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A Minoan Experimental House – Paying Tribute to Middle Bronze Age Cretan Vernacular Architecture

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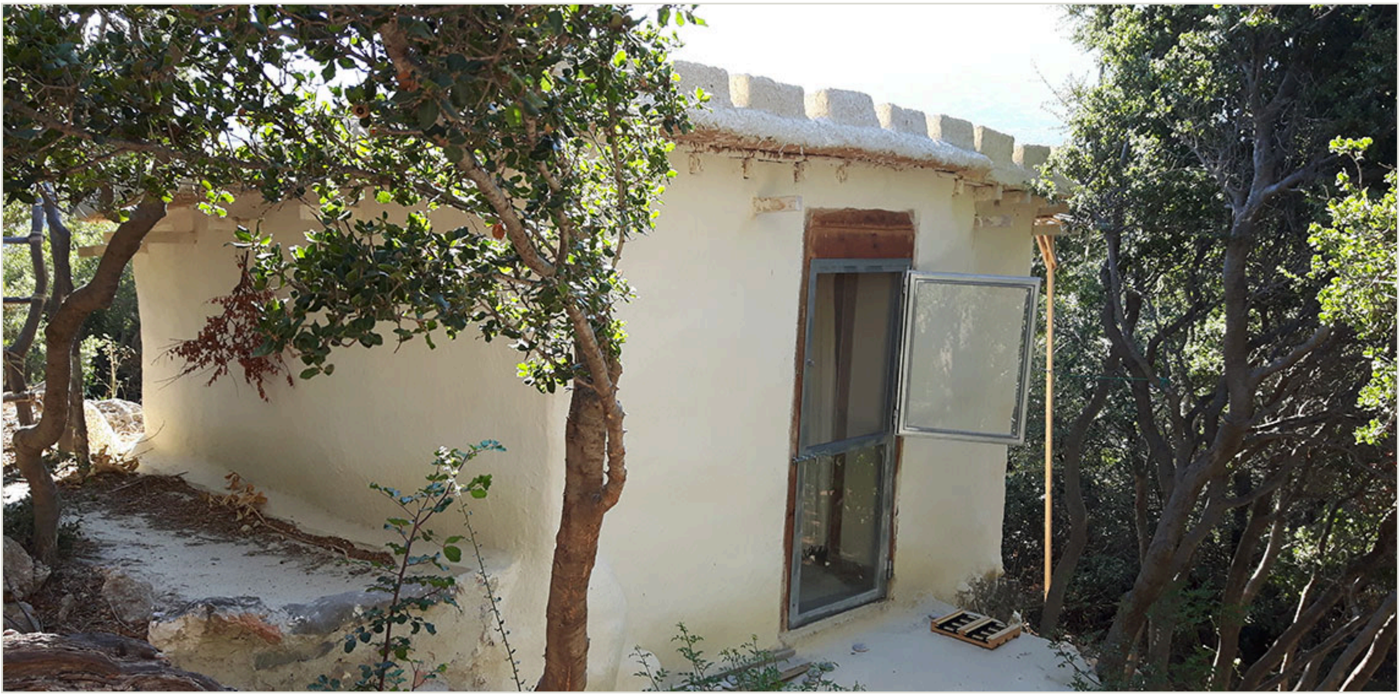

In the mountains south of Agios Nikolaos, north-east Crete, the Minoans of the Middle Bronze Age (2000-1650 B.C.) left behind several kinds of ruins, which were studied in my PhD thesis (Beckmann 2012a). The 337 ancient sites discovered during this investigation were arranged in a loose settlement pattern, with dwellings ca. 150 m from each other, composed of manifold field- enclosures and animal pen walls surrounding variably sized houses and connected by an extensive network of paths.

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Prototypes, situation, general description

Especially impressive are the often massive ruins of dwelling foundations referred to as 'oncolithic' in my typology (for details see Beckmann 2012a).These foundations neutralize the often steep slope incline they are built upon, so that the original houses would have stood in a horizontal position. The settlement pattern and surface findings indicate that these installations were vernacular in character and probably housed mixed agricultural farms (*ibid*.). Traces of upper structures (especially timber) could not be detected apart from two sites where fragments of what seemed to be typical Minoan (albeit accidentally fired) mudbricks could be seen (See Fig(See Figure 1). Consequently, I suggested that upper structures must have consisted of unfired mudbrick. This study was based exclusively on surface findings, therefore no analyses of any raw materials detected exist.

To my knowledge no reconstructions of Minoan vernacular (or other) houses have been undertaken yet. As a landscape archaeologist, I had no more experience in experimental architecture than having re-built part of a traditional German farm house with a light kind of cob (at the time still a pioneering feat) in the 1980's.

Architecture

Apart from the preserved foundations of undressed massive blocks (See Figure 2), *ca*. 4000 years of the ruins' exposure to the Cretan high mountain climate (snow and rain in winter, heat in summer and wind year round) had left no upper structures. None of the ruins show traces of window openings in the sometimes high remaining foundations, while few door openings (*ibid.* 123) exist, the latter always on the upslope sides.

The few preserved mudbrick fragments seen in the mountains were similar to the unfired mudbricks known from excavated Minoan sites such as Quartier Mu in Malia, the largest currently known and excavated Middle Minoan urban site with preserved mudbrick structures (cf. Poursat et al. 1978, Poursat 1996[1]). These urban mudbricks – with sizes of ca. 40-50 x 20-30 x 10-15 cm - (See Figures 5-7) were usually tempered with organic matter (straw or sea-grass, depending on availability). The very small samples from my study area did not show obvious inclusions of plant material, although tiny round holes/voids might indicate the use of pine needles as temper, suggesting utilisation of the pine forest close to the settlement region. Other small, accidentally fired pieces of mud seen on the surface indicated larger plant inclusions (Beckmann 2012a:135) and may have originally belonged to bricks, plaster, or even roofing. The scarcity of mudbrick findings also suggests that there were no major conflagrations to end Minoan settlement in the mountains.

Experimental Possibilities

With a relatively large number of available ruins for study, I could determine that the dwelling part of the houses must have sat horizontally on their levelling oncolithic foundations, although the basic digital equipment used in this research did not allow the slope to be presented entirely accurately in a digital reconstruction. If one tries to visualize that the goats in Fig. 2 would have been situated on the house's horizontal plane, one can imagine how steep the slope is in this example (Site 33, in Beckmann 2012a:299,542).

While experimenting with the available computer reconstruction possibilities, I realized that even the most sophisticated software would leave too many questions unanswered. As a result, I decided to attempt to reconstruct a small house in a corner of my own (partly covered in wilderness) Cretan garden, some7 km from (and ca. 600m and more below) the mountain originals.

Although we know of the mudbricks existence, the possible appearance of the houses has been informed by Late Minoan art such as the 'town mosaic' from Knossos and the small clay model house from Archanes (See Figure 3).

It is likely that these examples only show urban houses. Vernacular houses probably did not have a second floor with columns, and some basic architectural details can be identified from them, such as the roofing with round wood beams, the existence of open courts, window construction, and the possibility of balconies.

Preparations

The extent of experimental work for such a house naturally depends on the expected outcome. In this case, the desired result was to reconstruct a similar foundation to the Middle Minoan mountain ruins, along with a mudbrick structure, to discover if/how the two could be connected. We were also interested in determining what implications the challenging landscape had on construction - would specialized tools and knowledge have to be used on a slope?

Mudbrick

A visual inspection of Quartier Mu (See Figures 5-7) provided important information on tempering content, as considerable amounts of sea grass (*Posidoniaoceanica*) was used in the bricks of the building, a typical choice for a site on the seashore (cf. Guest-Papamanoli 1978:6). Much was also learned about building and positioning techniques.

For the mudbricks we obtained several cubic meters of local soil (*terra rossa*) which, after a first screening using a shake test (Weismann& Bryce 2006:45) proved to be ideal for building. We then built a mould measuring 40x20x12 cm and produced several test bricks (See Figure

4), employing various tempers to reduce shrinkage. It was observed that added elasticity may be gained through the use of organic temper, an important factor in earthquake-prone regions like Crete.

For our experiment several varieties of bricks were tested (See Figure 4):

1. Plain mud: These broke into many small pieces after drying after two weeks.
2. Mud with ca. 30% sand: These also suffered several deep cracks within two weeks.
3. Mud with locally sourced pine needles: These produced a stable brick which remained damp and soft after two weeks; the needles had minimal filling ability, so the brick was comparatively heavy.
4. Mud with ca. 50 volume % wheat straw: The straw soaked up much of the mixing water within hours, so these bricks were useable, although slightly pliable – after two days in the sunDepending on the amount of plant temper used, the weight and temperature isolating abilities change naturally. I adjusted the mixture to a macroscopically roughly similar one with that visible in Malia Quartier Mu – cf. (See Figures 5-7)

Judging from the remaining examples it seems probable that the mountain Minoans may have used sand or a[2] sandier soil than our comparatively pure clay from a colluvial lowland polje, rather than straw. This seems a logical choice when taking into account that straw might have been a precious commodity in mixed agriculture. Still, being situated in the lowlands, we decided to use straw as did most of the analysed Bronze Age cases in Nodarou et al. (2008). Theoretically pine needles would also be a good choice for the mountain surroundings, according to the usually observed principle of local availability (ibid.).We tried to apply that principle as often as possible, to avoid various labour-intensive features as this was a privately financed experiment(see mainly the paragraph on timber below).

We have since discussed if animal hair such as sheep or goat would be an option as additional temper. In a shepherding society it would also be economically justifiable as an amount of discarded wool is always left over from shearing.

Subsequently, we chose a medium of the known brick sizes from all over Minoan Crete of 40x20x12cm. This allowed the possibility to change direction in the laying of the bricks (header-stretcher), although the Quartier Mu remains were inconclusive in answering how and when header-stretcher directions were changed (See Figures 6 and 7). My observations suggest they mainly used pure header constructions, while bonding was obviously often done without paying attention to where the perpend (the vertical joint between two bricks) was positioned (See Figure 6), even though it should have been obvious already in the Bronze Age that aligned perpends produce comparatively unstable walls. It should be interesting in this context to compare these Middle Minoan constructions with any available Late Minoan constructions to see if earthquake experiences impacted on this observed indifference.

While our brick thickness of 12 cm was greater than the example known from the mountains (*ca*. 50% more than the *ca*. 8 cm there), it was a more economical solution in terms of manpower. With the same number of movements in laying bricks, 50 % more wall height is reached - and for us, manpower was by far the most expensive element in the experiment. A similar effect may have been achieved by making the bricks as large as they were in Malia, although bricks of this size would have to have been much drier before building, so as not to fold when lifted.

The use of stones to fill gaps was a feature we adopted from the Middle Bronze Age example in Malia, as it turned out to be much easier than trying to use more mortar, which was often impractical, especially when the comparatively fluid mortar would just run out of larger gaps.

In retrospect, had we had the luxury of drying time and adequate space, the pine needle temper bricks would have been my preferred building material, due to the durability of this version. After two years of continuous exposure to the Cretan climate the test bricks' condition resulted in the following:

1. Sand: Surface rounded by erosion but main mass partly intact, although with now widened cracks.
2. Pine needles: Surface slightly eroded, whole shape still intact, no cracks.
3. Plain: Nearly totally dissolved and hardly recognizable due to the many cracks that all enlarged the erodable surface.
4. Straw: About 0.5cm of surface eroded so that the straw temper is more visible, general shape intact (no cracks).

From the comparatively flat shape of the Minoan mud bricks we concluded that Minoan builders must have had a longer drying period than we used (two days was enough in our case), and thus harder bricks. This must have had other consequences, such as the need for greater amounts of mortar to be used, as the bricks are less adaptable to already built, uneven layers underneath, a fact that can be seen in Figures 5 and 6, where thick layers of mortar are obvious, together with the regular use of stones as chinking in larger gaps.

As a base for mortar we used differently coloured clay that was recommended by a specialist in clay mortar (mainly baking ovens) due to its exceptional quality. Geologically it is a calcarious marl (for the geological details of Cretan soils see for example John A. Gifford in Shaw & Shaw 2014:59), and called *kouskouras* or *asprochoma* ("whitesoil") in Crete. It consists of a whitish, clayey, very dense and nearly totally waterproof when wet kind of soft stone. In situ our version seemed to be like "stone", although practically it is densely packed clay that when passed by a tractor with a plough turns into fine dust in summer – or deep mud in winter. It was sourced some 12 km from our site, and offered the advantage of clearly seeing the difference between the basic, red-brown bricks and the beige mortar and plaster (See

Figure 8). An additional advantage is that the various elements and procedures of building can be demonstrated much more easily.

Timber and other raw materials

While we know from Late Minoan urban sites like Knossos that cypress timber was used (Evans 1921:341), this seems improbable for the building of vernacular houses, especially as cypress has always been a valuable export product (Chaniotis 1999:209, with bibliography). Ethnographic parallels show the logical choice of timber from whatever wood is locally available. We did not experimentally prepare any wooden elements ourselves as the locally available timber is mostly kermes oak (*Quercus coccifera*) or olive (*Olea europaea*); both extremely hard, heavy kinds of timber, which, if worked in a Bronze-Age-like manner, would have surpassed our work-hour schedule and hence our budget considerably.

The raw material we wanted to use for the later roof covering, giant cane (*Arundodonax),* came from the coast, some 5 km from the site, but could have grown closer at other times. It is a bamboo-like plant that has been used in architecture in the Bronze Age Aegean (Thornton 2007:77, Vlachopoulos & Zorzos 2014:194) and seemed like a good choice, even though we do not know much about Minoan roof constructions. There are some small fragments of accidentally fired mud with plant impressions (mainly small irregular twigs) in the surroundings of the mountain sites, as mentioned above, but they are too small to establish what part of the construction they may have belonged to. In any case, Bronze Age roofs must have been partly mud, although hardly anything can be learned from Middle Minoan sites. See the traces of "reeds" – as they are usually called in the bibliography, only Vlachopoulos & Zorzos call them *Arundodonax* based on phytoliths - on top of the beams in the reconstruction in Figure 5, based on plant impressions in the mud. (For this and other possibilities cf. also Shaw 1977:229 and Passim.) These bamboo-like grasses were put aside to dry until they were to be used. We did realize that transporting all these materials on donkeys and human backs would also massively effect the man/donkey-power needed. Bronze Age builders would have most likely, wherever possible, chosen materials from as close by as possible.

