 0.82 m, with only three to four courses of stone on either side of its central doorway) compared to the immediately adjacent sections of the north and south walls of the building (the former, judging by the height of the north ramp, which was built against it) (Popham, et al., 1993, p. 10, pls 6b, 9, 11ab; see also Touchais, 1982, figs 110, 111) - why would this particular wall have been dismantled to a lower height than its adjacent north and south walls? It is also unlikely that the partition wall between CR-ER was robbed in modern times (contra Popham et al. 1993, 34, where it is nevertheless admitted that such a hypothesis presents difficulties); no evidence of stone-robbing activity was found in connection with it, unlike

the north wall of the building (Popham, et al., 1993, p. 37, pl. 37-East Section) nor is it shown as robbed in Popham, et al., 1993, pl. 5. In fact, the north wing of this wall is preserved at the same, very low height as that of the walls that form the stone socle of the nearby staircase, because it would have supported the wooden treads of the staircase's second flight and would therefore have had to be built at the same time as the latter (see Coucouzeli, et al., 2024, Appendix 4: I).

89 This is to be expected if most of the partition wall between CR-ER, in which the wooden treads of the second flight of the staircase would have been inserted, had only started being built (supra and n. 88). See also Coucouzeli, et al., 2024, Appendix 4: I.

90 In this case, the 'large part of a mudbrick' found against the opening's east face may simply be a fallen mudbrick rather than part of a door frame consisting of mudbricks, as assumed by the excavators (Popham, et al., 1993, p. 6), especially since all the other door frames, traces of which were found in the building, were made of wood.

91 Supra and Coucouzeli, et al., 2024, Appendix 4: II.

92 See Coucouzeli, et al., 2024, Appendix 5.

93 Vitruvius, De Architectura 3.3.9, on the raison d'être of the pteroma or peristyle of the Greek temple; see also Popham, et al., 1993, pp. 58-59. Another practical function of the veranda could have been the storage of firewood (cf. the suggested function of the '(pseudo-)buttresses' around the Danubian Neolithic houses - see Coucouzeli, et al., 2024, Appendix 1: B.2.1); cf. also Sobon and Schroeder, 1984, p. 173).

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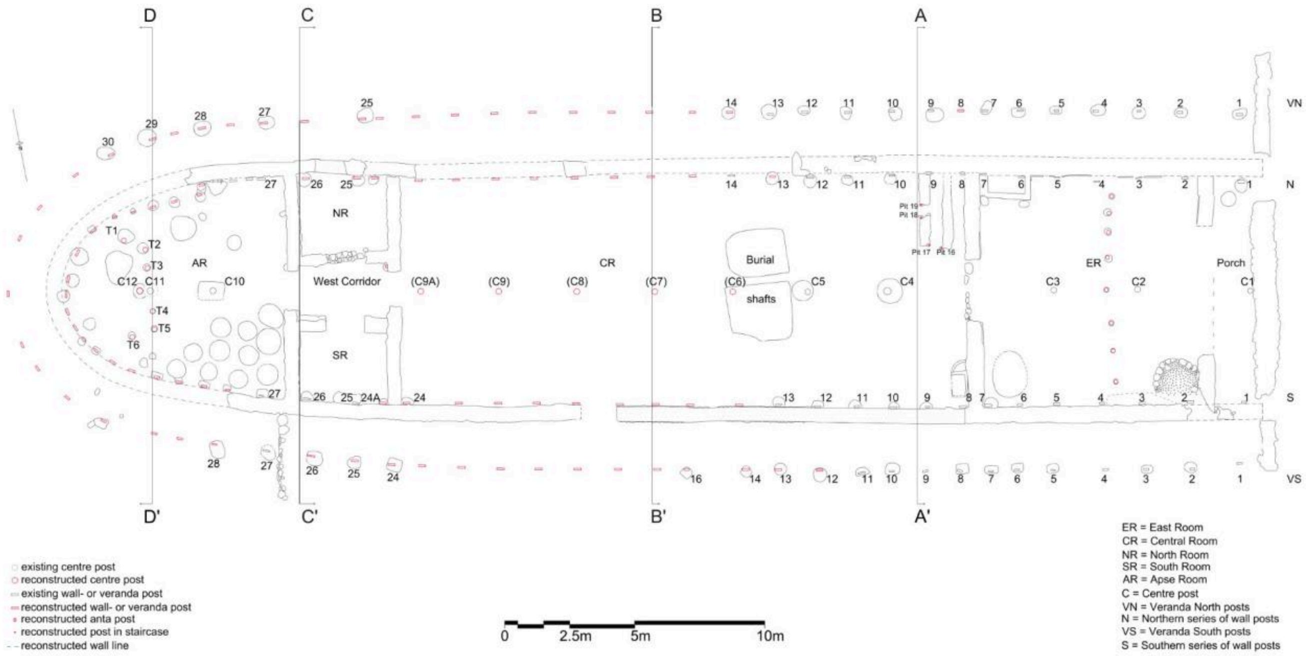

FIG 1. GENERAL PLAN OF THE LK-T BUILDING.

