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## The Cylindrical Heating Pipes from the Late Roman Bath at 'Ayn Gharandal, Jordan

### Introduction

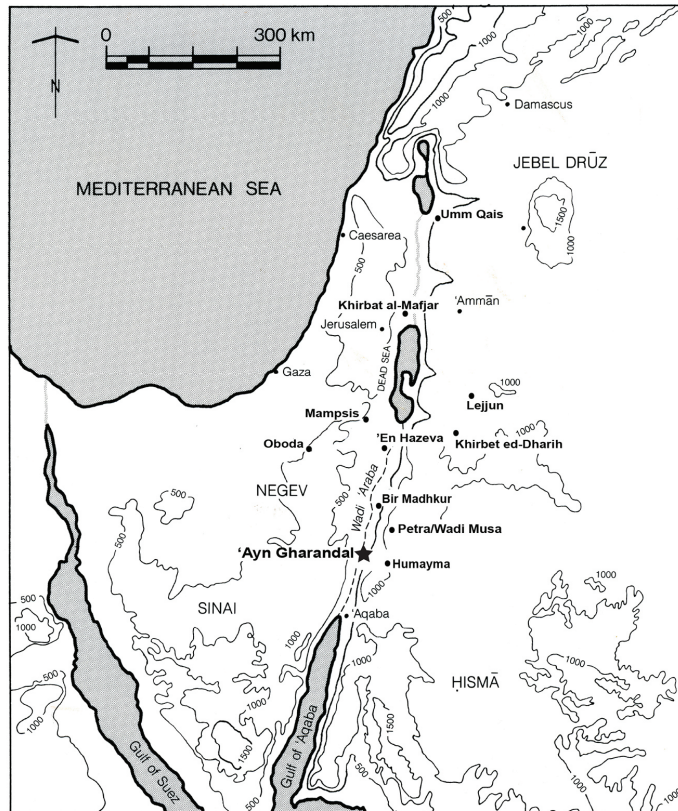
In the summer of 2015, the 'Ayn Gharandal Archaeological Project excavated a large section of the site's Late Roman bath. This excavation resulted in the collection of a considerable quantity of ceramic building materials, including bricks, *tubuli* (specialized rectangular heating pipes), and cylindrical pipes used in the heating system. This large corpus represents a significant opportunity to study this material that typically receives little scholarly attention, and a preliminary study and typology of the ceramic bricks and *tubuli* has already been published in *SHAJ* 13 (Harvey 2019). The intent of this article is to present the cylindrical pipes from the bath at 'Ayn Gharandal and to provide a brief discussion of their unconventional use within the heating system. It is hoped that this publication will provide an overview of the types of

cylindrical pipes used within the 'Ayn Gharandal bath and serve as a reference for future work on this class of material both at this site and within the wider region.

### 'Ayn Gharandal

Situated on the eastern edge of the Wādī 'Araba, the site of 'Ayn Gharandal is *ca.* 70 km north of the Gulf of Aqaba and *ca.* 40 km southwest of Petra (FIG. 1). Archaeological exploration of the site has revealed that it was once home to a Late Roman outpost, comprising a *castellum* and its associated bathhouse. The foundation of the fort has been securely dated to the reign of Diocletian, thanks to the discovery of the fort's dedicatory inscription found outside its main gate (Darby 2015).

Numerous explorers and archaeologists have visited 'Ayn Gharandal, with Alois Musil being one of the first



1. Map showing location of 'Ayn Gharandal and mentioned sites (C.A. Harvey after Reeves and Harvey 2016: fig. 1).

in 1902 (Musil 1907: 193–7; R. Darby and E. Darby 2015: 461). In 2009, the 'Ayn Gharandal Archaeological Project conducted a survey of the site and subsequently undertook excavations in 2010, 2011, 2013, 2014, 2015, 2017, and 2019, with further excavation seasons planned (Darby *et al.* 2010; R. Darby and E. Darby 2012; 2015; 2016; E. Darby and R. Darby 2017; 2018). Thus far, the excavation of the site has primarily focused on the Late Roman *castellum*, the later church that was found within its walls, and the nearby garrison bath. These excavations have also uncovered

a large number of ceramic building materials, with the majority coming from the bath's heating system.

### The Bath

The garrison bath at 'Ayn Gharandal is located about 60 m east of the fort and remains only partially uncovered. Excavation of the structure 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 (*praefurnium*: FIG. 2:4), a latrine (FIG. 2:5), and a section of a large courtyard (FIG. 2:6). It is possible that the bath belongs to a larger caravanserai, similar to those at Bir Madhkūr

(Smith 2010: 147) and En Hazeva (Cohen and Israel 1996: 111–2).

Although not confirmed through excavation, the bath is likely contemporaneous with the Diocletianic *castellum*. The heating system, however, seems to have undergone at least one major renovation at some point during its use, as reflected in the ceramic building material (Harvey 2019: 169, 178–9). In the last phase of its use, the wall-heating system employed a wide variety of rectangular *tubuli* as well as cylindrical pipes of the type normally used to convey water. It is these cylindrical heating pipes from the wall-heating system that are the focus of this article, and their form and function will be discussed in greater detail below.

