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ORIGINAL PAPER

Mud-brick composition, archeological phasing and pre-planning in Iron Age structures: Tel ‘Eton (Israel) as a test-case

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Abstract The eighth century BCE city at Tel ‘Eton (Israel) was destroyed by the Assyrian army, probably during Sennacherib’s campaign of 701. Building 101, sealed within the heavy conflagration caused by this destruction, was uncovered almost in its entirety on the top of the mound. From the beginning, it was apparent that the structure had two major building phases, and while its initial construction was of high quality, later additions were much inferior. Analyses of mud-brick walls for firing temperatures, texture, carbonate content, color, and dimensions approved the observation regarding the differences between the two phases, but consistently pointed out that one wall, initially attributed to the first phase, was analytically different, comprising an intermediate phase. This conclusion not only altered our understanding of the building construction, adding heretofore unknown building phase, but also gave us insights into the pre-planning of Building 101, indicating that some rooms had originally two doorways. Such a configuration allowed easy subdivision of spaces according to needs, without harming the overall structural stability. Differences in inner division of similar Iron Age houses were identified in the past and were attributed to differences in the life cycles of families. The evidence from Tel ‘Eton suggests that such future changes were taken into considerations when the structures were built.

Keywords Tel ‘Eton · Mud-bricks · Four-room house · Iron-age · Israel · Planning

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Introduction

Architecture, and especially domestic architecture, is a major field of inquiry within archeology (e.g., Kempinski and Reich 1992; Lawrence and Low 1990; Parker Pearson and Richards 1994; Wright 1985), and building materials and technology also had their share of scholarly attention (e.g., Adam 2005; Nicholson and Shaw 2000; Wright 2000). The discovery of well-preserved Iron Age II architectural remains at Tel ‘Eton, Israel, enabled us to conduct a detailed study of various aspects of those buildings, their construction, and destruction; special attention has been devoted to building materials, including mud-bricks, which were used for the construction of the houses. The mud-bricks were subsequently studied as to their texture (grain size distribution), size, firing temperatures, carbonate content, color, and more. Surprisingly, this “technical” study, and the analytical examination of the material, altered our understanding of the relative dating of the constructional phases of the building, and even gave us insights into the cognition of the planners and the pre-planning of one of the buildings, and by extension to that of Iron Age houses at large.

Tel ‘Eton

Tel ‘Eton is a large mound in the southeastern Shephelah (lowlands), Israel, about 11 km southeast of Tel Lachish, near the trough valley that separates the lowlands from the Hebron highlands (Fig. 1). The site, which is commonly identified with the biblical city of Eglon (Joshua 10:34–36, 12:12, 15:39), is located near a major road junction, where the north-south road that meandered along the trough valley met the east-west road that passed along Nahal Adoraim (the brook of Adoraim) and connected Lachish and Hebron, and in proximity to good agricultural land. Brief salvage

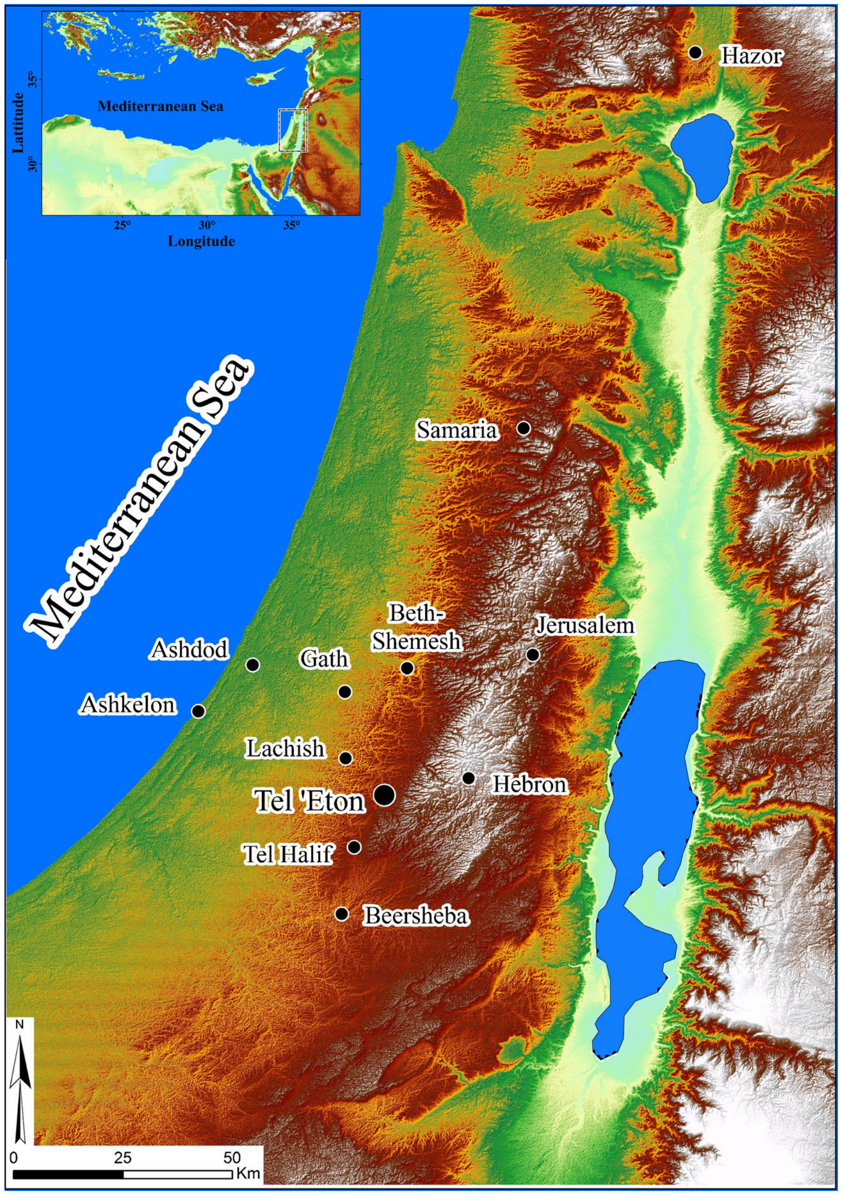

Fig. 1 Map of the eastern Mediterranean (*inset*) and location of Tel ʻEton. Base map uses ASTER Global DEM data. ASTER GDEM is a product of METI and NASA

excavations were conducted at the site in the 1970s by the Lachish Expedition (Ayalon 1985; Zimhoni 1985), exposing two Iron Age II strata. Since 2006, the site has been excavated by a Bar-Ilan University expedition. The results indicate that the mound was settled during the Early Bronze Age, and from the Late Bronze Age to the early Hellenistic period (with a gap during the seventh-fifth centuries BCE). The main period of settlement encountered so far is that of the eighth century BCE (Iron Age IIB), when a large, fortified Judahite town thrived on the mound (Faust 2011, 2014; Faust and Katz 2015). This city was violently destroyed toward the end of this century. The destruction sealed the houses and their content within a massive destruction layer, preserving the remains in an excellent condition. The rich ceramic assemblage unearthed, along with the relevant historical documents, suggests that the city was most likely destroyed during the campaign of the Assyrian king, Sennacherib, in 701 BCE (Faust 2011, 2014; Faust and Katz 2015; Katz and Faust 2012; for a detailed discussion of the campaign, with many references, see Faust 2008).

