

Craig A. Harvey
Interdepartmental Program in Classical
Art and Archaeology
The University of Michigan
Ann Arbor, MI, USA
caharvey@umich.edu

Craig A. Harvey

A Preliminary Typology of Brick and Tubuli from the Late Roman Bath at ‘Ayn Gharandal, Jordan

Introduction

During the 2015 field season of the ‘Ayn Gharandal Archaeological Project, excavators uncovered a large corpus of ceramic building materials from the heating system of the site’s late Roman bath. Such material typically receives little scholarly attention, yet its study can reveal a great deal about the construction and renovation of buildings, as well as regional trade and economy. The intent of this article is to present a preliminary typology of the bricks and *tubuli* found during excavation of the bath at ‘Ayn Gharandal and to provide a brief discussion of their use within the heating system. The nature of the bath’s ceramic building material precludes a quantitative typological study and the limitations of this publication format prevent its complete presentation here. It is hoped, nevertheless, that this article will be a resource for similar studies and will serve as a reference for future work on this class of material both at ‘Ayn Gharandal and other sites in the region.

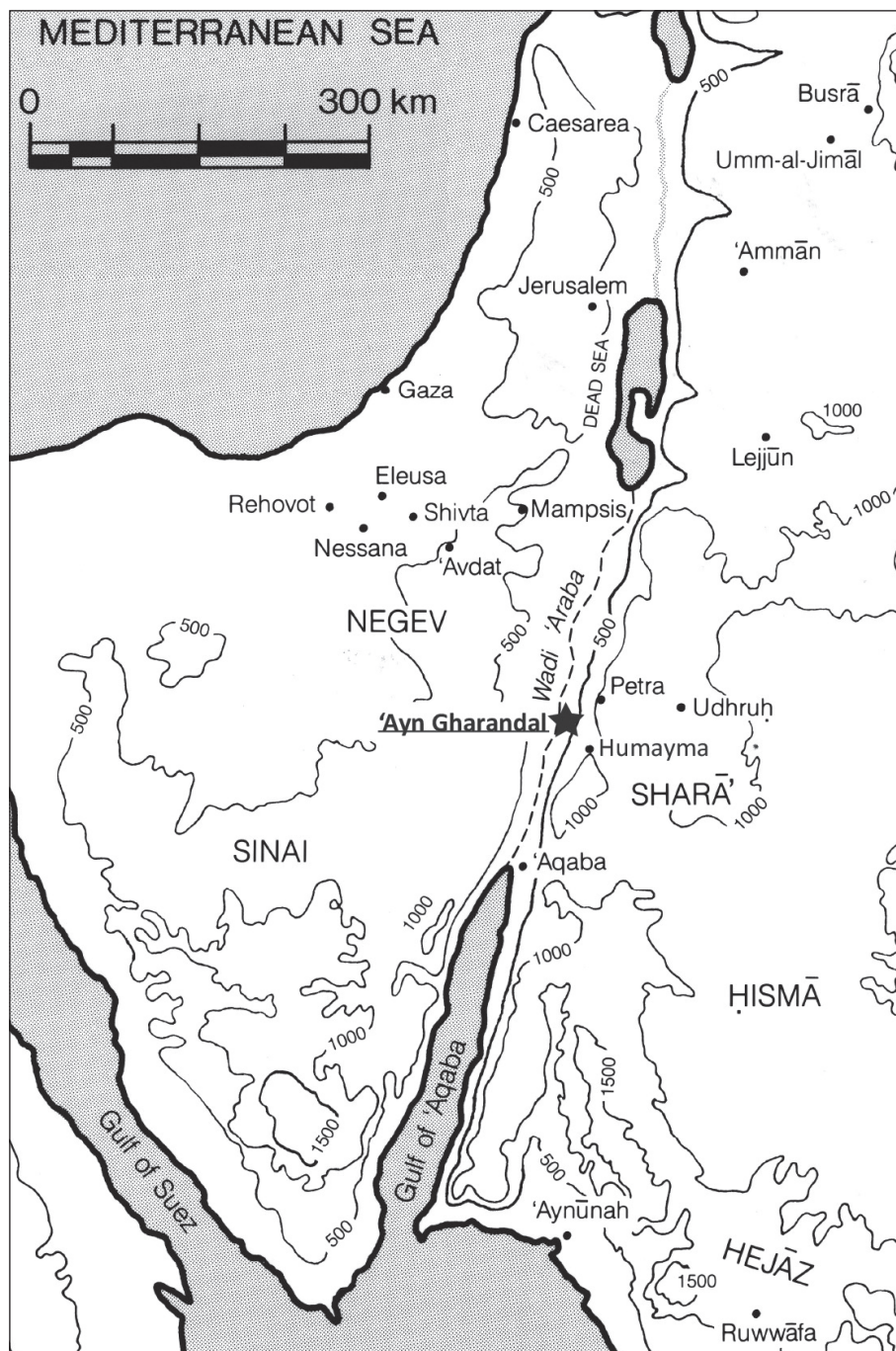
‘Ayn Gharandal

The site of ‘Ayn Gharandal is located *ca.* 70 km north of the Gulf of Aqaba and *ca.* 40

km southwest of Petra (FIG. 1). Situated on the eastern edge of the Wādī ‘Arabah and immediately west of a spring feeding a small oasis, the site consists of a late Roman outpost, comprising a *castellum* and its associated bath. The fort’s dedicatory inscription, found during excavation outside the main gate, securely dates the foundation of the fort to the reign of Diocletian (Darby 2015).

Beginning with Alois Musil in 1902, numerous explorers and archaeologists have visited ‘Ayn Gharandal (Musil 1907: 193-97; Darby and Darby 2015: 461). Excavation of the site, however, only began with the ‘Ayn Gharandal Archaeological Project, which first conducted a survey of the site in 2009 and subsequently undertook excavations in 2010, 2011, 2013, 2014, and 2015, with further excavation seasons planned (Darby *et al.* 2010; Darby and Darby 2012, 2015, 2017). The focus of these excavations has primarily been on the Late Roman *castellum* and its associated bath.

Excavation within both the fort and bath found a wide range of ceramic building material, including bricks, cylindrical pipes, and *tubuli* (specialized rectangular heating pipes). The



1. Site of 'Ayn Gharandal (C. A. Harvey, after Reeves and Harvey 2016).

complete absence of any roof tiles on the site suggests that pitched and tiled roofs were not present at 'Ayn Gharandal. The ceramic building material from the fort is relatively scarce and mostly consists of fragments of brick and cylindrical pipe no longer *in situ*. The occasional *tubulus* find could indicate the presence of a heating system within the fort, but most likely comes from the nearby bath. The vast majority of ceramic building material found on site comes from the bath, and specifically its heat-

ing system, and it is this material on which this article focuses.

Bath

The bath at 'Ayn Gharandal is located about 60 m east of the fort and remains only partially uncovered. Ongoing excavation of the bath has thus far revealed two heated rooms (the *caldarium* (FIG. 2:1) and *tepidarium* (FIG. 2:2), an unheated room (*frigidarium*) (FIG. 2:3), the furnace (*prae-furnium*) (FIG. 2:4), a latrine



(FIG. 2:5), and a section of a large courtyard (FIG. 2:6). Future excavation should clarify whether or not this facility is part of a larger caravanserai, similar to those at Bir Madhkur (Smith 2010: 147) and En Hazeva (Cohen and Israel 1996:111-12).

Prior to the bath's excavation, illicit digging had severely damaged the heating system within the *tepidarium* (Darby *et al.* 2010: 190- 91). The 2009 survey of the site recorded this disturbance and collected samples of the bricks and pipes that the looters had removed from the bath (Darby *et al.* 2010:193-4, 198, figs. 19, 20). Actual excavation of the bath began in 2010 with the intent to clarify the damage to the structure and reveal its architecture for study. The 2010 field season saw the clearing of the *tepidarium*, the latrine, and parts of the *caldarium* and *frigidarium* (Darby and Darby 2012: 407-411, 2015: 463-26). The removal of the disturbed sand within the *tepidarium* revealed a large hole through the hypocaust floor created by the looters. The excavation also unearthed a large quantity of

ceramic building material removed from the heating system during the clandestine digging. Although much of this material remained on site for study in the 2015 season, a few samples were collected and have already been published (Darby and Darby 2012: 411, figs. 11,12; 2015: fig. 7). The renewed excavation of bath in 2015 resulted in the full exposure of the *caldarium* and *tepidarium*, as well as the removal of sand from the looter's hole into the hypocaust. During this last season, excavators collected every fragment of ceramic building material, including those dumped on site in previous seasons.