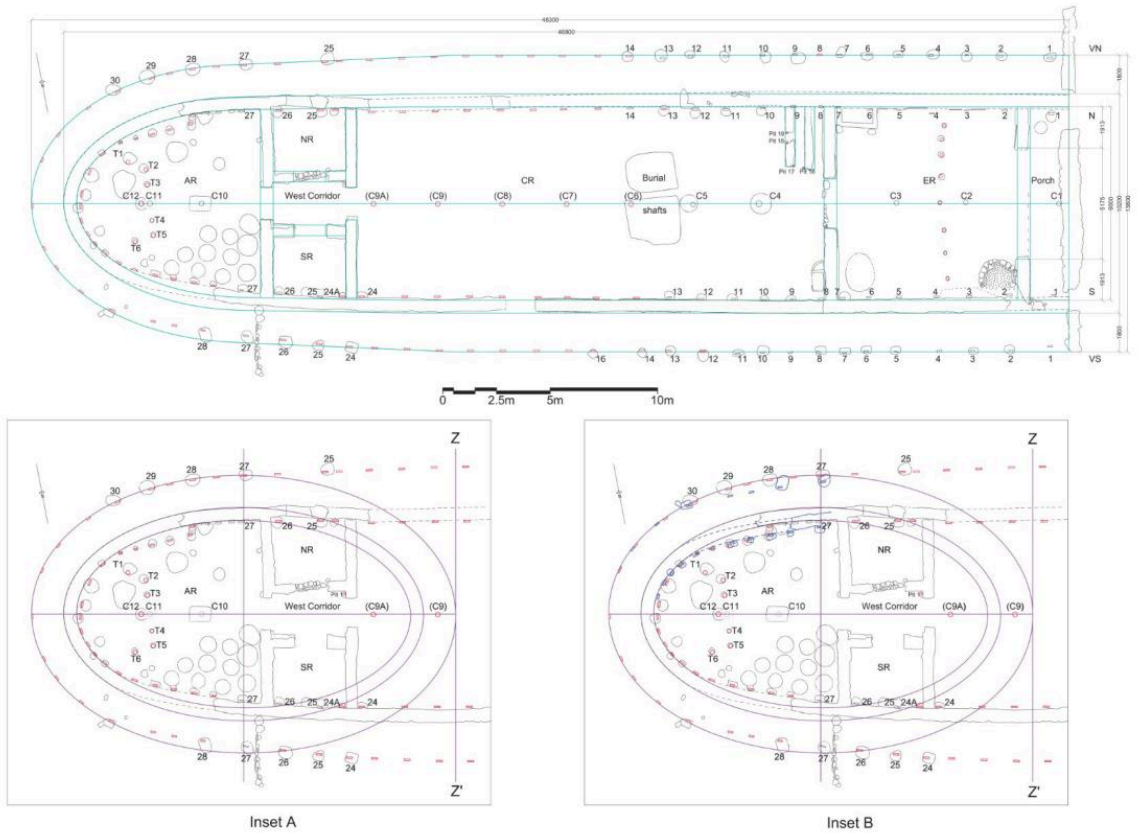

FIG 2. IDEALISED PLAN OF THE LK-T BUILDING (IN GREEN) SUPERIMPOSED ON THE EXISTING PLAN (IN BLACK). INSET A: A GEOMETRICALLY GENERATED TRIPLE-CONTOUR ELLIPSE (IN PURPLE) APPLIED ON THE APSIDAL END OF THE BUILDING. INSET B: THE OUTLINE OF THE WALL POSTS IN THE SOUTHERN HALF OF THE AR PROJECTED ONTO THE NORTHERN HALF OF THE AR (IN BLUE), RESULTING IN A LARGELY SYMMETRICAL PATTERN.