Building 101

Near the southern edge of the mound, on its highest part, we uncovered parts of a few eighth century BCE buildings. The largest of those was Building 101 (Fig. 2). This is a large four-room house (see explanation below), whose estimated ground floor area is about 230–240 m^2 (most urban Iron Age dwellings in the region were in the scale of 40–70 m^2, and the larger ones tended to be in the scale of 120 m^2, exemplifying the relative large size of the discussed building). Massive work preceded the construction of the building, and in the few

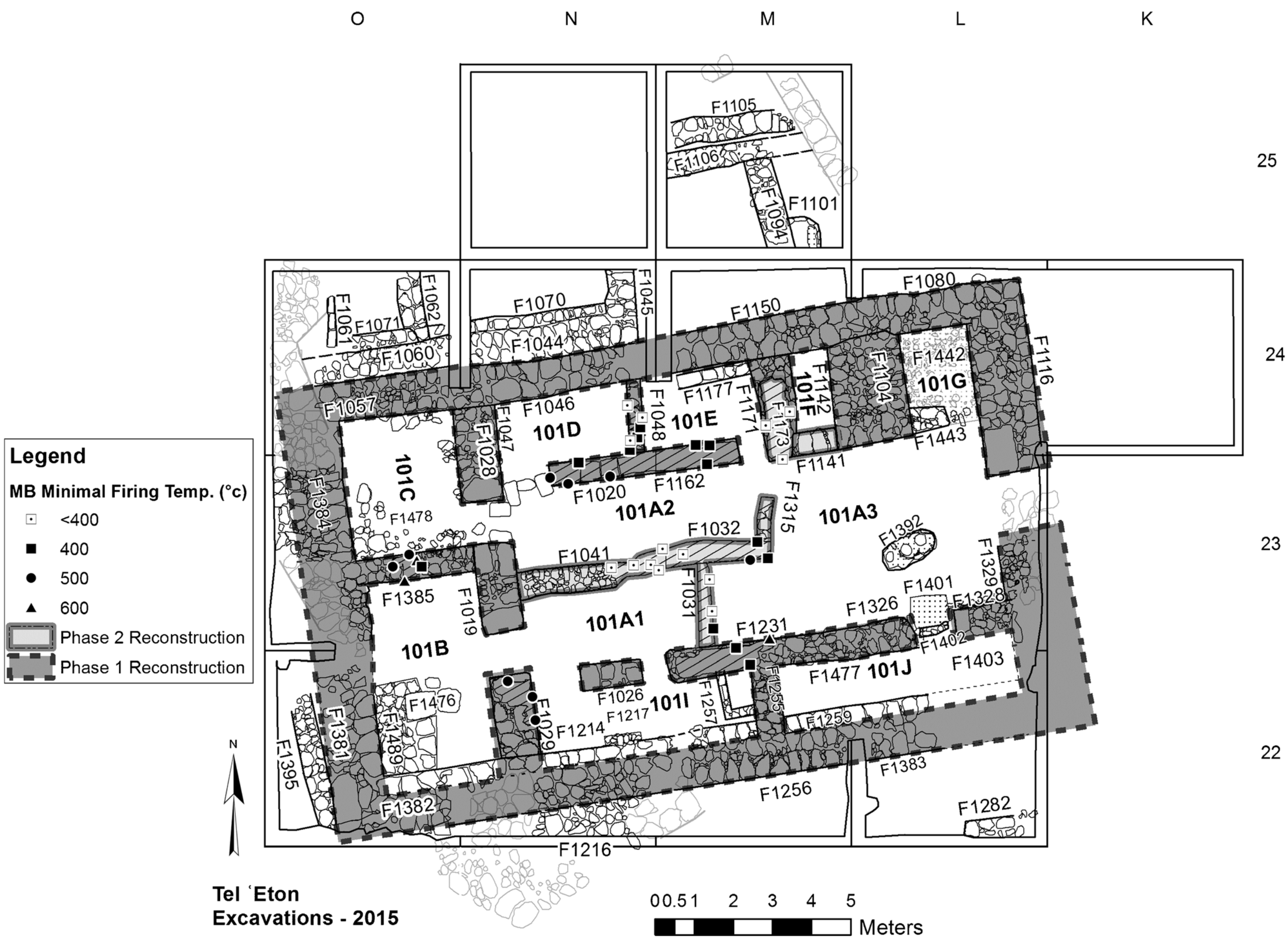

Fig. 2 Building 101. The lower courses of walls F1020/F1162, F1231, F1385, and F1029, from phase 1, are made of stone. Wall F1048 was estimated to be of the same phase, though it lacks stone courses. Walls F1031, F1032/F1041, and F1315 are thinner walls from the structure's later stage (phase 2). Wall F1173 was included in phase 2 because it used similar mud-bricks and is clearly later than the original construction, but it lacks clear association with phase 2 walls. The sample locations with representation of the FTIR analysis results are presented on the plan. For additional information, see discussion in the text

places where we penetrated below the floors, we uncovered evidence of massive preparation work, sometimes reaching 1 m deep; even below the courtyard, chalk plates were positioned below the floor. The use of continuous foundations, massive walls, ashlar stones in corners and doorways, along with the quality of the mud-bricks (to be discussed below) are also quite impressive, and are extraordinary when compared with other Iron Age II buildings at Tel 'Eton and in other sites. The distribution of the finds and the evidence for second story floors that were unearthed in most of the rooms suggest that an upper story was built over part of the structure (Faust 2011; Faust and Katz 2015). The structure is located in the highest point of the mound and controlled most of the city and much of its surroundings, including the fields in the valleys around the mound, and segments of the roads that passed nearby. The finds within the building include dozens of storage vessels, and additional evidence for the storage of food surpluses, along with a small collection of bullae, sealings, and a seal, attesting some administrative activity. Thus, the size of the building and its location, along with the quality of the construction and the finds unearthed in it, led us to label it as the "governor's residency" (Faust 2011; Faust and Katz 2015). The building does not only belong to the group of elite Iron Age buildings, but is actually part of the upper echelon of this group (for comparative data and the discussion of wealth in the Iron Age, see Faust 2012, and many references). Many of the inner walls were built of mud-brick courses on top of stone courses, but it is possible that the outer walls were built of stone only, as we never found mud-bricks on top of the stone courses in these walls. In the late eighth century BCE, probably during Sennacherib's 701 BCE campaign, the building was destroyed in a conflagration, as evidenced by the charred botanic remains that was accompanied by dozens arrowheads that were unearthed within the debris. The preservation was excellent—some of the walls were preserved to a height of about 1.5 m. Although the building experienced some changes during the course of its life, its plan did not change drastically and the outer walls were not altered.

Building 101 was a large four-room house. This term refers to a typical Iron Age building whose idealized plan is that of a long structure which is divided into three longitudinal spaces (with the entrance located in the central one) and a broad space at the back, perpendicular to the longitudinal spaces (there are many subgroups within this genre; Bunimovitz and Faust 2002; Faust and Bunimovitz 2003, 2014; Holladay 1997; Netzer 1992; Shiloh 1970). In most excavated four-room houses, the various spaces (usually with the exception of the central longitudinal room) are subdivided, and those buildings typically contain more than four rooms (hence, four areas, or four spaces, would be a more appropriate term; still, for the sake of consistency and clarity, we prefer to use the common convention). The entrance to Building 101 was from the east, and the central room was originally (phase 1, Fig. 2) a large open (unroofed) courtyard (room 101A, subdivided in phase 2 into rooms 101A1-3). The longitudinal northern and southern spaces were, however, subdivided into smaller rooms. In phase 1, we identified rooms 101D, 101E, 101F, and 101G in the northern space, rooms 101I and 101J in the southern space, and rooms 101B and 101C at the back. The construction of the building in this phase is characterized by high quality and great investment, reflected by large ashlar stones in some of the corners of the building, and thick and massive stone walls, the inner of which were topped by mud-bricks, as well as the massive preparation that preceded the construction of the building, the continuous foundations that were used, and more. Only one inner wall, F1048 (between rooms 101D and 101E) was built of mud-bricks without stone courses. The wall was also thinner, and its lowest course appears to be different in its color and quality. This constructional difference was explained by its being located under a roof and therefore protected from weathering effects.