Methodology

The early looting of the *tepidarium* and the variation in collection methods between excavation seasons complicates the study of the bath's ceramic building materials and precludes the possibility of a fully quantitative study and typology of the material. Furthermore, there was no purposeful removal of ceramic building material from *in situ* contexts, with the result

that an understanding of this material and the creation of this typology relied primarily on fragments and the partially reconstructed bricks and pipes they formed. In total, the 2015 excavation of the bath collected 2,106 fragments of ceramic building material, weighing 266kg, from which a subsequent study season in 2016 identified only 65 complete or partially reconstructed bricks and 24 partially reconstructed *tubuli*. During this subsequent study season, the form and fabric of these bricks and pipes were described in detail using the same conventions of a similar study of ceramic building materials from the nearby site of al-Ḥumayma (Reeves and Harvey 2016, TABLE 1). These qualitative descriptions of the complete or partially reconstructed bricks and *tubuli* formed basis of the following typology. Although the corpus used for this typology is very small and a few types are represented by as few as two samples, the qualitative differences between types are distinct enough to be sure of the categorization. Nevertheless, the preliminary typology presented here should only be taken as an initial investigation using what evidence was available.

Brick (TABLE 1)

With the exception of a few fragments re-used as packing within the wall heating system, all the bricks collected from the bath for this study were those torn from the hypocaust by the looters. A total of 362 fragments and whole bricks, weighing over 168kg, were available for study. This corpus comprises four distinct groups representing three sizes of brick: *bessalis* (*bessales*), capping brick, and covering brick. In what follows, only the smallest of the bricks can be assigned a Latin term, as the measurements of this brick type correspond to those of a typical *bessalis*, which measure 2/3 of a Roman foot (*pes Monetalis* = 29.59 cm) on each side. Neither the so-called capping brick nor the covering brick correspond in size to the typical Roman *pedalis* (one Roman foot square) or *bipedalis* (two Roman feet square).

Bessales (FIGS. 3:1, 3:2, 4-5)

The *bessalis* (*bessales*) was the smallest and most common brick used within the hypocaust. Stacks of these square bricks formed the columns (*pilae*) upon which the elevated floor (*suspensurae*) rested. Although a total of 60 complete *bessales* were available for study, 24 of these were still mortared together and thus could provide individual measures but not weights and descriptions of their surfaces. All the *bessales* collected for study are fairly uniform with the exception of a variant type (represented by only two bricks), which differ in form and surface treatment but not fabric from the others. These two variant bricks are discussed after the description of the normal bricks.

The typical *bessalis* (FIGS. 3:1, 4) found within the bath is represented by 58 complete bricks, 34 of which are relatively free of mortar. The sides of these 58 bricks range from 16.3cm to 18.9cm, with a mean of 18.2cm long. They are between 2.1cm to 2.8cm thick, and their mean is 2.4cm thick. The weight of 34 complete bricks range from 1076g to 1465g, with a mean of 1302g. The fabric varies from light reddish brown (5YR 6/4) to light brown (7.5YR 6/4) to yellowish brown (10YR 5/4), while the surface is usually white (10YR 8/2) or very pale brown (10YR 8/3). A few samples have a pale brown (10YR 6/3) core. Typical inclusions are medium sub-rounded multicoloured sand, with some white inclusions and a few small pebbles. The top surface is typically flat and even, although a few samples have raised rounded ridges along edges. All bricks with visible top surfaces show linear bands of smoothing across the face, overlaid by a perpendicular band of smoothing on one or two of the edges. The bottom surface is flat, even, and rough, with no sign of smoothing. The sides are flat, even, and smooth. In rare cases, finger impressions are visible from handling when the brick was not fully dried. Mortar is typically present on both the top and bottom surfaces. In some cases, this mortar obscured the surface treatment or two

Table 1. Descriptions of Individual Bricks.

Entry	Brick Type	Registration #	Description	% Complete	Context	Length (cm)	Width (cm)	Thickness (cm)	Weight (g)	Colours	Fabric	Notes on Surface
1	Bessalis		Unbroken	100%	D:7-6/14-13.1211.2	17.8	17.6	2.6	1299.0	*	*	Top face smoothed.
2	Bessalis		Unbroken	100%	D:7-6/14-13.1211.2	18.6	18.4	2.5	1395.0	*	*	Top face smoothed.
3	Bessalis		Unbroken	100%	D:7-6/14-13.1211.2	18.4	18.3	2.4	1221.0	*	*	Top face smoothed.
4	Bessalis		Unbroken	100%	D:7-6/14-13.1211.2	18.9	18.4	2.5	1294.0	*	*	Top face smoothed.
5	Bessalis		Unbroken	100%	D:7-6/14-13.1211.2	18.6	18.6	2.4	1326.0	*	*	Top face smoothed.
6	Bessalis		Unbroken	100%	D:7-6/14-13.1211.2	18.7	18.2	2.8	1363.0	*	*	Top face smoothed.
7	Bessalis		Unbroken	100%	D:7-6/14-13.1211.2	18.5	18.5	2.5	1341.0	*	*	Top face smoothed.
8	Bessalis		Unbroken	100%	D:7-6/14-13.1211.2	18.4	18.3	2.6	1420.0	*	*	Top face smoothed.
9	Bessalis		Unbroken	100%	D:7-6/14-13.1211.2	18.5	18.3	2.6	1368.0	*	*	Top face smoothed.
10	Bessalis		Unbroken	100%	D:7-6/14-13.1211.2	18.9	18.4	2.5	1400.0	*	*	Top face smoothed.
11	Bessalis		Unbroken	100%	D:7-6/14-13.1211.2	18.5	18.4	2.5	1273.0	*	*	Top face smoothed.
12	Bessalis		Unbroken	100%	D:7-6/14-13.1211.2	18.9	18.6	2.4	1333.0	*	*	Top face smoothed.
13	Bessalis		Unbroken, mortar-covered	100%	D:7-6/14-13.1211.2	18.1	17.9	2.3	**	**	**	**
14	Bessalis		Unbroken, mortar-covered	100%	D:7-6/14-13.1211.2	18.3	17.9	2.3	**	**	**	**
15	Bessalis		Unbroken, mortar-covered	100%	D:7-6/14-13.1211.2	18.8	18.6	2.3	**	**	**	**
16	Bessalis		Unbroken, mortar-covered	100%	D:7-6/14-13.1211.2	18.0	17.9	2.5	**	**	**	**
17	Bessalis		Unbroken, mortared to second brick	100%	D:7-6/14-13.1211.2	18.4	18.3	2.4	**	**	**	**
18	Bessalis		Unbroken, mortared to second brick	100%	D:7-6/14-13.1211.2	17.9	17.6	2.4	**	**	**	**
19	Bessalis		Unbroken, mortared to second brick	100%	D:7-6/14-13.1211.2	16.6	16.6	2.4	**	**	**	**
20	Bessalis		Unbroken, mortared to second brick	100%	D:7-6/14-13.1211.2	16.6	16.3	2.3	**	**	**	**