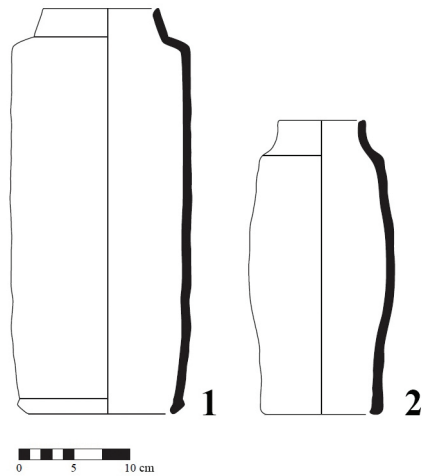
Prior to excavation by the 'Ayn Gharandal Archaeological Project, illicit digging had partially cleared the bath's *tepidarium*, breaking through the hypo-



2. Plan of bath: 1. *Caldarium*, 2. *Tepidarium*, 3. *Frigidarium*, 4. *Praefurnium*, 5. Latrine, 6. Courtyard (Th. Fournet).

caust and damaging the wall-heating system in the process (Darby *et al.* 2010: 190–1). The 2009 survey of the site recorded this disturbance to the bath and collected samples of the bricks and pipes (including cylindrical heating pipes, which were labeled water pipes) that had been removed from the heating system and discarded on the surface (Darby *et al.* 2010: 193–4, 198 figs. 19–20). In 2010, the 'Ayn Gharandal

Archaeological Project began excavating the bath to document further the extent of the damage and to study the surviving architecture. This initial field season resulted in the clearing of the *tepidarium*, the latrine, and parts of the *caldarium* and *frigidarium* (R. Darby and E. Darby 2012: 407–11; 2015: 463–7). The 2010 excavation also uncovered a large quantity of ceramic building material that had been removed from the heating



3. Drawings of cylindrical heating pipes removed from bath in 2010 (A. Hendrick).

system during the clandestine digging (FIG. 3). Although much of this material was left on site for future study, a few samples (including cylindrical heating pipes) were collected and appear in publications (R. Darby and E. Darby 2012: 411 figs. 11–12; 2015: 465 fig. 7). The renewed excavation of the bath in 2015 exposed the entirety of the bath's heating system in the *caldarium* and *tepidarium* as well as the *praefurnium*. During this last season, excavators collected every fragment of ceramic building material, and it is this material that forms the corpus of the present study.

### The Wall-Heating System

Both the *tepidarium* and *caldarium* of the 'Ayn Gharandal bath had wall-heating systems built with ceramic pipes installed against the interior walls. These pipes created voids through which hot air rising from the hypocaust could circulate and help heat the room.

Two types of heating pipes were used in the heating system at 'Ayn Gharandal. The first was the specially designed wheel-made tube with a rectangular profile, which is called a *tubulus* or box-flue. Stacked on top of each other, these *tubuli* had lateral vents cut into their sides that aided the horizontal flow of air between adjacent *tubuli*. Within the 'Ayn Gharandal bath, these rectangular *tubuli* were primarily found in the *caldarium*, although at least one example was found in the *tepidarium*. Similar *tubuli* are found in heating systems across the region, and a typology of those from 'Ayn Gharandal has already been published (Harvey 2019: 170–9). The second type of heating pipe was the cylindrical pipe.

### The Cylindrical Heating Pipes

The cylindrical pipes used in the wall-heating system of the 'Ayn Gharandal bath are of the same type as those used in hydraulic installations throughout the wider region. These ceramic tubes are characterized by their two distinct ends: the spigot (narrow or “male” end) that comprises an often inverted neck (or collar) that slopes towards a turned shoulder, and the socket (wide or “female” end, or “bell”), featuring a wide opening. The socket end of the pipe was designed to fit around and receive the spigot end of an adjacent pipe, thereby ensuring a tight join, which was further sealed by the application of mortar around the join and by embedding the pipes in mortar. Examples of this type of pipe being used to convey water are found at many sites in the region, such as Petra (Bellwald *et al.* 2003: 56–7; Bellwald 2008: 90; Bedal, this volume), Wādī Musā ('Amr and al-Momani 2001: 270–1), and al-Ḥumayma (Oleson 2010: 330–1; Reeves and Harvey forthcoming).

Within the 'Ayn Gharandal bath,



these cylindrical pipes were primarily found in the *tepidarium*, where they comprise the near entirety of the wall-heating system (FIGS. 4–5). Several of these tubes were also found in the *caldarium*. While the installation of these pipes against the wall in columns allowed for the vertical flow of hot air from the hypocaust, the lack of lateral vents like those on rectangular *tubuli* prevented

4. Photograph of cylindrical heating pipes *in situ* in southeast corner of the *tepidarium* (R. Darby).

5. Close-up photograph of cylindrical heating pipes *in situ* in southeast corner of the *tepidarium* (R. Darby).



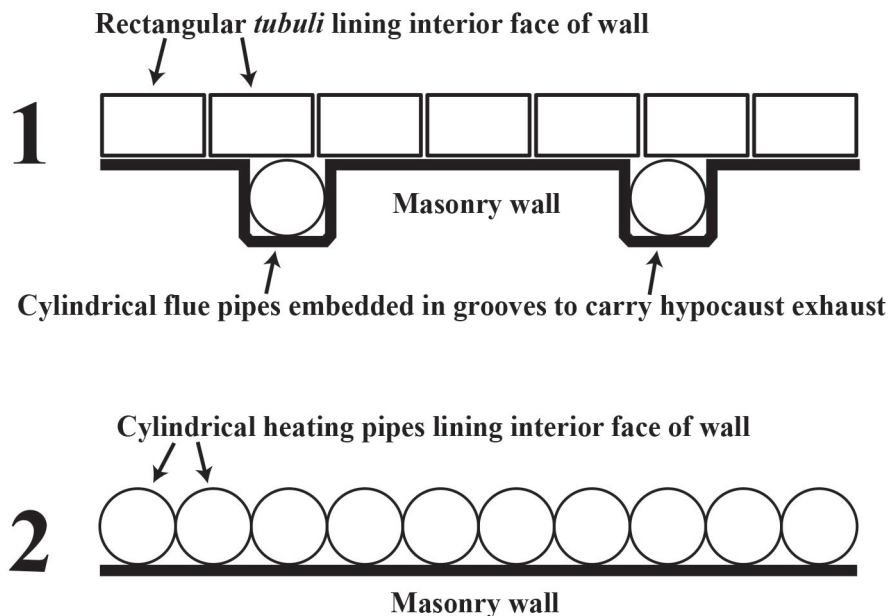
the hot air from flowing between columns. This restricted air flow theoretically resulted in a less efficient wall-heating system than one built entirely out of traditional *tubuli*. For this reason, and as will be discussed below, the use of these cylindrical pipes in the heating system is curious, although it is not without parallel.