Notably, by the time of the destruction of the building (phase 2, Fig. 2), the inner courtyard (the central longitudinal space) was divided into three spaces (101A1-3) by thinner mud-brick walls, which were clearly not part of the original construction; they were built on top of the original floor, they obstructed movement within the building and were built in a completely different manner (see also Faust 2011, 2014; Faust and Katz 2015). Although they were exposed to the elements, they were built of weak mud-bricks. Few of the other walls were also suspected as being later changes, or at least had the potential to be so (e.g., F1173—a mud-brick wall on-top of the phase 1 stone wall F1171), but their phasing could not be determined with certainty.

The study of the mud-bricks, however, unintentionally sharpened our understanding of the various construction phases, and enabled us to better identify the various stages of the building, and even gave us some insights into the pre-planning of this large structure.

Mud-bricks in Tel ‘Eton

Many of the mud-bricks of Building 101 were examined as to their dimensions, texture (granulometry), carbonate content, color, and firing temperatures.

Dimensions The dimensions of the mud-bricks in Building 101 were taken, where possible, from in situ mud-bricks (all mud-bricks that could be measured for their length, width, and height were measured). Measurements were taken using a millimetric measuring tape. The results (Table 1) are generally consistent with the above division into two phases. All the mud-bricks of the phase 1 walls are quite similar in size, in contrast to the mud-bricks of the phase 2 walls (below). Still, the mud-bricks from wall F1048 are generally higher than the mud-bricks from the other phase 1 walls. The mud-bricks from phase 2 were composed of very loose and fragile material and, due to the poor preservation (before and after their exposure), their contours could not usually be identified. Only rarely did we manage (partially) to identify contours of mud-bricks in those walls, but the bricks were usually broken or incomplete. The height (but not the width and length) of two of these mud-bricks could be measured and is 15 cm, which is

Table 1 Dimensions of mud-bricks

Wall	Course	Length × width × height (cm)
F1020/F1162	1	63 × 34 × 13
F1020/F1162	1	56 × 37 × 13
F1020/F1162	1	59 × 34 × 12
F1020/F1162	2	56 × 39 × 12
F1020/F1162	2	56 × 39 × 12
F1020/F1162	2	(?)56 × 34 × 13
F1020/F1162	3	59 × 34 × 13
F1020/F1162	3	59 × 34 × 13
F1020/F1162	3	59 × 34 × 13
F1020/F1162	3	59 × 34 × 13
F1020/F1162	4	56 × 34 × 14
F1231	2	(?)61 × 35 × 15
F1231	2	61 × 34 × 14
F1385	1	56 × 33 × 14
F1048	7	55 × 34 × 15
F1048	5	55 × 34 × 19
F1048	4	53 × (?)34 × 16

Mud-brick courses are numbered from the lowest one. For wall locations, see Fig. 2 (note that sampling points on the plan relate to samples taken for analyzing temperatures, texture, carbonate content, and color, and not to the bricks examined for size). All mud-bricks which could be accurately measured were examined, and where no clear measurement could be taken, a question mark is noted. No measurements from typical phase 2 mud-bricks were taken due to the technical difficulties mentioned in the text, but two of the heated phase 2 mud-bricks were measured for their heights (see discussion in the text)

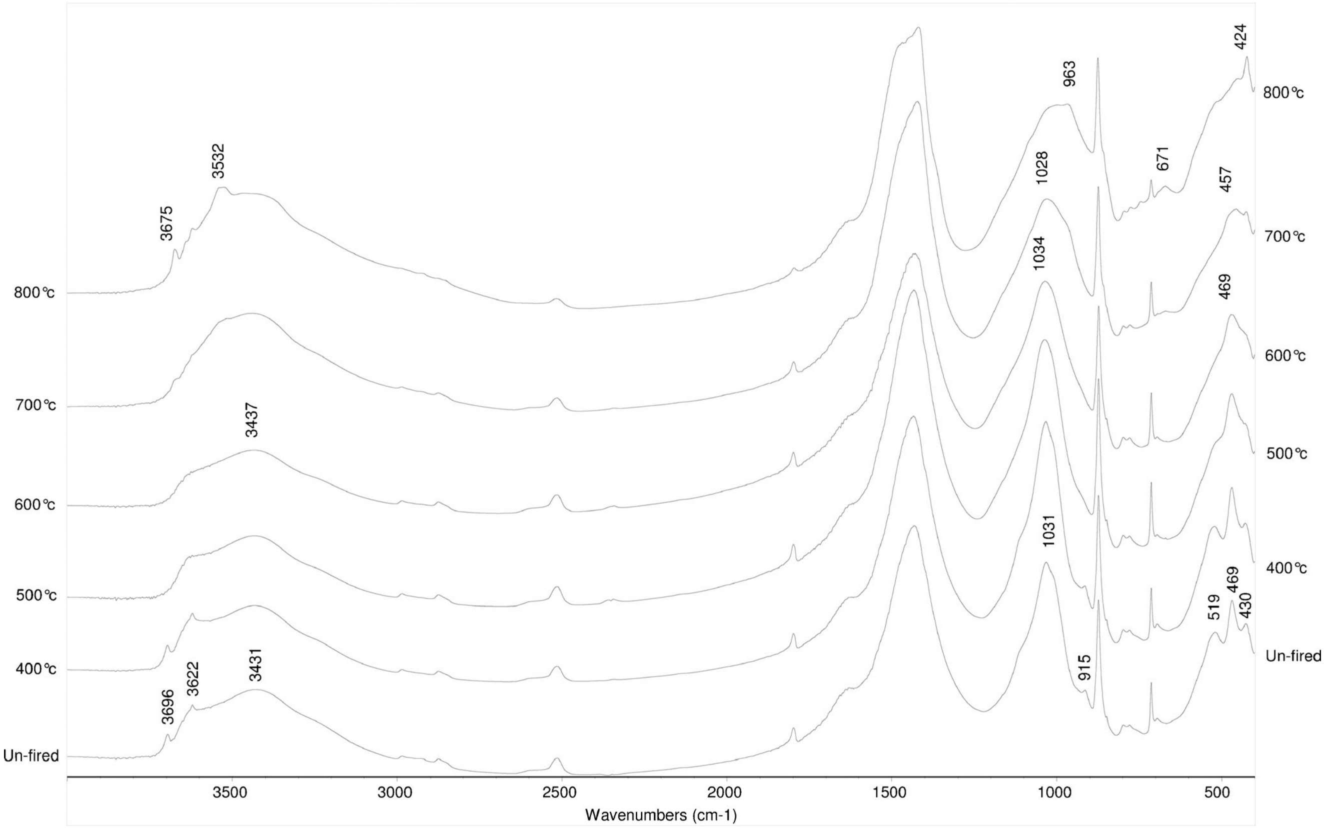

Fig. 3 FTIR analysis results of a control sample from the surrounding soil that was heated in oven to high temperatures. The plots show the changes that occur at the different temperatures and are detectable starting from between 400-500 °C. Note, for example, how the small peaks at 430, 519, 915, 3622, and 3696 cm^{-1} are becoming vague (shoulder instead of peaks) at 500 °C and disappear at 600 °C

slightly higher than the typical phase 1 mud-bricks, and lower than most of those of wall F1048 mud-bricks. Given the small number of phase 2 mud-bricks whose height could be determined, however, it is difficult to assess the significance of this observation. As we will see below, those appear to be older mud-bricks that were originally used elsewhere and were reused in the construction of the phase 2 walls. The finding of those mud-bricks rules out the possibility that the phase 2 walls were made solely of puddled earth (terre pisé) or related technologies, since in this case, no single mud-bricks were supposed to be found. These bricks were sampled, of course, but since they are exceptional, they cannot represent the type of bricks used in phase 2 (more details below).