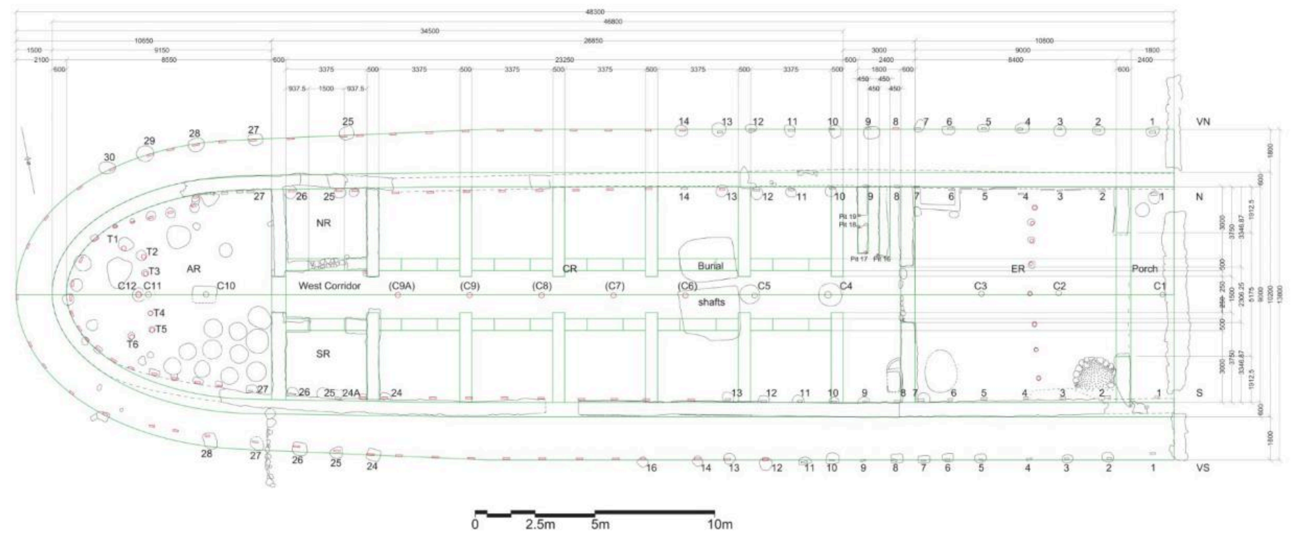

FIG 3. RECONSTRUCTION OF THE IDEALISED PLAN OF THE LK-T BUILDING WITH TWO ROWS OF ANTITHETICAL ROOMS IN THE CR (IN GREEN) SUPERIMPOSED ON THE EXISTING PLAN (IN BLACK).

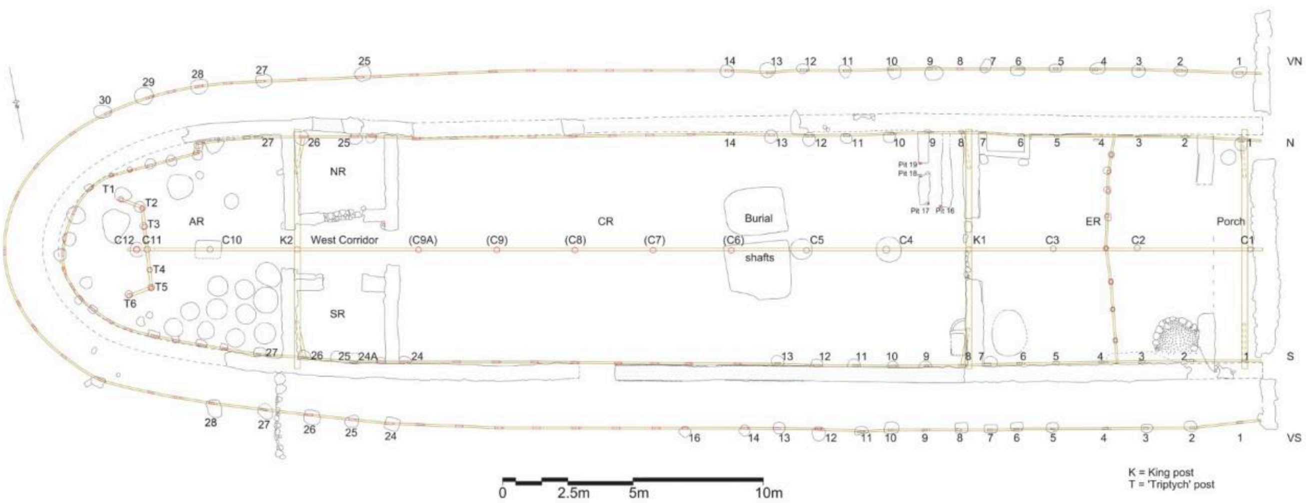

FIG 4. RECONSTRUCTED PLAN OF THE RIDGE BEAM(S), PLATES AND CROSSBEAMS (IN BROWN) SUPERIMPOSED ON THE EXISTING PLAN (IN BLACK).

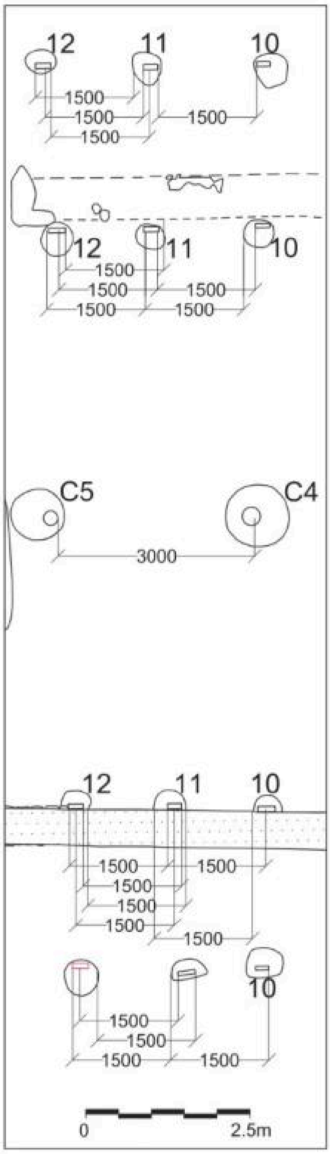

FIG 5. TYPICAL SECTION ACROSS THE BUILDING WITH GENERAL TRANSVERSE ALIGNMENT OF ALL POSTS.

