SUMMARY

At the sanctuary of Hermes and Aphrodite, in the remote area of Syme, roofs utilizing terracotta tiles appear only in a late period of the architectural evolution of the site. The earliest example is building E[137], which, according to the excavation data and the typology of the roof-tiles, dates to the Classical period. In contrast, in mainland Greece, the first roofs of important buildings[138] covered with terracotta tiles had appeared almost two centuries earlier, in the 7th century BC, with examples known in Olympia[139], Corinth[140] and Isthmia[141]. It should be noted, however, that dating roof-tiles presents particular difficulties. Attempting to correlate tiles similar in shape but of different origin may lead to incorrect conclusions, as the architectural features of Cretan temples remained relatively conservative[142], while published examples and technical descriptions of Cretan roof-tiles are lacking. It is remarkable that at the Syme sanctuary the earliest tiles of Type I[143], associated with Building E, show several similarities in formal and geometrical features, both with roof-tiles from the temple of Apollo at Thermos in Aitolia[144], dated in 480-460 BC, as with those from the archaic temple of Elike[145], dated in 560-550 BC, but also with roof-tiles from the Archaic temple of Apollo in the ancient Metropolis of Thessaly[146] dated in 570-550 BC. It is generally very difficult to identify an evolutionary process in the practice of tile construction since, as we shall see below, the various solutions adopted solve case-by-case problems, which depend mainly on the architectural type of the building, the particular climatic conditions and the geomorphology of each particular region.

The transition from flat roofing, covered with clay, to lean-to roofs, covered with terracotta tiles, is a milestone in the evolution of roofing methods[147], providing significant benefits, such as better rain water runoff, reduced constant loads, the potential to bridge larger gaps, as well as better resistance to adverse weather conditions, resulting in a longer roof life. In particular, in the case of the Syme sanctuary, the interval between successive repairs or re-tiling of the roof has been estimated at about thirty years on average[148].

The manufacture of terracotta roof tiles required specialized experience. Tile manufacturers, as experienced craftsmen, consistently strived to achieve the optimum balance of dimensions, weight, ease of transportation, ease of installation and technical adequacy of their products. We do not know the origin of the tiles used in the buildings of the Syme sanctuary. The hitherto known examples of pottery workshops are scarce,

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[137] See above, chapt. 1.1.
[138] Sapirstein 2016, 46.
[139] Heiden 1955.
[140] Rhodes 2003; Sapirstein 2009.
[141] Hemans 1989
[142] Chaniotis 1987, 273.
[143] See above, chapt. 3.1.
[144] Hubner 2018a.
[145] Kolia 2014, 416, fig. 10.
[146] Manidaki 2018, 154.
[147] Sapirstein 2016, 46-47.
[148] The calculation is based on the fact that the 24 different types of tiles, derived from the buildings of the Syme sanctuary, are distributed over a period of approximately eight centuries, i.e. 800/24=33 years.

and only those in the workshop area at the southwestern edge of Knossos have confirmed roof-tile production[149]. We should not underestimate the fact that tile craftsmen had to solve problems of fixing or attaching tiles to the roof and to adapt them to its given dimensions, as well as fitting overlapping layers of roof tiles to prevent water inflow. Furthermore, roof tiles had to adhere to the wooden framework of the roof, so that they would not be swept away by strong winds. The effort to solve all these problems resulted not only in the continuous improvements and formal variations of roof-tiles but also in the evolution of the infrastructure of the roof. Therefore, when repairing or replacing roof tiling, after any damage, partial destruction or total collapse, evidence of improvement in the design or construction is often visible.

In the numerous and varied types of roof tile fragments, which were collected from building E[150] and the shrine C-D[151] at Syme, constant efforts to improve their technical features are evident. However, perhaps due to the mountainous location and the particular climatic conditions in the area of the sanctuary, the roofs remained of the lean-to type, with no particular variations in incline and construction, unlike the widespread gable roofs of Cretan temples[152]. It cannot be excluded that this consistently conservative practice is due, among other things, to the centuries-long knowledge of the particular climatic conditions and the direction of the stormy winds that would have affected the sanctuary during the winter months.