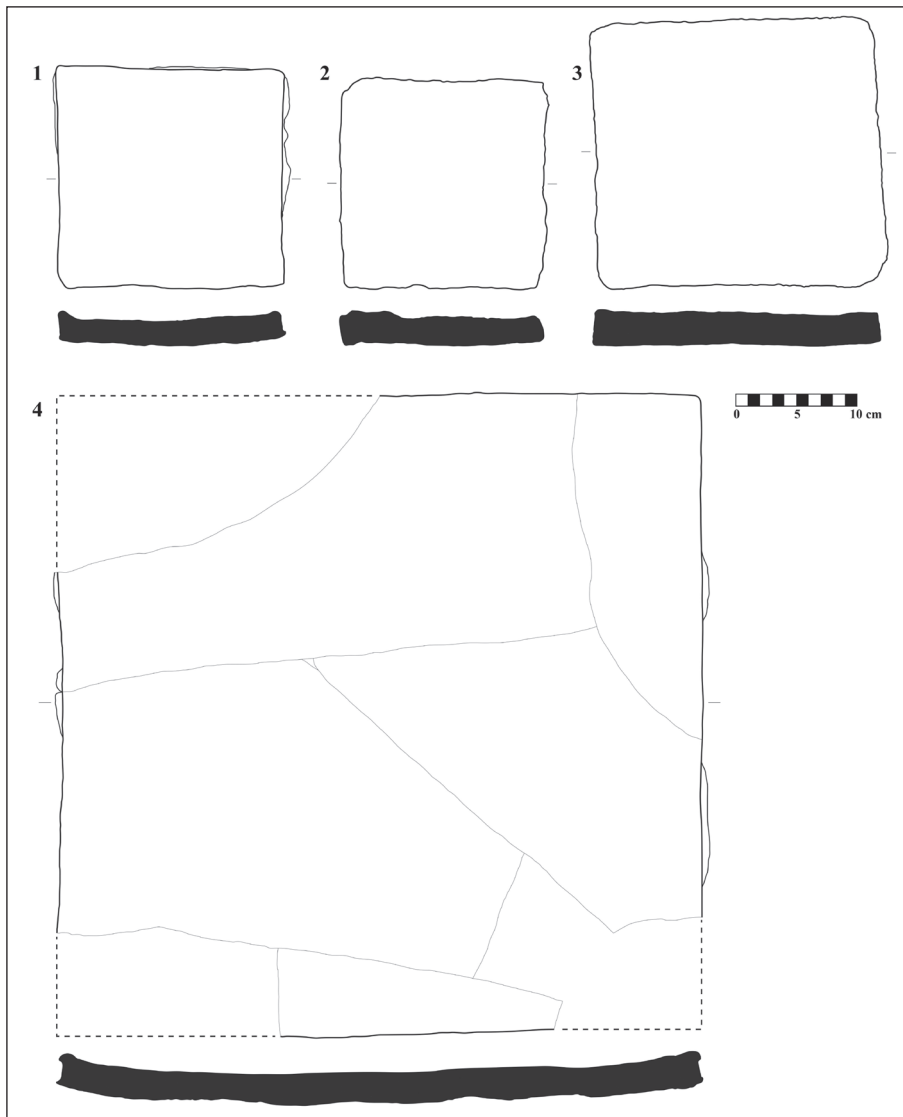
21	Bessalis	3004	Unbroken	100%	D:7-6/14-13.1211.4	18.1	17.9	2.7	1303.0	Fabric: 7.5YR 6/4; Surface: 10YR 8/2	Medium and course sand, very few small voids.	Top face smoothed.
22	Bessalis		Unbroken	100%	D:7-6/14-13.1211.4	18.1	17.4	2.4	1150.0	*	*	Top face smoothed.
23	Bessalis		Unbroken	100%	D:7-6/14-13.1211.4	18.4	17.5	2.4	1137.0	*	*	Top face smoothed.
24	Bessalis		Unbroken	100%	D:7-6/14-13.1211.4	18.0	17.5	2.4	1138.0	Fabric: 10YR 5/4; Surface: 10YR 8/3	Medium sand, some coarse inclusions, very few small voids.	Top face smoothed.
25	Bessalis		Unbroken	100%	D:7-6/14-13.1211.4	17.4	17.9	2.2	1076.0	*	*	Top face smoothed.
26	Bessalis		Unbroken	100%	D:7-6/14-13.1211.4	17.5	18.0	2.2	1173.0	*	*	Top face smoothed.
27	Bessalis		Unbroken	100%	D:7-6/14-13.1211.4	17.9	18.4	2.4	1261.0	*	*	No Smoothing.
28	Bessalis		Unbroken	100%	D:7-6/14-13.1211.4	18.6	18.2	2.6	1395.0	*	*	Top face smoothed.
29	Bessalis		Unbroken	100%	D:7-6/14-13.1211.4	18.4	18.3	2.4	1307.0	*	*	Top face smoothed.
30	Bessalis		Unbroken	100%	D:7-6/14-13.1211.4	18.4	18.3	2.5	1465.0	*	*	Top face smoothed.
31	Bessalis		Unbroken	100%	D:7-6/14-13.1211.4	18.4	18.3	2.3	1369.0	*	*	Top face smoothed.
32	Bessalis		Unbroken	100%	D:7-6/14-13.1211.4	18.5	18.3	2.3	1343.0	*	*	Top face smoothed.
33	Bessalis		Unbroken	100%	D:7-6/14-13.1211.4	18.4	18.3	2.5	1291.0	*	*	Top face smoothed; raised edges on top face.
34	Bessalis		Unbroken	100%	D:7-6/14-13.1211.4	18.6	18.3	2.6	1410.0	*	*	Top face smoothed.
35	Bessalis	3005	Unbroken	100%	D:7-6/14-13.1211.4	18.1	18.0	2.7	1194.0	Fabric: 7.5YR 6/4; Surface: 10YR 8/2	Medium sand, some white inclusions, many small voids.	Top face smoothed; raised edges on top face.
36	Bessalis		Unbroken	100%	D:7-6/14-13.1211.4	18.7	18.4	2.4	1329.0	*	*	Top face smoothed.
37	Bessalis		Unbroken	100%	D:7-6/14-13.1211.4	18.5	18.5	2.1	1440.0	*	*	Top face smoothed.
38	Bessalis		In three fragments	100%	D:7-6/14-13.1211.4	18.7	18.2	2.2	1256.0	Fabric: 7.5YR 6/4; Core: 10YR 6/3; Surface: 10YR 8/2	Medium sand, some white inclusions, many small voids.	Top face smoothed.
39	Bessalis	3006	In two fragments	100%	D:7-6/14-13.1211.4	18.6	18.5	2.5	1450.0	Fabric: 5YR 6/4; Surface: 10YR 8/2	Medium and course sand, some white inclusions, a few very small pebbles, some small voids.	Top face smoothed.

40	Bessalis	Unbroken	100%	D:7-6/14-13.1211.4	18.5	18.4	2.5	1120.0	*	*	Top face smoothed; raised edges on top face.
41	Bessalis	Unbroken	100%	D:7-6/14-13.1211.4	18.8	18.5	2.5	1377.0	*	*	Top face smoothed.
42	Bessalis	Unbroken, mortar-covered	100%	D:7-6/14-13.1211.4	18.5	18.2	2.4	**	**	**	**
43	Bessalis	Unbroken, mortar-covered	100%	D:7-6/14-13.1211.4	18.5	18.3	2.5	**	**	**	**
44	Bessalis	Unbroken, mortar-covered	100%	D:7-6/14-13.1211.4	18.7	18.6	2.5	**	**	**	**
45	Bessalis	Unbroken, mortar-covered	100%	D:7-6/14-13.1211.4	18.5	18.3	2.3	**	**	**	**
46	Bessalis	Unbroken, mortar-covered	100%	D:7-6/14-13.1211.4	18.1	17.3	2.6	**	**	**	**
47	Bessalis	Unbroken, mortar-covered	100%	D:7-6/14-13.1211.4	18.6	18.6	2.2	**	**	**	**
48	Bessalis	Unbroken, mortar-covered	100%	D:7-6/14-13.1211.4	18.2	18.0	2.3	**	**	**	**
49	Bessalis	Unbroken, mortared to second brick	100%	D:7-6/14-13.1211.4	18.3	18.2	2.1	**	**	**	**
50	Bessalis	Unbroken, mortared to second brick	100%	D:7-6/14-13.1211.4	18.5	18.2	2.3	**	**	**	**
51	Bessalis	Unbroken, mortared to second brick	100%	D:7-6/14-13.1211.4	18.8	18.4	2.3	**	**	**	**
52	Bessalis	Unbroken, mortared to second brick	100%	D:7-6/14-13.1211.4	18.8	18.2	2.5	**	**	**	**
53	Bessalis	Unbroken, mortared to second brick	100%	D:7-6/14-13.1211.4	18.6	18.6	2.2	**	**	**	**
54	Bessalis	Unbroken, mortared to second brick	100%	D:7-6/14-13.1211.4	18.4	17.9	2.3	**	**	**	**
55	Bessalis	Unbroken, mortared to second brick	100%	D:7-6/14-13.1211.4	18.8	18.3	2.4	**	**	**	**
56	Bessalis	Unbroken, mortared to second brick	100%	D:7-6/14-13.1211.4	18.7	18.6	2.5	**	**	**	**

57	Bessalis		Unbroken, mortar-covered	100%	D:7-6/14-13.1233.73	18.2	17.9	2.4	**	**	**	**
58	Bessalis		Unbroken	100%	D:7-6/14-13.1233.77	17.9	17.6	2.5	1235.0	*	*	Top face smoothed.
59	Variant bessalis	3003	Unbroken	100%	D:7-6/14-13.1211.4	17.5	17.1	2.5	948.0	Fabric: 7.5YR 6/4; Surface: 10YR 8/2	Medium sand, some white inclusions, many small voids.	No smoothing.
60	Variant bessalis	3008	One corner missing	90%	D:7-6/14-13.1233.77	17.1	16.1	2.5	1090.0	Fabric: 5YR 6/4; Surface: 10YR 8/2	Medium sand, some white inclusions, many small voids.	Top face smoothed.
61	Capping brick	3001	Unbroken	100%	D:7-6/14-13.1211.2	23.5	21.9	2.7	2365.0	*	*	Top face smoothed.
62	Capping brick		One corner missing	90%	D:7-6/14-13.1211.2	23.7	22.0	2.7	2080.0	Fabric: 5YR 5/1; Surface: 7.5YR 8/2	Coarse and very coarse sand, many white inclusions, a few very small pebbles. A few very small voids	Top face smoothed.
63	Capping brick		One corner missing	80%	D:7-6/14-13.1211.2	23.4	21.8	2.7	2065.0	Fabric: 2.5YR 6/6; Core: 7.5YR 6/0; Surface: 10YR 8/2	Medium and coarse sand, many white inclusions, a few very small pebbles, some very small voids.	Top face smoothed.
64	Capping brick	3007	In two fragments	100%	D:7-6/14-13.1211.4	23.2	21.7	3.1	2515.0	Fabric: 5YR 6/6; Core: 7.5YR 6/0; Surface: 10YR 8/2	Coarse and very coarse sand some white inclusions, A few very small voids	Top face smoothed.
65	Covering tile	3002	Five fragments giving full length and width	85%	D:7-6/14-13.1211.2	52.7	52.6	3.4	9115.0	Fabric: 10R 6/8; Surface: 7.5YR 7/2	Coarse to very coarse sand, some white inclusions, few small pebbles up to 0.4 cm long, many small voids.	Top face smoothed.