Another important component needed for making mud bricks is water. While modern Cretan conditions bring water via networks to most settlements, the more or less free use of water during the Bronze Age would have been restricted to the "rainy" season, from October to May. Warm and sunny weather is needed for the bricks to dry, and the roof cannot be constructed as long as the bricks have not been laid. Therefore, the question of the time of year when building would have taken place remains unclear.

Beginning work: the foundation

The first step of building is naturally the choice and preparation of the space for the future house. As could be expected for most cases of Minoan Bronze Age plots, cutting trees and bushes occurred after choosing the space, which simultaneously produces a certain amount of timber. In our case, as mentioned earlier, we did not use this timber but bought ready cut imported timber for economic reasons, such as the insertion of the horizontal lintel into the upper layers of the brick wall over the "Minoan" window in Figures 8, 22 and 24.

We also tried to preserve as many of the surrounding trees on the plot as possible, to protect the house from driving rain. This turned out to be a good idea, because one of the building's sides, with a distance of 2m from a protective tree, still was not protected enough, as later developments proved. We also chose a place with as many large rocks as possible, so as to be able to build our foundation with minimal efforts. The space cleared of big stones on the upslope side of the house, demonstrated clearly why and how many of the mountain houses actually seemed to have had a court on the upslope side. This side is in many cases also the lee-side in terms of winter weather conditions, which gives the space an extra quality for use as an outdoor activity area. In our experimental case the downslope side is the weather side and so eventually required protective measures to be implemented for the exposed wall.

We used two kinds of tools for our foundation, a big sledge hammer to clear the bedrock parts which had to be broken off, and then a lever for moving the blocks to their final position. For a few days we employed only one worker, but discovered that two workers were the minimum requirement, as together they could move many of the big blocks (See Figure 9). One working individual most certainly required a lever, a tool which would have been difficult to produce, even if using fire-hardened hardwood, before the use of iron. The weight of the stones we moved would have broken most wooden levers, while with two (or more) workers the need for a lever was much smaller. The question of what might have been used in the place of a sledge-hammer in Bronze Age Crete remains open for debate, as all hammer-like tools that I know of would be too small for this task. Naturally uncontrolled cracking of bedrock by fire (usually only used to get rid of bedrock) or controlled cracking by wooden wedges swelled with water, as known from ethnography, would have been a possibility, too. Bedrock, frequently integrated into Minoan mountain foundations, gives the buildings greater stability, especially in the case of earthquakes.

Having erected the frame of the foundation as much as possible in the Middle Minoan way (Beckmann 2012a, chapter 2, Beckmann 2012b:36-37c), we filled this with smaller stones. Some mountain houses may have used the space inside the foundation as a cellar *vel sim.*, while others were filled to create a level base for the upper structures (ibid., and Figure 10).

We realised that rainwater running over the surface above the house would inadvertently lead to an eventually unstable upslope wall during the rainy season. Therefore we cleaned about a meter's breadth of soil from the upper foundation and filled that space with rubble.

Then, on top of that, we added several layers of waterproofing clay with an outward incline (See Figure 10, under the yellow bucket). Into the final layer, constructed for a clean surface only after the whole house was finished, we inserted with some 20cm distance from the final, plastered wall a shallow drainage channel (made from ridge-tiles) which has functioned perfectly since then (See Figure 27). Drainage channels like this are known from various ancient sites (see the list in Shaw 2004:173-4, n4).

The realization of this problem prompted me to return to one of the unexcavated prototype sites in the mountains, where an unauthorized bulldozer had scraped flush along the ruin wall and exposed the upslope part of the filling behind. Shortly after the bulldozing I had discovered that there were several stone slabs embedded in the soil close to the modern surface and hence probably not exactly in their original position. At the time, I had considered these to have been traces of an ancient flagged terrace or the like. When revisiting this site, unfortunately most of the originally clear-cut edge was gone and only one slab remained, so I reverted to my original, older photographs[3] . I could see now that the slabs must have been part of a construction diverting water from the house wall (See Figure 11). A good example to show of how well suited experimental archaeological work is to informing us about understanding ancient features.

Mudbrick construction

After finishing the stone-building section up to a height where splashing water from winter rains would not harm the mudbrick construction easily (one big block layer above the surface, as in the mountains), the whole raised platform was levelled with layers of fine rubble-sand-mud to create a good base for the later floor. This kind of composition can also be seen on the broken edges of floors in Bronze Age Malia Quartier Mu.

We started producing the mudbricks (which had been decided upon after reviewing the test bricks), by filling a wooden mould with a mixture of 50% red clayey soil and 50% wheat straw, with as much water as was needed for a smooth, even consistency where all the straw was well covered in mud.

In the beginning, we produced this mixture in the traditional way by treading with our feet. After the first batch the workers suggested using a cement mixer for the clay-water mix, then pouring the mix over the straw in a wheelbarrow, mixing it by hand and then transporting the wheelbarrow to the space where the moulding and drying was carried out (See Figure 12). After two days, the mudbricks were dry enough (while still agreeably pliable) to be used in building (See Figure 13).

After a few days, we had reached a rhythm of building, where one batch of bricks (ca. 90-100 pieces produced by the two workers in one work session) would dry out for two days and then be utilised in construction. Following this a day of pause for producing more bricks was also advisable to give the built bricks more time to dry and thus not be deformed too much by the weight of the following layers. For the mortar we used a mixture of *kouskouras* in the same mixing ratio as the bricks, but freshly made every day and thus more fluid for instant building. The straw for the mortar was chosen from shorter pieces than the brick mixture to improve its workability. As an easy Bronze Age parallel the use of mud mortar in Malia Quartier Mu is well visible e.g. in Figures 6 and 7.

The first layer of bricks was laid without further bonding onto the upper layer of rocks, equalized by plenty of mortar and a few filling stones where necessary. It seems that the rough surface of the un-worked blocks, together with the weight of the wall, produced ample cross-bracing to make the connection stable, as the first earthquake showed about six months after the house was finished. At 6.1 on the Richter scale, it was strong enough to produce a slight crack on the building's weakest part, over the door, but did not cause cracks elsewhere[4] .

In the following two layers of brick, some of the inequalities remaining from the first layer were adjusted where necessary, with more mortar and a few extra stones (as also visible in the Bronze Age wall in Malia, Figure 6), which were also used to fill other gaps (See Figure 14).

The layers were changed between header and stretcher rows and perpends were mostly offset to increase bonding. Due to an oversight, one small section of the wall was built without offset, (similar to the part visible under the "window" in Figure 16), producing a major argument between the two workers who wanted to rebuild the whole part of the wall. I insisted on not rebuilding, as there are clear examples that the Minoan builders e.g. in Malia also had not always thought to avoid vertically continuous perpends (see Figure 6). After plastering, none of this remains visible and the earthquake did not produce any crack in that area of the wall. This was particularly interesting as it seems the construction with still humid and pliable mudbrick might improve the mortar-block interface and thus the shear strength, as the walls become more solidified.

We had erected the door casing from the beginning, so as to be able to bond it with the bricks as the layers were rising. Header rows were adjoined to the frame whereas in stretcher rows the bricks were cut on their ends in order to fit into the space between the inner and outer part of the frame. Some wooden pieces, like twigs or strips of cut timber, were also inserted to improve the connection (See Figure 15) We know that the Minoans often constructed their doors with a similar wooden casing (for Malia cf. Poursat and Schmid 1996: 74), as even though the timber has vanished, the hollows often remain. However, I am not aware if they did or did not use this extra reinforcement.

The "window"

The Minoans seem to have regularly included a rather peculiarly shaped window in their houses, as observed in two of the walls (with four and six openings) of the Late Minoan house model from Archanes (See Figure 3).

The workers ceased building layer by layer after the first few rows, and instead raised some parts higher than the rest, creating a stepped appearance (See Figure 16, 17). One evening when I revisited the construction site after everyone was gone, I noticed that they had left one loose brick lying on top of two others which had some space in between, next to one such stepped wall-part. The similarity in pattern with the Archanes model's windows was striking, and I realized how logically this kind of opening could be integrated into such a brick wall without large disturbances to the building process, and without giving up the stabilizing or weight-bearing qualities of the brick construction. Originally I had not planned to include any windows in the construction of such a small house - following ethnographic examples only a small opening for cross ventilation was scheduled.

On the next day we constructed, in the width of a window and on the last even header-layer underneath, a single outer row of stretcher bricks, leaving an opening of half a brick in the middle, covered by another stretcher with quarter-brick openings on both its sides. This was again covered by two stretchers spaced with a half brick distance in the middle (See Figure 16). On the outside this produced a level wall with openings, and on the inside it appeared as a recess in the wall of a whole window's size of 1.5 bricks width and 3 bricks height (See Figures 16, 17, 24). This was satisfactory, even though some of the perpends turned out again aligned (See Figure 16), – but after the earlier argument one of the workers came early the next day – knowing that I would probably not want to change things - and reconstructed on his own the whole thing with correctly offset perpends.

Subsequently, construction continued smoothly for a day – and then the unexpectedly early first rain came (See Figure 17), while the window-construction was only spanned by the timber lintel, to better spread the weight, that hadn't been integrated into the mudbricks yet.

Although everything appeared a sea of mud afterwards, the actual brick surfaces had hardly suffered at all (See Figure 18). This provided a first hint at how amazingly resistant this material seems to be to rain, even when still soft and with its surface exposed - something that would never happen again in the future, as long as the roof would remain intact.

Within less than a month all the brick walls were completed and only the uppermost layers needed some extra work due to the incline we wanted to give the roof. I realized that mudbrick-construction without a timber frame is a much faster kind of building than I had expected, despite having additionally produced our own building material pin tandum with the building process (all in all over 900 mudbricks).

The roof

As stated earlier, there is a paucity of knowledge as to how Middle Minoan roofs were constructed. Although the Late Minoan houses of urban Akrotiri on Santorini are preserved to an amazing height, archaeologists know little about their original roofs[5] , from the layering to the shape. Usually Minoan houses are supposed to have been flat, an assumption which may have to do with the shape of traditional Cretan houses as much as the traces known from floor constructions in multi-storey Bronze Age urban houses (See Figure 5). The only certainty is the absence of any kind of tiles or slabs covering the Minoan mountain dwellings, as not a single building of the 337 ruins examined showed traces of tiles. It seems as if the few published cases of roof layering – irrespective of the roofs' slope – have a similarity with traditional Cretan roofs (Lenuzza 2013:80) as visible in Figure 21.

We decided to follow the general lines of traditional Cretan houses, with a slight incline, which would allow rainwater to run off easily. This is also supported by the existence of roof drain spouts in Bronze Age Crete (Lenuzza 2013:84). These could not have functioned without a slight incline to the roof, while relative flatness would still allow a use of the roof-space for various activities. We chose timbers similar in size to those which we could have produced in the sites' surroundings. This also corresponded to the type of timber known from the voids visible in the Malia Quartier Mu houses (See Figure 5).

The local timbers would have been rather crooked, a fact which corresponds with traditional Cretan vernacular building, where everything wooden available or dispensable – due to a general sparseness of trees – would have been used for constructing roofs. Often whole trunks of olive trees, complete with branches, had to serve as the most stable timber for beams as well as for columns (where needed). A rather neat example in the mountains, and therefore likely made of kermes oak, can be seen in Figure 20. Many houses, depending on their geographical position, had to use olive for timber, and only old, non-productive trees would be sacrificed, gnarled by decades of pruning, often producing bizarre roof constructions.

Because of this crookedness a vernacular house probably would not have had the beams as closely set as they were in urban Quartier Mu (See Figure 5). Also, the extremely heavy kermes oak beams in this dense packing would bring a large extra weight to the whole construction. Thus, and for economical reasons as mentioned above, we used imported pine timber. Similar timber might have been used in the Bronze Age mountain houses as they are partly situated in a pine forest that may have already existed 4000 years ago.

Due to the small size of our experimental house, columns would not be needed, and after consulting with my father, Ing. G. Beckmann,a structural engineer, concerning the load capacity of our timber in relation to the thickness of roof and its tons of weight, the respective timbers were laid into a mud bed. This is one of the few Bronze Age roofing features actually known from Cretan archaeology (See Figure 5). The weight of the roof was to be distributed over the upper (front-door) and lower walls of the house via a ring-beam and over the side walls of the house via the 2 main beams additionally spanning the interior. As a mudbrick wall thickness from 30cm is load bearing (Dimiziania and Ortolani2014:12), no vertical columns within the walls are needed. Still, from a static point of view, vertical timbers would probably improve the earthquake resistance of the building. This may have been one reason why vertical timbers were introduced in Late Minoan architecture (*Tsakanika-Theohari 2009).*

Our two large main beams were stabilized with stones on both sides, while the ring-beam was intended to ascertain the horizontal stability of the roof, always bearing in mind that Crete has frequent earthquakes.

Another typical feature of many traditional Cretan houses is a slight overhang which we decided to adopt in order to give the walls some additional protection from rain. As in the roof construction we were not trying to be true to any Bronze Age prototypes, we did not work with wooden pecks or bindings in leather as an ancient building would have employed. Instead we resorted to the modern solutions of binding with wire, nails and screws, which was cheaper in terms of working hours.

The actual layering on traditional Cretan roofs varies greatly with the local availability of material. The basics are thus: load bearing timber beams are covered with several increasingly finer layers of plant material (e.g. branches, twigs, leaves; or branches, brushwood, sea grass) covered with a layer of soil and/or finally a layer of *domatochoma* ("roof soil"). Each region has its own source, which the elderly locals still always know; it is usually the most waterproofing clay rich soil available in the area. In some cases this layer was only thinly applied (See Figure 21), a task that often had to be repeated every winter, which resulted in many layers. Interestingly some of the known fragments of Minoan roofing show exactly this kind of layering (Lenuzza 2013).

We used, as mentioned in the beginning, densely arranged haulms of the bamboo-like giant cane on top of thin timber beams, taking the place of tree branches in traditional architecture (See Figure 22). Branches are also the only solution when beams are made of knarled trees, as giant canes need a horizontal base.

The following layer of thin woven cloth was added to prevent dust from falling through the slits in the cane, something the ancient and the traditional Cretans may have solved with a layer of overlapping leaves (Devolder 2006:80). As I intended to use the experimental house later as storage space or even as an occasional guest room, I decided to make sure in this case.

