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These proceedings are dedicated to the memory of
C. Sebastian Sommer,
dear friend and colleague,
man who dedicated his entire life to the Roman limes.

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The Manufacture of Ceramic Building Materials from the Roman Fort at Hauarra (Modern Humayma, Jordan)

ABSTRACT

This short article presents findings from a recent study of the ceramic building materials found in the second to fourth century AD Roman fort at Hauarra (modern Humayma, Jordan). While ubiquitous in the region, this material (i.e. bricks, cylindrical pipes, *tubuli*, and roof tiles) generally receives only cursory attention in excavation reports. As a result, little is known about the production, distribution, and use of ceramic building materials along the *Limes Arabicus*. This article, which focuses on the manufacturing processes of this material, attempts to address this gap in scholarship. It is hoped that this article will also serve to encourage further studies on ceramic building materials from Roman forts in the eastern provinces.

Key Words: Ceramic building material, Humayma, Roman Arabia, *Limes Arabicus*, bricks, roof tiles, *tubuli*, pipes

Although ceramic building materials (hereafter CBM) were produced and used by the Roman military throughout the Roman world, scholarly interest in this material has been decidedly more prominent for military sites in the Roman West than for those in the eastern provinces. This difference results in part from the fact that only a single legionary kiln works has been excavated in the eastern provinces, at Jerusalem,[1] and only a few sites in the region have produced military tile stamps.[2] Consequently, many excavation reports of military sites in the Roman Near East provide only superficial descriptions of CBM, thereby hindering the creation of regional typologies and obscuring the role of this important material. In response to this oversight, the present authors undertook a detailed examination of CBM recovered from the Roman fort at Hauarra (modern Humayma, Jordan) with the goal of elucidating the source and production of this material and to

[1]Arubas, Goldfus 2005; Murphy *et al*. 2018
[2]E.g. Jerusalem (Geva 2003), Legio (Tepper 2007, 66), Bostra (Brulet 1984), Zeugma (Kennedy 1998, 133–135)

provide a much-needed reference for future studies of CBM in the region. In addition to creating typologies based on form and fabric, this study also investigated the manufacturing processes of this material. This examination has resulted in a much better understanding of the local CBM industry and is the first step towards placing the production of this material within its regional and extra-regional contexts. The final results of this study will be published in the third volume of the Humayma Final Report Series.[3] This short article presents a few highlights from this study, with particular attention to the manufacture of the bricks, cylindrical pipes, *tubuli*, and roof tiles.

The site of Humayma is located in the Hisma Desert of southern Jordan, roughly 45 km south of Petra and 55 km northeast of Aqaba (Fig. 1). Founded by the Nabataeans in the first century BC, the site became home to one of the earliest Roman forts in the region soon after the annexation of the Nabataean Kingdom by Trajan in AD 106 (Fig. 2). A late second- or early third-century AD inscription found in the neighbouring *vicus* attests to the presence of a detachment of the *Legio III Cyrenaica* at the fort, and it is also possible that it was at some point manned by a detachment from the *Legio VI Ferrata*.[4] In addition, the *Notitia Dignitatum* mentions the presence of a unit of *equites sagittarii indigenae*, probably in the fourth century AD (*ND Or.* 34.25).[5] Excavation within this military fort, under the direction of John P. Oleson (1993-2005) and later by M. Barbara Reeves (2012), succeeded in uncovering many of its structures, including the *principia*, the *praetorium*, a *horreum*, a barracks building, an industrial complex containing a brewery and latrine, and a large reservoir.[6]

The Hauarra fort also produced a large quantity of CBM; however, the collection strategies used for this material varied from year to year. While earlier seasons recorded all CBM found, the use of a "count, weigh, and discard" strategy resulted in less than 1% of excavated CBM being retained for further study. By comparison, the 2012 season saved all CBM pieces for subsequent typological analyses. These different collection strategies have resulted in a sampling bias that prevents a truly quantitative study of the material. Instead, the emphasis of our examination of CBM (both from the fort and across Humayma) has been on creating typologies, where possible, based on form and fabric. Each piece was categorized by its architectural type (i.e. brick, cylindrical pipe, *tubulus*, roof tile) and then described in terms of its characteristics (i.e. subtype, such as *bessalis*, *pedalis*, etc., shape, dimensions, weight, fabric, production techniques, surface treatment, drying environment, handling, amount and location of mortar/plaster, amount and location of heat exposure, and context).[7]

Bricks

Within the Hauarra fort, ceramic bricks were not widely used as a building material, but instead were found only in the construction of a hypocaust system in the *praetorium*[8] (Fig. 3) and a floor in the *horreum* (Fig. 4).[9] Excavation also uncovered a stack of three bricks (perhaps an installation) in a structure identified as a barracks and workshop. Nearly all of the bricks from the fort have measurements relating to modules of the Roman foot (*pes monetalis*) of 29.6 cm, and thus it was decided to categorize them, when possible, by standard Roman brick names (i.e. *pedalis*, *bessalis*, etc.). For example, a square brick recovered from within the *horreum* measured 29.3 cm by 29.7 cm, clearly denoting this brick as a *pedalis* (a brick measuring one Roman foot by one Roman foot). The circular bricks that formed the pillars of the hypocaust system had diameters ranging from 19.3 to 19.8 cm (roughly two-thirds of a Roman foot), which corresponds to the measurement of a typical *bessalis*. While this use of the Roman foot as a module of measurement suggests direct Roman influence in the production of these bricks, it is important to note that the Nabataeans were producing ceramic bricks with Roman measures long before annexation.[10]