* Time constraints during processing prevented recording the fabric of these bricks.

** The presence of thick layers of mortar or an adhering brick made it impossible to record the weight, fabric, and surfaces of these bricks.



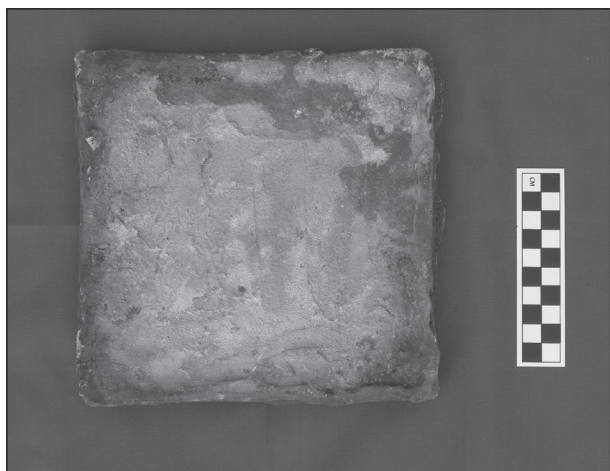
3. Drawing of bricks - 1. *Bessalis* - 3005; 2. Variant *bessalis* - 3003; 3. Capping brick - 3001; 4. Covering brick - 3002 (C. A. Harvey).

bricks remain mortared together. Soot staining is present on all surfaces, particularly on sides and edges of the bricks.

The two variant *bessales* (FIGS. 3:2 , 5) are slightly smaller than the typical *bessalis*, measuring 17.1cm by 16.1cm and 17.5cm by 17.1cm. Both are 2.5cm thick. They weigh 1090g and 948g. The fabric of these variant *bessales* is identical to that of the typical *bessales* described above. The variant type differs from the typical version primarily in its surface treatment, as the lateral smoothing that characterizes the typical *bessalis* is absent on one of the variants and very faint on the other. Furthermore, the sides of these two bricks are less straight and their corners less square than those

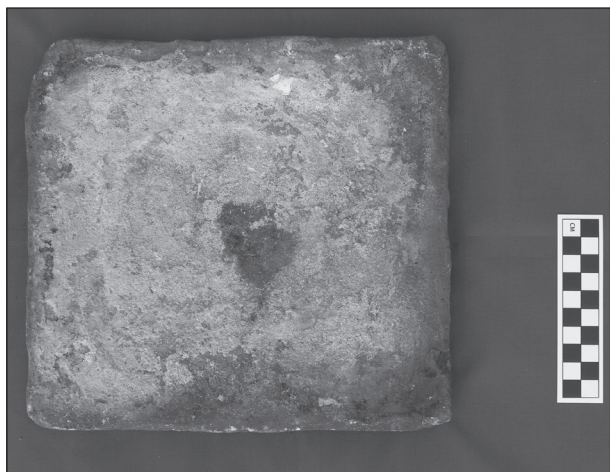
on the typical *bessales*. In general, these two bricks seem to be less carefully made than the others, or made in different molds.

Although the characteristics that distinguish the variant *bessales* are primarily qualitative, they suggest that their manufacture followed different steps. Unfortunately, the lack of data on *in situ* bricks prevents a firm understanding of the relationship between the variant and non-variant *bessales*. The variant bricks could represent a different phase, or simply a different batch of bricks made in a different mold or by a different brick-maker. It is also entirely possible that more examples of this variant exist in the samples collected, but the amount of mortar adhering to them inhibits their identification as such.

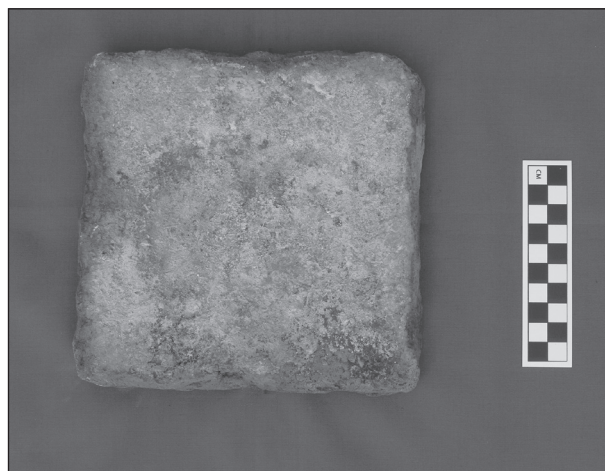
4. *Bessalis* - 3005 (C. A. Harvey).*Capping Bricks* (FIGS. 3:3, 6)

The capping bricks are approximately square and slightly larger than a *bessalis*. These bricks formed the uppermost part of the *pilae* and acted much in the same way as a column capital, broadening the *pilae* and concentrating the weight of the supported floor upon them. Far less common than *bessales*, few complete capping bricks were available for study, and the following description is based on only two complete and two nearly complete capping bricks.

The slightly longer side of the four complete or nearly complete bricks ranges from 23.2cm to 23.7cm and has a mean of 23.45cm, while the slightly shorter side ranges from 21.7cm to 22.0cm and has a mean of 21.85cm. The thickness of these four bricks range from 2.7cm to 3.1cm, with a mean of 2.8cm. The weight of the two complete bricks are 2365g and 2515g. The



6. Capping brick - 3001 (C. A. Harvey).

5. Variant *bessalis* - 3003 (C. A. Harvey).

fabric varies from grey (5YR 5/1) to light red (2.5YR 6/6) to reddish yellow (5YR 6/6). The core is typically grey (7.5YR 6/0), while the surface can be a very pale brown (10YR 8/3) or pinkish white (7.5YR 8/2). Typical inclusions are medium to very coarse sub-rounded multi-coloured sand, with numerous white inclusions and occasional small pebbles. There are also a few very small voids. The top surface is typically flat and even, with evidence of smoothing that runs across the brick. The bottom surface is also flat and even, but is not smoothed. The sides are flat, even, and smooth. In rare cases, finger impressions are visible from handling when the brick was not fully dried. Mortar is typically present on both the top and bottom surfaces. Soot staining is present on all surfaces, particularly on sides and edges of the bricks.

Covering Bricks (FIGS. 3:4, 7)

Covering bricks were the largest but also least common bricks found within the bath-house. These bricks rested on four adjacent *pilae*, with each of their four corners on a separate *pila*, much like a table on four legs. Two layers of these covering slabs topped with a thick layer of mortar and stone paving slabs formed the suspended floor in the *tepidarium*. Excavation uncovered only one fragmented covering brick (no. 3002) and a few fragments of suspected covering brick.

This nearly complete covering brick has full



7. Covering brick - 3002 (C. A. Harvey).

measures of 52.6cm by 52.7cm and ranges between 3.0cm to 3.4cm in thickness. Although only about 85% complete, the fragments of this brick weigh a total of 9115g. The fabric is light red (10R 6/8), and the surface is pinkish grey (7.5YR 7/2), although fragments of suspected covering bricks show that the fabric can also be light red (2.5YR 6/6) or reddish brown (5YR 5/3), a grey (5YR 6/1) core can exist, and the surface can also be white (10YR 8/2). Typical inclusions are coarse to very coarse sub-rounded and sub-angular multicoloured sand, with some white inclusions, a few small pebbles, and some angular rock inclusions up to 0.4cm in diameter. It also has many small to very small voids. The top surface is typically flat, even, and smoothed. The smoothing is evidenced by lateral strokes across the face and smoothing along the edges. The bottom surface is also flat and even, but not smoothed. The sides are flat, even, and smooth, with outward protruding ridges at the top and bottom. The nearly complete brick has two finger impressions on the bottom of one of the sides. It also has trace amounts of mortar on its bottom face and the sides. This brick was evidently face-down and rested directly upon the *pilae*, as there is heavy soot staining across its top face with the exception of the extant corners, which rested on *pilae* and were thus not exposed to smoke.

The Use of Bricks, their Phasing, and Comparanda

Though none of the collected bricks were found *in situ*, photos of bricks in the extant hypocaust system reveal their use (FIG. 8). Stacks of *bessales* formed the *pilae* upon which the elevated floor (*suspensurae*) rested. Two or three capping bricks placed on top of each stack of *bessales* served to broaden the *pilae* and concentrate the weight of the supported floor upon them, just like column capitals. Covering bricks rested on four adjacent *pilae*, with each of their four corners on a separate *pila*, much like a table on four legs. In turn, each *pila*, excluding those in corners or against walls, helped to support the corners of four separate covering bricks. Two layers of these covering slabs topped with a thick layer of mortar and stone paving slabs formed the *suspensurae* in the *tepidarium*.