The study of the distribution of the various types of tile fragments[153], including those found disturbed contexts, made it necessary to date them approximately and correlate them with the buildings from which they originated. It should be noted, that for the correlation of roof-tiles with the buildings from which they were derived it has to be taken into consideration the fact that, according to a standard practice, in any repair of the roof tiling, old tiles were discarded in the building's surrounding area to be replaced by new ones.

The systematic study of the numerous fragments, six hundred and fifty in all, joined from fragments or not, led to the classification of the tiles into six main types, I to VI[154], which correspond to the architectural overhauls of buildings E and C-D and represent successive changes, repairs and remodeling of the roofs, with the attendant search for technical improvements, over a period of approximately eight centuries, from the Classical period (5th century BC) to the Roman era (3rd century AD) (pl. 8).

Based on the study of the technical characteristics of the tiles, together with the limited evidence of the fragment distribution[155], categories I and II were assigned to building E[156], while the remaining four (III, IV, V and VI) to corresponding architectural phases of C-D[157].

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[149] Tsatsaki 2014, 291-292.
[150] See above, chapt. 1.1.
[151] See above, chapt. 1.2. and 1.3.
[152] Chaniotis 1987, 273.
[153] See above, chapt. 2.
[154] See above, chapt. 3.
[155] See above, chapt. 2.
[156] See above, chapt. 1.1.
[157] See above, chapt. 1.2. and 1.3.

Furthermore, based on the study of the individual technical characteristics of the fragments[158], a total of 24 subcategories of tiles have been identified. The subcategories of each main category of roof-tiles show great similarities in the composition of the clay, their shape and technical characteristics, whereas minor differences between them can be interpreted as small-scale improvements and modifications to their molds. The occurrence of lead clamps for joining broken tiles is also evidence of small-scale repairs[159].

During the study of the numerous fragments of roof-tiles no holes were found that would serve to attach them to the wooden framework of the roof with nails. It is, therefore, assumed that the attachment of the roof-tiles was based on their weight as well as on their adhesion to the underlying mud layer that covered the timber construction of the roof. Consequently, the latter's gradient could not have been greater than 15 degrees.

The graduated layout of the roof-tiles mounted on the timber substructure limited the final slope of their upper surface by approximately four degrees, as shown in the relevant drawing (fig. 40), thereby limiting the runoff rate of the rain water. It cannot be excluded that the gradient of the timber roof of buildings E and C-D did not exceed 10^0 and as a result the incline of the tiles was no more than 6^0, permitting marginally adequate runoff of the rain water.

In any case, terracotta tiling, even on a roof with a minimal gradient, created a water-proof layer, ensured a better runoff of the rainwater and at the same time provided the advantage of a lesser constant load on the roof in comparison to flat roofing. The constant tile load ranged from $600N/m^2$ to $900N/m^2$ and the constant load of the mud supporting layer was estimated at $1600N/m^2$. On the other hand, the weight of a flat roof clay layer exceeded $5000N/m^2$ to $6000N/m^2$. This significant reduction of $2500N/m^2$ and at least 50% of the constant load, allowed, where applicable, wider gaps to be bridged, lighter roof construction and thinner walls[160] (pl. 9).

The stabilization of the terracotta tiles on the roof was ensured by their heavy weight and by their adhesion to the mud layer, which covered the timber construction. This was confirmed in excavation, when a layer of chips of schist and clay was found over the fallen and carbonized roof beams in Building E[161]. The large size and heavy weight of the tiles[162] were meant to reduce the number of gaps between them and to impede their displacement under the pressure of strong winds.