[3]Reeves, Harvey, In preparation
[4]Oleson 2009, 535
[5]Oleson 2010, 53–55
[6]Oleson *et al*. 1995, 1999, 2003, 2008; Reeves *et al*. 2017
[7]Reeves, Harvey 2016, 450, table 1
[8]Reeves *et al*. 2017, 126–132
[9]Oleson *et al*. 2003, 46
[10]Reeves, Harvey 2016, 463, 467

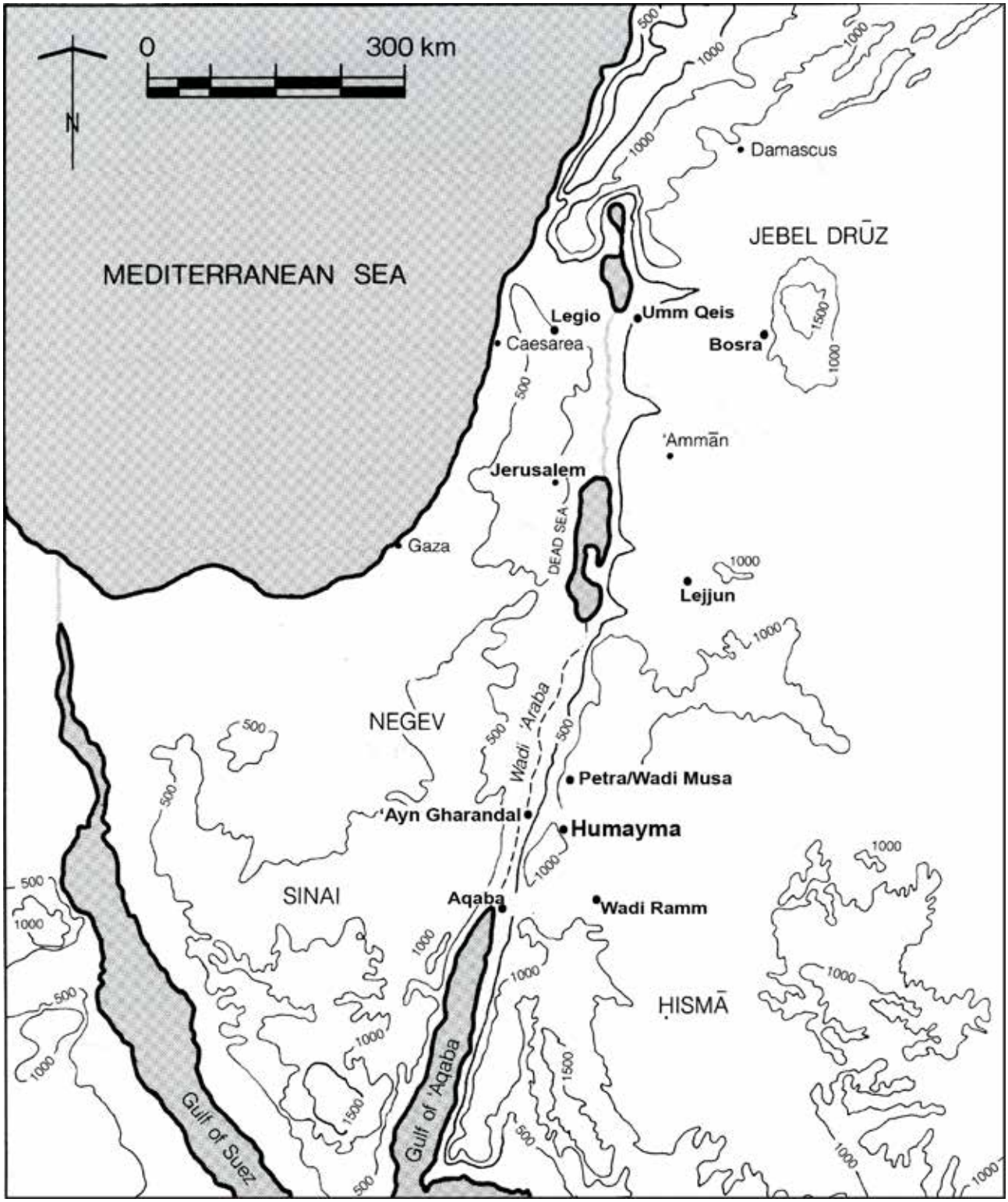

Fig. 1 - Map of the region with the relevant sites highlighted in bold. (map by the authors, after Oleson 2010, fig. 2.1)

In addition to categorizing the bricks by size, the study also attempted to identify assemblages of bricks with common fabrics, production characteristics, and archaeological contexts. Interestingly, nearly all the bricks used within the heated room of the *praetorium* seem to belong a single assemblage of CBM that