Brick fragments could also be used as packing within the wall system, as evidenced by a fragment of capping brick found within the wall heating system of the *tepidarium*. This use as packing is suggestive of reuse and may in fact be a result of a reconstruction or repair of the heating system. It is likewise possible that the variant *bessales* come from an earlier phase of the hypocaust than the non-variant type, but this theory is currently only speculative.

The lack of similar studies of hypocaust bricks makes it difficult to identify *comparanda* for this material. One of the only regional sites where there has been an emphasis on the study



8. Cross-section of hypocaust in *tepidarium* (Th. Fournet).

of ceramic building materials is al-Ḥumayma (Reeves and Harvey 2016). While numerous types of hypocaust bricks exist at al-Ḥumayma, they are all slightly larger than those found at ‘Ayn Gharandal and are of a different fabric. Hopefully, the publication of this preliminary typology will help to identify regional *comparanda* and spur similar studies of this material elsewhere.

Wall Heating Pipes

Both the *tepidarium* and *caldarium* at ‘Ayn Gharandal had wall heating systems consisting of specialized rectangular *tubuli* and cylindrical pipes of the type typically found in hydraulic installations. Within the *tepidarium*, all four walls had heating systems built primarily with cylindrical pipes with only a few rectangular *tubuli*. In the *caldarium*, wall-heating systems existed against all but the south wall and mostly consisted of rectangular *tubuli* mixed with some small cylindrical pipes. The extensive use of cylindrical pipes in the *tepidarium* is curious and may be a result of a shortage of the more traditional rectangular *tubuli*, which allowed for the lateral flow of air and created more efficient wall heating systems. The builders evidently recognized the benefit of using rectangular *tubuli* and prioritized these pipes for the *caldarium*, where higher temperatures and thus more efficient heating systems were necessary.

No typology currently exists for the cylindrical heating pipes from ‘Ayn Gharandal, and it is not possible within the scope of this article to give a full description of these pipes. The remainder of this article will therefore primarily focus on the rectangular *tubuli* found during excavation of the bath.

Tubuli (TABLE 2)

Tubuli are ceramic pipes with rectangular profiles, designed to be stacked against walls in rows and columns, creating a continuous void that allowed hot air to rise from the hypocaust and heat the walls. Vents cut into the sides of *tu-*

buli allowed for the lateral flow of air between adjacent columns of pipe. All the *tubuli* from ‘Ayn Gharandal were wheel-made. Once removed from the potter’s wheel, the *tubuli* were pressed into their box-like shape by hand, resulting in one end being rectangular while the other remained more oval. Before drying and being fired, the *tubuli* had their lateral vents cut out with a knife.

The 2015 excavation of the bath uncovered a total of 1,248 *tubulus* fragments, weighing 37,624g. Regrettably, there was no removal or detailed study of *tubuli* from *in situ* contexts, with the result that the exact use of the *tubuli* is unclear and the creation of this typology relied entirely on fragments and the partially reconstructed *tubuli* they formed. The preliminary typology presented here includes only reconstructed *tubuli* for which the following three criteria have been met. First, there is more than one sample from the type, proving that it is not a unique specimen. Second, the full height, width, and depth of the type is known from one or more samples. Third, the type is qualitatively different in form or fabric from the other types. This typology is therefore qualitative and not quantitative and is not inclusive of all the fragments collected, but it does represent a step forward in our understanding of this material and an important first step in the study of *tubuli* at ‘Ayn Gharandal.

Type 1 (FIGS. 9, 10)

The first type of *tubulus* is the most common type found during excavation and is characterized by its squat oval vents and its fabric, which is unique from the other types in that it is not of the typical Petra ware type. The following description is based on nine partially reconstructed pipes (nos. 60008, 60009, 60019, 60034-36, 60041, 60043, and 60045).

Nine full heights range from 17.6cm to 20.0cm and have a mean of 18.9cm. Four full widths range from 16.3cm to 18.4cm, with a mean of 17.45cm. Five full depths range from

Table 2. Descriptions of Individual Tubuli.

	Flue Type	Registration #	Description	Context	Height (cm)	Width (cm)	Depth (cm)	Thickness (cm)	Weight (g)	Colours	Fabric	Top Rim	Bottom Rim	Shape of lateral vent(s)
1	1	60008	Reconstructed, nearly complete	D:7-6/14-13.1211.2	18.4	17.4	8.0	0.6-0.7	970.0	Fabric: 5YR 6/6; Surface: 10YR 7/2	Fine/medium subrounded quartz, few small voids	Thickened; rounded overhang on exterior; rounded edge on interior	Thickened, flattened; rounded overhang on exterior; rounded but rough overhang on interior	Oval
2	1	60009	Reconstructed, nearly complete	D:7-6/14-13.1211.2	19.4	17.7	8.7	0.5-0.8	1225.0*	Fabric: 5YR 6/6; Surface: 7.5YR 7/4	Fine/medium subrounded quartz, few small white inclusions, few small voids	Thickened; rounded overhang on exterior; rounded edge on interior	Thickened, flattened; rounded overhang on exterior; rounded but rough overhang on interior	Oval
3	1	60019	Reconstructed, nearly complete	D:7-6/14-13.1224.42	18.1	18.4	8.5	0.6	734.0	Fabric: 5YR 6/6; Surface: 10YR 7/2	Fine subrounded quartz, few small voids	Thickened; rounded overhang on exterior; rounded edge on interior	Thickened, flattened; rounded overhang on exterior; rounded edge on interior	Oval
4	1	60034	One large sherd	D:7-6/14-13.1224.53	19.6	?	?	0.5-0.9	191.0	Fabric: 2.5YR 6/6; Surface: 7.5YR 6/4	Fine/medium subrounded quartz, few small white inclusions, few small voids	Thickened; rounded overhang on exterior; rounded edge on interior	Thickened; rounded overhang on exterior; rounded but rough overhang on interior	Oval
5	1	60035	One large sherd	D:7-6/14-13.1224.53	17.6	?	?	0.5-0.8	194.0	Fabric: 2.5YR 6/6; Surface: 7.5YR 6/4; Core: 2.5YR 6/0	Fine/medium subrounded quartz, few small white inclusions, few small voids	Thickened; rounded overhang on exterior; rounded edge on interior with slight overhang	Thickened; rounded overhang on exterior; rounded but rough overhang on interior	Oval
6	1	60036	Reconstructed, partially complete	D:7-6/14-13.1224.53	18.8	?	?	0.6-0.8	280.0	Fabric: 5YR 6/6; Surface: 10YR 8/2	Fine/medium subrounded quartz, few small white inclusions, few small voids	Thickened; rounded overhang on exterior; rounded edge on interior with slight overhang	Thickened; rounded overhang on exterior; rounded but rough overhang on interior	Oval

7	1	60041	Reconstructed, partially complete	D:7-6/14-13.1231.64	20.0	?	10.6	0.6-0.8	481.0	Fabric: 5YR 6/6; Surface 7.5/7/6	Fine/medium subrounded quartz, few small white inclusions, few small voids	Thickened; rounded overhang on exterior; rounded edge on interior with slight overhang	Thickened; rounded overhang on exterior; rounded but rough overhang on interior	Oval
8	1	60043	Reconstructed, partially complete	D:7-6/14-13.1235.66	19.4	?	?	0.6-0.8	373.0	Fabric: 5YR 6/6; Surface: 10YR 7/2	Fine/medium subrounded quartz, few small voids	Thickened; rounded overhang on exterior; rounded edge on interior	Thickened; rounded overhang on exterior; rounded but rough overhang on interior	Oval
9	1	60045	Reconstructed, nearly complete	D:7-6/14-13.1233.68	18.6	16.3	8.7	0.5-0.7	955.0	Fabric: 5YR 6/6; Surface: 10YR 7/3	Fine/medium subrounded quartz, few small white inclusions, few small voids	Thickened; rounded overhang on exterior; rounded edge on interior	Thickened; rounded overhang on exterior; rounded but rough overhang on interior	Oval
10	2	60023	Reconstructed, partially complete	D:7-6/14-13.1225.47	13.3	?	9.5	0.4-0.6	229.0	Fabric: 2.5YR 5/6; Surface: 10YR 7/3	Fine/medium subrounded quartz, few small white inclusions, few small voids	Thickened, flattened; rounded slight overhang on exterior; sharp slight overhang on interior	Thickened, rounded; slight rounded overhang on exterior; sharp edge on interior	Oval
11	2	60024	Reconstructed, partially complete	D:7-6/14-13.1225.47	?	15.2	?	0.3-0.5	198.0	Fabric: 2.5YR 5/6; Surface: 10YR 7/3	Fine/medium subrounded quartz, few small white inclusions, few small voids	Thickened, rounded; rounded overhang on exterior; rounding on interior without overhang	?	Unclear
12	2	60025	One large sherd	D:7-6/14-13.1225.47	13.1	?	?	0.4-0.5	90.0	Fabric: 2.5YR 5/6; Surface: 10YR 7/3	Fine/medium subrounded quartz, few small white inclusions, few small voids	Thickened, flattened; rounded overhang on exterior; slight rounded overhang on interior	Thickened, rounded; rounded overhang on exterior; sharp edge on interior	Oval?