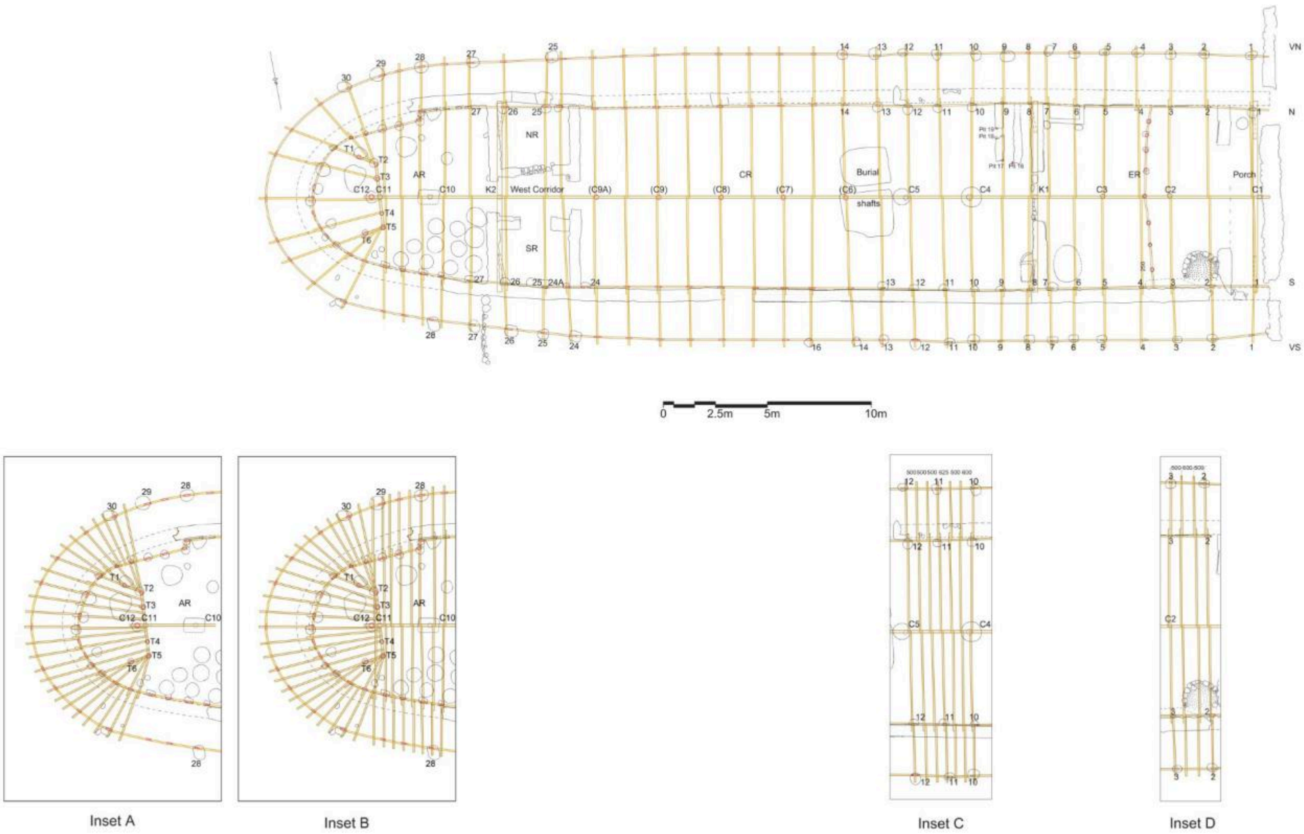

FIG 6. RECONSTRUCTED PLAN OF THE ROOF WITH PRINCIPAL RAFTERS (IN BROWN) SUPERIMPOSED ON THE EXISTING PLAN (IN BLACK). INSETS A-D: PRINCIPAL AND COMMON RAFTERS IN THREE DIFFERENT PARTS OF THE BUILDING.