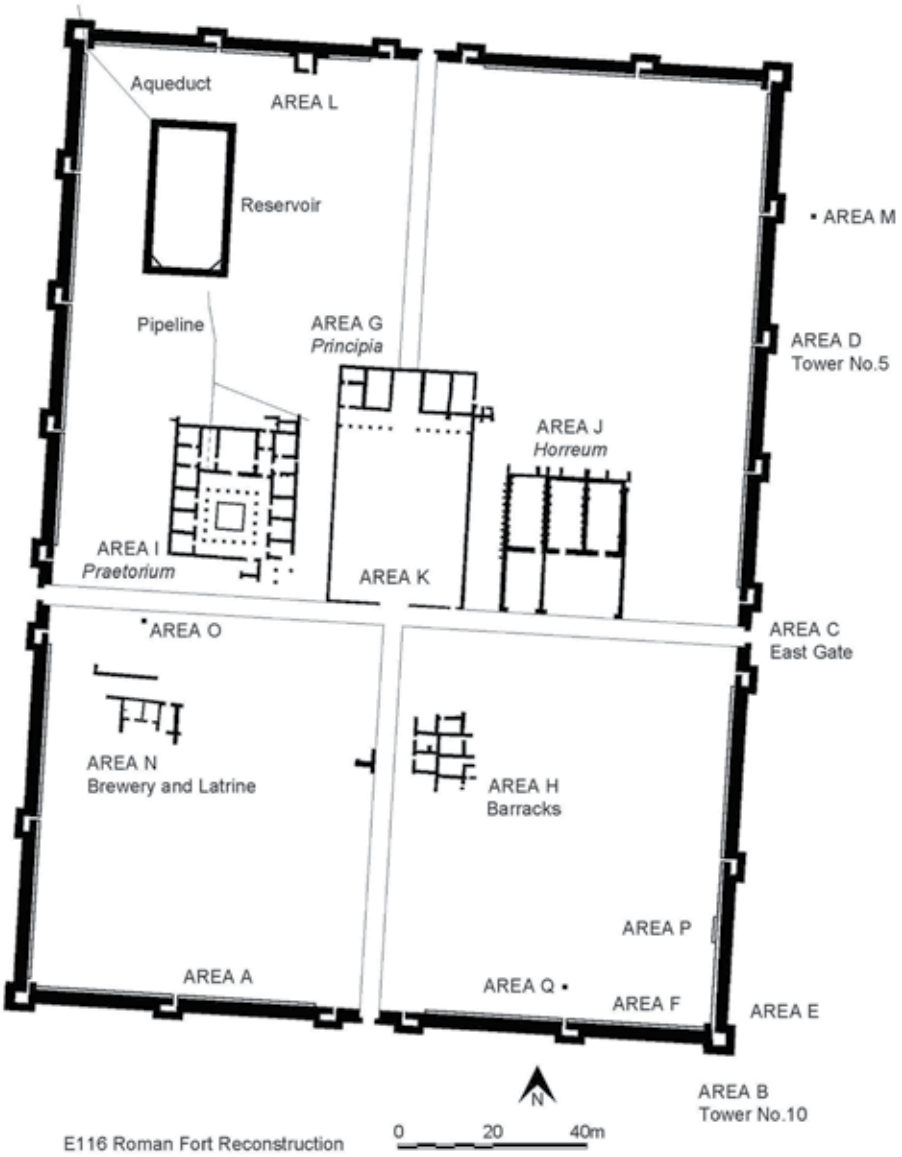

Fig. 2 - Reconstructed plan of the Hauarra fort showing the excavated structures. (courtesy of J. P. Oleson)

also included heating pipes.[11] This homogeneity and the discovery of this material in its primary use suggest that this assemblage was imported as a unit for the construction of the *praetorium*'s hypocaust, which has been dated to fourth century AD. Conversely, the *pedalis* found in the *horreum* belongs to a separate assemblage that has also been identified in the garrison's extramural bath.[12]

The study of these bricks also included close examination of their surface treatment, which provided important information on how this material was produced. As all of the collected bricks had sides that were flat, even, and smooth as well as thin projections of clay along their bottom edge, it seems very likely that they were made in a mould without a bottom. Some of these bricks had distinctive linear marks on their sides, likely formed by the tool used to release them from the mould. The square and rectangular bricks all showed signs of smoothing on their top face by hand or tool, whereas their bottom faces often contained the imprints of straw or other material from the surface on which they were set to dry. The square *pedalis* removed from the *horreum* contained human footprints

[11]The "Praetorium Room J Type", Reeves, Harvey 2016, 471, Fig. 10, Table 4

[12]The "Smoothed Top/Ovoid Bottom Type", Reeves, Harvey 2016, 471–472, Fig. 11, Table 5

Fig. 3 - Bricks from the *praetorium* hypocaust system. 1. *In situ* stack of circular *bessales*. 2. *Pedalis* showing shadow of circular *bessalis* on which it was placed. 3. *In situ* stack of small rectangular bricks. (Humayma Excavation Project)

impressed into its smoothed upper face, further indicating that this face was up during the drying phase (Fig. 4). The production process appears to have been slightly different for the circular bricks found in the hypocaust. These circular *bessales* were smoothed on both faces and their edges were trimmed with a knife before firing.

As this is the first detailed study of bricks in this region, the identification of parallels has proven difficult. As there is no evidence for ceramic production of any sort at the site, these bricks must have been imported to Hauarra.[13] It is hoped that the detailed publication of Hauarra's bricks will assist in the future identification of parallels.

Cylindrical Pipes

Excavators of the Hauarra fort retained several examples of cylindrical pipes for further study. These ceramic pipes are of the standard form found throughout the region with two distinct ends: a spigot (narrow end), often featuring a short narrow collar, and a socket (wide end or bell), featuring a wide opening. The spigot of one pipe was inserted into the socket of another in order to form a better connection between adjacent pipes.