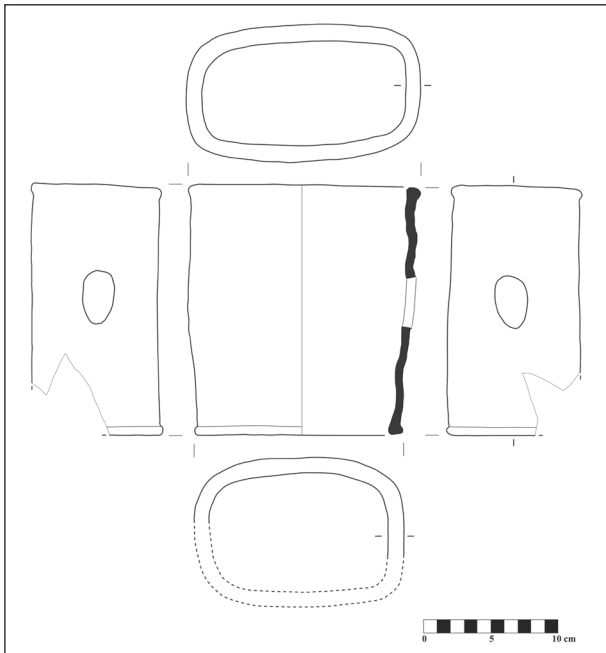
13	3	60026	Reconstructed, partially complete	D:7-6/14-13.1225.47	?	22.5	9.6	0.5-0.8	685.0	Fabric: 5YR 6/6; Surface: 10YR 8/3; Core: 7.5YR 5/0	Medium sub-rounded quartz, few small white inclusions, few small voids	?	Thickened, rounded; rounded edge on exterior; rounded but rough edge on interior	?
14	3	60039	Reconstructed, nearly complete	D:7-6/14-13.1229.61	24.2	21.7	9.8	0.4-1.0	1179.0	Fabric: 2.5YR 6/6; Surface: 10YR 8/3; Core: 7.5YR 5/0	Medium sub-rounded quartz, few small white inclusions, few small voids	Thickened, flattened, slightly inverted; rounded edge on exterior; rounded edge on interior with slight overhang	Thickened, rounded; rounded edge on exterior; rounded but rough edge on interior with slight overhang	Oval, irregular oval
15	4	60016	Reconstructed, nearly complete	D:7-6/14-13.1215.36**	19.4	15.1	10.4	0.5-0.8	1044.0	Fabric: 5YR 5/6; Surface: 5YR 5/6	Medium sub-rounded quartz, few small white inclusions, few small voids	Thickened; overhang on exterior coming to rounded point; rounded on edge on interior	Thickened, flattened; rounded overhang on exterior; slight rounded overhang on interior	Irregular oval
16	4	60037	Reconstructed, partially complete	D:7-6/14-13.1224.53	19.5	?	?	0.5	196.0	Fabric: 5YR 5/6; Surface: 5YR 5/6	Medium sub-rounded quartz, few small white inclusions, few small voids	Rounded; slight overhang on exterior; rounded on edge on interior	Thickened; rounded overhang ending in point on exterior; rough and rounded edge on interior	Pointed oval
17	5	60010	Reconstructed, nearly complete	D:7-6/14-13.1211.2	16.0	13.3	10.2	0.5	248.0	Fabric: 5YR 6/6, 5YR 6/6; Core: 7.5YR 6/0	Medium sub-rounded quartz, few small white inclusions, few small voids	Thickened, hooked; rounded overhang on exterior; pointed hooked overhang on interior	Thickened, flattened; rounded overhang on exterior ending in point; sharp and rough edge on interior	Oval?
18		60011	Reconstructed, partially complete	D:7-6/14-13.1211.2	17.3	?	9.4	0.4-0.7	275.0	Fabric: 5YR 6/6; Surface 7.5/6	Medium sub-rounded quartz, some small white inclusions, few small voids	Thickened, flattened; rounded overhang on exterior ending in point; rounded edge on interior	Thickened; rounded overhang on exterior; sharp and rough edge on interior	Irregular oval

19	60012	One large sherd	D:7-6/14-13.1211.2	16.9	?	?	0.3-0.5	174.0	Fabric: 2.5YR 6/6; Surface: 5YR 6/6	Medium sub-rounded quartz, few small white inclusions, few small voids	Thickened, pointed overhang on exterior; sharp edge on interior	Thickened, flattened, rough	Oval?
20	60018	One large sherd	D:7-6/14-13.1216.37**	?	16.5	?	0.5	177.0	Fabric: 5YR 6/6, 2.5Y 7/4	Fine/medium subrounded quartz, few small white inclusions, few small voids	Thickened, rounded; rounded overhang on exterior	?	Unclear
21	60020	One large sherd	D:7-6/14-13.1224.42	16.3	?	?	0.5-0.7	181.0	Fabric: 5YR 5/6; Surface: 5YR 5/6	Medium sub-rounded quartz, few small white inclusions, few small voids	Thickened, rounded; rounded overhang on exterior; rounded and rough edge on interior	Thickened, rounded; rounded overhang on exterior; rounded and rough edge on interior	Oval?
22	60027	Reconstructed, nearly complete	D:7-6/14-13.1225.47	19.0	19.5	11.0	0.6-0.8	860.0	Fabric: 2.5YR 5/6; Surface: 10YR 6/3; Core: 10YR 7/4	Medium sub-rounded quartz, few small white inclusions, few small voids	Thickened, rounded	Thickened, rounded; rounded edge on exterior; rounded and rough overhang on interior	Oval
23	60030	One large sherd	D:7-6/14-13.1224.49	23.0	?	?	0.5-0.7	454.0	Fabric: 7.5YR 6/6; Surface: 7.5YR 7/6	Medium sub-rounded quartz, few small white inclusions, few small voids	Thickened, flattened; both edges sharp, with slight overhang on interior, and none on exterior	Thickened, rounded; rounded edge on exterior; sharp edge on interior with slight overhang	Oval?
24	60038	One large sherd	D:7-6/14-13.1224.53	16.6	?	?	0.5-0.6	131.0	Fabric: 2.5YR 6/8; Surface: 10YR 6/3	Medium sub-rounded quartz, few small white inclusions, few small voids	Rounded, thickened	Rounded; sharp edge on exterior	?

* This weight includes a large chunk of mortar adhering to the tubulus.

** These two tubuli fell from walls during excavation and are the only two tubuli in this corpus found *in situ*.

8.0cm to 10.6cm and have a mean of 8.9cm. The wall thickness varies from 0.5cm to 0.9cm. The fabric is light red (2.5YR 6/6) or reddish yellow (5YR 6/6), and the surface is most often light grey (10YR 7/2), light brown (7.5YR 6/4), or very pale brown (10YR 7/3). One sample has a grey (2.5YR 6/0) core. Typical inclusions are fine and medium clear quartz, with a few small white flecks. Macroanalysis suggests that this fabric is not Petra ware, but rather of an unknown source. Rims on the rectangular top end tend to be thickened with a rounded overhang



9. Drawing of Type 1 *tubulus* - 60045 (C. A. Harvey).



10. Photo of Type 1 *tubulus* - 60045 (C. A. Harvey).

on the exterior and a rounded edge on the interior that has a slight overhang on some samples, while those on the oval bottom are thickened and slightly flattened with a rounded overhang on the exterior and a rounded but rough edge on the interior that has a slight overhang on some samples. Lateral vents are oval, and range in height from 2.8cm to 4.6cm and in width from 1.8cm to 2.9cm. The presence of off-white mortar with carbon inclusions on the exterior and soot staining on the interior of reconstructed examples indicates that this type was used in the wall heating system.