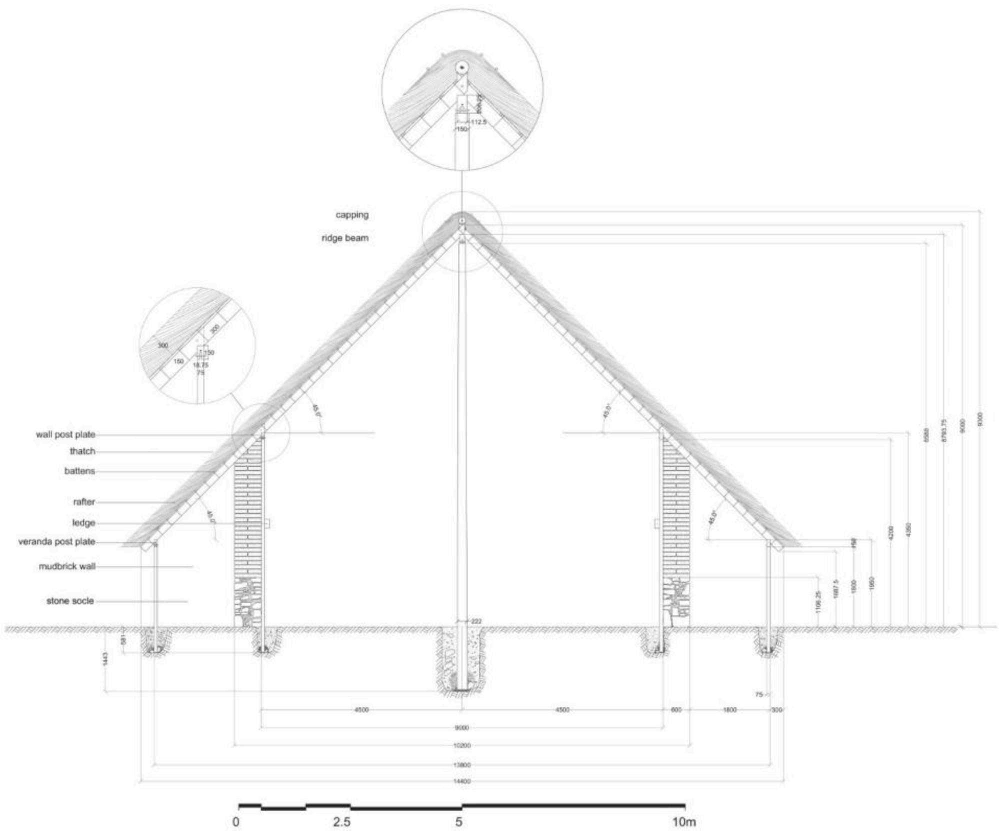

FIG 7. IDEALISED RECONSTRUCTION OF A CROSS-SECTION OF THE BUILDING IN THE AREA EAST OF B-B′, WITH ‘PROP-AND-RIDGEPOLE’ OR ‘COLUMN-AND-RIDGEPOLE’ ROOF CONSTRUCTION. THE DETAILS OF THE WALLS AND POST PITS ARE HYPOTHETICAL.

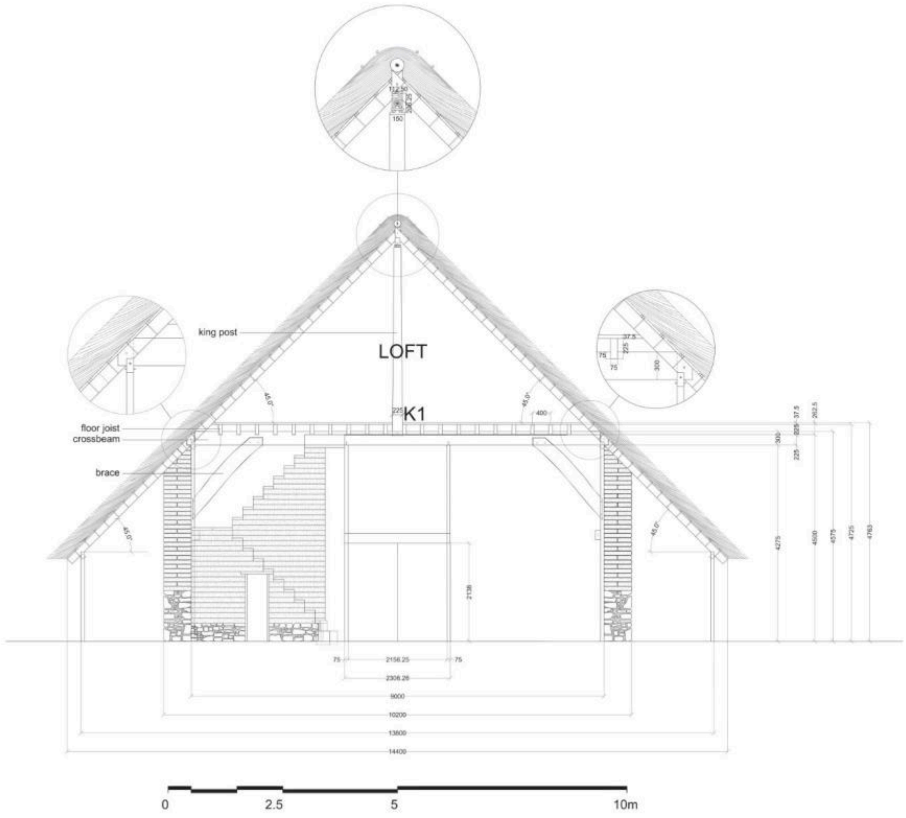

FIG 8. IDEALISED RECONSTRUCTION OF CROSS-SECTION A-A′, WITH ‘PROP-AND-LINTEL’ OR ‘POST-AND-BEAM’ ROOF CONSTRUCTION. THE DETAILS OF THE WALLS ARE HYPOTHETICAL. THE POST PITS HAVE BEEN OMITTED.

