

*Tubuli and their Use in Roman Arabia, with a Focus on Humayma (Ancient Hauarra)*

by

Craig Andrew Harvey  
BAH, Queen's University, 2011

A Thesis Submitted in Partial Fulfillment  
of the Requirements for the Degree of

MASTER OF ARTS

in the Department of Greek and Roman Studies

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## **Supervisory Committee**

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Dr. John P. Oleson (Department of Greek and Roman Studies)  
**Supervisor**

Dr. R. Brendan Burke (Department of Greek and Roman Studies)  
**Departmental Member**

Dr. M. Barbara Reeves (Department of Classics, Queen's University)  
**Additional Member**

## Abstract

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This thesis examines the *tubulus*, a ceramic heating pipe developed by the Romans to create wall cavities through which hot air could circulate. An extension of the hypocaust system, *tubuli* systems were one of the most advanced heating systems used in antiquity, and were employed throughout the Roman Empire. This thesis focuses on the *tubuli* from Roman Arabia and particularly those from the site of Humayma, in modern Jordan, where a large corpus of this material has been found. This thesis represents the first study specifically on *tubuli* in Roman Arabia, and as such, it presents an initial examination of the material and lays the foundation for future studies on the topic. The first chapter of this thesis introduces *tubuli*, the region of Roman Arabia, and the history of baths in Roman Arabia. In the second chapter, *tubuli* and their use at Humayma are discussed in detail, and a chronological *tubulus* typology is presented. The Humayma *tubuli* are put into their regional context in the third chapter, which looks at *tubuli* found at sites throughout Roman Arabia. This final chapter also examines the regional trade and reuse of this material. Although this study only scratches the surface of this topic, it is able to reach several conclusions regarding *tubuli* and their use in Roman Arabia. These findings include revelations about the Nabataeans' adoption and adaption of the *tubulus* before the Roman annexation of their territory and insights into the production and trade of this previously poorly understood material.

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## **Chapter One: An Introduction to *Tubuli* and Roman Arabia**

Ceramic analysis constitutes a major component of both Roman archaeology and classical archaeology in general. The ubiquity, durability, and variety of ceramic material on archaeological sites have provided modern archaeologists with a wealth of knowledge. Not only do ceramic typologies form the basic means by which sites are dated, but ancient economies, including production centres and trade routes, can be reconstructed through ceramic analysis. Additionally, ceramic material was so ubiquitous in Roman society that there was hardly an area untouched by it. Pliny himself celebrates this fact in his writing (*HN* 35.159-61). From the very rich to the very poor, in business and in leisure, from Britannia to Arabia, ceramic material was all-pervading, and its study can therefore provide information on many aspects of Roman culture.

Modern studies on Roman ceramics are nearly as varied as the material itself; however, the vast majority of these studies limit themselves to the analysis of ceramic vessels or figurines. While these categories may include the most beautiful examples of ceramic material, they leave out an equally important category of Roman ceramics, that of ceramic building material.

The term ceramic building material (or CBM) refers to bricks, roof tiles, hypocaust bricks, pipes, and other objects made from fired clay for use specifically within structures. Just like other ceramic material, CBM is found in large quantities on many sites throughout the Roman world. Its ubiquity reflects its importance to the Romans, who relied heavily on its versatility and inexpensiveness for their building projects. The extent to which this material was produced, traded and consumed makes it a

significant resource for modern archaeologists, who can discern much about the ancient economy through its study. Being literally the building block of Roman structures, this material also provides invaluable information on Roman building techniques. Since it was used within the buildings themselves, CBM is often found *in situ*, meaning archaeologists can see and understand exactly how the Romans employed it, a rarity for most artefacts.

Despite its importance, this material is often neglected in the field, where it is considered too bulky to collect and too mundane to be of much use for cultural analysis. This neglect has resulted in a clear lack of studies on Roman CBM, although several significant publications have done much to open up the topic to wider discussion (e.g. McWhirr 1979; Brodrigg 1983; DeLaine 2001; and Warry 2006a, 2006b).