### Comparanda

In other baths of this region, cylindrical pipes were commonly used in wall-heating systems; however, they primarily served a different function than those at Ayn Gharandal. Typically, cylindrical pipes were embedded in vertical grooves cut into the masonry of the wall and acted as flues to carry the draft and exhaust of the heating system to the exterior (FIG. 6.1). In front of these cylindrical pipes, and on the

interior surface of the wall, rectangular *tubuli* could be installed. While these rectangular *tubuli* served to distribute heat from the hypocaust across the wall surface, the cylindrical tubes that were embedded into walls served to carry the hypocaust exhaust and maintain the draft that was necessary for the overall function of the heating system. The use of cylindrical pipes strictly as flue pipes is apparent at the site of Humayma, where such tubes were found associated with vertical grooves in which they were once inserted (Reeves *et al.* 2017: 122, 128). A similar use is also documented in a bath at Umm Qays (Nielsen *et al.* 1993: 122, 192 pl. 34). Such recessed tubulation also seems to have been used in the *caldarium* of the garrison bath at Lejjun (de Vries and Lain 2006: 217).

Compared to the use of rectangular *tubuli*, it was much less common to use



6. Drawing of top-down view of wall-heating systems: 1. Use of rectangular *tubuli* along face of wall, with cylindrical flue pipes placed in vertical grooves in masonry wall; 2. Use of cylindrical heating pipes along interior face of masonry wall (C. A. Harvey).

cylindrical pipes as the primary wall heating system by installing them in closely packed columns on the face of the wall, as was done at 'Ayn Gharandal (FIG. 6.2). Nevertheless, comparanda do exist at several sites in the Negev Desert. At Oboda, modern Avdat, excavation of the site's well-preserved bath uncovered closely packed cylindrical pipes along the surface of the walls in the *caldarium* (Negev 1997: 175). Although the shape of these pipes is not specifically mentioned, their depiction in the plan of the bath (Negev 1997: fig. 26) indicates that they are cylindrical in profile, a fact confirmed by personal observation. These pipes likely date, not to the bath's initial construction in the 4<sup>th</sup> c. AD, but rather to the renovations that took place sometime after an early 5<sup>th</sup> c. AD earthquake (Erickson-Gini 2014: 97). Another example of cylindrical pipes being used for heating comes from the bath at the site of Mampsis. On the walls of this bath's *caldarium*, excavators recorded mortar impressions of pipes measuring 10 cm in diameter (Negev 1988: 176). There is no published image of these impressions or the heating pipes, which are not specifically referred to as cylindrical. The stated diameter of these pipes, however, strongly suggests that they were cylindrical, as there are no known rectangular *tubuli* with such narrow diameters. Personal observation of the excavated bath at En Hazeva also noted the presence of mortar impressions of cylindrical pipes along the walls of the heated rooms.

Outside of the Negev Desert, cylindrical pipes are attested in at least two later baths in the Levant. Within the sanctuary precinct at Khirbat adh-Dhariḥ, excavation uncovered a small bath dating to the Byzantine period. Within the heated room of this bath is a wall-heating system built with both

rectangular *tubuli* and cylindrical pipes (Sartori 2015: 128 figs. 7–8). Further north, the early Islamic *hammam* in Hisham's Palace at Khirbat al-Mafjar also seems to have used cylindrical heating pipes. The excavation report of this complex states that pipes "rebated to fit into each other" were installed against the walls of the heated rooms to carry hot air from the hypocaust (Hamilton 1959: 56). The description of these heating pipes as "rebated" is likely a reference to the spigot ends of the cylindrical pipes. Unfortunately, publications of heating systems do not always provide enough detail or images to ascertain the types of materials used in their construction, and it is entirely possible that further examples of cylindrical heating pipes exist.

#### The Use of Cylindrical Pipes at 'Ayn Gharandal

While paralleled elsewhere, it is not entirely clear why the 'Ayn Gharandal bath used cylindrical pipes within the heating system. As discussed earlier, the absence of lateral vents constricted airflow within the walls and limited its efficiency. The most obvious explanation for their use is that the builders of these baths did not have enough *tubuli* and as a result had to use whatever materials were available. Supporting this theory is the heterogeneity of both the cylindrical pipes and the *tubuli* used, which suggests the builders were using the materials they could acquire. Close examination of one *tubulus* type indicated that the builders were even reusing old *tubuli* from a previous phase of the bath (Harvey 2019: 179). It is likely that the builders of the 'Ayn Gharandal bath recognized the limited efficiency of the cylindrical pipes and, faced with an inadequate number of *tubuli*, prioritized the use of the more efficient *tubuli* in the *caldarium*. They

then used cylindrical pipes as substitutes for *tubuli* in the *tepidarium*, where the relative inefficiency of these pipes would have been less noticed.