Next, several layers of roof-soil were laid on one another, first dry (to make transport/application as easy as possible) and then wet and compressed, according to local custom (See Figure 23), until it reached a thickness of ca. 20cm.

By this time the rainy season had arrived, so unfortunately the roof never really dried off in the first winter. Still it obviously developed cracks – albeit not visible on the surface – so that each rain caused extensive dripping inside the house. Drip-holes[6] also appeared in the applied basic floor layers. When expressing my disappointment, and asking locals what we had done wrong, the first wise old lady looked at me with a grin and said "who told you traditional roofs didn't leak"?

Further research into local roofing customs still have not led to a conclusive solution. When the next rainy season commenced, the roof leaked again and we changed tactics. We took down some 5 cm of the uppermost clay, the layer we had already changed several times, applied a thin polythene film and covered that again with clay. At the same time we set up 4 frames of ca. 1.2x1.2m with various roof layering variations to see if it was possible on this smaller scale to find out which roof solution would be the best. This test is ongoing as the 2015-2016 winter had very little rain, and we shall continue it until a possible next experimental house is built (see below).

From some Bronze Age roofs we know that a drain spout was probably inserted in the edge of the clay construction (Shaw 2004, Lenuzza 2013). After the first heavy rains, and before the last roof layer was compressed, we also inserted a spout into the lowest point of the roof so that the wall below was not soaked and the intense flow speed could not erode the clay any more.

The plaster

When the roof was nearly finished, with the last layers applied parallel to working on the plaster, the roughcast was applied. It was based on a similar mixture as the bricks, although instead of straw we used chaff to prevent the surface from becoming too rough. When that had dried, the final rendering was applied, again containing chaff, but in the finest grade available, with some added lime to give it a harder surface. The cracks in the roughcast were welcome in this case as they provided a better hold for the final rendering (See Figure 24). Both the interior and exterior of the house were treated in the same way.

The chaff provided us with an extra smile as after about 10 days, the seeds remaining in the fine straw started to sprout and covered the walls in a thin green cereal field (visible in Figure 27). Finally, we painted several walls with a traditional (also present in the Bronze Age) mixture of lime and mud, the latter mainly for the colour, but also for extra protection from humidity (See Figure 25).

We treated the surface of the stairs leading up to the entrance in a similar way, as I had noticed that in Malia Quartier Mu some outdoor stairs had also been covered in what looked like a clay surface. Subsequently, I added sand to the surface when wet, as the clay kept turning into sticky mud, but with time - and sand -the mixture improved. Still I believe now that the Quartier Mu steps may well have had a plaster surface heavy in lime and were only coloured to brownish by the many years of use and by being covered deep under brown soil for centuries.

A setback – or was it?

When we finished the house we were well into the rainy season, and by Christmas 2014 the roof and plastered walls had sprouted. As mentioned the dripping from the edge of the overhang above the door produced holes in the clay entrance platform, so I improvised with a few flat pebbles, set where the drip-holes were (See Figure 27), suggesting how stones foreign to the surroundings of Bronze Age houses might turn up in the material record of their surroundings. The rainwater falling from the spout high above the ground splattered back to the wall and left it dirty and wet, so I applied an old trick used in south German farmhouses, where a heap of small stones would be placed underneath the spout to prevent the water from splattering back up – another feature I would not have understood during an excavation until then.

The most dramatic destruction caused by weather conditions came in January, after the first snow, when heavy, driving rain and hail hit the still slightly moist surface of the western side and a whole slab of plaster – roughcast and all –fell off the wall. The originally pristine lime-painted surface was pocked with small holes from the hail just as the unpainted other half of the wall. This was the point where we decided to put to use the extra small beams which we had inserted into the top of the walls for just such an occasion, as I had theorised that some kind of perishable rafters would have been applied in the Bronze Age - not only for protection of the walls from the weather but also for the benefit of the inhabitants who could sit and work outside in the shade. Our rafters were constructed from giant cane and have functioned perfectly since then (See Figure 26).

Since the workers assured me at the time of the damage that it would not make sense to repair the plaster during the rainy season, we left it as it was – and it turned out to be one of the most visited spots of the experimental house, as only at that spot I could actually show visitors in detail the makeup of the walls from mudbrick to plaster. Thus it seems we managed to make the most of the difficult experience, and there has been no other damage since then.

When the whole construction had sufficiently dried out, I also decided on a metal and glass door to be fitted into the Bronze Age simile frame. No Minoan doors have survived the centuries, and the inside of the house would have become rather dark with a massive wooden door. It probably would have only been shut when people went inside their houses to go to sleep, and darkness would not have bothered them. I opted for a clean break from ancient forms, with a door that is obviously modern (See Figures 27, 28).

Future prospects

The experimental house was admired among locals as well as foreign visitors. This produced the idea that an Open-air museum with experimental, life-size reconstructions of houses from the area's past could be an interesting project. We drew plans and even found a suitable plot of land owned by the municipality, which is currently an unused wilderness. We imagined how fascinating it would be to have life-size, archeologically accurate reconstructions not just of Minoan houses from the various Bronze Age periods, but also of houses from the Iron Age, the Roman occupation and Medieval times.

Furthermore we considered workshops where visitors and students could take part in the reconstructions of the houses and their equipment. Re-enactments of diachronic activities like olive oil production, medicinal herb growing and collecting, and even perfume making could also be provided.

Several Universities from various countries and EXARC (International organisation of Archaeological Open-Air Museums and Experimental Archaeology) gave us written support. The locals were ready to house students in the elementary schools which are empty over summer.

Unfortunately, we have been waiting for an answer from the municipality for more than a year now, and even though we did not ask for financial support (an impossible endeavour in these current times of financial crisis) the town fathers/mothers could not make up their minds. Now, by the end of October 2016, they finally decided that they do want such a museum, but on a different plot. While this is currently too small they have decided to buy more land to reach a better size (hopefully finding an acceptable price). As part of the plot seems to be occupied by a small Early Minoan settlement, we might be able to integrate this – and possibly its excavation – into our museum plans however, time will tell.

We are sure that if a plot was available without cost to us, we would be able to finance the project through a combination of international and local support. This would be a natural tourist attraction, and could benefit enterprises such as the local hospitality industry as a whole.

We have not given up yet, although I waited for months to write this article, hoping I would be able to report with more detail on this plan and forthcoming activities. As it is, this shall have to wait for a hopefully more decisive future.

I would like to cordially thank here all my helpers, workers, and supporters in spirit. The experimental reconstruction of a Middle Minoan vernacular mountain house was a great experience!

1 For mudbrick in the Aegean and Crete in general cf. Guest-Papamanoli 1978, in Middle Minoan Monastiraki cf. Como & Marazzi 2006, in Late Minoan Mochlos cf. Soles & Davaras 1994, in Palaikastrocf.Devolder 2006. Detailed analyses in Nodaru et al. 2008. Please note that these excavated sites were all of urban nature.

2 For the directly used, not mixed character of soil in Minoan mudbricks see Nodarou et. al 2008.

3 This was an occasion to enjoy the existence of digital photography which made it possible for me to have now 14.000 photographs, which have at least virtually preserved conditions since then gone forever on several occasions already.

4 A similar (but more severe) damage appeared in the cob experimental house of the Stanley Park Earthen Architecture Project in Vancouver BC at 7.2 Richter, also at first over the door (cf. https://www.youtube.com/watch?v=ChbccUQhpJc at minute 5.00, last seen on 29.8.2016). Cf. also Dimiziania and Ortolani 2014: 6.

5 A very good synopsis of what we do know has recently been achieved by Lanuzza, 2013, an article I unfortunately wasn't aware of when we built the experimental house, although it would not have changed our decisions.

6 It might be interesting to study if any such drip-holes are visible in known archaeological floors.

Keywords (re)construction
construction of building

Country Greece

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Gallery Image

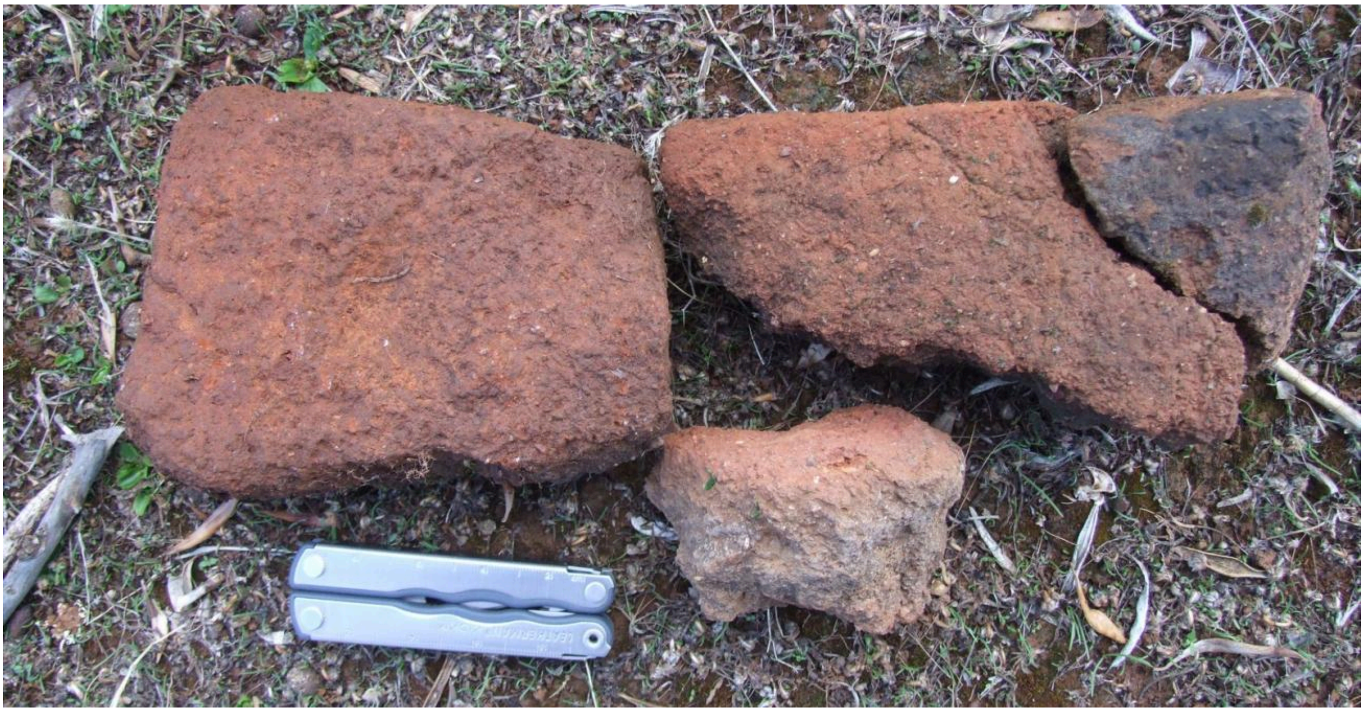

FIG 1. ACCIDENTALLY FIRED FRAGMENTS OF MUDBRICK AT A MIDDLE MINOAN SITE – NOTE THE DIFFERENCES IN COLOUR

FIG 2. MIDDLE MINOAN ONCOLITHIC SITE, GOATS STANDING ON THE HORIZONTAL LEVEL OF THE RUIN INDICATING STEEPNESS OF SLOPE.

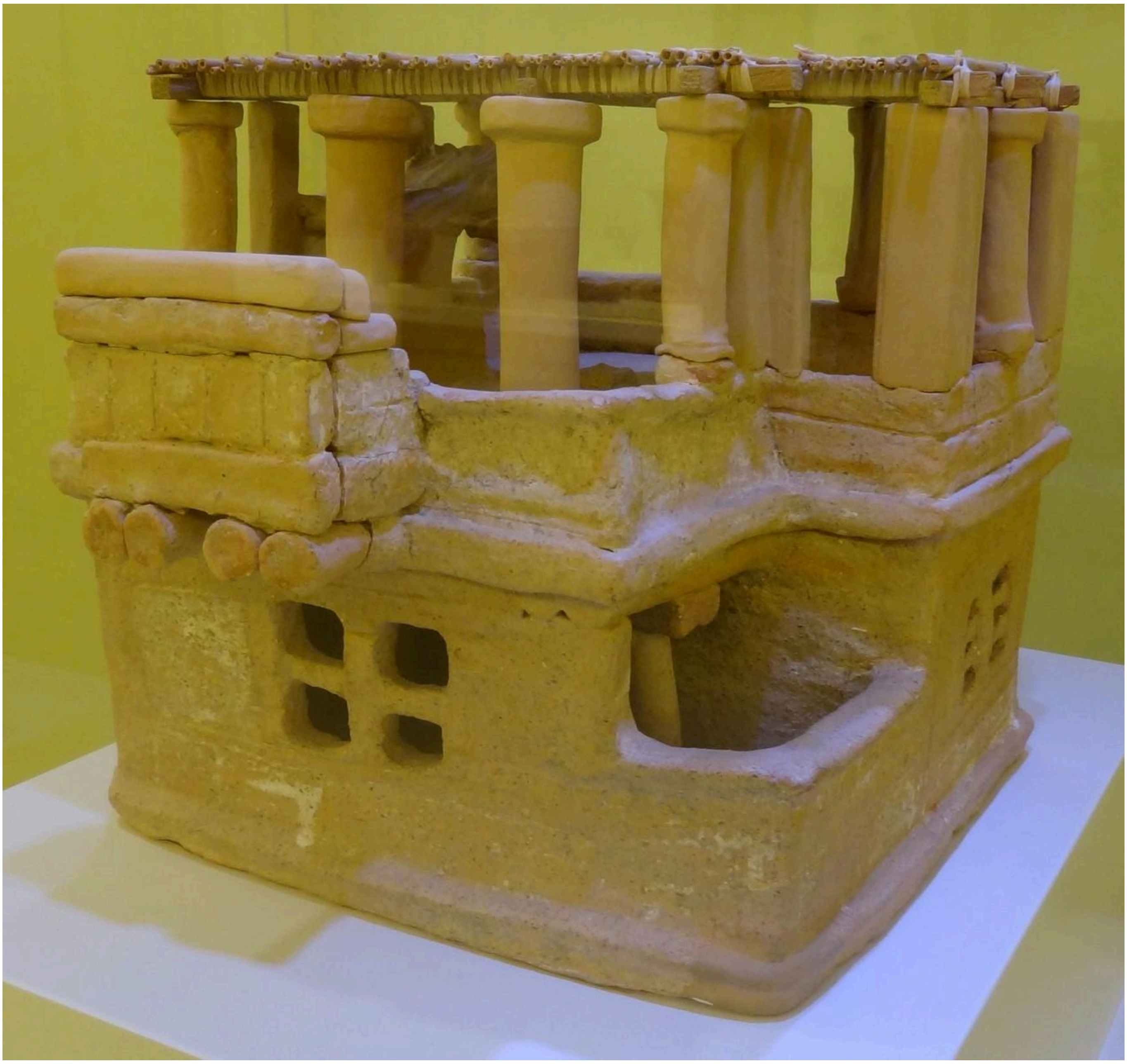

FIG 3. LATE MINOAN HOUSE MODEL FROM ARCHANES (HTTPS://COMMONS.WIKIMEDIA.ORG/...)