This study will focus on only one type of CBM, the *tubulus*, and primarily on *tubuli* from Roman Arabia. *Tubuli* are ceramic pipes created specifically for use in wall-heating systems, and, while they are only one type of CBM, *tubuli* in Roman Arabia are common and varied enough to warrant separate study. *Tubuli*, and indeed all CBM from Roman Arabia, are almost completely unstudied, and therefore this investigation has the potential to fill that gap, as well as provide further information on the Roman presence in Arabia. While geographically limited in scope, this study draws parallels from across the empire. Likewise, findings are derived from broader studies on CBM, which are very useful for gaining insight on the trade of *tubuli*, and its place in the Roman economy.

In addition to being significant to modern archaeologists, CBM was very important to the Romans. This importance results from the numerous advantages ceramic has over other building materials. Ceramic can be as durable as stone, but it is relatively

cheap to make and can be mass-produced. These properties allowed the Romans to build quickly, without sacrificing strength. The uniform sizes of brick, for instance, eliminated the need to resize blocks on site for proper fitting, enabling lower-skilled labourers to work with them and thereby increase the speed of assembly. The versatility of ceramic made it the material of choice for objects requiring specific shapes, such as roof tiles and water pipes. A further property of ceramic is its resilience to intense heat and fluctuating temperatures. This last advantage made CBM the ideal building material for hypocaust systems. In fact, Vitruvius recommended that the entire hypocaust system be constructed using CBM, and wrote that the mortar between the bricks should be made of clay mixed with hair (*De Arch.* 5.10.2).

### **Hypocausts**

The hypocaust, from the Greek *ὑπό* meaning “beneath” and *καυστ-* meaning “burning”, was a remarkable engineering innovation, first invented by the Greeks and perfected by the Romans. The hypocaust system functioned by forcing hot air and smoke to flow through subfloor channels or under a suspended floor that was raised by columns, known as *pilae*. From here, the heat from the air radiated through the floor, heating both the floor surface and the room. Traditionally, the invention of the hypocaust was credited to Sergius Orata who built *pensiles balineas* (literally “hanging baths”) to heat his oyster ponds (Pliny *HN* 9.168; Val. Max. 9.1.1). Although until recently modern scholars had given full weight to this story (see discussion in Delaine 1988: 14-15), more recent research has refuted the claim, and it is now seen as purely anecdotal (Fagan 1996; Yegül 2013: 87-88, note 55).

Modern scholars generally agree that the system of heating floors first developed in Greek baths in the third century BC (Fournet and Redon 2013: 240). These early hypocaust systems used subfloor channels that directed hot air under the heated rooms. An example of these “proto-hypocausts” comes from a late second century BC bathhouse found at Tel Anafa, in the Upper Galilee (Herbert 1994: 67). The effect of these heated channels was an uneven heating; while some parts of the floor were unheated, those directly above the hot air ducts were extremely hot. The solution to this problem was to extend the heated area across the entire floor, thereby ensuring an even distribution of heat. This was achieved by supporting a suspended floor (*suspensurae*) on top of pillars (*pilae*) of brick, stone, or other material. The construction of such a hypocaust system is described in detail by Vitruvius (*De Arch.* 5.10.2), and it is therefore known to scholars as a Vitruvian hypocaust. The earliest example of a Vitruvian hypocaust comes from the baths at Fregellae, in Latium, and is dated to before 125 BC (Tsiolis 2013: 95). By the end of the second century BC, the Stabian Baths in Pompeii were also outfitted with a proper Vitruvian hypocaust system (Yegül 2010: 84).

### **Wall-heating**

A further development of the hypocaust system was to extend the heated area from the floor to include the walls. This was done by creating a hollow space within the surrounding walls, which was connected to the hypocaust below, thereby allowing the hot air to rise up and circulate around the room. The use of wall-heating increased the heated surfaces of the room and therefore the overall efficiency of the heating system. Such an arrangement was described by Seneca the Younger in his discussion of luxury (*Prov.*

4.9), in which he states: *cenationes subditus et parietibus circumfusus calor temperavit*, “the dining-halls have been tempered by hot air passing beneath the floor and circulating round the walls”.