For the other analyses, at least three mud-bricks were sampled from every available mud-brick wall of Building 101. The samples were chosen randomly, and only the outer 1–2 cm were taken from each sampled mud-brick. The samples came from different mud-bricks and different courses whenever possible (see Fig. 2 for sample locations).

Firing temperatures Previous studies showed that sediments that were heated to above 400 °C can be identified using FTIR analysis (Berna et al. 2007; Forget et al. 2015; Friesem et al. 2014). We used the same method, including the preparation of control samples (Fig. 3). The results (Table 2, Fig. 2) showed homogeneity in phase 1 and heterogeneity in phase 2. All the mud-bricks from phase 1 were exposed to temperatures of above 400 °C, while most of the phase 2 bricks showed no firing signs. Wall F1048 is similar in this parameter to phase 1, with the caveat that all the sampled bricks from the upper courses were fired to 400–500 °C, while most of the bricks from phase 1 were heated to above 500 °C (the mud-bricks of the lowest course were all unfired). The question whether the firing was intentional or simply a result of the conflagration during the destruction is intriguing but is beyond the scope of this article and will be discussed at length elsewhere. In the present context, we can only state that the evidence strongly suggests that firing was intentional.

Texture analysis (commonly referred to as granulometry or grain size distribution analysis) This is a well-established method in geology and pedology. It may be used to perform intra- and inter-site comparison of mud-bricks and to follow the changes of the construction techniques through time, as reflected by the variation in the selection of the source material—the proportions of the sediments fractions (namely sand, silt, and clay) in the mud-bricks. Moreover, the variation in the sediments fractions of the bricks may influence their quality and durability (Fathy 1973; Homsher 2012; Kemp 2000; Love 2012; Rosen 1986: chap. 5; Wright 1985: 106–107). One of the sources to the soils and the sediments in the area are calcareous rocks, and therefore calcite might constitute a major portion of soils and sediments. Therefore, in order to study the complete composition of the sediments, we did not remove the carbonates from the samples. Grain size distribution was determined by the sedimentation method (Baver 1956: 59; Wright 1939).[1] Each sample was sifted through 2 mm mesh (minimal grinding).[2] About 5–6 g were taken from each sample for this analysis. The sediments were first dispersed with 0.5 % Na_2CO_3 solution and separated into three grain size fractions by multi-decantation from 0.05 % Na_2CO_3 solution: clay (<2 μm), silt (2–50 μm), and sand (50–2000 μm).

The results (Table 2, Fig. 4) show that the phase 1 mud-bricks are homogeneous in texture, with the exception of the samples from wall F1048. As noted above, in most cases, we could not identify the contour of the bricks in the walls of phase 2 and most of the samples were taken from these undistinguished mud-bricks. Generally speaking, the mud-bricks of the phase 2 walls are much richer in clay compared to those of phase 1. The exceptions are samples MB15 and MB27–29 (Table 2), which were taken from the few mud-bricks which were fired and whose contours had been identified. Those bricks, which survived after years of exposure (following their discovery in the first seasons of excavations) are very different (both visually and analytically) from the typical mud-bricks in the walls in which they were embedded. These differences in the characteristics are ascribed to their firing and might reflect mud-bricks that were fired and used in other walls, and reused when the walls of phase 2 were built (below).

It is quite clear that there is correlation between the firing temperatures and the sediment texture presented above, and that the firing changes the texture (Ketterings and Bigham 2000; Terefe et al. 2008; Ulery and Graham 1993). Still, we must stress that the FTIR analysis is insufficient to make the texture analysis obsolete, since FTIR analysis alone would not have enabled us to confidently distinguish F1048 from other phase 1 walls. The upper courses of F1048 were all fired to a temperature of 400–500 °C, like many of the mud-bricks in phase 1 walls, but the texture of the sediments differed, enabling us to identify the bricks as belonging to a different group. The same clearly applies to the lowest, unfired (and hence unchanged) course of F1048, and the granulometry results distinguished it from all other groups, including the unfired bricks of phase 2.

Carbonate content This analysis measures the percentage of the carbonates in the material, which influences the aggregation (Zwikel 2004; see also Stavi et al. 2008). Unlike grain distribution analysis, however, carbonate content is not influenced by firing below 1000 °C (Certini 2005: 4), and hence, observed differences are results of source material (see also Love 2012). The analysis was done in a calcimeter, according to the procedure outlined by Shaharabani (1985; see also Loeppert and Suarez 1996). We used the same samples that were taken for the texture analysis, adding samples from the vicinity of Tel ‘Eton for control.[3] The results (Table 2, Fig. 5) in samples taken from walls which are clearly from phase 1 (F1020/F1162, F1029, F1231, and F1385) are homogeneous (total average of 12.4 ± 3.34 %) and lower than in samples from the environment. This would not mean that the mud was imported, only that we did not sample the exact location of the mud quarrying, since the value that we found in one locus is just slightly higher than the mud-bricks of phase 1. Wall F1048 which was built in a different manner than the other walls of phase 1 is different also in the carbonate content, which is significantly higher (arcsin transformation, $p < 0.001$, total average of 27.3 ± 2.02 % for wall F1048), strengthening the view that this wall was built as part of a different phase. The phase 2 walls are more varied in their carbonate content (total average of 23.8 ± 12.07 %)—wall F1032/F1041 has a wide range, generally higher than phase 1 walls and similar to the samples from the environment, while walls F1031 and F1173 are similar to phase 1 walls in this regard. There is no significant difference between wall F1048 to phase 2 walls in carbonate content, probably due to the small number of samples.

We cannot tell whether the carbonates are the cause for the different texture of wall F1048. The differences might be a result of other initial mechanical composition, such as the initial size fractions or the amount of the organic content before the firing, but at any event, this would point at different mud composition or different preparation method, supporting the notion that this wall was indeed different.

Color The color of sediments may be influenced by many parameters, such as texture, aggregation, organic matter, carbonate content, and chemical composition. For example, the Hue of samples becomes redder as a consequence of heating to high temperatures, and organic matter darkens the Value (Forget et al. 2015;

[1] While other methods are commonly used (pipette method or hydrometer method), the advantage of the method used here is its accuracy. Its main shortcoming is that it is time-consuming due to the sedimentation time and the number of decantation cycles (it took us 3–4 weeks for sets of 20 samples).

[2] We should note that in all the material that was sifted out from the samples, we did not find pottery sherds or other artifacts, and only a few small stones were identified.

[3] For details on the provenance of the environmental samples see Forthcoming, Sapir Y, Sarah P, Sapir Y, Katz H, and Faust A. How are Tells Formed? On the Formation of Mound Topsoil at Tel ‘Eton.