[13]Oleson *et al*. 2003, 328, 337; Reeves *et al*. 2017, 136

The most common use of these pipes was as conduits for water, and many of the pipes collected from the fort were *in situ* in hydraulic pipelines. Several other examples were found within the *praetorium*'s heated room and contain soot and signs of heat damage on their interiors. These cylindrical pipes likely acted as exhaust or chimney pipes for the hypocaust system. Four types of cylindrical pipes were identified from the Hauarra fort; however, because so few of the fort's many pipes were collected and available for study, this typology cannot be considered as representative of all the pipes that may have been used (Fig. 5).

In all collected examples, these cylindrical pipes display rilling (wheel-marks) on their interiors and exteriors, indicating that they were manufactured on a potter's wheel, with finishing touches added after the pipe had been removed. This production method was the standard technique used by local Nabataean potters in the century before Roman annexation of the region and was the method by which pipes from Petra and the surrounding region were produced.[14] The discovery of wheel-made cylindrical pipes at the kiln works of the *Legio* X *Fretensis* at Jerusalem also suggest this was the fabrication method employed by the military in this region.[15]

Past publications of ceramic pipes from southern Jordan rarely provide enough details about their shape and fabric to allow definitive comparisons, and thus it has been difficult to identify close parallels for the Humayma cylindrical pipes. Similarities do exist, however, between the Humayma pipes and those found in Wadi Musa, particularly the fourth-century AD pipes from az-Zurraba, the first-century AD pipes from Dar al-Birka, and the second-century AD pipes from Jabal az-Zuhur.[16]

Tubuli

Another type of pipe found within the fort, but one with a very distinctive shape, is the *tubulus* (elsewhere referred to as box flue-tiles). These ceramic tubes were designed specifically to be installed against the walls of heated rooms in order to create a hollow void in which hot air from the hypocaust could circulate and thus contribute to the heating of the room. Vents cut into their sides enabled the lateral flow of air between columns of pipes. Within the Hauarra fort, the greatest concentration of *tubulus* fragments unsurprisingly came from a small heated room in the *praetorium*, which contains the only known hypocaust in the fort.[17] Excavation of this small room uncovered thousands of *tubulus* sherds, nearly all of which appear to belong to a single type (Fig. 6). This uniformity is noteworthy, as other wall-heating systems in the region were built with *tubuli* of various sizes and shapes.[18]

The presence of rilling on all collected samples clearly indicate that these heating pipes were initially formed on a potter's wheel before being pressed into their characteristic box-like shape. The presence of finger indentations on their exterior reveals that this shaping was done by hand. Curiously, only one end of the tube was shaped in this way, resulting in *tubuli* that uniformly had one end that was more rectangular than the other end, which retained a more oval shape. Before firing, vents were cut into the short sides.

The manufacture of these *tubuli* on a potter's wheel differs from the various methods of producing *tubuli* using slabs of clay common in other regions of the Roman Empire. For example, in Britain, *tubuli* were produced by wrapping a clay sheet around a wooden frame,[19] while in the Decapolis region, of northern Jordan, *tubuli* were made from slabs of clay placed into a wooden mould.[20]

Wheel-made *tubuli* (as opposed to slab-made) therefore seem to have been a local variant and have been

[14] 'Amr – al-Momani 2001, 270, Fig. 24; Bellwald 2008, 90, Fig. 66
[15] Rosenthal-Heginbottom 2005, 279-80, no. 217
[16] 'Amr – al-Momani 2001, 270, Fig. 24
[17] Reeves *et al*. 2017, 126–132
[18] Harvey 2019, 170–179
[19] Morgan 1979, 395–397
[20] Vriezen, Mulder 1997, 330

Fig. 4 - Drawing of *pedalis* from the *horreum* showing footprints. (Humayma Excavation Project)

found in other heating systems in southern Jordan, including in the extramural garrison bath at Humayma.[21] These variant *tubuli* also appear in other military baths along the southern *Limes Arabicus*, such as at Lejjun[22] and 'Ayn Gharandal.[23] Elsewhere in the region, excavation has also uncovered wheel-made *tubuli* from non-military sites, including the first-century AD baths at Wadi Ramm[24] and at various locations in Petra.[25] The presence of wheel-made *tubuli* in Nabataean heating systems that date before the Roman annexation suggests that this production technique was a local innovation.

Roof Tiles

The last category of CBM found within the Hauarra fort is roof tiles, which can be divided into two sub groups: *tegulae* and *imbrices*. The *tegula* is a large rectangular tile with a flat underside and two raised flanges running along its long sides. The underside sits on surface of the roof so that the flanges of one tile abut those of the horizontally adjacent *tegulae*. Vertically adjacent tegulae on a sloping roof overlap so that the upper end of one is covered by the lower end of the tile above it. The *imbrex* (or cover tile) was designed to sit overtop the seam between two horizontally adjacent *tegulae*, covering the gap between their flanges. One end of the

[21]Harvey 2013, 61–84; Reeves, Harvey 2016, 471-473, Fig. 12; Reeves *et al*. 2017, 121-122
[22]Parker 2006, 361, Figs. 16.76-16.79
[23]Harvey 2019, 170-179
[24]Reeves, Harvey 2016, Fig. 8, table 2
[25]E.g. Wadi Farasa (Schmid 2002, 261, Fig. 13), Zantur IV (Kolb, Keller 2000, 361-62, Fig. 9)