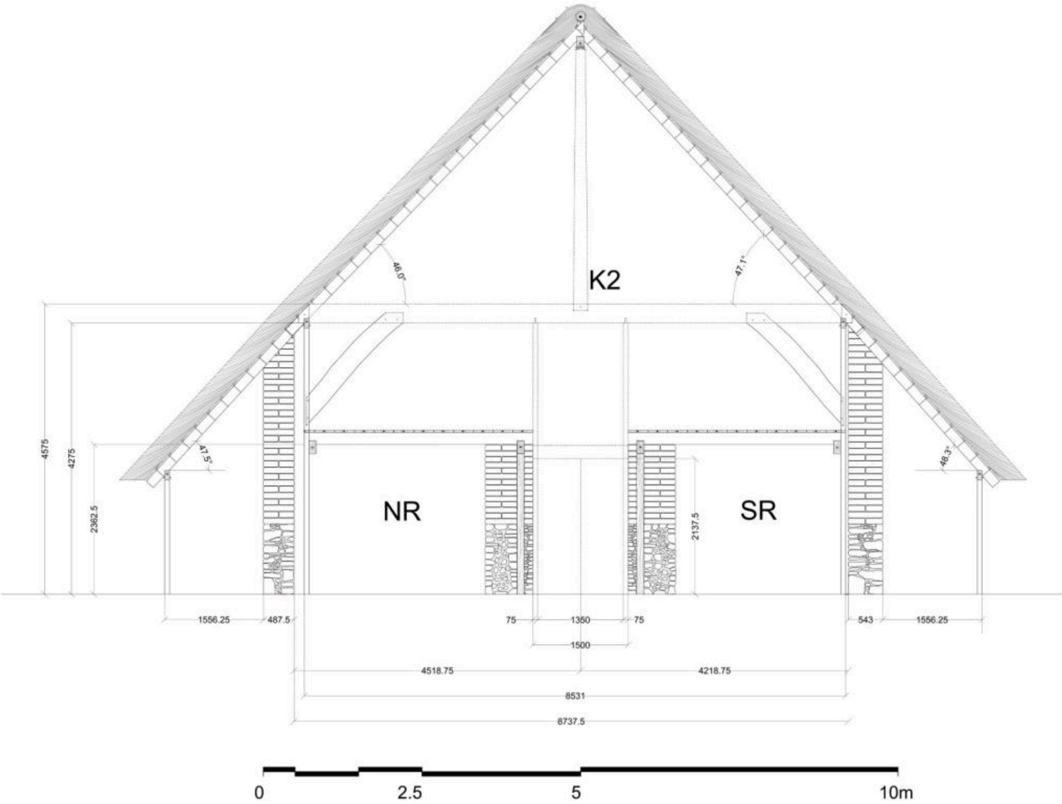

FIG 9. RECONSTRUCTION OF CROSS-SECTION C-C′, WITH ‘PROP-AND-LINTEL’ OR ‘POST-AND-BEAM’ ROOF CONSTRUCTION AND INCLUDING THE NORTH ROOM (NR) AND SOUTH ROOM (SR). THE DETAILS OF THE WALLS ARE HYPOTHETICAL. THE POST PITS HAVE BEEN OMITTED.