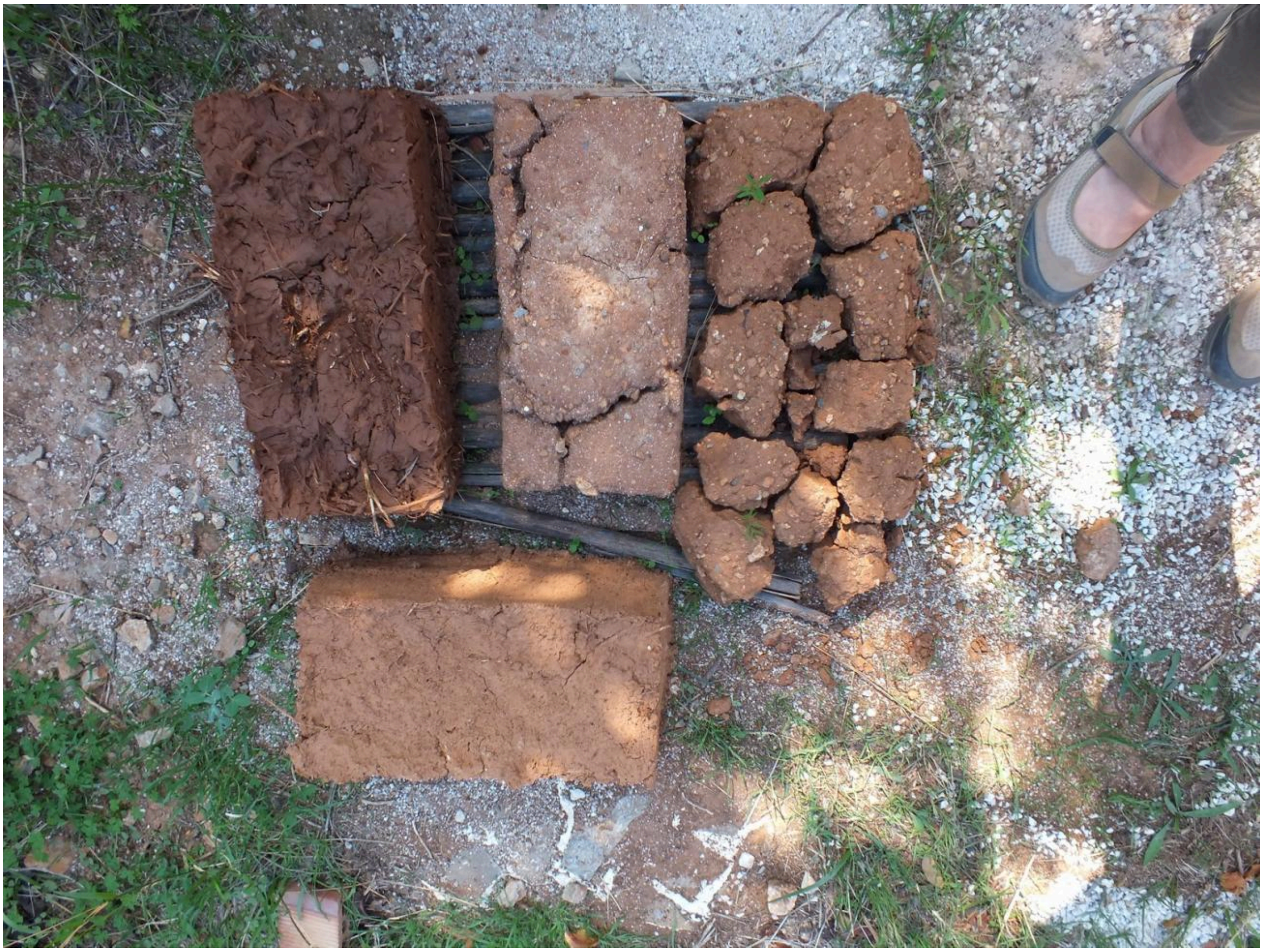

FIG 4. TEST BRICKS (FROM TOP LEFT): STRAW, SAND, PLAIN, PINE NEEDLES (CA. 4 WEEKS OLD)

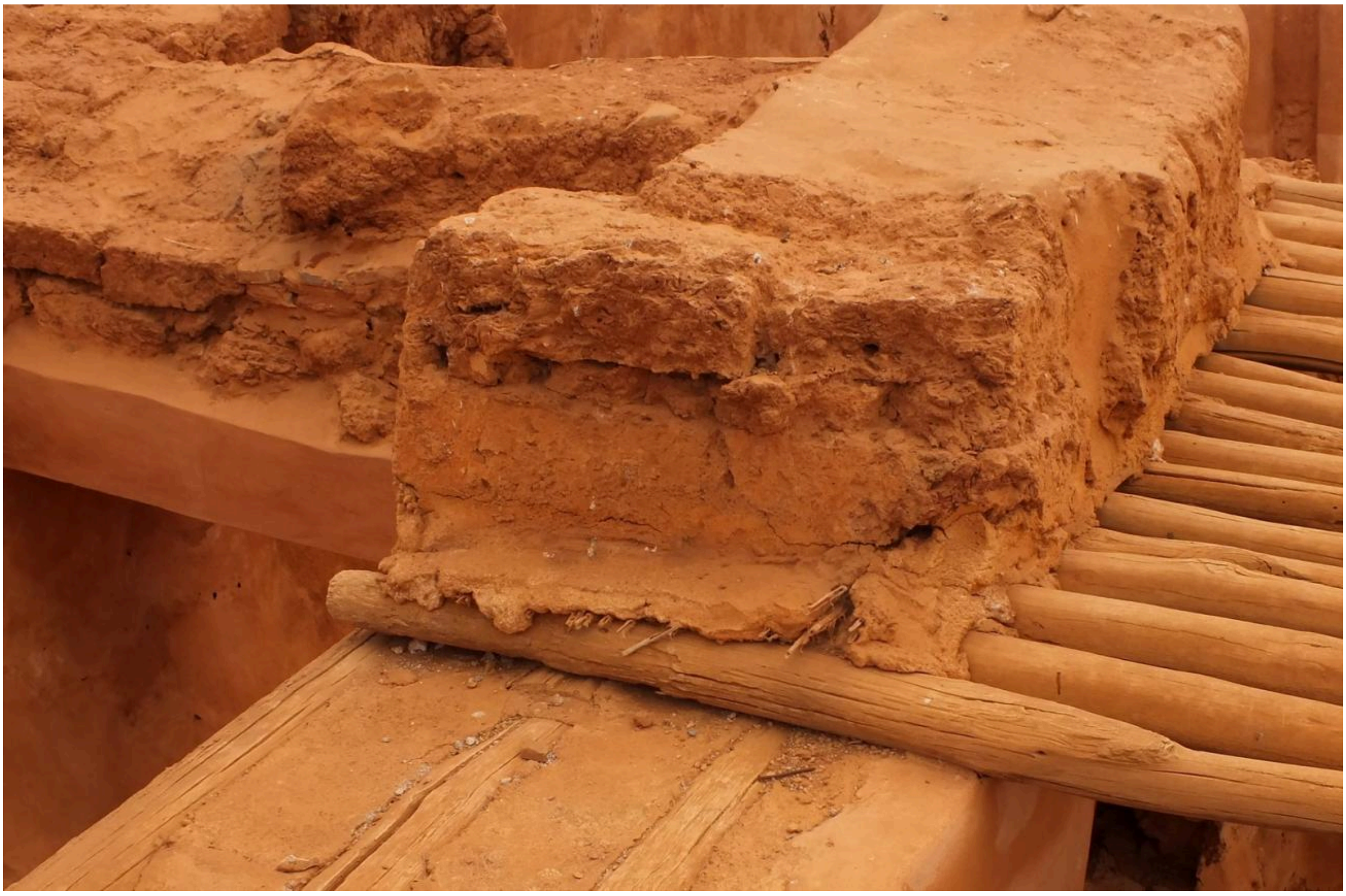

FIG 5. MUDBRICKS IN QUARTIER MU, MALIA (THE BEAMS – HERE AS FLOOR BASE FOR THE SECOND FLOOR - ARE RECONSTRUCTIONS FILLING THE VOIDS PRESERVED IN THE MUD PARTS OF THE RUINS). HEADERS AND STRETCHERS SEEM TO BE RANDOMLY MIXED.

FIG 6. MALIA QUARTIER MU MUDBRICK WALL WITH SEVERAL PERPENDS ALIGNED.

FIG 7. MALIA QUARTIER MU MUDBRICK WALL WITH OFFSET PERPENDS.

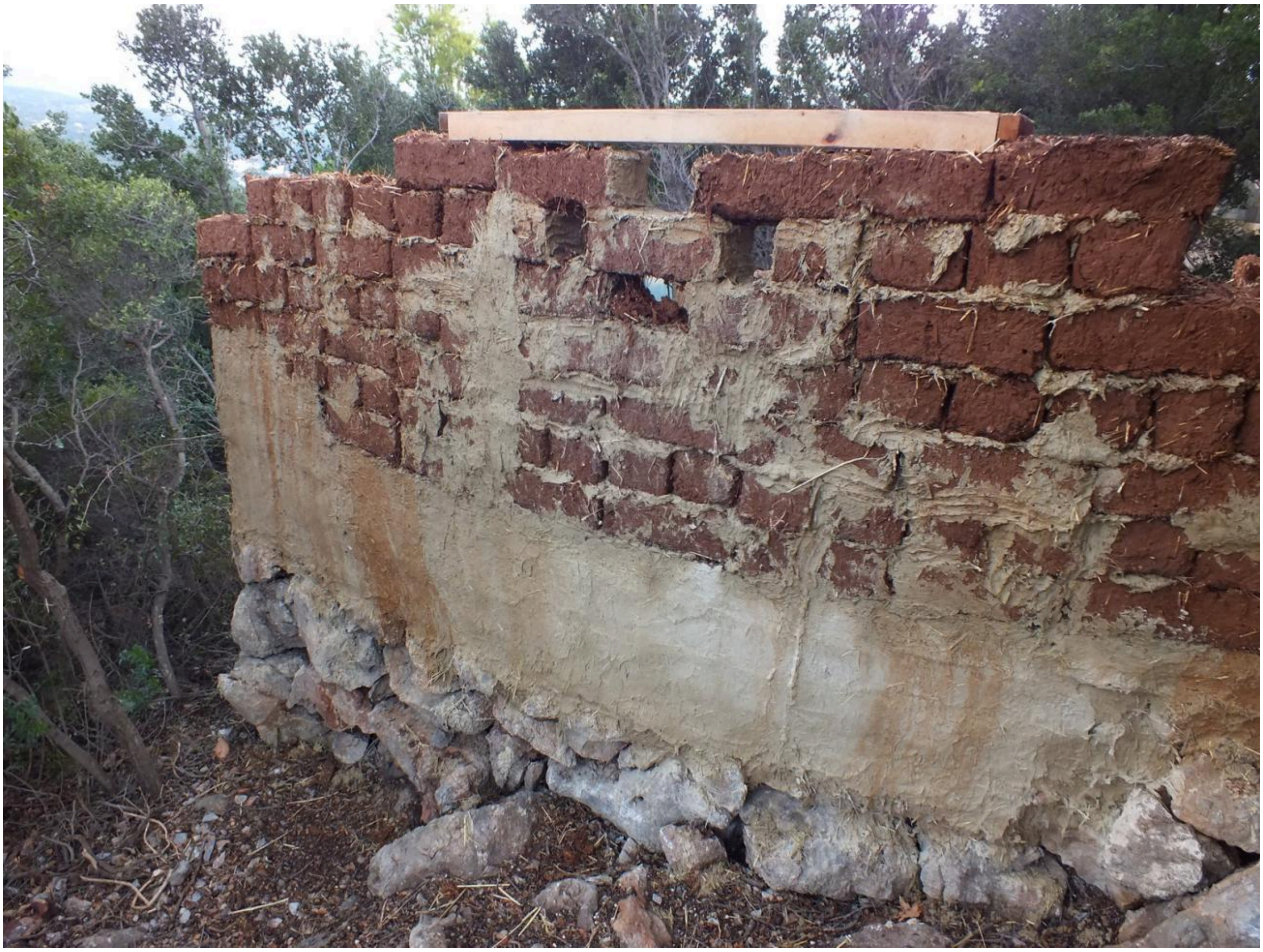

FIG 8. THE SOUTHERN WALL WITH THE “WINDOW” DURING THE FIRST RAIN, BRICKS BROWN, MORTAR AND PLASTER BEIGE, THE SLIGHT AMOUNT OF BRICK DISSOLVED BY RAIN IS VISIBLE AS DARKER STAINS ON THE BEIGE SURFACE (PRODUCED DURING CLOSING PERPENDS). THE FOUNDATION STONES ARE NOT FILLED IN.