### Methodology

The study of the cylindrical pipes from the 'Ayn Gharandal bath was carried out in 2016 alongside the study of the site's *tubuli* and brick (Harvey 2019). The disturbance caused by the clandestine digging combined with the inconsistent collection methods between excavation seasons prevented a fully quantitative study of this material. Furthermore, the absence of any purposeful removal of material from *in situ* contexts limited a detailed understanding of exactly where and how these pipes were used within the wall-heating system.

Of the 2,106 fragments of ceramic building material available for study in 2016, 339 fragments, weighing 23.4 kg, were cylindrical heating pipes. The vast majority of these sherds were too fragmented to be studied; however, a total of 19 pipes were partially reconstructed, 14 of which are presented here. Although the cylindrical pipes used for heating are identical in form to those used in hydraulic installations, the presence of black soot on their interior surfaces, resulting from their exposure to hypocaust fumes, clearly distinguishes them from pipes used to convey water (FIG. 7). The form and fabric of these reconstructed pipes are described in detail below using the same conventions used by a similar study of ceramic building materials from Humayma (Reeves and Harvey 2016: table 1; forthcoming).

Unfortunately, it is not possible to propose a typology for the cylindrical heating pipes as was done with the bricks and *tubuli* from the 'Ayn Gharandal bath. Instead, the full descriptions of selected examples are presented along



7. Photograph of cylindrical heating pipe (cat. no. 8) showing soot on interior surface and exterior of neck (C.A. Harvey).

with profile drawings in the following catalogue. These examples should not be taken as a comprehensive representation of all cylindrical pipe forms that were used in the heating system, but rather only as an exemplification of the range of pipes used based on what evidence was available during their study.

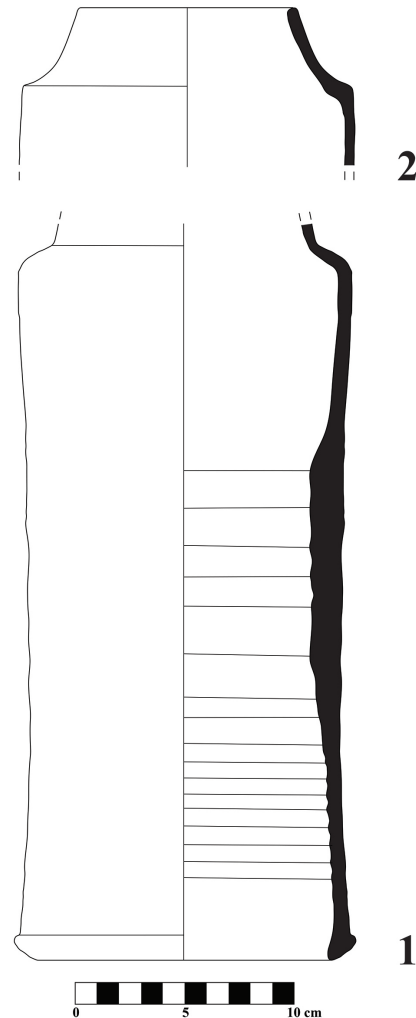
### Catalogue of Cylindrical Heating Pipes

In the following catalogue, the cylindrical heating pipes are organized by room, with those from the *tepidarium* presented first. Within this division, the examples are roughly organized by similarity of form. For each example, the sherd number (e.g., 60,013) is given, followed by its archaeological context [e.g., D: 7-6/14-13.1211.2 (Square. Locus. Bucket)] along with a verbal description of that context.



1. (60,013) D: 7-6/14-13.1211.2, found in 2010 backfill removed from *tepidarium* (FIG. 8:1). Cylindrical pipe section, nearly complete, missing only its spigot rim. Large wheel-made ceramic pipe with cylindrical body, narrow shoulder, triangular socket rim, and a wall that greatly thickens in middle. MEASUREMENTS: MPL 33.5 cm; D 14.7 cm; Th of walls 0.6–1.3 cm. WEIGHT: 1,975 g. FABRIC: rough, sandy light red (5YR 6/6) fabric and a reddish yellow (5YR 6/8) surface. INCLUSIONS: medium sub-rounded sand, with a few white inclusions. WARE: Petra. SPIGOT: rim is not extant; there is a sharp turn where the neck meets the sloped shoulder; the shoulder turns less sharply where it meets the body; D at shoulder 15.2 cm. SOCKET: slightly inverted triangular rim (Th 1.2 cm); rounded overhang on exterior; rounded interior edge; no interior ledge; D of opening 13.0 cm. INTERIOR: rilling. EXTERIOR: slight rilling. MORTAR: grey mortar with ash inclusions on exterior and rim. SOOT: interior and exterior. COMMENTS/COMPARANDA: this pipe seems to be of the same type as cat. no. 2 (60,014), described below. Based on personal observation, both appear similar to the large cylindrical pipes that remain *in situ* in the *tepidarium*. Several of these large pipes, which had been torn away by the clandestine digging, were removed during excavation of the bath in 2010 and were not available for study in 2016. A drawing of one of these complete pipes, generously provided for this publication by the directors of the project, confirms this similarity (FIG. 3:1).