Table 2 Mud-brick analysis results

Brick (basket)	Wall	Phase	Clay %	Silt %	Sand %	Carbonates %	Firing temperature (°C)	Color
MB10 (B11212)	F1020/ F1162	1	2.6	29.7	67.7	18.1	400–500	7.5YR5/6
MB11 (B11200)	F1020/ F1162	1	2.7	35.0	62.3	12.6	400–500	7.5YR5/6
MB12 (B11209)	F1020/ F1162	1	3.5	34.6	61.9	13.2	400-500	7.5YR5/6
MB20 (B11086)	F1020/ F1162	1	2.6	24.5	72.9	8.6	>500	7.5YR5/8
MB21 (B11090)	F1020/ F1162	1	2.8	26.0	71.2	10.8	>500	7.5YR5/6
MB22 (B11088)	F1020/ F1162	1	1.8	24.6	73.6	11.9	>500	7.5YR5/6
MB6 (B11210)	F1020/ F1162	1	2.8	35.4	61.8	9.9	400–500	5YR5/8
MB1 (B11211)	F1029	1	2.9	35.4	61.7	13.2	>500	7.5YR4/6
MB2 (B11218)	F1029	1	2.2	30.6	67.2	9.4	>500	7.5YR5/6
MB3 (B11215)	F1029	1	1.8	28.1	70.1	7.1	>500	5YR5/8
MB16 (B11202)	F1231	1	1.9	22.3	75.8	11.7	>500	7.5YR5/6
MB17 (B11203)	F1231	1	2.6	36.7	60.7	12.0	400–500	7.5YR5/6
MB18 (B11213)	F1231	1	3.2	29.9	67.0	9.2	400-500	7.5YR5/6
MB34 (B11483)	F1385	1	1.4	21.9	76.6	12.0	>500	7.5YR5/6
MB35 (B11484)	F1385	1	2.5	23.7	73.8	12.2	>500	7.5YR5/6
MB36 (B11485)	F1385	1	2.4	14.7	82.9	16.6	>500	7.5YR6/6
MB37 (B11486)	F1385	1	1.7	24.6	73.6	14.7	>500	7.5YR5/6
MB38 (B11487)	F1385	1	2.2	25.4	72.4	20.2	400–500	7.5YR5/6
MB7 (B11217)	F1048 upper courses	1?	9.0	52.3	38.7	26.7	400–500	7.5YR6/4
MB8 (B11205)	F1048 upper courses	1?	7.7	38.2	54.1	31.1	400–500	7.5YR6/4
MB9 (B11216)	F1048 upper courses	1?	4.9	39.7	55.4	26.7	400–500	7.5YR6/4
MB39 (B11498)	F1048 lowest course	1?	29.9	46.7	23.4	27.6	<400	7.5YR6/4
MB40 (B11499)	F1048 lowest course	1?	23.1	50.5	26.4	26.1	<400	7.5YR6/4
MB41 (B11500)	F1048 lowest course	1?	13.0	58.4	28.6	25.4	<400	7.5YR6/6
MB13 (B11207)	F1031	2	29.7	41.3	29.0	18.6	<400	5YR5/6
MB14 (B11206)	F1031	2	33.2	43.2	23.6	12.6	<400	5YR5/6
MB15 (B11214)	F1031	2	1.4	30.1	68.4	15.2	400-500	10YR5/6
MB4 (B11204)	F1032/ F1041	2	41.9	39.1	18.9	20.3	<400	7.5YR5/6
MB5 (B11208)	F1032/ F1041	2	35.6	48.5	15.9	42.4	<400	7.5YR6/4
MB19 (B11127)	F1032/ F1041	2	36.6	43.5	19.8	24.5	<400	10YR4/6
MB27 (B11241)	F1032/ F1041	2	4.8	27.4	67.8	45.3	400-500	10YR6/4
MB28 (B11242)	F1032/ F1041	2	3.6	26.6	69.8	48.0	400-500	10YR7/3
MB29 (B11243)	F1032/ F1041	2	2.2	20.7	77.1	15.5	>500	7.5YR6/4
MB31 (B11480)	F1032/ F1041	2	35.1	40.8	24.1	24.4	<400	7.5YR5/4
MB32 (B11481)	F1032/ F1041	2	37.8	37.1	25.1	25.5	<400	7.5YR5/4
MB33 (B11482)	F1032/ F1041	2	29.4	46.0	24.7	24.5	<400	7.5YR4/3
MB23 (B11237)	F1173	2?	32.6	43.3	24.1	11.6	<400	5YR4/8
MB25 (B11239)	F1173	2?	36.6	46.1	17.3	15.3	<400	7.5YR4/6
MB26 (B11240)	F1173	2?	35.7	43.0	21.3	12.9	<400	7.5YR5/6

Wall F1048 was included in phase 1 but with a question mark due to its different construction method. Wall F1173 was included in phase 2 but with a question mark due to lack of phasing evidences. MB34 and MB36 are samples from the mud coating of wall F1385, but generally speaking, they are in line with the mud-bricks of the same wall

Ketterings and Bigham 2000; Pomies et al. 1998; Sánchez-Marañón et al. 2004; Ulery and Graham 1993). Color was examined by standard Munsell color charts for air-dried fine earth (2 mm sieved) samples. The results (Table 2, Fig. 6) show that the range of phase 1 samples is generally narrower than phase 2, and that phase 1 walls contain mainly samples with Hue of 7.5YR (along with two redder samples, Hue of 5YR). The walls of phase 2 reveal not only general variability but also intra-wall variability. Wall F1048 is

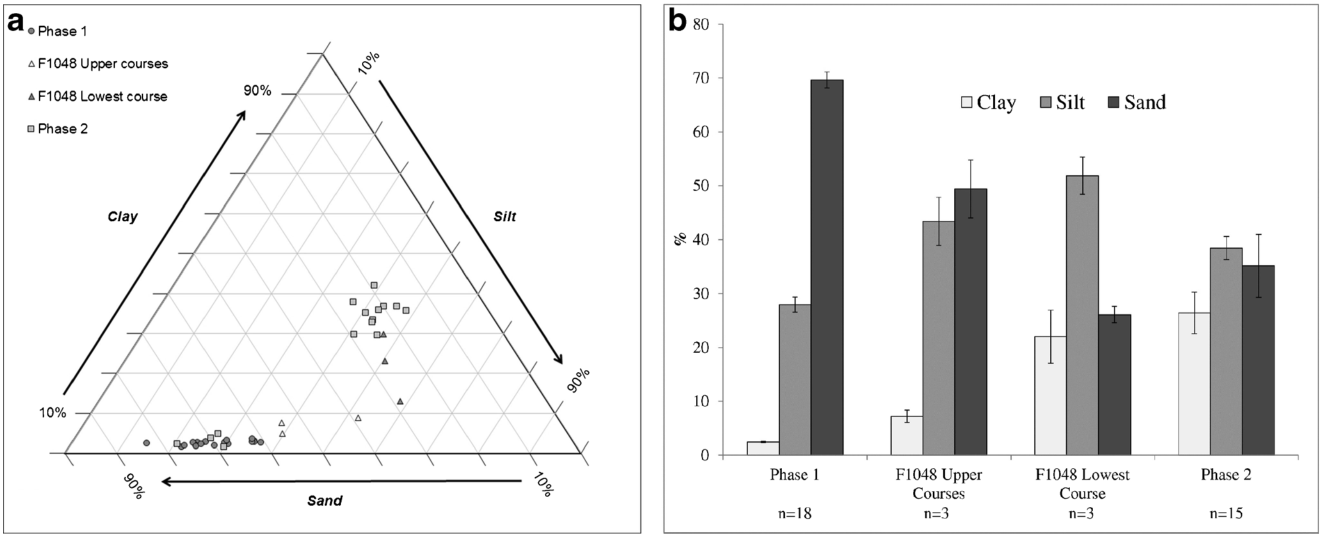

Fig. 4 **a** Sediments texture triangular diagram for the mud-brick samples collected from Building 101 walls. The sediments were separated into three grain size fractions: clay (<2 μm), silt (2–50 μm), and sand (50–2000 μm). The samples from phase 1 are homogeneous, and the samples from phase 2 are heterogeneous (some of phase 2 samples are inside the range of samples from phase 1). Wall F1048 had one range for its upper courses, and second range for its lowest course. Plotting was done according to Graham and Midgley (2000) software. **b** The averages and the standard errors of the phases show the differences of the fractions and their variability between the groups. F1048 is divided to upper courses and lowest course