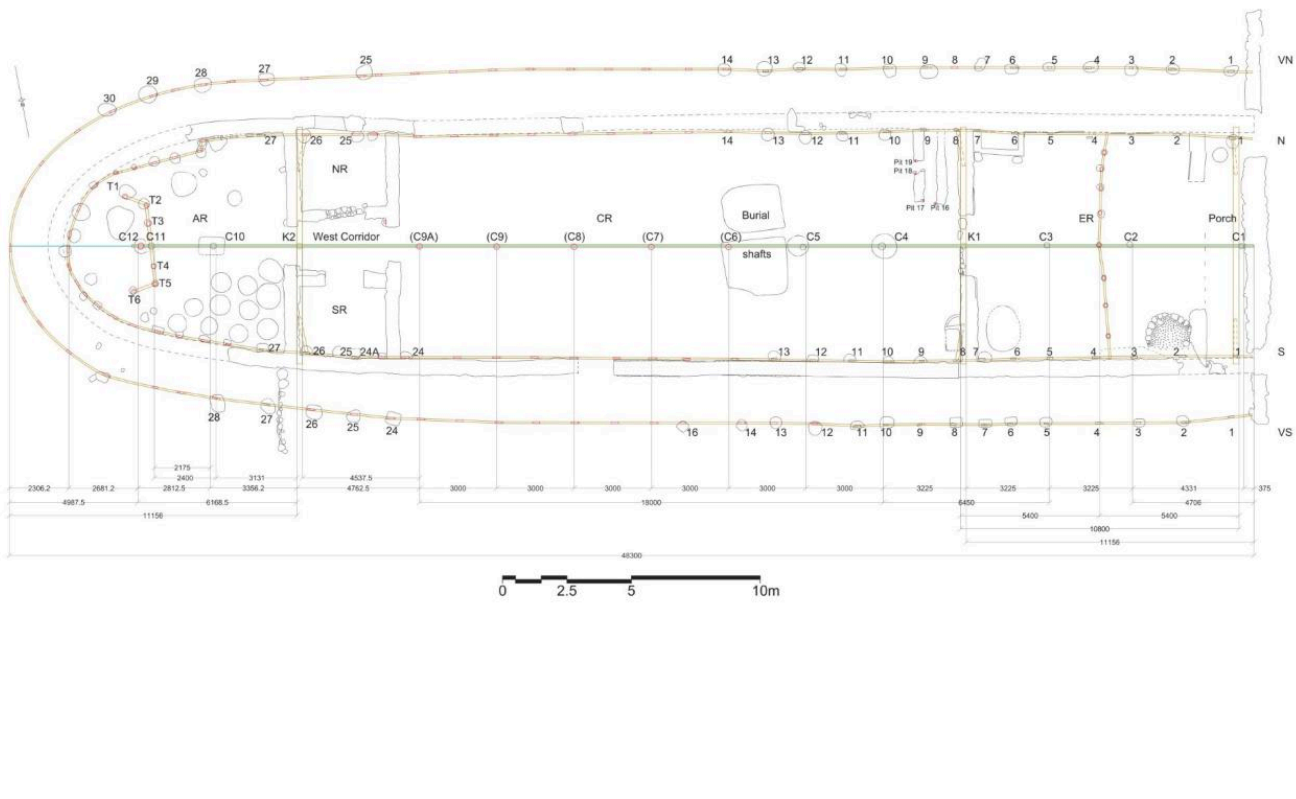

FIG 10. RECONSTRUCTION OF THE INTERVALS BETWEEN THE TIMBER UPRIGHTS ON THE LONG AXIS OF THE BUILDING.

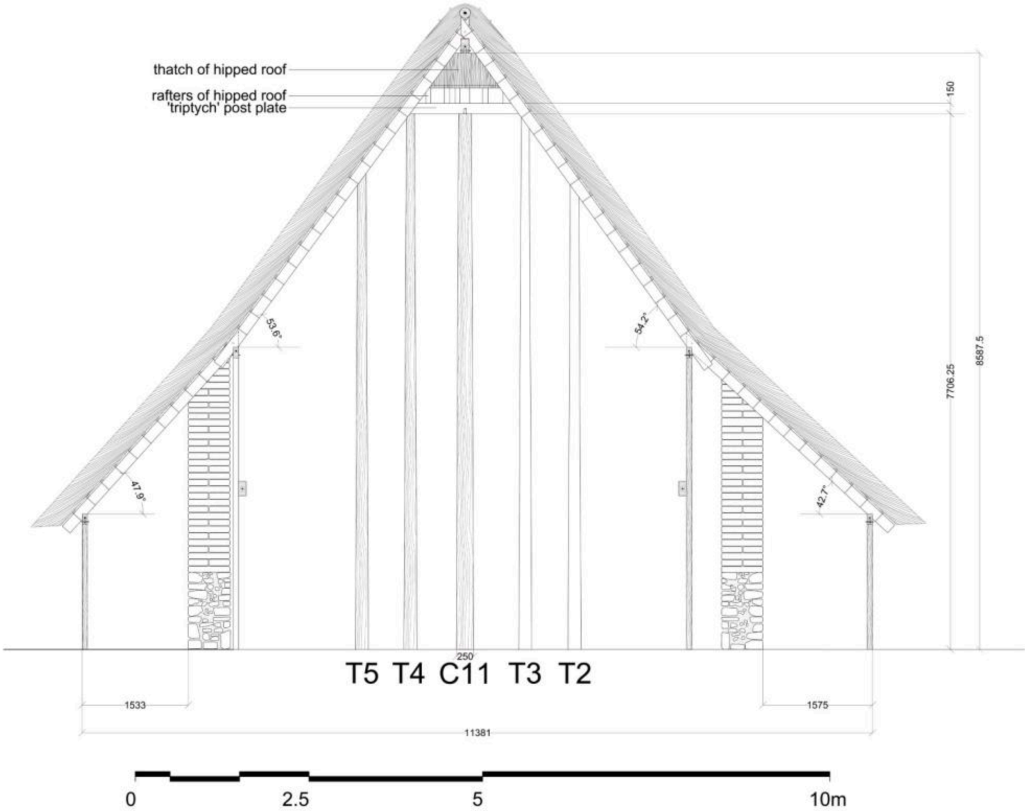

FIG 11. RECONSTRUCTION OF CROSS-SECTION D-D′, SHOWING THE MAIN PART (T2-T3-C11-T4-T5) OF THE ‘TRIPTYCH’ STRUCTURE SUPPORTING THE HIPPED ROOF OVER THE WEST END OF THE APSE. THE DETAILS OF THE WALLS ARE HYPOTHETICAL. THE POST PITS HAVE BEEN OMITTED.