2. (60,014) D: 7-6/14-13.1211.2, found in 2010 backfill removed from *tepidarium* (FIG. 8:2). Cylindrical pipe section, preserving only its spigot end. Large wheel-made ceramic pipe with

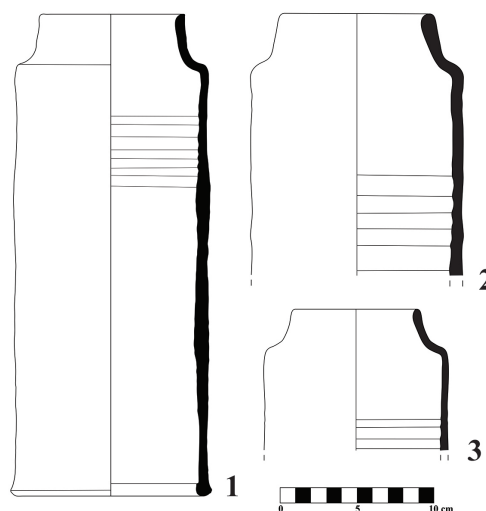


8. Drawings of cylindrical heating pipes from the *tepidarium*: 1. cat. no. 1 (60,013); 2. cat. no. 2 (60,014) (C.A. Harvey).

inverted and curving neck and a sharp turn at the shoulder. MEASUREMENTS: MPL 7.3 cm; D 16.0 cm; Th of walls 0.4 cm. WEIGHT: 41 g. FABRIC: rough, sandy reddish yellow (5YR 6/8) fabric with a reddish grey (2.5YR 5/1) core and a reddish yellow (5YR 7/6) surface. INCLUSIONS: medium sub-rounded sand, with a few white inclusions.

WARE: Petra. SPIGOT: simple rounded rim (Th 0.5 cm); neck is inverted and gently slopes to the shoulder; shoulder turns sharply where it meets the body; D at shoulder 15.5 cm; D of opening 9.0 cm. SOCKET: not extant. INTERIOR: slight rilling. EXTERIOR: slight rilling. MORTAR: trace amounts on exterior. SOOT: none. COMMENTS/COMPARANDA: this pipe seems to be of the same type as cat. no. 1 (60,013), described above. Based on personal observation, both appear similar to the large cylindrical pipes that remain *in situ* in the *tepidarium*. Several of these large pipes that had been torn away by the clandestine digging were removed during excavation of the bath in 2010 and were not available for study in 2016. A drawing of one of these complete pipes, generously provided for this publication by the directors of the project, confirms this similarity (FIG. 3:1).

3. (60,047) D: 7-6/14-13.1233.68, found in disturbed soil filling hypocaust hole in *tepidarium* (FIG. 9:1). Cylindrical pipe section, preserving full profile. Wheel-made ceramic pipe with cylindrical body, narrow shoulder with a sharp turn, and bulbous socket rim. MEASUREMENTS: L 31.4 cm; D 13.3 cm; Th of walls 0.5–0.8 cm. WEIGHT: 1,045 g. FABRIC: rough, sandy light red (2.5YR 6/6) fabric with a light brown (7.5YR 6/4) core and a pink (5YR 7/3) surface. INCLUSIONS: medium sub-rounded sand, with a few white inclusions. WARE: Petra. SPIGOT: simple rounded rim (Th 0.6 cm) on slightly inverted neck that curves to the shoulder; the shoulder turns sharply where it meets the body; D at shoulder 12.5 cm; D of opening 8.4 cm. SOCKET: thickened rim (Th 1.0 cm) with flattened and rough top, rounded overhang on exterior, sharp and rough edge on interior; no interior ledge; D of opening 11.2 cm. INTERIOR: rilling.



9. Drawings of cylindrical heating pipes from the *tepidarium*: 1. cat. no. 3 (60,047); 2. cat. no. 4 (60,049); 3. cat. no. 5 (60,017) (C.A. Harvey).

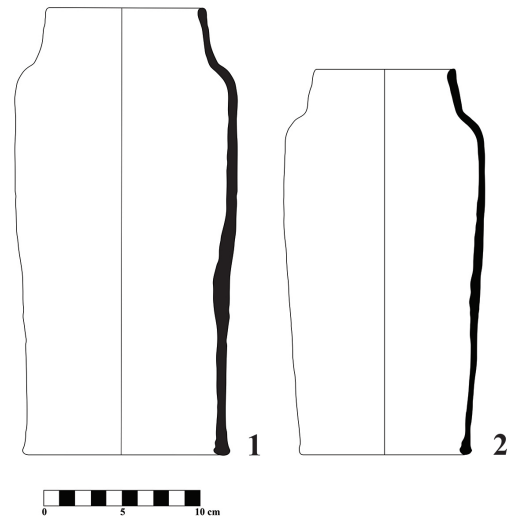
EXTERIOR: slight rilling. MORTAR: grey mortar with ash inclusions on exterior. SOOT: interior and exterior of neck.

4. (60,049) D: 7-6/14-13.1233.68, found in disturbed soil filling hypocaust hole in *tepidarium* (FIG. 9:2). Cylindrical pipe section, preserving only its spigot end. Wheel-made ceramic pipe with cylindrical body, narrow shoulder, and inverted neck. MEASUREMENTS: MPL 17.3 cm; D 14.0 cm; Th of walls 0.8 cm. WEIGHT: 256 g. FABRIC: rough, sandy brown (7.5YR 5/4) fabric and a brown (7.5YR 5/4) surface. INCLUSIONS: medium sub-rounded sand, with a few white inclusions. WARE: Petra. SPIGOT: rounded thickened rim (Th 1.0 cm) on inverted neck that curves to the shoulder; the shoulder turns sharply where it meets the body; D at shoulder 14.0 cm; D of opening 8.2 cm. SOCKET: not extant. INTERIOR: rilling. EXTERIOR:

slight rilling. MORTAR: none. SOOT: interior and exterior of neck.