highly homogeneous with identical colors, and only one sample differs with lower Chroma.

Analytical results and constructional phases

When the results were examined and plotted on the plan of Building 101, a very clear pattern appeared, which only partially conformed to the way we initially perceived the constructional phases. While the distinction between phases 1 and 2 clearly holds, and is now supported by the analytical data regarding the size of the bricks (or even the mere ability to identify them), their firing temperatures, texture, carbonate content and color, it appears that there was an additional group of mud-bricks—that of F1048. Those apparently composed an intermediate phase, hence changing the way we understand the construction phases of the building. We can now suggest new constructional phases for Building 101 (Fig. 7):

Phase 1.1, which is the equivalent to most of the walls of our previous phase 1 (above), includes mud-bricks on stone walls F1020/F1162, F1029, F1231, and F1385. This phase is characterized by bricks with heights of 12–15 cm, very low

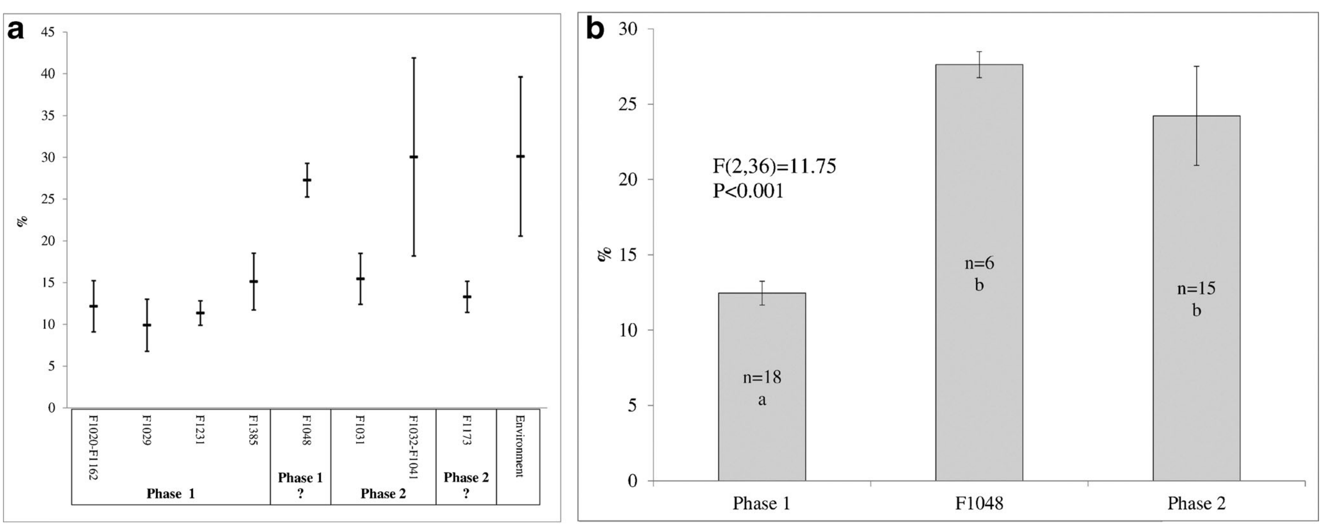

Fig. 5 **a** Carbonate content averages per wall (*error bars* represent one standard deviation). The number of samples per wall is as follows: F1020/F1162, $n = 7$; F1029 $n = 3$; F1231, $n = 3$; F1385, $n = 5$ (two samples from the mud coating); F1048, $n = 3$ for upper courses and $n = 3$ for lowest course; F1031, $n = 3$; F1031/F1041, $n = 9$; F1173, $n = 3$; environment $n = 7$. **b** The average of the phases shows two statistical groups (a and b inside the bars). Wall F1048 is not significantly distinguished from phase 2, but it has much narrower range (*error bars* represent one standard error)

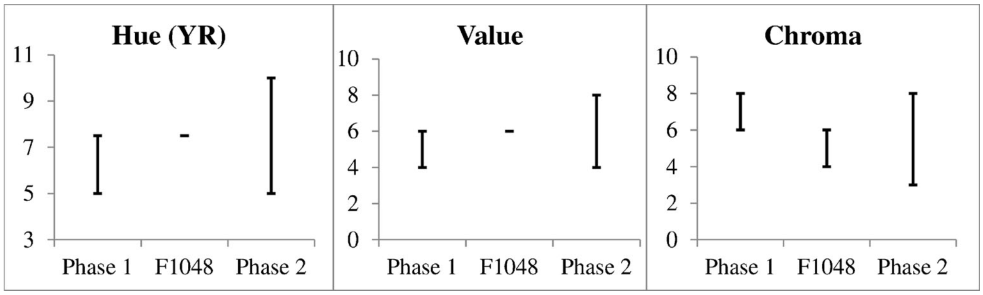

Fig. 6 Munsell color parameters range for the mud-bricks. Hue, in YR scale (reddening of sediments means decrease in YR), Value, and Chroma. Note that for all the color parameters, phase 1 range (n = 18) is narrow compared to phase 2 (n = 15), and wall F1048 has a very tight range for both the lowest (n = 3) and the upper (n = 3) courses, and it differ from phase 1 in one of the Chroma results

clay, medium silt, and high sand fractions (2.4, 28.0, and 69.6 % in average, respectively), firing temperatures of above 400 °C (and mostly above 500 °C), low carbonate content (12.4 % in average), and tight color range. Not only are the samples different from these of the other phases, but they also form a homogenous and close-fitting group.