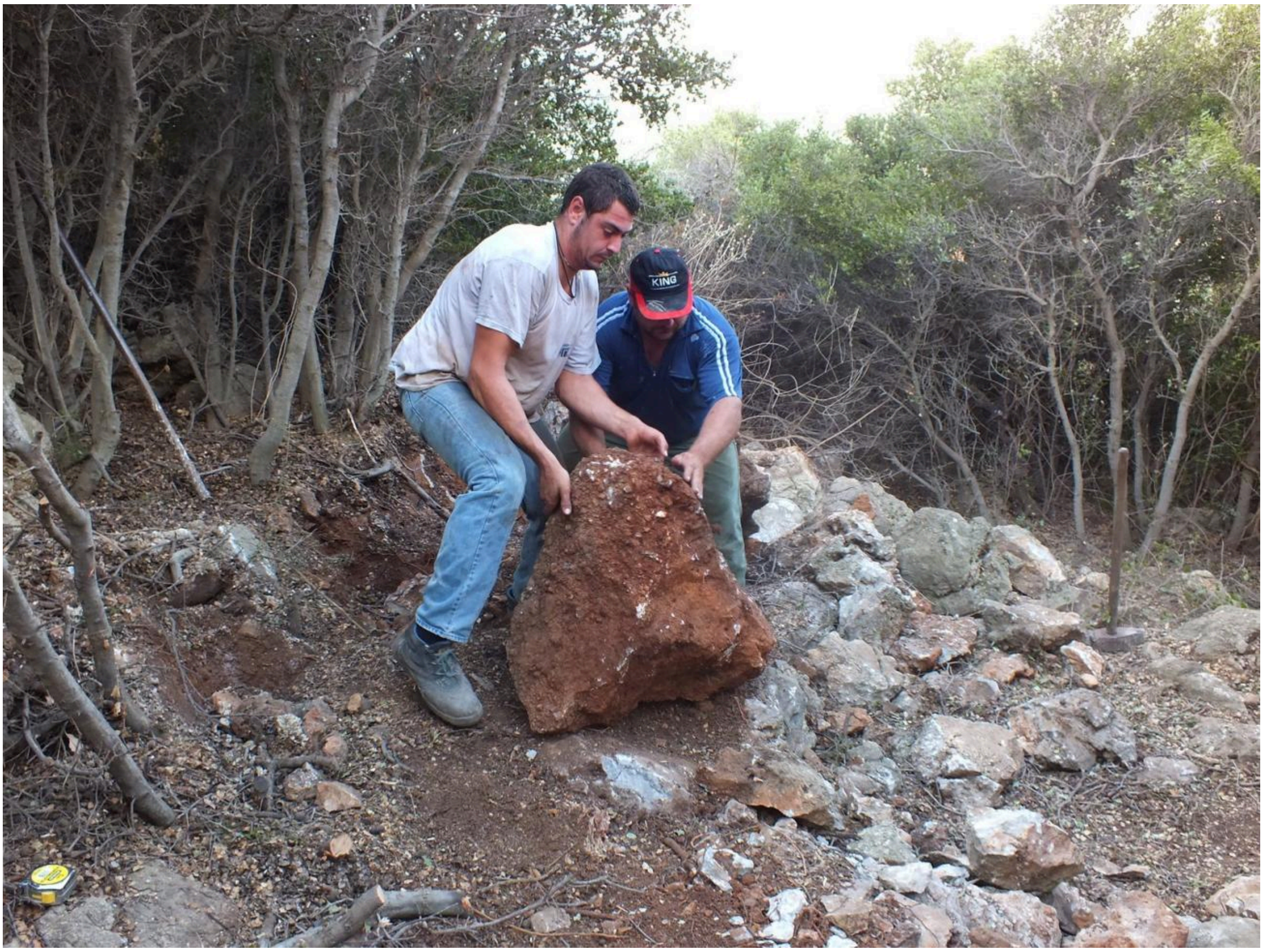

FIG 9. MOVING ONCOLITHIC BLOCKS FROM THE UPPER LEVEL OF THE LATER FOUNDATION. UPSLOPE WORKING DOES NOT SEEM LIKE AN OPTION.

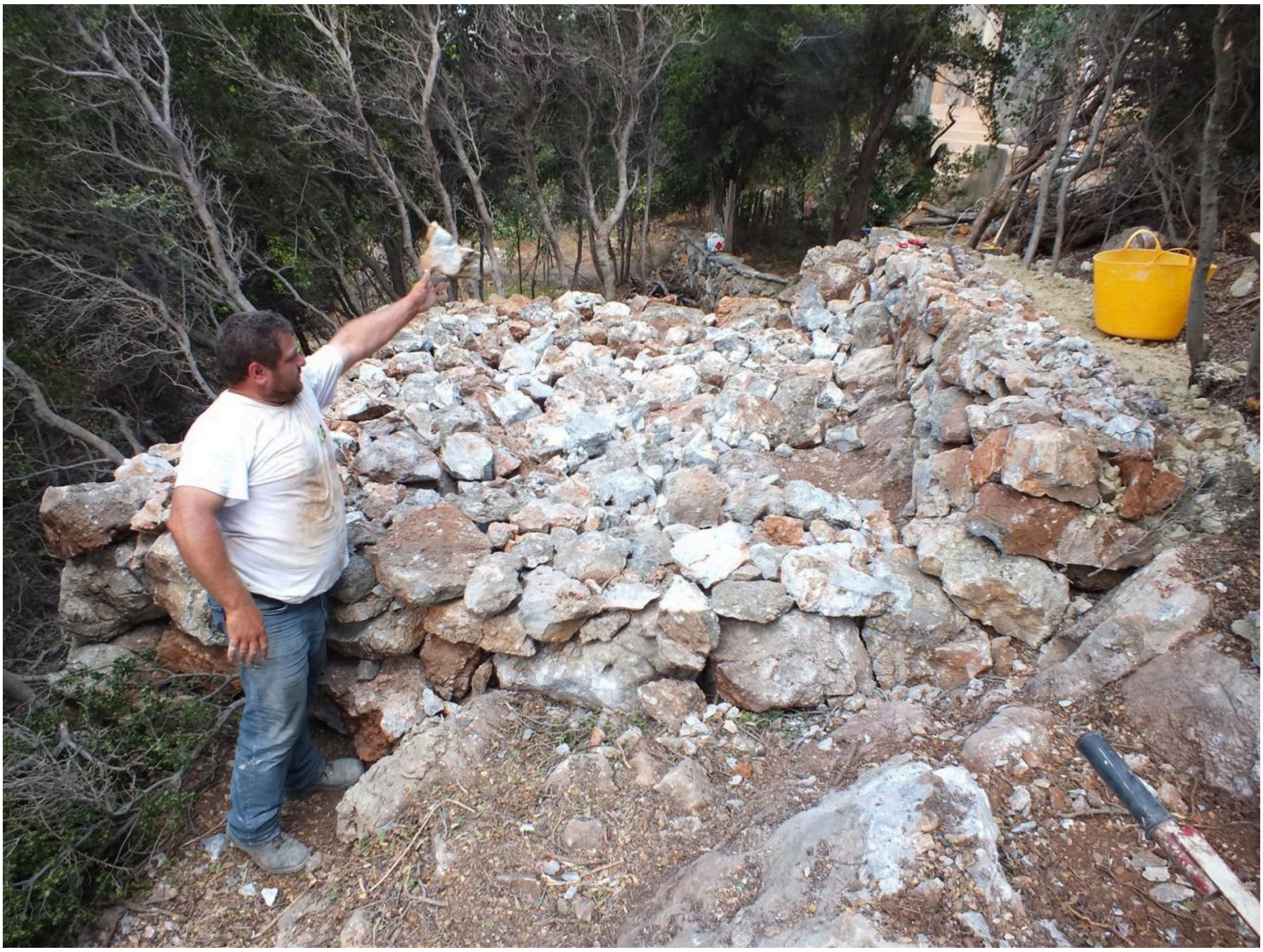

FIG 10. FILLING THE ONCOLITHIC FOUNDATION WITH RUBBLE AND THE UPSLOPE SIDE WITH WATERPROOFING CLAY OVER RUBBLE.

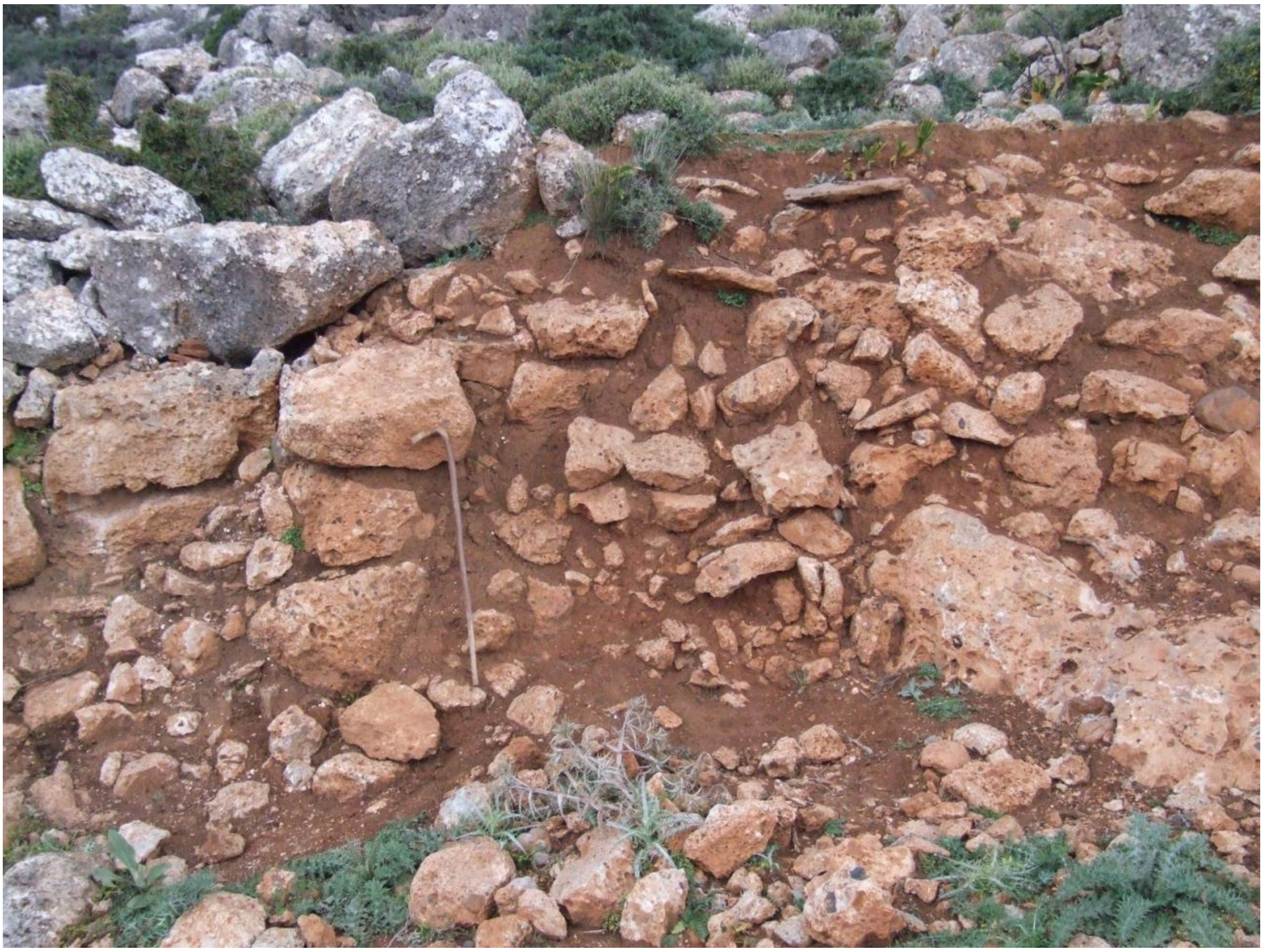

FIG 11. UPSLOPE PART OF A MIDDLE MINOAN RUIN ACCIDENTALLY CLEANED BY BULLDOZER (2008). THE SLABS IN THE SOIL RIGHT OF THE BIG FOUNDATION BLOCKS NEAR TO THE MODERN SURFACE MUST HAVE BEEN PART OF AN ANCIENT DRAINAGE CONSTRUCTION (CHANNEL?), MAY BE EVEN IN TWO PHASES. NOTE ALSO THE FILLING OF SMALL RUBBLE (FOR DRAINAGE AS WELL?) UNDERNEATH AND THE DEEP-REACHING FOUNDATION BLOCKS UNDER THE BUILDING'S CORNER (AT WALKING STICK, 90CM HIGH FOR SCALE).

FIG 12. FINISHED MUDBRICKS WITH THE MOULD (CENTRE RIGHT) AND ITS LID THAT ALLOWED FOR EASIER PRESSING OF THE BRICK FROM THE MOULD (ON BOTTOM RIGHT BRICK).

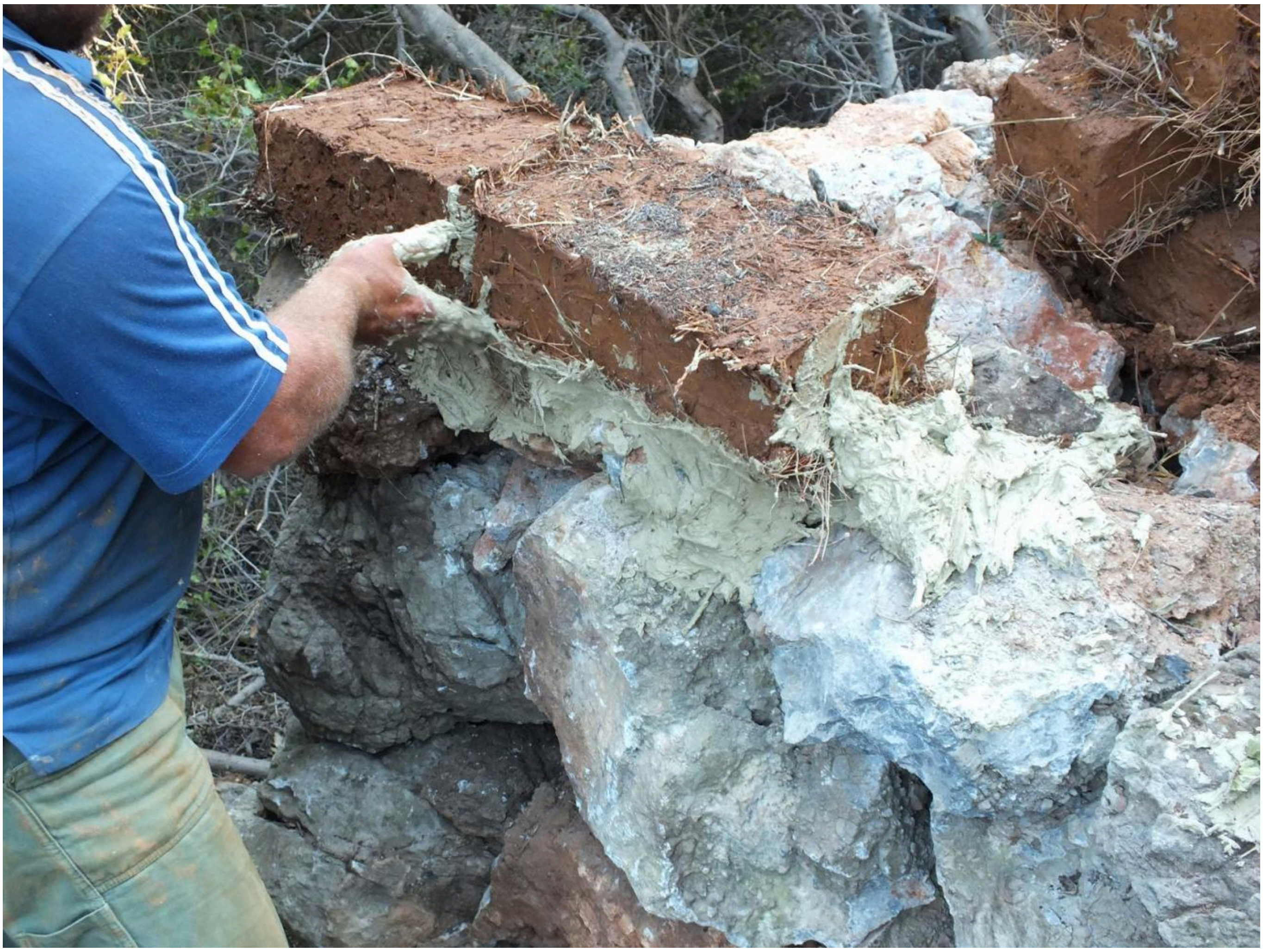

FIG 13. THE FIRST LAYER OF TWO DAY OLD MUDBRICKS, USING KOUSKOURAS-BASED MORTAR MIXED WITH FINER STRAW.