5. (60,017) D: 7-6/14-13.1215.36, knocked down from the east wall of the *tepidarium* (FIG. 9:3). Cylindrical pipe section, preserving only its spigot end. Wheel-made ceramic pipe with cylindrical body, narrow shoulder, and inverted neck. MEASUREMENTS: MPL 9.3 cm; D 11.9 cm; Th of walls 0.4 cm. WEIGHT: 112 g. FABRIC: rough, sandy light red (2.5YR 6/6) fabric and a very pale brown (10YR 7/4) surface. INCLUSIONS: medium sub-rounded sand, with a few white inclusions. WARE: Petra. SPIGOT: simple rounded rim (Th 0.5 cm) on inverted neck that curves to the shoulder which turns sharply where it meets the body; D at shoulder 12.5 cm; D of opening 7.4 cm. SOCKET: not extant. INTERIOR: rilling. EXTERIOR: slight rilling. MORTAR: trace amounts on exterior. SOOT: interior and exterior.

6. (60,050) D: 7-6/14-13.1233.77, found in disturbed soil filling hypocaust hole in *tepidarium* (FIG.10:1). Cylindrical pipe section, preserving full profile. Wheel-made ceramic pipe with rounded shoulder and a body that tapers toward the socket end. MEASUREMENTS: L 28.6 cm; D 14.4 cm; Th of walls 0.5–0.9 cm. WEIGHT: 683 g. FABRIC: rough, sandy light red (10R 6/8) fabric and a pinkish white (7.5YR 8/2) surface. INCLUSIONS: medium sub-rounded sand, with a few white inclusions. WARE: Petra. SPIGOT: simple rounded rim (Th 0.5 cm) on a slightly inverted neck that turns at the rounded shoulder; D at shoulder 14.0 cm; D of opening 9.8 cm. SOCKET: thickened rounded rim (Th 0.9 cm) with rough surface; sharp and rough edge on interior; no interior ledge; D of opening 11.9 cm. INTERIOR: rilling. EXTERIOR: slight rilling. MORTAR: trace amounts on exterior. SOOT: interior, exterior, and on neck. COMMENTS/COMPARANDA:



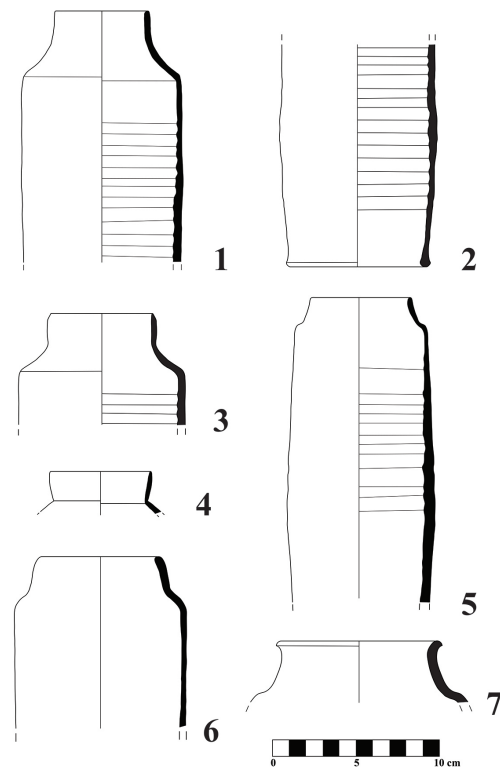
10. Drawings of cylindrical heating pipes from the *tepidarium*: 1. cat. no. 6 (60,050); 2. cat. no. 7 (60,046) (C.A. Harvey).

this pipe is of a similar form as cat. no. 7 (60,046), described below, but it is larger in size. The form also appears similar to the pipes in Pipeline D at the Petra Garden and Pool Complex, which likewise have rounded shoulders as well as a tapering profiles and date to the late 2<sup>nd</sup> to mid-4<sup>th</sup> c. AD (Bedal, this volume).

7. (60,046) D: 7-6/14-13.1233.68, found in disturbed soil filling hypocaust hole in *tepidarium* (FIG.10:2). Cylindrical pipe section, preserving full profile. Wheel-made ceramic pipe with rounded shoulder and a body that tapers toward the socket end. MEASUREMENTS: L 24.4 cm; D 12.9 cm; Th of walls 0.3–0.5 cm. WEIGHT: 321 g. FABRIC: rough, sandy red (2.5YR 5/6) fabric and a light grey (10YR 7/2) surface. INCLUSIONS: medium sub-rounded sand, with a few white inclusions. SPIGOT: simple rounded rim (Th 0.5 cm) on a slightly

inverted neck that turns at the rounded shoulder; D at shoulder 12.7 cm; D of opening 8.0 cm. SOCKET: thickened rounded rim (Th 0.8 cm); round but rough edge on interior; no interior ledge; D of opening 9.6 cm. INTERIOR: rilling. EXTERIOR: slight rilling. MORTAR: off-white mortar with ash inclusions on exterior. SOOT: interior and on exterior of neck. COMMENTS/COMPARANDA: this pipe is of a similar form as cat. no. 6 (60,050), described above, but it is smaller in size. The form also appears similar to the pipes in Pipeline D at the Petra Garden and Pool Complex, which likewise have rounded shoulders as well as a tapering profiles and date to the late 2<sup>nd</sup> to mid-4<sup>th</sup> c. AD (Bedal, this volume).