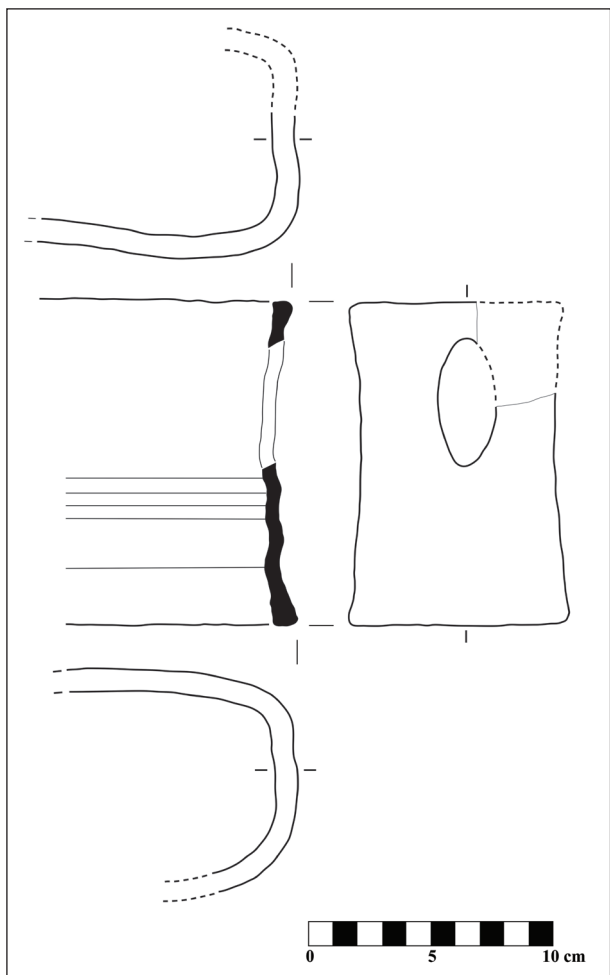
Type 2 (FIGS. 11, 12)

The type two *tubulus* is characterized by its small size. The following description is based on three partially reconstructed examples (nos. 60023-25).

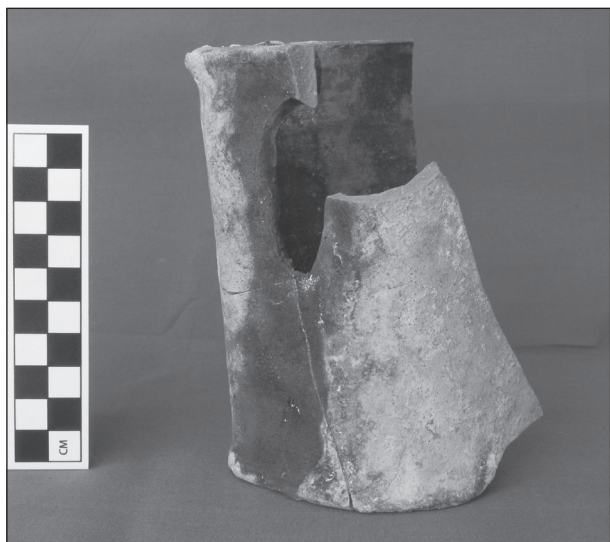
Two full heights are 13.1 and 13.3cm, the only full width is 15.2cm, and the one full depth is 9.5cm. The wall thickness varies from 0.3cm to 0.6cm. The fabric is red (2.5YR 5/6) with a very pale brown (10YR 7/3) surface. Typical inclusions are fine and medium clear quartz, with a few small white flecks. Macroanalysis suggests that this fabric is Petra ware. Rims on the rectangular top end tend to be thickened and flattened with a rounded overhang on the exterior and a sharper lip on the interior, while those on the oval bottom are thickened and rounded with a rounded overhang on the exterior and a sharper interior lip. Lateral vents are oval, and the one fully preserved vent is 5.0cm high by 2.2cm wide. Curiously, the lateral vents are always located in the top half of the pipe, being between 1.7 to 3.4cm from the top rim. The presence of grey mortar with carbon inclusions on the exterior and soot staining on the interior of reconstructed examples indicates that this type was used in the wall heating system.

Type 3 (FIGS. 13 , 14)

The third type of *tubulus* is characterized by its relatively large size. The following descrip-



11. Drawing of Type 2 *tubulus* - 60023 (C. A. Harvey).

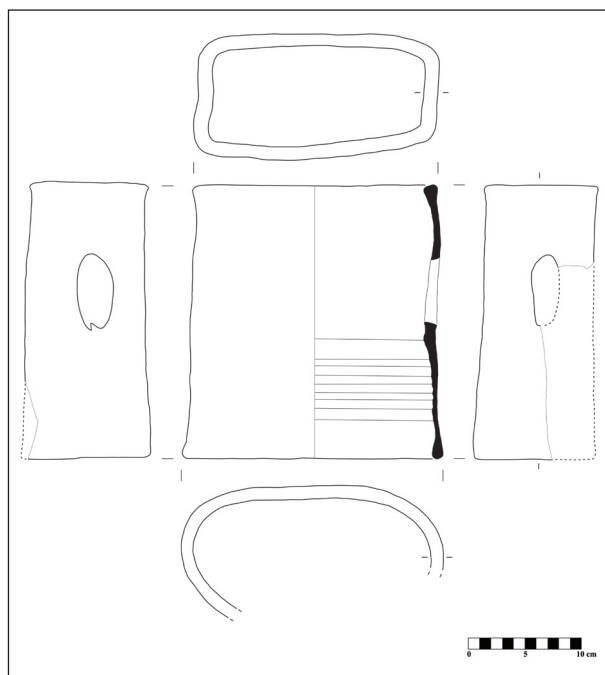


12. Photo of Type 2 *tubulus* - 60023 (C. A. Harvey).

tion is based on only two partially reconstructed pipes (nos. 60026 and 60039).

The only surviving full height is 24.2cm, two full widths are 21.7cm and 22.5cm, and two full

depths are 9.8cm and 9.6cm. The wall thickness varies from 0.4cm to 1.0cm. The fabric is light red (2.5YR 6/6) or reddish yellow (5YR 6/6) with a grey (7.5YR 5/0) core and a very pale brown (10YR 8/3) surface. Typical inclusions are medium sub-rounded clear quartz, with a few small white flecks. Macroanalysis suggests that this fabric is Petra ware. Rims on the rectangular top end tend to be thickened and slightly inverted with a rounded edge on the exterior and interior and a slight overhang on the



13. Drawing of Type 3 *tubulus* - 60039 (C. A. Harvey).



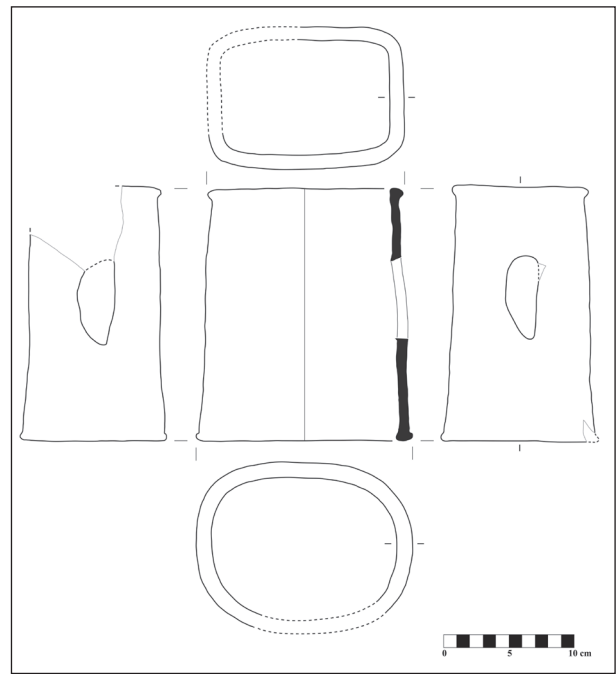
14. Photo of Type 3 *tubulus* - 60039 (C. A. Harvey).

interior. The rims on the oval bottom are thickened and rounded with a rounded edge on the exterior and a rounded but rough edge on the interior. Lateral vents are oval or irregular oval and are located in the centre of the side, closer to the top than the bottom. The vent size ranges between 5.9cm and 6.2cm high, while the only preserved width is 2.9cm. The presence of off-white mortar on the exterior and soot staining on the interior of reconstructed examples indicates that this type was used in the wall heating system.

Type 4 (FIGS. 15, 16)

The fourth type of *tubulus* is characterized by its large and irregularly shaped lateral vents. The following description is based on only one nearly complete reconstructed and one partially reconstructed pipe (nos. 60016 and 60037).

The full heights of these samples are 19.4cm and 19.5cm, the only surviving full width is 15.1cm, and the only surviving full depth is 10.4cm. The wall thickness varies from 0.5cm to 0.8cm. The fabric and surface is yellowish red (5YR 5/6). Typical inclusions are fine and medium sub-rounded clear quartz, with a few small white flecks. Macroanalysis suggests that this fabric is Petra ware. Rims on the rectangular top end are thickened with a slight overhang on the exterior coming to a rounded point, and a rounded edge on interior. Rims on the oval bottom are thickened with a rounded overhang on the exterior, sometimes ending in a rounded point, and a rounded but rough lip on interior that can have a slight overhang. Lateral vents are irregular or pointed ovals and are located in the centre of the side, slightly closer to the top than the bottom. The vent size ranges between 6.4cm and 6.8cm high, and 2.3cm and 2.7cm wide. The most complete of these examples (no. 60016) fell from the wall during excavation, proving that this type was used in the wall heating system. Both samples have a relatively high amount of soot and heat damage compared to the other *tubuli*.