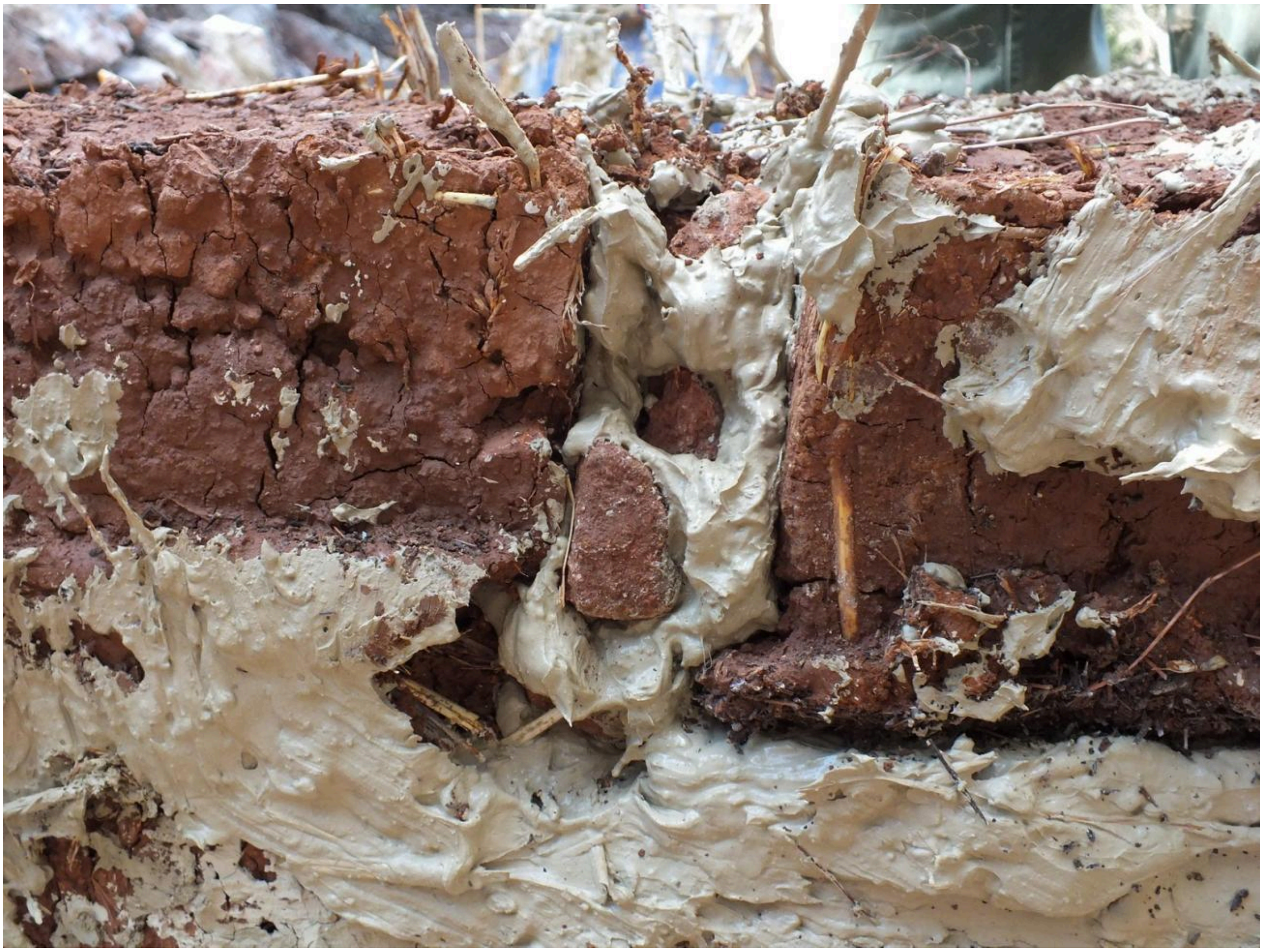

FIG 14. MUDBRICK WALL WITH KOUSKOURAS MORTAR USING ADDITIONAL STONES TO FILL GAPS.

FIG 15. MUDBRICKS WITH CUT EDGES TO PROVIDE A BETTER BONDING WITH THE DOOR CASING.

FIG 16. MINOAN STYLE "WINDOW" CREATED BY SPACING A SINGLE ROW OF BRICKS.

FIG 17. RAISING THE MUDBRICK WALLS -HEADER AND STRETCHER ALTERNATING- BUT NOT BY LAYER. THIS FIRST RAIN CAME EARLY IN 2014.

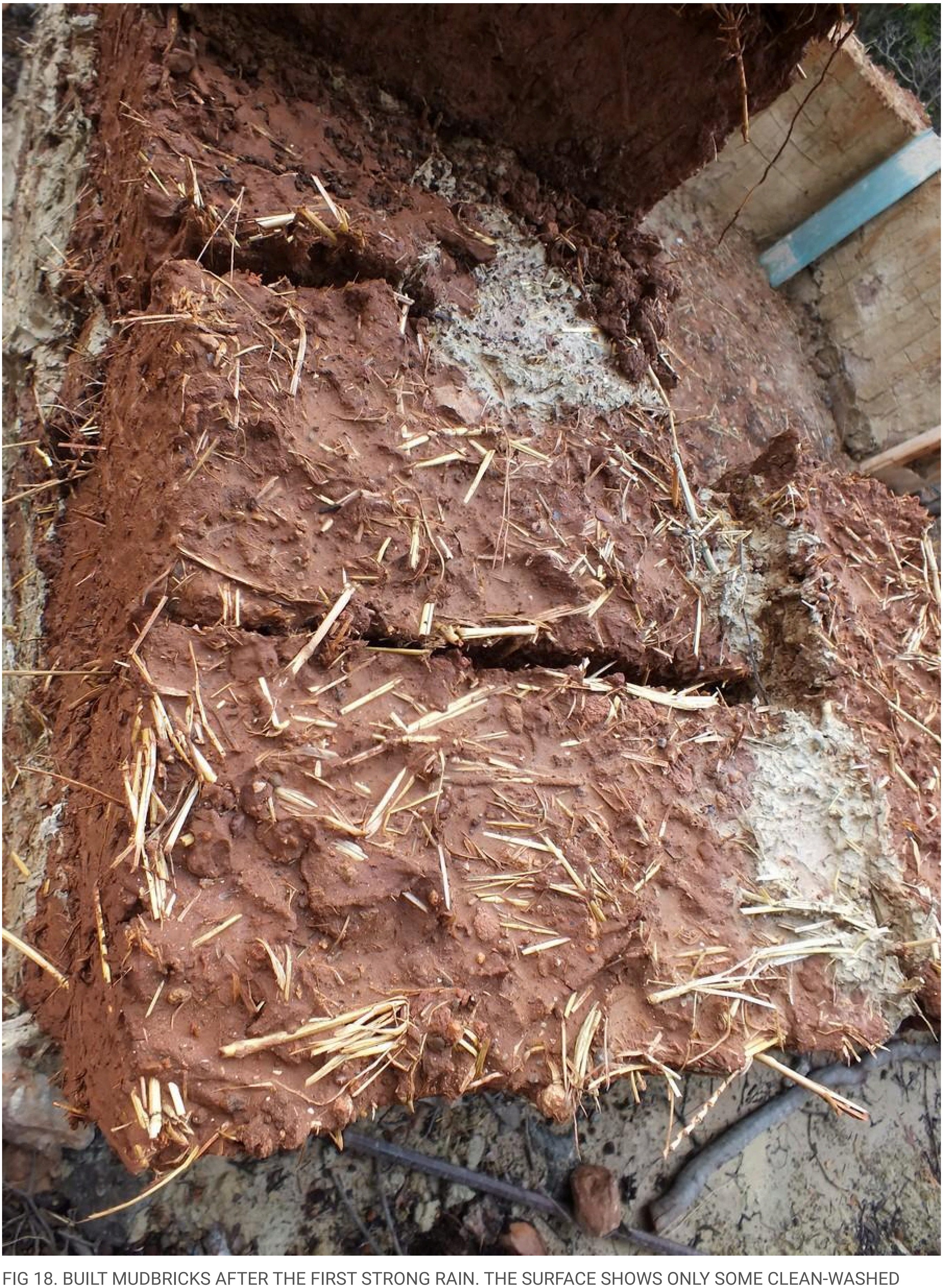

FIG 18. BUILT MUDBRICKS AFTER THE FIRST STRONG RAIN. THE SURFACE SHOWS ONLY SOME CLEAN-WASHED STRAW HAULMS.

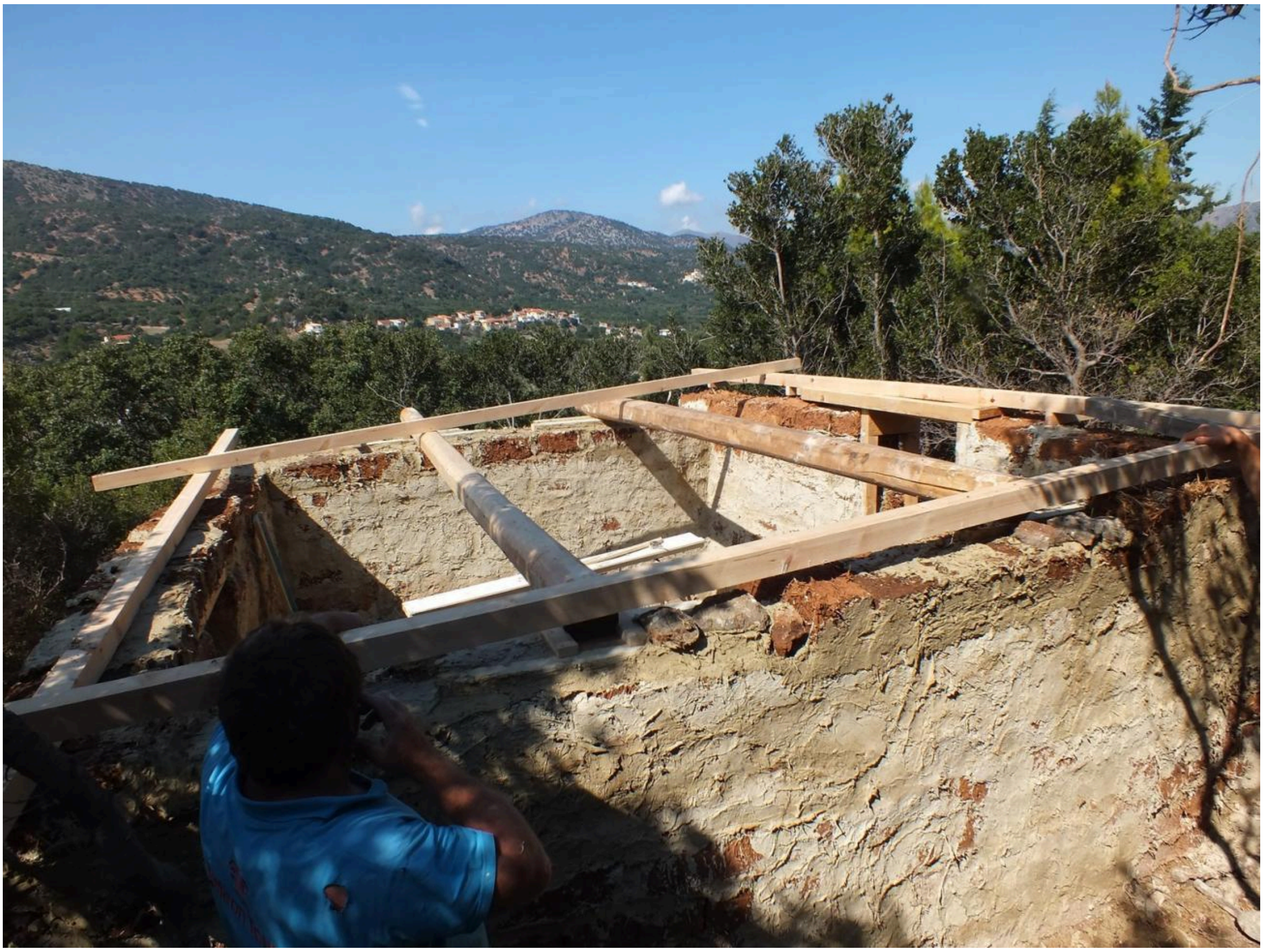

FIG 19. THE BASIC ROOF CONSTRUCTION - BEAMS BEDDED IN COB WITH A RINGBEAM ON TOP. THE SPACES UNDERNEATH ARE LATER FILLED WITH COB.