8. (60,033) D: 7-6/14-13.1225.50, found in loose sand above the *alveus* (tub) in the southern half of the *caldarium* (FIGS. 7 and 11:1). Cylindrical pipe section, preserving only its spigot end. Wheel-made ceramic pipe with cylindrical body and sloping shoulder with a sharp turn where it meets the body. MEASUREMENTS: MPL 15.2 cm; D 9.7 cm; Th of walls 0.3–0.4 cm. WEIGHT: 146 g. FABRIC: rough, sandy yellowish red (5YR 5/6) fabric and a very pale brown (10YR 7/4) surface. INCLUSIONS: medium sub-rounded sand, with a few white inclusions. WARE: Petra. SPIGOT: simple rounded rim (Th 0.4 cm) on a neck that curves into a sloping shoulder; shoulder turns where it meets the body; D at shoulder 9.2 cm; D of opening 5.1 cm. SOCKET: not extant. INTERIOR: heavy rilling. EXTERIOR: slight rilling. MORTAR: grey mortar with ash inclusions on exterior. SOOT: interior, exterior, and on neck. COMMENTS/COMPARANDA: the diameter, fabric, and rilling of this pipe suggest it may be of the same form as cat. no. 9 (60,040), described below; however, the absence of a full profile



11. Drawings of cylindrical heating pipes from the *caldarium*: 1. cat. no. 8 (60,033); 2. cat. no. 9 (60,040); 3. cat. no. 10 (60,022); 4. cat. no. 11 (60,029); 5. cat. no. 12 (60,032); 6. cat. no. 13 (60,028); 7. cat. no. 14 (60,015) (C.A. Harvey).

prevents confirming this theory. The spigot end and diameter of this pipe also bear a slight resemblance to a pipe found within the Roman fort at Humayma (Reeves and Harvey forthcoming; cat. no. 12.11 fig. 12.11). Interestingly, this parallel was also found in a heating system where it was used as a flue pipe. It is unclear, however, whether this 'Ayn Gharandal pipe, which is missing its socket end, once had an interior ledge similar to the one on the socket end of the Humayma pipe.

9. (60,040) D: 7-6/14-13.1229.61, found in fill of the *alveus* (tub) in the southern half of the *caldarium* (FIG. 11:2). Cylindrical pipe section, preserving only its socket end. Wheel-made ceramic pipe with cylindrical body that tapers slightly towards the socket end, and a thickened, rounded socket rim. MEASUREMENTS: MPL 13.4 cm; D 9.3 cm; Th of walls 0.3–0.5 cm. WEIGHT: 138 g. FABRIC: rough, sandy light red (2.5YR 6/6) fabric and a very pale brown (10YR 8/2) surface. INCLUSIONS: medium sub-rounded sand, with a few white inclusions. WARE: Petra. SPIGOT: not extant. SOCKET: thickened rounded rim (Th 0.6 cm); rim is slightly bulbous; no interior ledge; D of opening 7.4 cm. INTERIOR: heavy rilling. EXTERIOR: slight rilling. MORTAR: large amount (Th 2.0 cm) of grey mortar with ash and lime inclusions on exterior. SOOT: interior. COMMENTS/COMPARANDA: the diameter, fabric, and rilling of this pipe suggest it may be of the same form as cat. no. 8 (60,033), described above; however, the absence of a full profile prevents confirming this theory.

10. (60,022) D: 7-6/14-13.1224.44, found in loose sand fill of the *caldarium* (FIG. 11:3). Cylindrical pipe section, preserving only its spigot end. Wheel-made ceramic pipe with cylindrical body and sloping shoulder with a sharp turn where it meets the body. MEASUREMENTS: MPL 6.8 cm; D 10.0 cm; Th of walls 0.5 cm. WEIGHT: 31 g. FABRIC: rough, sandy light red (2.5YR 6/8) fabric and a light brown (7.5YR 6/4) surface. INCLUSIONS: medium sub-rounded sand, with a few white inclusions. WARE: Petra. SPIGOT: rounded rim that comes to a point (Th 0.4 cm) on a straight neck that turns at curved and sloping shoulder; shoulder turns where it meets the body; D at shoulder 10.0 cm; D of opening 6.9 cm.

SOCKET: not extant. INTERIOR: rilling. EXTERIOR: slight rilling. MORTAR: trace amounts on exterior. SOOT: interior, exterior, and on neck. COMMENTS/COMPARANDA: the spigot rim of this pipe and the diameter of its opening bear a close resemblance to cat. no. 11 (60,029), described below; however, the neck of this pipe is far less everted than cat. no. 11. The spigot end and diameter of this pipe also bear a slight resemblance to a pipe found within the Roman fort at Humayma (Reeves and Harvey forthcoming: cat. no. 12.11, fig. 12.11). Interestingly, this parallel was also found in a heating system where it was used as a flue pipe. It is unclear, however, whether this 'Ayn Gharandal pipe, which is missing its socket end, once had an interior ledge similar to the one on the socket end of the Humayma pipe.

11. (60,029) D: 7-6/14-13.1225.47, found in loose sand above the *alveus* (tub) in the southern half of the *caldarium* (FIG. 11:4). Cylindrical pipe section, preserving only its spigot end. Wheel-made ceramic pipe with everted neck that turns very sharply where it meets the shoulder. MEASUREMENTS: MPL 2.6 cm; D unclear; Th of walls 0.4 cm. WEIGHT: 21 g. FABRIC: rough, sandy light red (2.5YR 6/6) fabric and a very pale brown (10YR 7/4) surface. INCLUSIONS: medium sub-rounded sand, with a few white inclusions. WARE: Petra. SPIGOT: rounded rim that comes to a point (Th 0.3 cm) on an everted neck that turns very sharply where it meets the curved shoulder; D of opening 5.8 cm. SOCKET: not extant. INTERIOR: unclear. EXTERIOR: unclear. MORTAR: none. SOOT: interior and exterior of neck. COMMENTS/COMPARANDA: the spigot rim of this pipe and the diameter of its opening bear a close resemblance to cat. no. 10 (60,022), described above;

however, the neck of this pipe is much more everted than cat. no. 10.