15. Drawing of Type 4 *tubulus* - 60016 (C. A. Harvey).



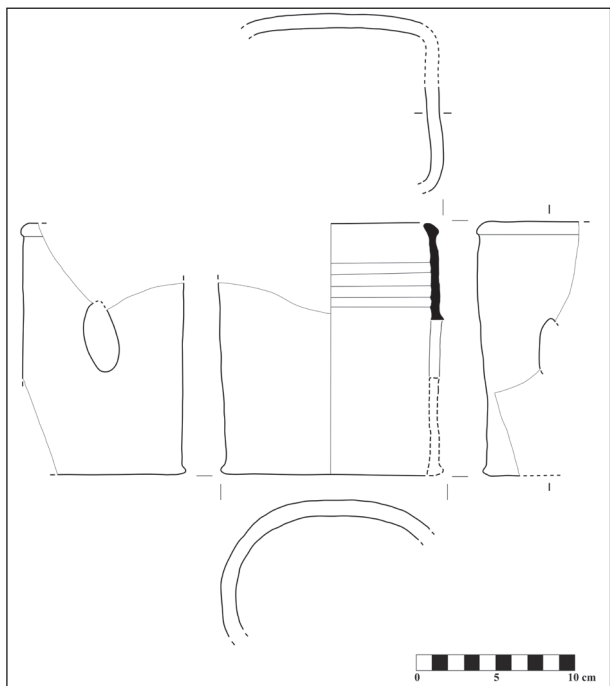
16. Photo of Type 4 *tubulus* - 60016 (C. A. Harvey).

Type 5 (FIGS. 17, 18)

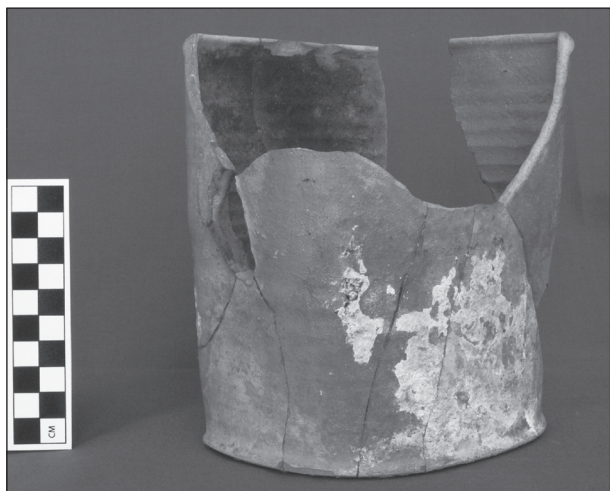
The fifth type of *tubulus* is characterized by its distinctive rim. The following description is based on only one reconstructed example (no. 60010); however, fragments from other examples of this type exist. A complete specimen of this type was uncovered during the 2010 excavation of the bath and previously published (Darby and Darby 2012: fig. 112; 2015: fig. 7).

The full height of the *tubulus* is 16.0cm, the

width is 13.3cm, and the depth is 10.2cm. The wall thickness is 0.5cm. The fabric is reddish yellow (5YR 6/6), and its core is grey (7.5YR 6/0). Typical inclusions are medium sub-rounded clear quartz, with a few small white flecks. Macroanalysis suggests that this fabric is Petra ware. Rims on the rectangular top end are triangular and can appear hooked as they come to a rounded point that curves to the interior with a slight overhang. On the exterior, the top rim has a rounded overhang. Rims on the oval bottom are thickened and flattened with a rounded overhang on the exterior that can end in a point



17. Drawing of Type 5 *tubulus* - 60010 (C. A. Harvey).



18. Photo of Type 5 *tubulus*- 60010 (C. A. Harvey).

and a sharp and rough edge on interior. Lateral vents are oval and are located in the centre of the side, slightly closer to the top than the bottom. The best-preserved vent measures 4.1cm high and 2.1cm wide. The presence of mortar on the exterior and soot staining on the interior of this pipe indicates that this type was used in the wall heating system.

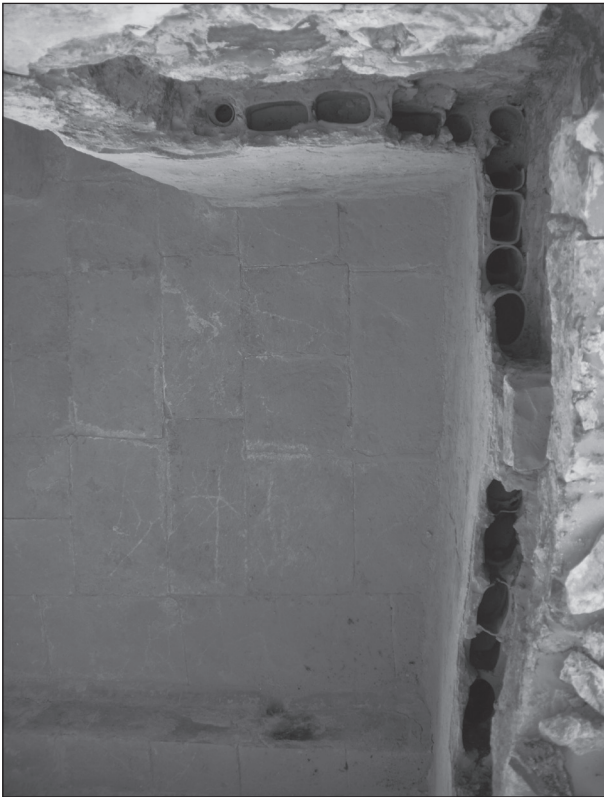
The Use of *Tubuli*, their Phasing, and Comparanda

With the exception of a single *tubulus* that collapsed from the eastern wall of the *tepidarium* during excavation (no. 60016), none of the *tubuli* available for study came from *in situ* contexts. As a result, it is impossible to say with complete certainty exactly how and where the *tubuli* discussed above were used, which is unfortunate as the variation in sizes may have reflected different or specialized uses. Like other wall heating systems, however, the *tubuli* lined the walls to create a continuous void through which hot air from the hypocaust could rise, circulate, and heat the walls (FIG. 19). One curious feature of the *tubuli* within the *caldarium* is that they were placed in staggered rows (like bricks in a wall), rather than in linear columns as done elsewhere, such as in Wādī Mūsā where mortar impressions attest this arrangement ('Amr *et al.* 1997:472, fig. 5).

The *tubuli* by themselves reveal very little about the phasing of the bathhouse; however, a close examination of the heating walls during excavation suggested that they underwent a major renovation during their lifetime. While the numerous types of *tubuli* may be the products of different workshops or represent specialized uses of the *tubuli*, they may also be the result of multiple phases of construction or renovation in the bath; however, without a quantitative study or a good understanding of how each type was used in heating system, this theory remains speculative. Nevertheless, the relative abundance of the Type 1 *tubulus* and the fact that these *tubuli* exhibit much less soot

build up and heat damage than the other types suggest that the Type 1 *tubulus* may date to a later renovation of the bath. Furthermore, the relative paucity of the Type 4 *tubulus*, the extent to which both examples are damaged by heat exposure, and the fact that one of these *tubuli* (no. 60016) fell from a wall in the *tepidarium* otherwise containing cylindrical flue pipes suggests that the Type 4 is a comparatively old type, possibly reused.

There are a number of sites in the wider region that have produced wheel-made *tubuli*. These sites include al-Ḥumayma (Reeves and Harvey 2016, figs. 10, 12, tables 4, 6), Yotvata (Meshel 1989: pl. 32 D), Petra (Kolb and Keller 2000: 362, fig. 8; Schmid 2002: 265), and al-Lajjūn (Parker 2006, 361, figs. 16.76-79). While the *tubuli* from these sites were produced in the same fashion as those from 'Ayn Gharandal, they do not appear from their publication to be exact parallels for any of the five types presented here. Further research and excavation may reveal closer *comparanda*.



19. Top down view of *tubuli* against wall in *caldarium*. (Th. Fournet).

Conclusion

The typologies presented here represent the first detailed study of ceramic building material in the Wādī 'Arabah and are an important contribution to the study of this material in the wider area. These typologies are preliminary, and further work remains to be done, including the examination of the cylindrical flue pipes, the continued search for parallels, and the possibility of fabric analysis. While the focus of this article has been on the typologies themselves, it has laid the groundwork for continued analysis of this material. For the site of 'Ayn Gharandal, this study opens a new avenue for the examination of the bath and its relationship to others in the region. This publication will also assist with the development of a regional typology of ceramic building material, which will not only result in a new tool for dating the construction and use of baths, but will in turn also lead to a better understanding of the local economy and supply in the region, particularly in connection with military establishments. Although the study of ceramic building material remains undeveloped, this publication will hopefully encourage similar endeavors at other sites.

Acknowledgments

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