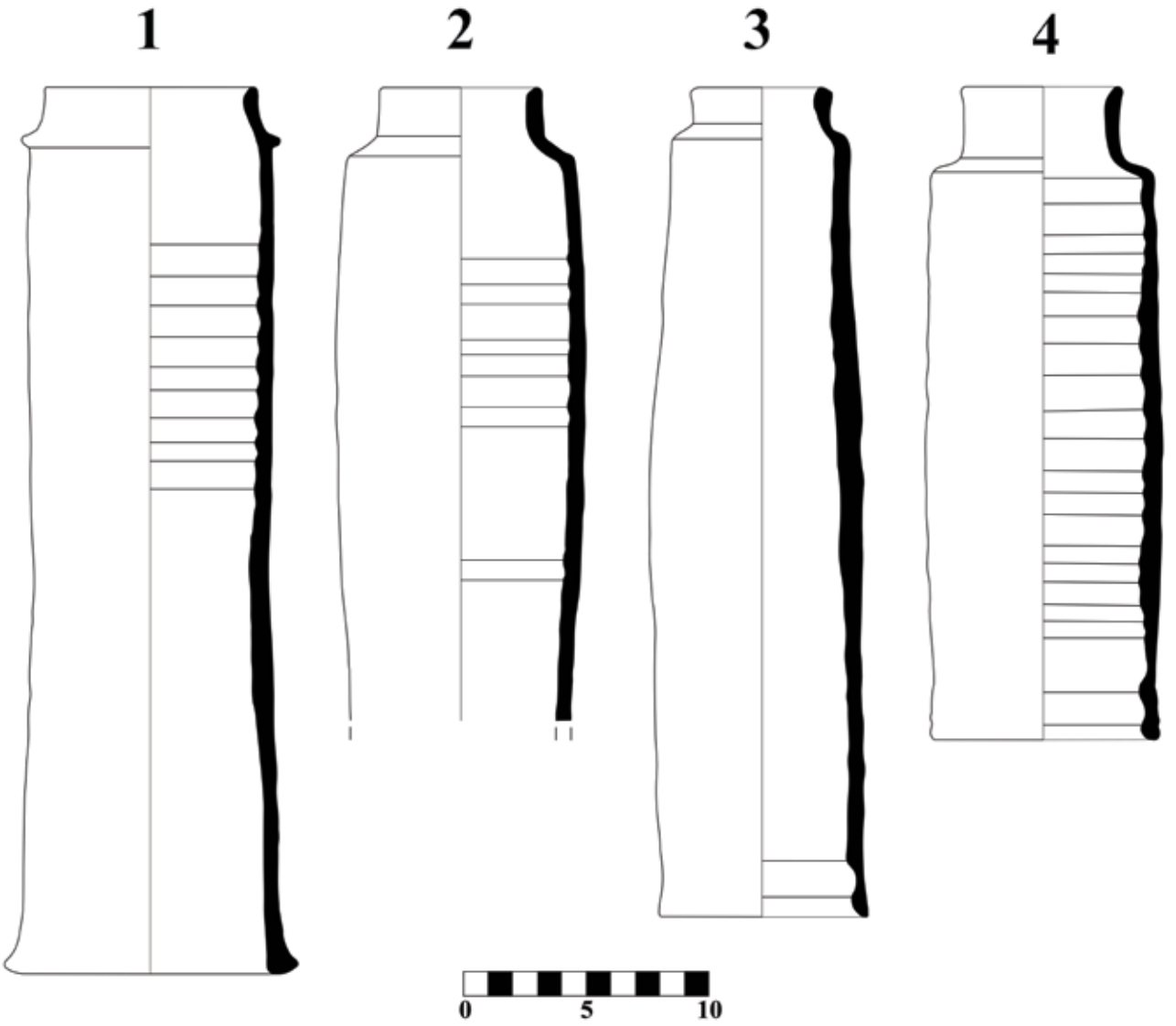

Fig. 5 - Drawings of four cylindrical pipe types. (Humayma Excavation Project)

imbrex is taller and wider than the other, allowing vertically adjacent *imbrices* to overlap so that the upper (shorter, narrower) end of one is covered by the lower (taller, wider) end of the *imbrex* above it on the roof. To help a *tegula* overlap the tile immediately below it on the roof, manufacturers typically cut away sections of the tile before firing. These cutaways generally removed the flanges at the top of the tile and the underside corners at the bottom end.[26] At Humayma, like other sites in the region,[27] these lower cutaways are absent suggesting this is another regional variant. Only the flanges at the top end of the tiles are cut away to help these tiles overlap.

Excavation at Humayma uncovered roof tile fragments throughout the fort, but it is likely that tiles were primarily used in the roofing of the *principia* and *praetorium*. Many of the fort's roof tiles were reused elsewhere in the settlement after its abandonment, and an estimated 18,000 *imbrices* from the fort were recycled as gutter tiles in an aqueduct renovation.[28] The very small number of *imbrices* retained for study prevented

[26]Brodribb 1987, 16–17; Barat 2002, Figs. 6-8; Warry 2006, 20-28; Shepherd 2007, 58-67

[27]Vriezen, Mulder 1997, 328-30; Hamari 2008, 380; 382, Fig. 10; Hamari 2017, 103

[28]This renovation was originally dated to the late third or late fourth century (Oleson 2010, 328–330), but recently a date of the seventh century has been proposed (Reeves 2019, 121).