**12.** (60,032) D: 7-6/14-13.1225.50, found in loose sand above the *alveus* (tub) in the southern half of the *caldarium* (FIG. 11:5). Cylindrical pipe section, preserving only its spigot end. Wheel-made ceramic pipe with very narrow shoulder and cylindrical body. MEASUREMENTS: MPL 18.5 cm; D 8.8 cm; Th of walls 0.3–0.6 cm. WEIGHT: 228 g. FABRIC: rough, sandy reddish yellow (5YR 6/6) fabric and a reddish yellow (7.5YR 6/6) surface. INCLUSIONS: medium sub-rounded sand, with a few white inclusions. WARE: Petra. SPIGOT: simple rounded rim (Th 0.3–0.4 cm) on an inverted neck that turns at the shoulder; the shoulder is very narrow and turns where it meets the body; D at shoulder 8.2 cm; D of opening 5.8 cm. SOCKET: not extant. INTERIOR: rilling. EXTERIOR: slight rilling. MORTAR: grey mortar with ash inclusions on exterior and neck. SOOT: interior, exterior, and on neck.

**13.** (60,028) D: 7-6/14-13.1225.47 found in loose sand above the *alveus* (tub) in the southern half of the *caldarium* (FIG. 11:6). Cylindrical pipe section, preserving only its spigot end. Wheel-made ceramic pipe with cylindrical body and inverted neck. MEASUREMENTS: MPL 10.4 cm; D 10.3 cm; Th of walls 0.3 cm. WEIGHT: 47 g. FABRIC: rough, sandy reddish yellow (5YR 6/6) fabric and a very pale brown (10YR 8/3) surface. INCLUSIONS: medium sub-rounded sand, with a few white inclusions. WARE: Petra. SPIGOT: simple rounded rim (Th 0.5 cm) on a slightly inverted neck that turns at the rounded shoulder; D at shoulder 10.3 cm; D of opening 6.2 cm. SOCKET: not extant. INTERIOR: rilling. EXTERIOR: slight rilling. MORTAR: none. SOOT: interior, exterior, and on neck.

**14.** (60,015) D: 7-6/14-13.1212.5, found in 2010 backfill removed from *caldarium* (FIG. 11:7). Cylindrical pipe section, preserving only its spigot end. Wheel-made ceramic pipe with curved neck that flares out. MEASUREMENTS: MPL 3.4 cm; D unclear; Th of walls 0.4 cm. WEIGHT: 17 g. FABRIC: rough, sandy light red (2.5YR 6/6) fabric and a very pale brown (10YR 8/2) surface. INCLUSIONS: medium sub-rounded sand, with a few white inclusions. WARE: Petra. SPIGOT: flaring, everted neck with a slightly pointed rim (Th 0.5 cm); neck curves down to shoulder which is partially extant; D of opening 9.0 cm. SOCKET: not extant. INTERIOR: unclear. EXTERIOR: unclear. MORTAR: none. SOOT: interior and on exterior of neck.

### Conclusions

The cylindrical heating pipes of the 'Ayn Gharandal bath are characterized by a high degree of heterogeneity, with many different forms of pipes being used. All of the studied examples, however, appear to be of Petra ware, suggesting a common place of manufacture. It is also noteworthy that none of these pipes have ledges on the interior of their socket ends, a feature present on some pipes from other sites, like Humayma (Reeves and Harvey forthcoming: cat. nos. 12.8–12.11). This absence is not surprising, however, as pipes from other sites also lack these ledges ('Amr and al-Momani 2001: fig. 24; Bedal, this volume).

It is worth re-emphasizing that the pipes presented here are not a comprehensive representation of all the cylindrical pipe forms that were used in the 'Ayn Gharandal heating system. This fact is exemplified by a cylindrical pipe that was collected in 2010 and was not available for this study (FIG. 3.2; R. Darby and E. Darby 2012: fig. 12; 2015 fig. 7). This pipe does not closely

resemble any of the cylindrical pipes presented here, and it is very likely that other forms were also used within the heating system.

Although no attempt was made at establishing a firm typology for the cylindrical pipes from the 'Ayn Gharandal bath, it is clear from the examples presented above that there is potential for one. For example, there seems to be two general forms of cylindrical pipes attested in the *tepidarium*: those with sharply turned shoulders and cylindrical bodies (cat. nos. 1–5; FIGS. 8–9), and those with rounded shoulders and bodies that taper toward their socket ends (cat. nos. 6–7; FIG. 10). Based on the sample presented here, the cylindrical pipes from the *tepidarium* also appear to be generally larger than those from the *caldarium* (cat. nos. 8–14; FIG. 11).

The use of cylindrical pipes in the wall-heating system of the 'Ayn Gharandal bath presents a clear example of builders making do with the materials available to them at the time. Such deviations from best practices are not surprising and are a topic worth exploring further. The study of ceramic building materials in Roman Jordan and the wider Roman East also requires more attention than this class of material has traditionally been given. This presentation and discussion of the cylindrical heating pipes of 'Ayn Gharandal is a step towards that goal. As was the case with the publication of the brick and *tubuli* from this bath, this article will assist in the development of a much-needed regional typology of ceramic building material. It is also hoped that it will serve as encouragement, a source of comparanda, and a model for future work on cylindrical heating and water pipes in the region.

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