The weight of pan-tiles certainly affected their production, their transportation and their placement on the roof, and that is why there was always a conscious effort to reduce it by limiting their thickness. Typical examples of pan-tiles of reduced weight (figs 12-14) are those of subcategories Ic[163], IIe[164], IIIa[165], IIId[166], Vd[167] and VId[168]. However,

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[158] See above, chapt. 3.

[159] Lebessi 224, pl. 165a.

[160] The dry clay layer load was calculated at $19000N/m^3$; its average thickness on the flat roof at 25 cm to 30 cm, while the mud layer beneath the tiles on a lean-to roof was estimated to be eight to 10 cm thick. It is also understood that the load from the wet clay on the flat roofs would be significantly heavier.

[161] Lebessi 1974, 223.

[162] The surface of pan-tiles ranges from 0.35 m^2 to 0.39 m^2 and their weight from 15 kg to 23 kg.

[163] See above, chapt. 3.1.3, fig. 74-75.

[164] See above, chapt. 3.2.5, fig. 84-85.

the reduction in weight, as a consequence of thinner pan-tiles, had a negative effect both on the adhesion of the tiles to the roofing and on their strength along the longitudinal and transverse axes, as can be seen from pan-tile fragments of subcategory Ib[169]. This problem seems to have been of concern to the tile makers, who came up with very successful solutions (figs 12-14), in designing pan-tiles of subcategories Ic[170], IIe[171], IIIa[172] and in particular of VId[173], the weight of which did not exceed 16 kg. The biconcave cross-section of pan-tiles of sub-category Ib[174] shows a first attempt to address the problem, while the remarkable triangular projection of the edges on the lower surface of pan-tiles of sub-categories IIe[175], IIIa[176], and VId[177], was the most appropriate solution both for improving roof adhesion and for securing increased strength (figs 12-14).

Given that in the lean-to roofs of both Building E and the shrine C-D, the tiles were confined by the side walls (figs 128-131), there was a major problem concerning the even distribution of pan-tiles within the existing limits, while avoiding the use of some, cut to the required dimensions –an undesirable solution that would present technical difficulties. In regards to the linear (i.e. perpendicular to the incline of the roof) distribution of the pan-tiles, the problem was solved with the proper design of cover-tiles, ensuring the possibility of laterally moving pan-tiles and allowing a gap from three to eight centimeters between them (pl. 10). This gap was filled with mud and by adjusting the cover-tiles the possibility of rainwater inflow was significantly reduced. A more advanced solution, in the case of the shrine C-D, can be seen in the case of subcategories IIIc[178] and IIId[179], where specially designed cover- tiles had been placed along the side edges of the tiling[180] (fig. 130).

A similar problem had to be solved in order to achieve an even distribution of overlapping layers of tiles along the slope of the roof. In this case, the solution was clearly simpler, as it was easy to slide an upper tile over the underlying one, as well as to allow a greater projection of the lower layer of tiles beyond the corresponding wall of the building. However, while allowing a small slide of the pan tiles over each other, provided the advantage of an easier adjustment to the roof dimensions, it also held the potential of an uncontrolled sliding and the resultant destruction of the roof. For this reason, the design of the rims that channeled the flow of water in pan-tiles of category IV[181] and the

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[165] See above, chapt. 3.3.1, figs 86-87.
[166] See above, chapt. 3.3.4, figs 96-97.
[167] See above, chapt. 3.5.4, figs 116-117.
[168] See above, chapt. 3.6.4, figs 124-125
[169] See above, chapt. 3.1.2, figs 72-73.
[170] See above, chapt. 3.1.3, figs 74-75.
[171] See above, chapt. 3.2.5, figs 84-85.
[172] See above, chapt. 3.3.1, figs 86-87.
[173] See above, chapt. 3.6.4, figs 124-125.
[174] See above, chapt. 3.1.2, figs 72-73.
[175] See above, chapt. 3.2.5, figs 84-85.
[176] See above, chapt. 3.3.1, figs 86-87.
[177] See above, chapt. 3.6.4, figs 124-125.
[178] See above, chapt. 3.3.3, figs 94-95.
[179] See above, chapt. 3.3.4, figs 96-97.
[180] As illustrated in fig. 130.
[181] See above, chapt. 3.4, figs. 51-57, 98-107.

way of mounting cover tiles over the pan tiles, excluded the danger of any displacement. The trapezoidal shape of the pan-tiles of sub-categories Va[182] and Vb[183] had a similar effect, but was soon abandoned in subcategories Vc[184] and Vd[185].