Fig. 6 - Drawing and photograph of wheel-made *tubulus* from the heated room in the *praetorium*. (Humayma Excavation Project)

the creation of a typology; however, it was possible to identify at least four types of *tegulae* from the fort, which probably correspond to different phases of occupation. Not a single tile from the fort contained a stamp, paralleling the absence of stamps at the legionary fortress at Lejjun.[29]

As with the other CBM from the Hauarra fort, the close examination of the tiles' surfaces revealed important clues regarding the manner in which they were produced. For example, many of the *tegulae* collected from the fort had a thin ridge extending outward around its bottom edges. This ridge is likely an unintended consequence of the production technique used, although the exact technique is uncertain. It may have been the result of wet clay leaking out of the bottom of a mould and could indicate that the *tegula*'s underside was down in an open bottomed mould.[30] Alternatively, such a ridge might also have been created while the side was being smoothed by a finger or tool.[31] A third possibility is that the tiles were formed in an inverted mould and this thin ridge resulted from clay being smoothed over top of the mould while the tile was face down. In support of the inverted mould theory, many of the *tegulae* samples show signs of smoothing on their undersides and imprints on their upper surface.

One such imprint (present on at least three fragments) is a raised circular ring, with a diameter of 7.8-8.0 cm (Fig. 7). On one fragment, this circular ring overlies a possible rectangular mark. To the left of this raised ring is a similarly raised linear ridge, seemingly running the length of the tile from its upper to lower edge. This raised ring and linear ridge appear in the same position on all three fragments, strongly suggesting that not only were these tiles mould-made, but likely the same mould was used for their manufacture.

[29]Parker 2006, 361

[30]cf. Warry 2006, 10

[31]cf. Vrizen, Mulder 1997, 329–30, Figs. 8, 9, 11

Another recurring imprint is a much smaller circular impression (maximum diameter 1.5 cm) in the upper right corner of at least two tile fragments (Fig. 8). These matching imprints likewise suggest that these two tiles were made using the same mould. Interestingly, a similar circular impression (also with a diameter of 1.5 cm) is recorded on a group of *tegulae* from Petra,[32] which raises the possibility that these tiles were produced using the same type of mould.

Many of the collected *tegulae* from the Hauarra fort have pitted surfaces, the pits ranging in diameter from 0.2 to 0.5 cm. It is not clear what caused this pitting, but one possibility is that it is the result of a work palette or mould interior covered in very fine to fine gravel or a textile in order to prevent the clay from sticking. Similar pitting, which has been interpreted as the impression of a textile, appears on two Roman period plaster surfaces at Humayma.[33] Textile imprints also appear on the surface of roof tiles found elsewhere in the Roman Empire.[34] Other tiles with a smoothed upper surface also could have had an originally pitted surface smoothed away after being removed from the mould. Cross-sections of the tile flanges also reveal clues about their manufacture. The presence of folds of clay in the flanges suggest that some of them were made by folding up the long edges of the slab. In some cases, the slab was only folded once, but in other cases it was folded twice (first up and then down towards the slab's surface). Similar folded flanges have also been found at Umm Qeis[35] and Petra.[36]

Like the *tegulae*, all the *imbrices* from the Hauarra fort were slab-made, and a close examination of their surfaces reveals how they were likely produced. Notable surface features include the presence of a lip along the bottom interior edge (on at least 7 out of 24 fragments), the presence of an interior pitted surface (on at least 6 out of 24 fragments), and the presence of longitudinal finger grooves on the apex (on at least 10 out of 24 fragments). The first step in the production of these *imbrices* was the creation of clay slabs by throwing clay into a wooden mould and running a wire or other tool across the top in order to peel away the excess clay.[37] It is possible that the lips on the interior of some *imbrices* may have been created at this time by peeling off less clay along one or both long edges. If this was the case, the *imbrex* face with the lip must have been face up in the mould used to form the slab. Another possibility is that the interior lips were formed by indentations in the former used to create the curved profile. As was the case with the *tegulae*, the pitted surface on some of the *imbrices* may have been caused by fine gravel or a textile placed on the work surface, mould, or former in order to prevent unwanted sticking (Fig. 9). To create the necessary U-shaped curve, the slab was placed over an upright former, and the tile's exterior surface was smoothed with fingers or a tool. This smoothing left longitudinal striations on the outside of the *imbrex*[38] and would have increased the exterior face's surface tension and weather resistance.[39] The deeper finger grooves along the apex of many Hauarra *imbrices* would have been added at this time, but it is not clear what function they served. Once shaped in this way, the *imbrices* were allowed to dry leather hard before being fired in a kiln.

As with the other types of CBM, the absence of similar studies in the region severely hinders the identification of comparanda. As a result, no parallels for the *imbrices* found at Hauarra have been located. On the other hand, many characteristics of one type of *tegula* (Fig. 8) correspond closely with the Ez Zantur Type 2 identified by Hamari at Petra and tentatively dated to the second century AD.[40] A complete example of another type of *tegula* at Humayma (Fig. 10) was used as pakking beneath an early floor in the *principia*. Based on appearance and archaeological context, both of these

[32]Hamari 2017, 92, Fig. 6.3

[33]These impressions appear on both a plaster sealing on a lead pipe (Oleson 2010, 334, Fig. 6.8) and the plastered surface of a *piscina* (immersion pool) in the garrison's bath (Reeves, personal communication).