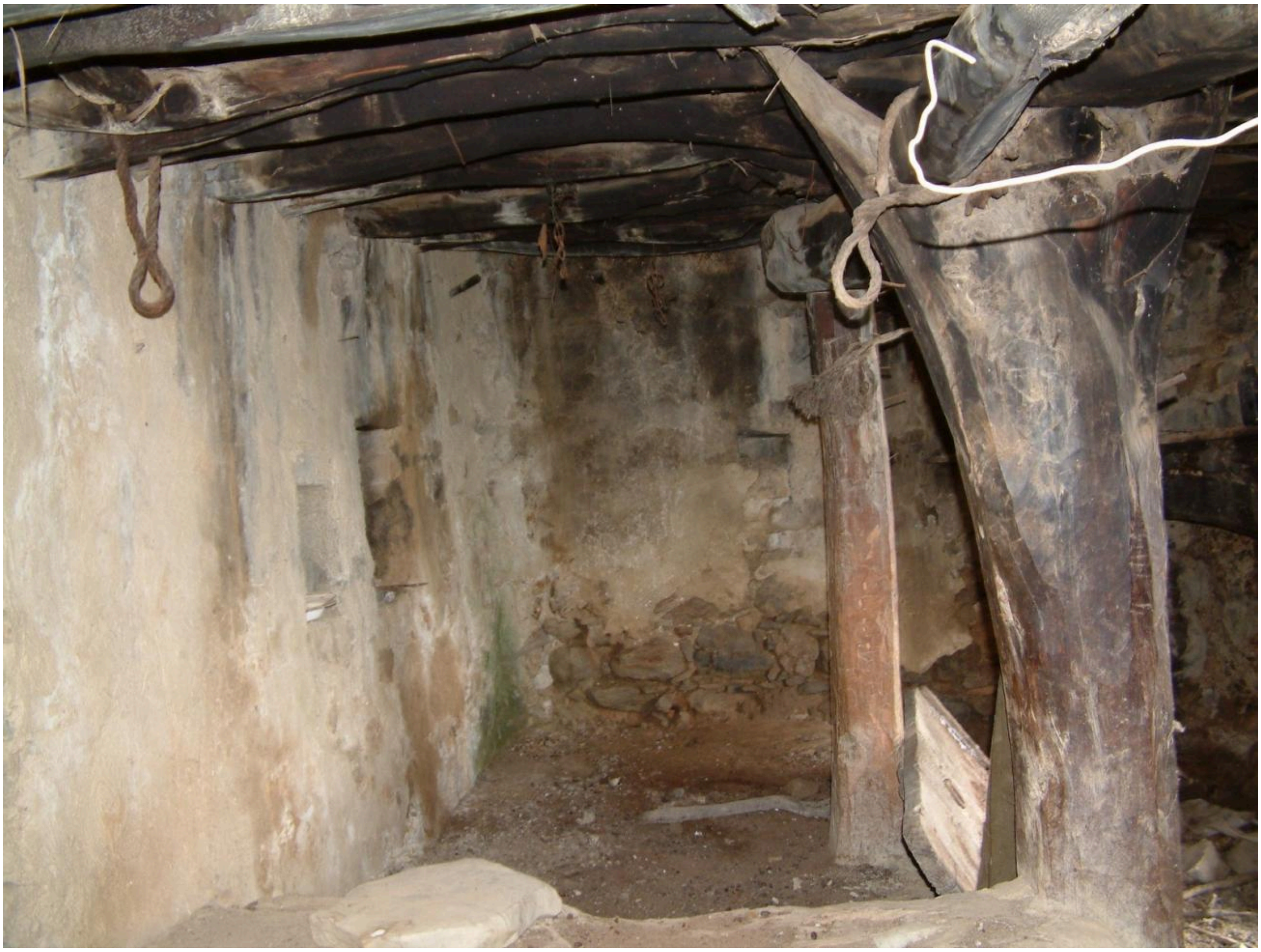

FIG 20. TRADITIONAL CRETAN ROOF CONSTRUCTION - THE TIMBER IS HERE PROBABLY OAK (SOOT-BLACKENED).THE WALLS ARE RUBBLE BUILT WITH MUD MORTAR, MUD PLASTER AND LIME PAINT.

FIG 21. LAYERING IN A TRADITIONAL CRETAN ROOF (CURRENTLY CRUMBLING). ALL THE VISIBLE LAYERS WERE AT SOME POINT TOPPED WITH CEMENT WHICH PRESERVED THE STRATIGRAPHY USUALLY LOST.

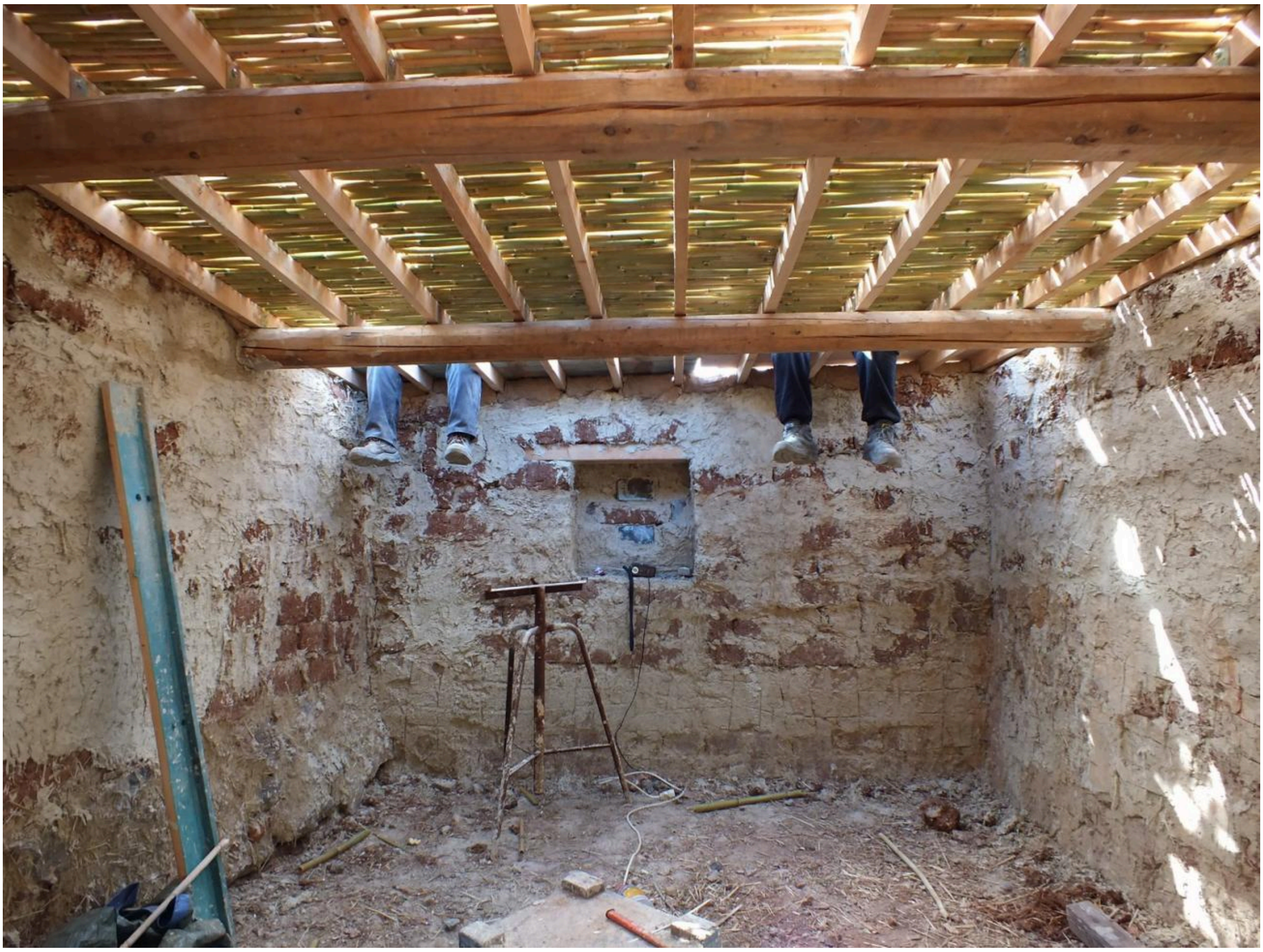

FIG 22. THIN BEAMS AND GIANT CANE AS FIRST ROOF LAYERS OVER THE MAIN BEAMS.

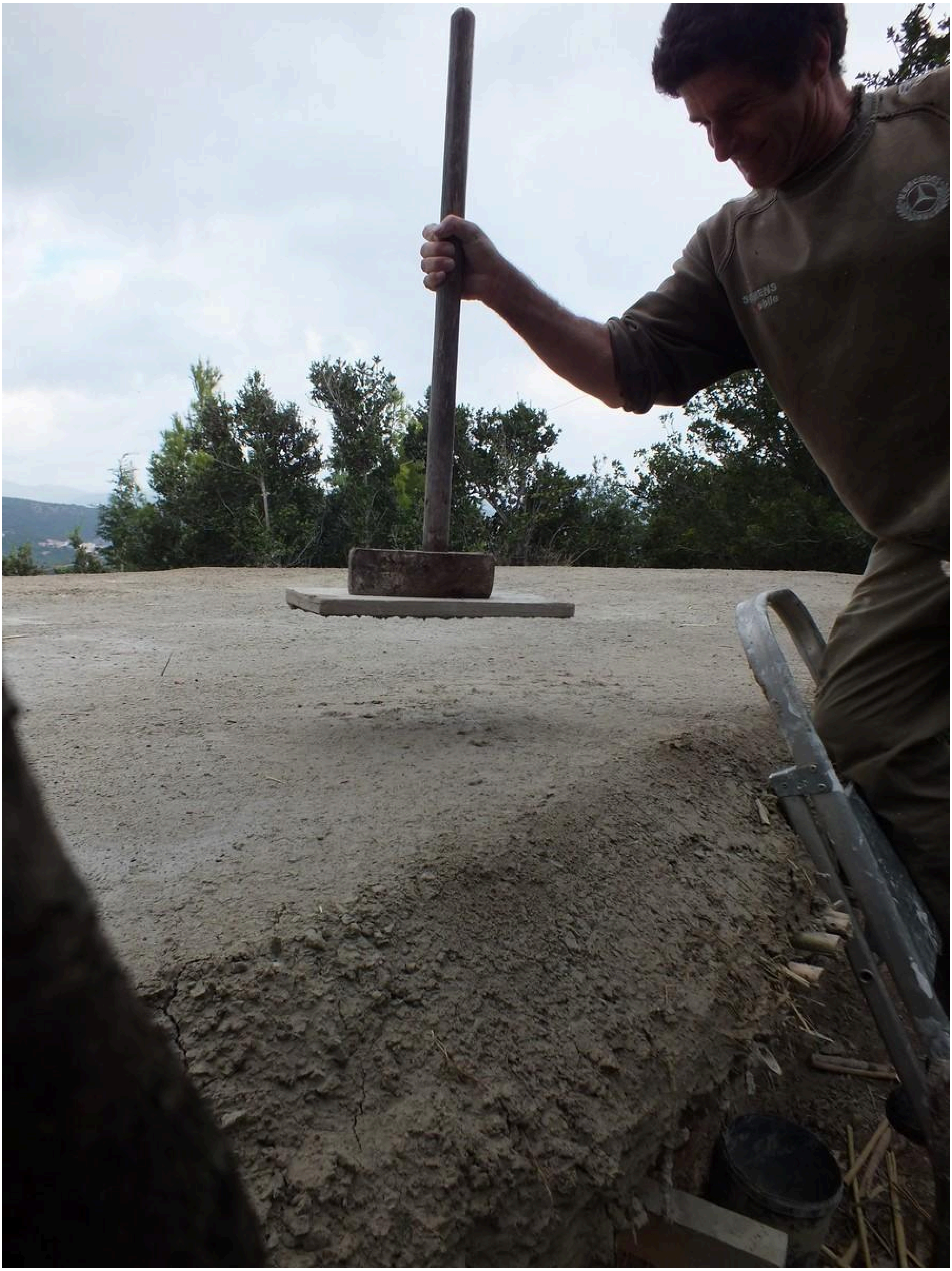

FIG 23. COMPRESSING THE LAST ROOF LAYER.

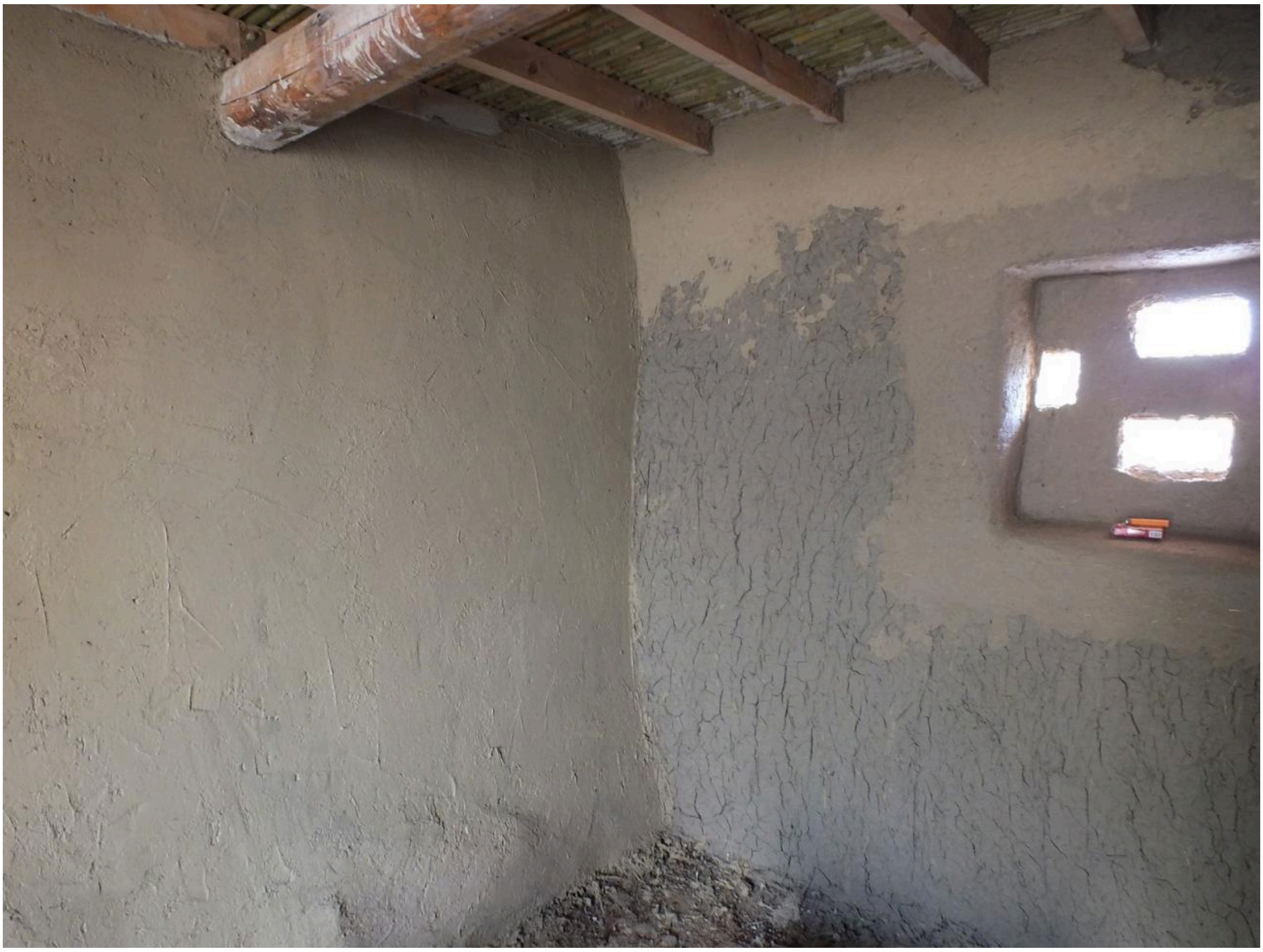

FIG 24. ROUGHCAST AND FINAL RENDERING OF THE PLASTER.