It appears, however, that F1048, which we initially considered as part of phase 1 (now phase 1.1) does not belong to this phase. The prevalent bricks of this wall (with the exception of the lowest course, see below) are also homogeneous but (1) the bricks of wall F1048 are different in size (higher, 15–19 cm) than those of phase 1.1 walls (typically 12–14 cm, with one mud-brick which reaches 15 cm). This implies that different brick-makers using different molds prepared the mud-bricks of this wall; (2) with a slightly higher clay, higher silt and lower sand fractions (7.2, 43.4, and 49.4 % in average, respectively) in comparison to the walls from phase 1.1; (3) the firing temperatures show generally lower temperature than most of phase 1.1 bricks, yet they were all heated to above 400 °C, which is not typical of phase 2 bricks. The mud-bricks of the lowest course of F1048 are exceptional with a different texture and no firing signs, perhaps due to constructional considerations; (4) the carbonate content of the bricks in this wall is significantly higher than in those of phase 1.1 (yet homogeneous, unlike phase 2); and (5) the colors of this wall (both the lowest course and upper courses) are highly homogeneous. The analytical differences in texture, height, carbonate content, color, and even firing temperature, along with the lack of stone courses below the mud-bricks of wall F1048 and the existence of an unfired mud-brick course at its base, are all suggesting that wall F1048 was not part of the same phase. Although we do not have any deposits that can be used to directly date the two phases, the mere fact that wall F1048 is abutting F1020 from phase 1.1 (and as we learned, they are not contemporaneous) suggests that F1048 must be later than it; hence, it postdates phase 1.1. We should add that unlike most of the walls of phase 1.1, wall F1048 has no constructive importance, and hence is more likely to be later than the other phase 1.1 walls. However, the overall similarity between F1048 and the phase 1.1 walls, when compared with the stark differences between it and the walls of phase 2 (and additional evidence for the latters' late date, see discussion below) suggests that wall F1048 is closer in time to phase 1.1, and earlier than phase 2. We, therefore, attribute F1048 to an intermediate phase—heretofore labeled phase 1.2.

Phase 2 includes walls F1031, F1032/F1041, and probably also F1173. This phase is characterized by unfired bricks (i.e., if they were heated, it was to temperatures below 400 °C) with much higher clay fractions (34.9 % in average) compared to phase 1.1 and the typical mud-bricks of phase 1.2. A few uncharacteristic bricks, which are very similar to the phase 1.1 walls in texture and firing temperatures (MB15, MB27–29), were unearthed in walls' corners or in joining points. These bricks were probably taken from other walls and reused (see below). The carbonate content is varied in this phase: in two walls (F1173, F1031), the results are low and similar to phase 1.1, while in the other wall (F1032/F1041), the values are varied and similar to the environment. Since the carbonate content is not affected by the firing (as opposed to the texture) and relates to the parent material, these mud-bricks were clearly taken from different mud quarries. The colors of phase 2 walls are also heterogeneous, even within the same walls. Not surprisingly, phase 1.1 and phase 2 are clearly distinct. The inter-wall differences within phase 2 might imply either different construction stages (occurring within a short time) or different construction teams that quarried the mud from different places, but since this phase is heterogeneous, we cannot define subphasing here.

As noted, within phase 2 walls, some mud-bricks which were different from the rest of the mud-bricks of the very same walls were identified (MB15, MB27–29). The exact dimensions of the mud-bricks could not have been determined, but as noted above, the height of two of them was 15 cm, i.e., more than the typical phase 1.1 mud-bricks (but less than the typical phase 1.2 mud-bricks). Since only two mud-bricks were measured, however, it is not clear how significant this difference is. Due to their carbonate content, these heated and low-clay bricks cannot be attributed as a group to neither phase 1.1 nor phase 1.2, and they also do not form a single

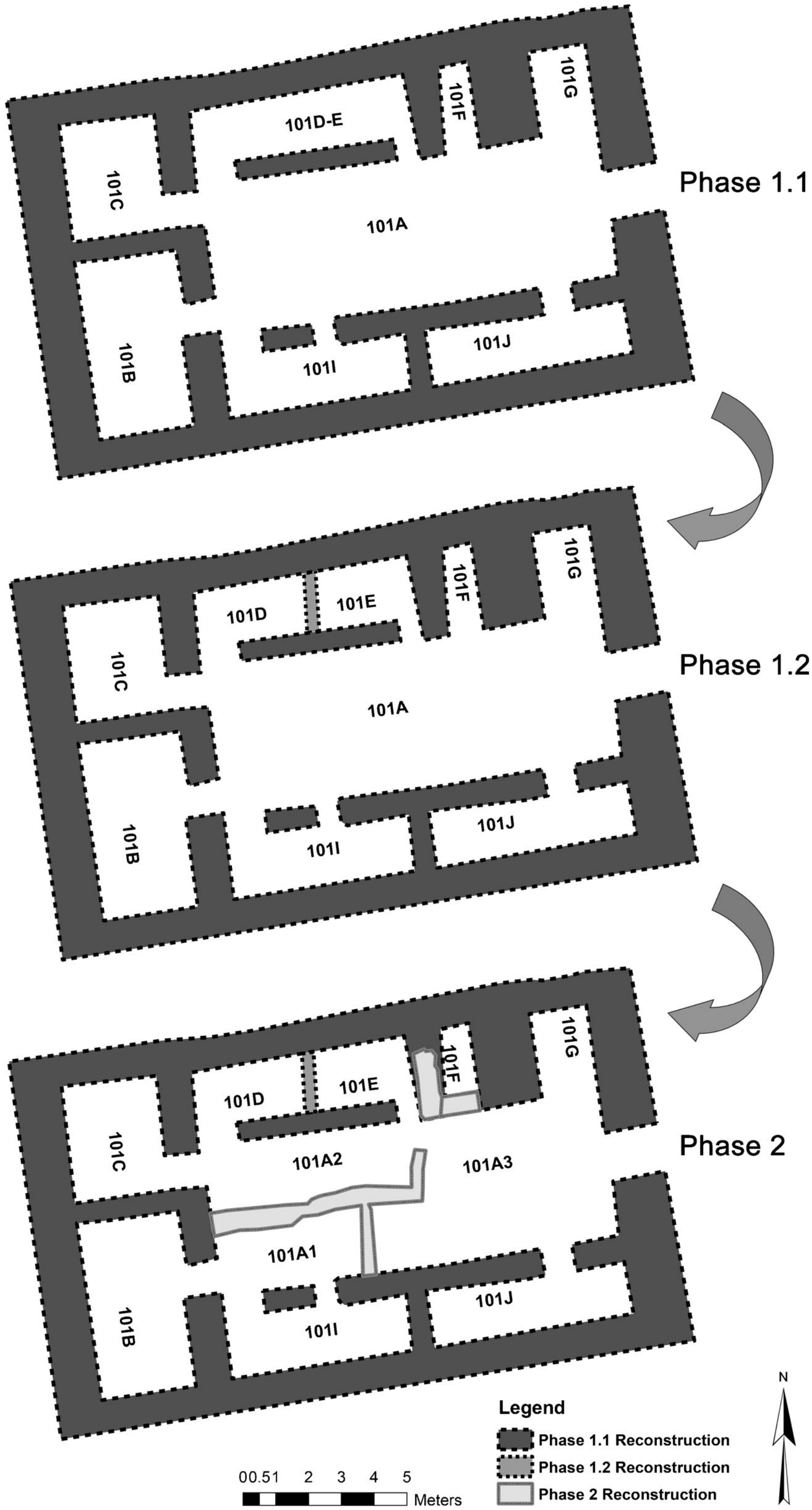

Fig. 7 Schematic plans, illustrating the phases of Building 101, as revealed in this study (cf. Fig. 2). In phase 1.1, both rooms 101D-E and 101I had two doorways, and in phase 1.2, wall F1048 divided room 101D-E into two rooms whereas room 101I remained undivided. In phase 2, the internal yard is divided by walls of lower quality and F1173 was built as a renovation to wall F1171

homogeneous group. This variability, along with the fact that those mud-bricks were fired, suggests that they were taken from some dismantled walls from another building and were reused, or were prepared in the same manner as in phase 1.1 but with the mud quarried from different places (one of them with high carbonate content). The locations of these mud-bricks within the phase 2 walls seem to be intentional, and it is likely that due to their strength, they were placed in hazardous constructional points within these walls, e.g., in corners (as in F1032, MB27–29) or in joints with phase

1.1 walls (as in F1031, MB15) in order to strengthen them (initial results, from wall F1020, suggest that the fired bricks had a considerable level of bearing capacity—peak strength 3.05 MPa).