[34]Brodribb 1987, 125

[35]Vriezen, Mulder 1997, Figs. 8, 9, 11

[36]Hamari 2008, 379

[37]Vriezen, Mulder 1997: 328, Fig. 7; Warry 2006, 36

[38]cf. Vriezen, Mulder 1997, 329, Fig. 7

[39]Warry 2006, 36

[40]Hamari 2017, 92–93, 102–103

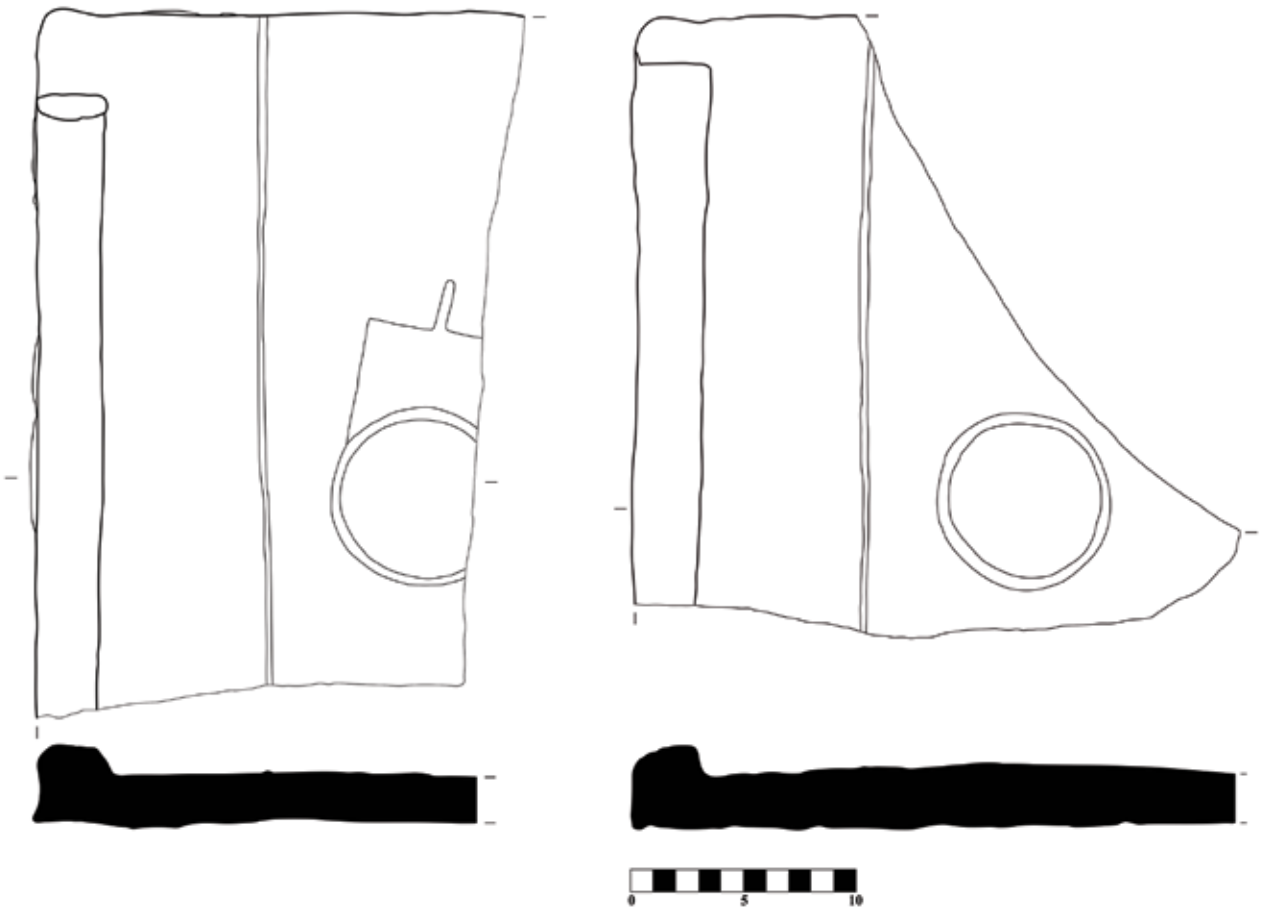

Fig. 7 - Drawings of *tegulae* with raised ring imprint. (Humayma Excavation Project)

tegulae types are tentatively dated to the first phase of the fort's construction (early second century AD). Two other *tegulae* types (e.g. Fig. 7) may date later, as they have similar widths to a published *tegula* from the Petra Church, which also lacks ridges across its top.[41]

Use of CBM at Hauarra

The limited use of CBM within the Hauarra fort is not surprising, as the scarcity of clay, water, and fuel in the region made the large-scale local production of CBM impossible. Consequently, CBM would have been expensive to produce and thus used only when necessary. For example, the heat resistance of bricks made them the material of choice for the construction of hypocausts, such as the one in the *praetorium*. The discovery of ceramic bricks as floor pavers in the *horreum* may also reflect best practices, as brick is recommended by several ancient authors for granary floors (Columella, *Rust.* 1.6.13; Palladius, *Ag.* 1.19.1).