FIG 25. THE WEATHER SIDE WALL AFTER FINISHING IN FALL 2014.

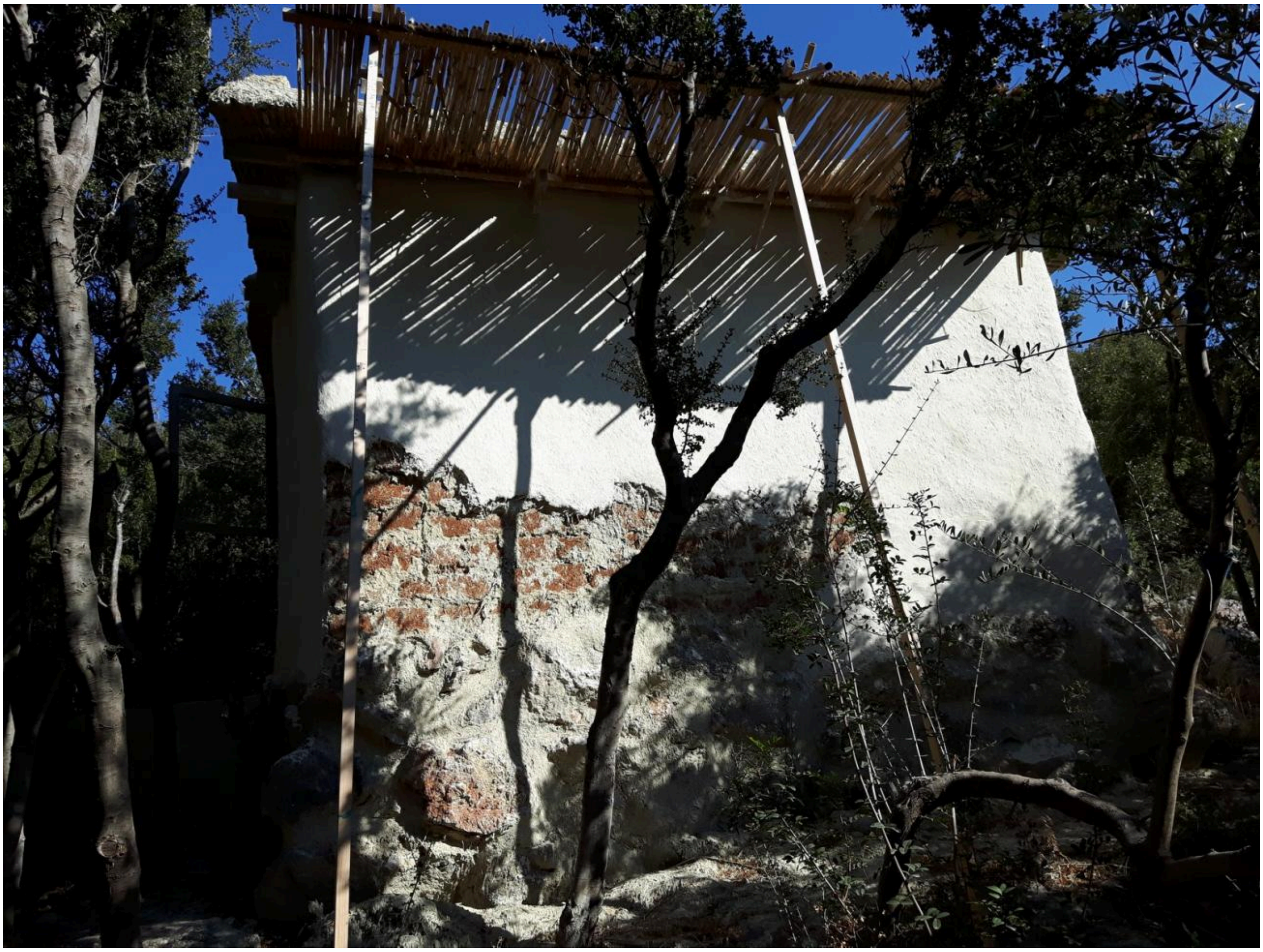

FIG 26. THE WEATHER SIDE WALL SINCE THE DAMAGE IN JANUARY 2015 WITH THE GIANT CANE RAFTERS PROTECTING THE WALL FROM FURTHER HARM.

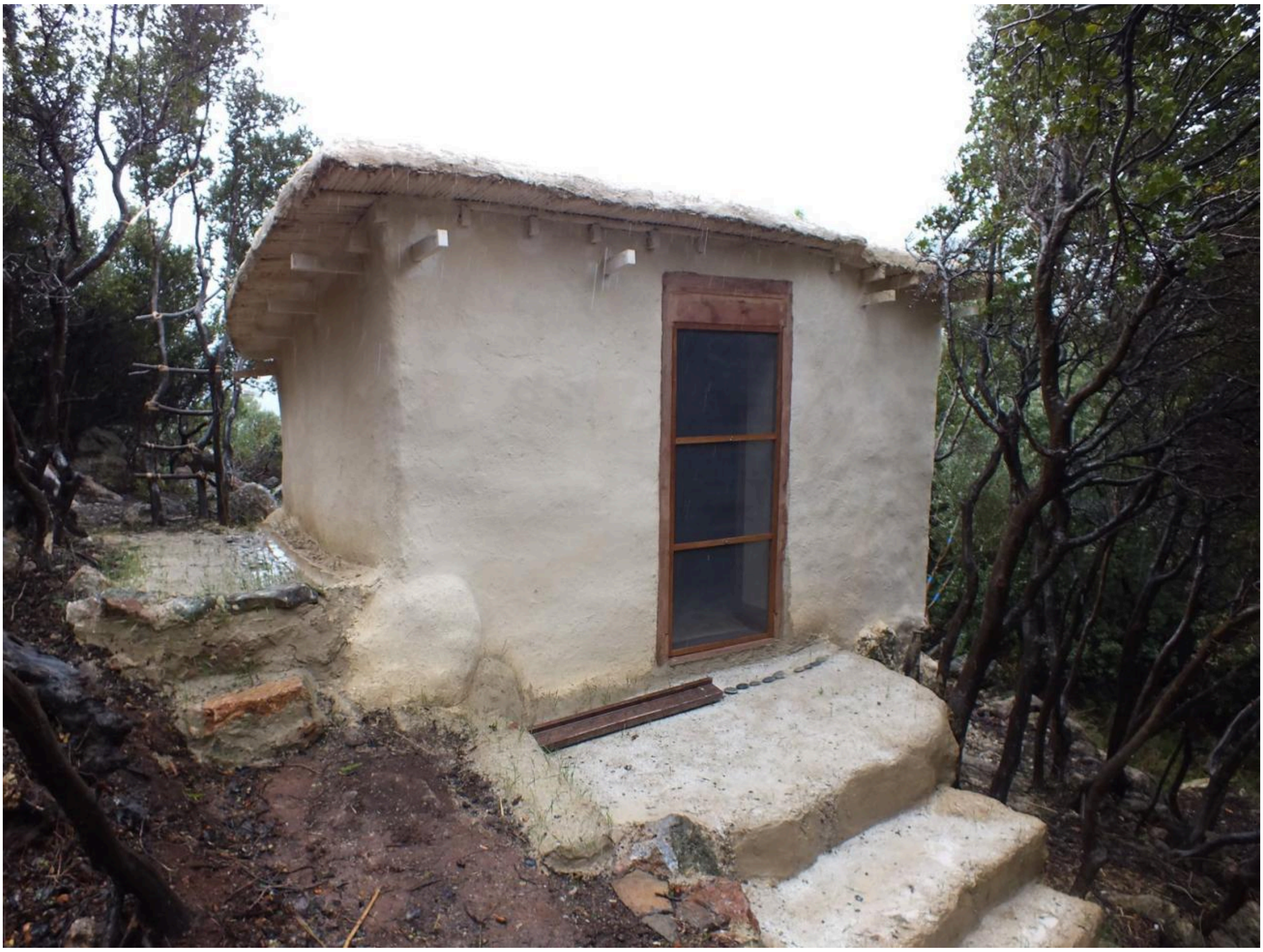

FIG 27. THE EXPERIMENTAL HOUSE JUST FINISHED WITH ITS TREE LADDER TO GET ON THE ROOF, THE DRAIN, THE PEBBLES UNDER THE DRIPPING RAFTERS AND THE PRELIMINARY DOOR, 12/2014. ON VARIOUS SURFACES CEREALS CAN BE SEEN SPROUTING FROM THE CLAY-CHAFF MIXTURE.

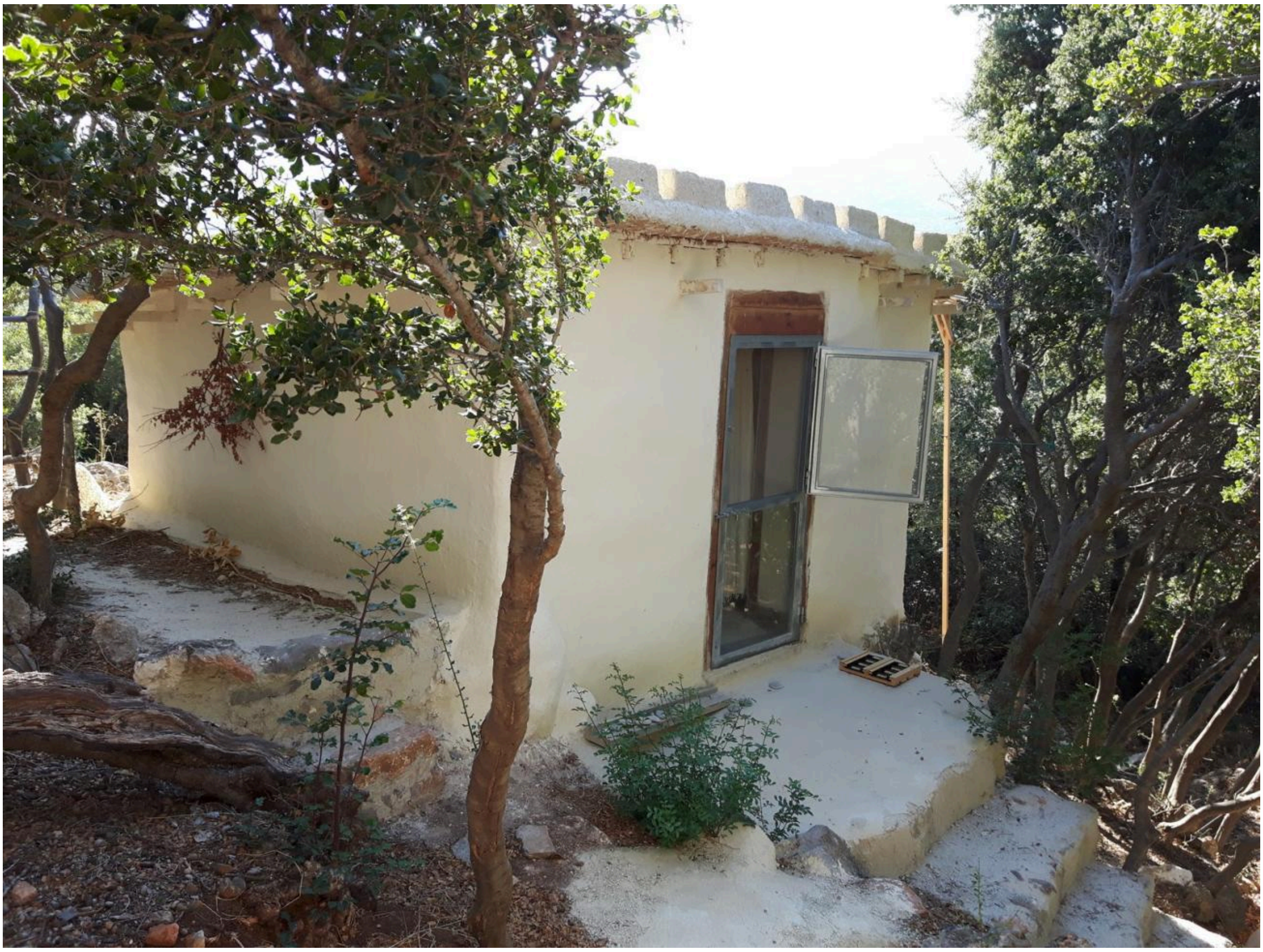
FIG 28. THE HOUSE IN 8/2016, WITH ITS METAL DOOR AND THE "PARAPET" MADE OF SOME REMAINING MUDBRICKS.