Constructional phases and pre-planning in Building 101

The understanding that wall F1048 is not part of the original plan (phase 1.1) paves the way to a new understanding of the planning of Building 101. Thus, in the first phase, the western part of both the northern and the southern wings was composed of a large space in each wing, with two doorways leading into each space (Fig. 7, phase 1.1; cf., Fig. 2). It appears that the rooms were intentionally built that way. The purpose of this may have been to enable further subdivision of each space into two smaller rooms, without the need to dismantle walls and endanger the structural integrity of the building. Differences in the inner division of structures, despite overall outer similarity, is a well-known phenomenon in the Iron Age (cf., Albright 1941-1943: pl. 6; Chambon 1984; Fig. 3; Dar 1986: 20; see also Faust 2012: 161–162), and was explained as resulting from changes in the life cycle of extended families, or in the function of the buildings (e.g., Faust 1999, 2000, 2012; cf., Moore 1986; Seymour-Smith 1994: 76; Wilk and Rathje 1982: 626).

Indeed, at some later point (phase 1.2), the large room in the north wing was subdivided by a wall (F1048), creating two smaller rooms (101D and 101E), each with its own doorway. Apparently, in the southern room (room 101I), there was no need to create such a division, and hence, it remains a large room, with two doorways leading into one space (or, perhaps, it has been divided, and the dividing wall was later dismantled, recreating the large room). The construction of F1048 was later than the original construction of the building, and this may explain why it was made with mud-bricks of different sizes (slightly higher), from a different source of materials (different carbonate content and texture range), fired in lower temperatures than most of phase 1.1 bricks and built using a different construction method (without stone courses below the mud-brick courses and with a lowest course of unfired mud-bricks). Still, judging by the homogeneity of the material and the overall similarity to the mud-bricks of phase 1.1, it appears that this change was done at a relatively early stage and as part of the changes in the use of space within the house, or in other words, as part of its life cycle.

Phase 2 is characterized by using materials of a less uniform quality which were less carefully selected. While this observation was made already during the excavations and on the basis of the architecture, it is now clearly supported by analytical examinations. There may be various reasons for the differences of the building materials used and to the suggested reuse of older mud-bricks. In theory, such differences could result from the participation of a large group (Nodarou et al. 2008: 3014), or multiple groups of peoples (Goodman-Elgar et al. 2015: 51), in the erection of the building, each with its own building tradition, and each might have used a different source for the mud-bricks. This, however, does not seem to account for the phenomenon observed, since if such differences are to be found, they are more likely to be found when the building was constructed, and not in what is evidently its final phase. All the walls that belong to the first phase, by contrast, are uniform in all measured parameters, indicating that such a tradition (in which many disparate groups participate in the construction of houses) was not practiced here. Only in the last phase of the building, apparently on the eve of its destruction (Katz and Faust 2012) when construction was under pressure of time, do we find variability in the source material or the quality of construction. The new walls apparently represent final changes and adjustments that were done as part of the preparation for the impending Assyrian campaign (such changes are often expressed in domestic architecture of elite buildings; cf. Hazor, where two new impressive dwellings built near the fort were interpreted as the houses of officials built during the reorganization of the city's defenses; Geva 1989: 41; Yadin 1972: 187–189). In Building 101, it seems that the modifications created a separation between the private and the public parts of the house, allowing people to enter the storage spaces within the house, while limiting the exposure of the private rooms. In light of the ceramic assemblage unearthed and the violent destruction of the building, we suggest that it is most likely that this phase should be dated to immediately before the destruction of the site in 701 BCE (Katz and Faust 2012). The construction, therefore, was done under pressure of time, and perhaps even with limited accessibility to quality building materials (if this was done when the Assyrian army already controlled the area), leading to the use of heterogeneous construction materials, which were partially taken from dismantled walls. That the mud-bricks were older ones, and were now only reused, is supported by the fact that although these mud-bricks were clearly identified within the nonfired mud-brick walls of phase 2, not a single mud-brick could be measured for its length and width (above). This suggests that the mud-bricks were damaged when scavenged from earlier walls (mud-bricks, unlike stones, are not typically reused in later construction). Although we cannot completely rule out the option that some of the older mud-bricks were reused in order to save and reduce expenses, we find it less reasonable, as the finds within the structure clearly indicate that when it was destroyed the house still served as an edifice (as is reflected in the surpluses unearthed in the building, and by the bullae, the sealings, and the seal unearthed in it; Faust 2011, 2014; Faust and Eshel 2012; Faust and Katz 2015). Thus, although the building still filled an important capacity, the siege or the impending siege led to the addition of lower quality walls in the courtyard, and to the change in its use of space. It appears that this is also the time when F1173 was built as a renovation of wall F1171.

Conclusions

The analytical examination of the mud-bricks from Tel ‘Eton significantly improved our understanding of the construction at the site, and even allowed us some insights into the understanding of mud-brick construction in general. Thus, for example, high-quality walls are texturally composed of very low clay and high sand fractions (due to firing). This settles well with studies about preferred mechanical composition for mud-bricks (e.g., Brown and Clifton 1978; Emery 2011; Goldberg 1979; Kemp 2000). The desired carbonate content, according to our results, seems to be low, in order to get high-quality bricks, which settles well with the conclusions of Zwikel (2004: 151–152) which showed that low carbonate content contribute to the stability of the aggregates (see also Stavi et al. 2008). However, in addition to the technical aspects of mud-brick construction (which will be discussed elsewhere), we would like to present two significant conclusions which in our view have implications that go beyond the study of Tel ‘Eton:

1. While not necessarily a universal feature, there are cases in which there is uniformity in the mud-bricks that are constructed at any given moment\building\site. Mud-bricks used in the same phase might be prepared together and hence similar in many ways. Still, in the course of time, there are many changes in the way the mud-bricks are prepared, and hence different phases can be distinguished visually (color and dimensions) and analytically. This is well-documented in many examples in which different brick-makers used different molds (e.g., Homsher 2012: 10; Nafsika et al. 2014: 18). While the mud-brick analysis confirmed our basic observation regarding the differences between the first phase (high quality and homogenous group) and the second phase (poorer quality and heterogeneous), it also allowed us to date wall F1048, originally attributed to the first phase, to a different intermediary stage, thus altering our understanding of the history of the building.

   We therefore conclude that even if there could be differences in the quality of bricks that are made at the same time (Kemp 2000: 84–88), there are probably always differences over time. Hence, if uniformity within phases of construction can be identified, then diversity between groups of bricks might be indicative of temporal differences. This can be tested, and if proved correct, can be also applied in other excavations.
2. Understanding F1048 as an added wall from a different phase allowed us to understand why some rooms (101I and 101D-E) had originally two doorways. Apparently, Building 101 was pre-planned to enable flexibility in its use, and some spaces were built in a way that allowed simple sub-division (and even re-division), according to circumstances. Differences in inner division of four-room houses, despite great similarity in the overall plan, were identified in many cases in the past, and were attributed to the differences in the life cycle of families (Faust 1999, 2000, 2012). The evidence from Tel ‘Eton suggests that such expected changes (resulting from the life cycle of the family, along with additional possible reasons) were a factor that was taken into consideration when structures were built, and the construction was planned in a way that allowed much future flexibility and changes, without harming the overall stability of the houses and their structural integrity.

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