Conversely, the use of ceramic roof tiles and pitched roofs in the fort was unnecessary, given the arid desert climate of the site. Instead, the decision to use this expensive and unnecessary roofing material was likely an expression of power and was designed to make high status buildings of the fort, such as the *principia* and *praetorium*, stand out from other buildings, particularly the flat-roofed structures in the neighbouring settlement. The use of such roofscapes to convey messages of status has also been argued for Beirut and Petra.[42]

Concluding Remarks

Although this article gives only a brief synopsis of the larger study of CBM from the Hauarra fort, its intent was to demonstrate how the careful analysis of this

[41]Kanellopoulos 2001, 185, Fig. 73
[42]Mills 2013, 112–114; Hamari 2017, 107–108

Fig. 8 - Left: *Tegula* fragment from Hauarra with circular imprint. (Humayma Excavation Project) Right: *Tegula* fragment from Petra with similar circular imprint. (courtesy of P. Hamari, after Hamari 2017, fig. 6.3)

Fig. 9 - *Imbrex* fragment showing pitting on interior surface. (Humayma Excavation Project)

material can help reveal how it was made and identify otherwise undetected types. The publication of the full study will appear in the third volume of the Humayma Final Report Series.[43] It is also hoped that this study will encourage other scholars in the region to publish CBM in greater detail, which will aid in the creation of regional typologies and lead to a much better understanding of this important but often overlooked material.

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Résumé

Ce court article présente les résultats partiels d'une récente étude concernant les matériaux de construction en terre cuite trouvés dans la forteresse romaine de Hauarra (aujourd'hui Humayma en Jordanie). Omniprésents dans la région, les matériaux de construction en terre cuite (qui comprennent les briques, les tuyaux, les *tubuli* et les tuiles) sont souvent négligés par les rapports de fouilles archéologiques. Par conséquent, on connaît peu de choses sur la production, la distribution et l'utilisation de ces matériaux le long du *Limes Arabicus*. La présente étude se concentre sur les processus de fabrication de ces matériaux et tente de combler cette lacune. Nous espérons que cet article encouragera de nouvelles recherches sur ces importants matériaux dans la région.

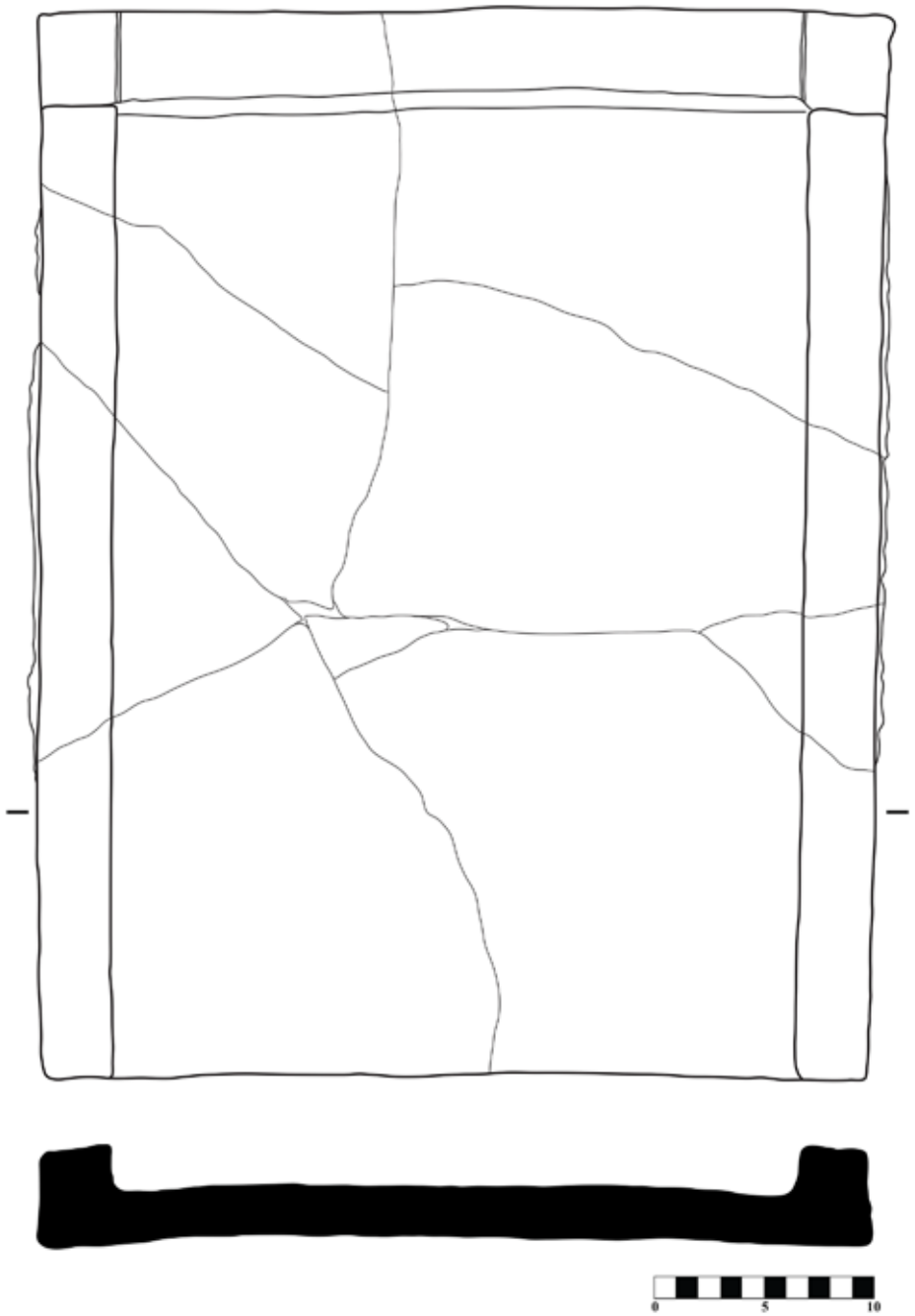

Fig. 10 - Drawing of complete *tegula* with ridge across its top. (Humayma Excavation Project)

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