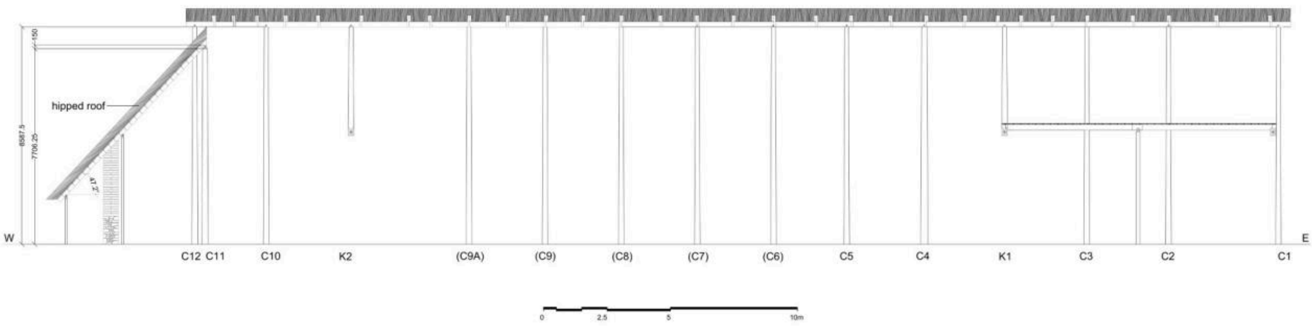

FIG 12. IDEALISED RECONSTRUCTION OF A CROSS-SECTION ALONG THE BUILDING, SOUTH OF ITS LONGITUDINAL AXIS. THE POST PITS HAVE BEEN OMITTED.

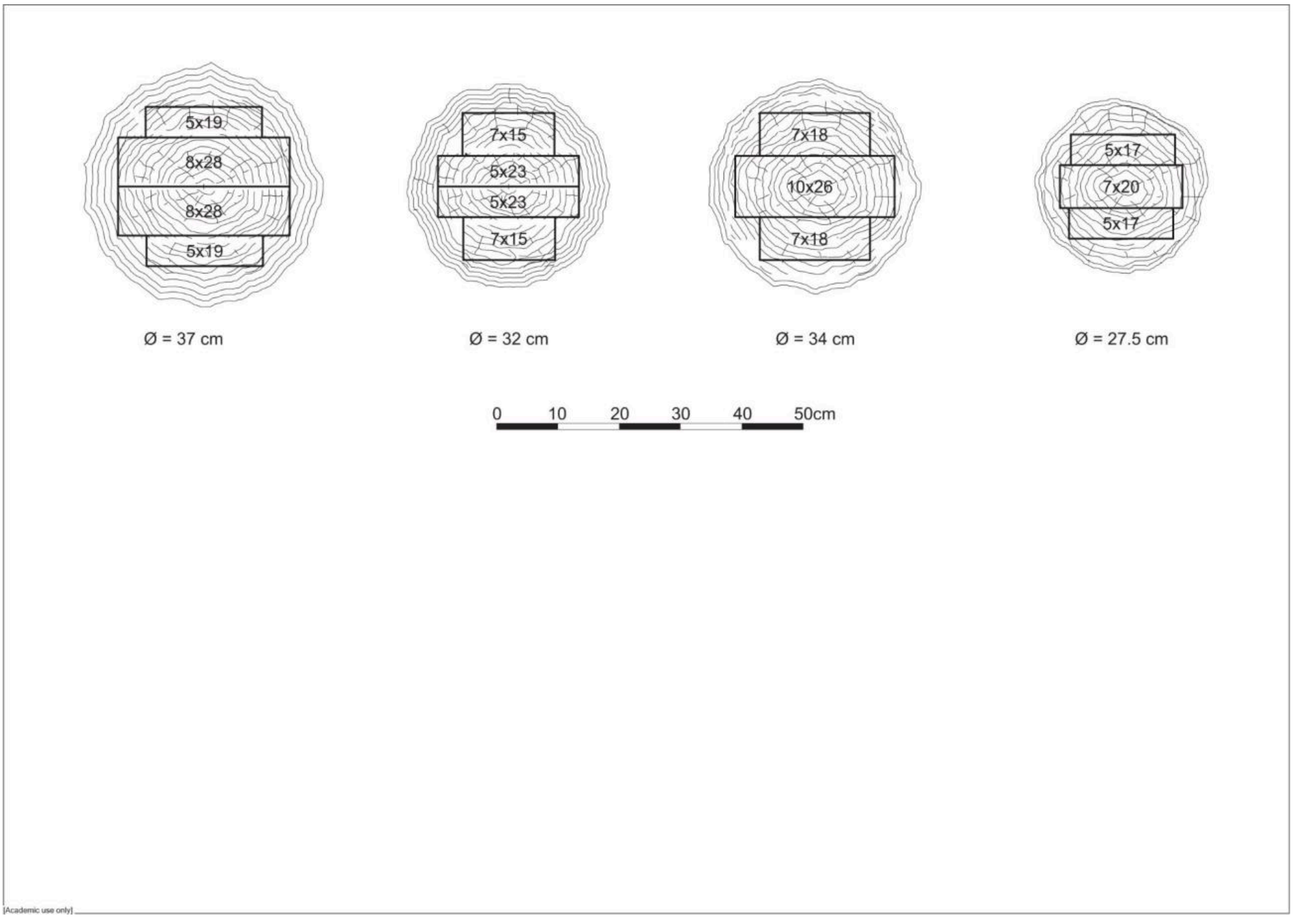

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FIG 13. DERIVING THE SCANTLINGS OF THE WALL- AND VERANDA POSTS THROUGH THE CONVERSION OF LOGS INTO SQUARED TIMBERS BY ‘SLABBING’.