Another interesting approach in roof-tile design is the creation of beveled bottom surfaces on the side walls of pan-tiles of subcategories IIIa[186] and IIIb[187], which took advantage of the weight of tiles and prevented sliding, a design that was, however, abandoned later in subcategories IIIc[188] and IIId[189]. The beveled edges on the lower surface of the side walls of pan-tiles are of particular interest as they ensure the existence of high lateral walls, in order to avoid excessive rainwater runoff, while reducing the differences in height between overlapping layers and preventing tiles from being displaced by strong winds (pl. 11) .

An interesting feature in tile subcategories IIIc[190], IIId[191] and IVa[192] is a shallow groove on the upper surface of cover-tiles that indicated the precise definition of the overlapping zone, preventing any adjustment in the placement of both cover-tiles and pan-tiles. A similar approach can be observed in the peculiar cover-tiles of subcategories Vc[193] and Vd[194], where a groove on their back surface defines precisely the overlapping area.

On the basis of high-precision, three dimensional digital models of tiles, it is clear that the difference in height between the overlapping layers of pan-tiles is, as expected, exactly the same as that of the overlapping layers of cover-tiles, and is directly correlated with the height of the pan-tile rims that controlled the overflow and the height of the lateral pan-tile walls. This observation, together with the variations of clay types and surface paint, contributed to the correlation of pan-tiles and cover-tiles of the various subcategories, when secure evidence was lacking.

According to the geometrical characteristics of cover-tiles of the early categories I and II (5th and 4th century BC), the dimensions of their cross-section remained identical throughout their length, and consequently the height difference of the overlapping layers of pan-tiles and cover-tiles was also identical. From the 3rd century BC onwards, in the next categories III[195] to IV[196], a new concept was introduced in the design of cover-tiles whose cross-sections at both ends were differentiated, as their height and width were smoothly increased from front to back. This represents a significant improvement, as it reduces weight, so resistance to winds is reduced, facilitates assembly,

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[182] See above, chapt. 3.5.1, figs 58, 110-111.
[183] See above, chapt. 3.5.2, figs 59, 112-113.
[184] See above, chapt. 3.5.3, figs 60-61, 114-115.
[185] See above, chapt. 3.5.4, figs 62-64, 116-117.
[186] See above, chapt. 3.3.1, figs 47, 86-87.
[187] See above, chapt. 3.3.2, figs 48, 88-89.
[188] See above, chapt. 3.3.3, figs 49, 93-95.
[189] See above, chapt. 3.3.4, figs 50, 96-97.
[190] See above, chapt. 3.3.3, figs 49, 93-95.
[191] See above, chapt. 3.3.4, figs 50, 96-97.
[192] See above, chapt. 3.4.1, figs 98-99.
[193] See above, chapt. 3.5.3, figs 114-115.
[194] See above, chapt. 3.5.4, figs 116-117.
[195] See above, chapt. 3.3.
[196] See above, chapt. 3.4.

allowing slight differences in the height of overlapping layers, improves runoff flow, as the upper surface is slightly inclined, and diminishes the risk of displacement of the cover-tiles.

The fact that, during the recording and study of the fragments, none were found with traces of angled surfaces, confirms the hypothesis that the roofs of both buildings E and C-D could not have been gabled. The only examples of a unique type of cover-tiles, corresponding to half the width of a complete tile, are assigned to subcategories IIIc[197] and IIId[198], associated with C-D. These specially produced tiles were used to provide better insulation between the edges of the roofing and the corresponding side walls of the building (fig. 130).

Painted tiles appeared around the end of the 4th century BC or a little later, in pan-tiles assigned to subcategory IIe[199], with indistinct brownish-black traces of color on their upper surface. Color was essentially a thin coat of clay solution, which when fired acquired a reddish-brown or brownish-black tint ensuring, at the same time, less water absorption and better resistance to adverse weather conditions. The application of paint, in conjunction with new concepts in tile design, marks a smooth transition from the tiles of building E to those of C-D. The application of brownish-black paint on the upper surface of pan-tiles, partially discolored due to their exposure to adverse weather conditions, is a characteristic feature of tile category III[200], dated approximately to the 3rd century BC. In the 2nd century BC, the application of paint extended to cover not only the upper surface of pan-tiles, but their lateral walls too, as well as the external surface of cover-tiles of subcategories IVa[201] and IVb[202]. A little later, probably in the 1st century BC, in subcategories IVc[203] and IVd[204] paint covered all surfaces visible or not, of both pan-tiles and cover-tiles, with traces indicating the use of a paint brush. Traces of a paint brush are visible on tiles of category V[205], where the color ranged from brownish-red to brownish-black. As the paint was applied in the form of a coating of a very thin clay solution, the color depended on the oxidation during firing. In tiles of the latest category VI[206], dated in the Roman period, the technique of applying a homogeneous coat of paint appears to have improved. There are no traces of a paint-brush anymore, suggesting that the tiles may have been dipped in the paint and that oxidation during firing did not fluctuate.

The evidence for the reconstruction of the wooden roofs of buildings E and C-D, is inadequate. The carbonized beams with cross-sections of up to 0.30 m. (figs 126-127) that were found during the excavation of Building E[207] were not thoroughly smoothed. The size of the beams, which were mounted approximately at intervals of 50cm., used in

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[197] See above, chapt. 3.3.3, figs 49, 93-95.
[198] See above, chapt. 3.3.4, figs 50, 96-97.
[199] See above, chapt. 3.2.5.
[200] See above, chapt. 3.3.
[201] See above, chapt. 3.4.1.
[202] See above, chapt. 3.4.2.
[203] See above, chapt. 3.4.3.
[204] See above, chapt. 3.4.4.
[205] See above, chapt. 3.5.
[206] See above, chapt. 3.6.
[207] Lebessi 1974, 223.

an aperture of 3.60 m to 4.50 m, is adequate for the constant load (of about 2500N/m^2) of the mud layer and of the tiles of the roof. Carbonized branches of wildwood, which were found in the same area, must have been spread on the beams and were probably covered by a layer of reeds and mud, on which the tiles were attached, as already mentioned, without the use of nails. After all, the size of the buildings and their general construction details do not suggest a special concern for the careful construction and durability of the timber roof[208].

Naturally, the construction of tiled roofs in such a remote area, such as that of the Syme sanctuary, was not elaborate and lacked decorative elements, such as antefixes, simas, water spouts etc., which would facilitate a much more precise dating of the various categories of roof tiles[209].Nevertheless, the tiled lean-to design of buildings E and C-D, which had an incline sufficient to ensure rain water runoff[210], is of particular interest within a more general architectural evolution, as an eloquent example of the transition from flat, clay covered roofing to the sophisticated, higher gable roofs of ancient temples, utilizing tiles fixed with nails on the timber substructure and ornamental architectural terracotta elements.

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[208] In building E, covering an area less than 20 m^2, the maximum opening of the roof to be bridged was 3.60 m, whereas in C-D, which, in its various architectural phases, covered an area from 20 m^2 to 30 m^2, the gap to be covered did not exceed 4.50 m.

[209] Hübner 2018b; Sapirstein 2012; Kolia 2014.

[210] Although apparently insufficient to withstand the accumulation of a thick snow layer.