Although wall-heating was widely used in the Roman world, the exact date and manner of its invention remains unsettled. Like the hypocaust, wall-heating seems to have its origins in the Greek and Hellenistic world. In the bathhouse at Gortys, one of the heated rooms contained a brick-lined wall cavity that was likely used as the exhaust flue for the hypocaust, but may have also contributed to the heating of the wall (DeLaine 1989: 113). Traditionally dated to the third century BC, there has been recent argument for re-dating this bath to the second century BC (Trümper 2009: 146-47).

In the baths at Fregellae, excavation found numerous ceramic pipes that date to before 125 BC and are thought by the excavators to be examples of early heating pipes, which would have been installed against the walls of the heated room (Tsiolis 2013: 95). It is also possible that these pipes were in fact the chimney pipes of the heating system. Such flue vents were vital for the function of any hypocaust system, since they carried away the exhaust and provided the necessary draught for the entire heating system.

One of the earliest unmistakable wall-heating systems comes from the Taposiris Magna baths in Egypt (Fournet and Redon 2013: 246-52). This wall-heating system was created by setting flat roof tiles (*tegulae*) vertically against the wall, leaving a hollow space between the tile and the wall through which hot air could circulate. This wall-heating system has been dated to the end of the second century BC. A close parallel to this wall-heating system also from Egypt comes from a small private bath in Edfu, which dates to the first century AD (Fournet and Redon 2013: 255, fig. 22).

Regarding the invention of wall-heating, it is possible that the practice developed out of chimney flues, which were installed within or against the walls. Although these flue vents were intended to provide the necessary draught for the hypocaust, due to the hot air and smoke passing through them, these vents also acted as unintended heating elements. The jump from chimney flue to wall heating could have taken place when their heating potential was realized and the flue vents were extended to purposefully heat a section of the wall. A good example of a wall-heating system from what is possibly this transitional stage of its development has been found at the Taposiris Magna baths in Egypt and dates from the end of the second to the mid first century BC (Fournet and Redon 2013: 246-52). Here, the exhaust from the furnace passed through a small wall-heating element on its way out of the bathhouse (Fournet and Redon 2013: figs. 13 and 17).

Just like the hypocaust, wall-heating systems were adopted and adapted by the Romans for their bathhouses. In the course of developing this technique further, the Romans employed several different methods of creating wall cavities, including the use of *tubuli*, the focus of this study. These different methods are discussed below.

### **Tegulae mammatae**

*Tegulae mammatae* are flat tiles that have conical projections (*mammae*, literally “breasts”) adhering to one face of the tile. These projections were made from lumps of clay and attached to the tile before firing. Typically, these projections are conical in shape and are found in each of the four corners of the tile, but a great deal of variation does exist (Degbomont 1984: 138). *Tegulae mammatae* were fixed vertically to the wall

surface with the projections acting as spacers, creating a void between the supporting wall and the inner face of the tile (fig. 1.1a). The tiles were held in place with metal “T”-shaped nails or clamps, which were driven between, or sometimes through, the tiles into the supporting wall. The result of this practice was a thin, but continuous, hollow cavity between the wall surface and the structural wall. This wall cavity was left open to the hypocaust below, allowing the hot air from the hypocaust system to flow into the wall cavity and circulate around the walls.

The practice of creating wall cavities by affixing flat tiles vertically to walls was not particular to the Romans. It has already been mentioned that flat roof tiles (*tegulae*) were used for this purpose in a bathhouse in Egypt, dating to before 125 BC (Fournet and Redon 2013: 246-52). It has been suggested that the first true *tegulae mammatae* were produced in Campania at the end of the second century BC (DeLaine 1989: 124). Without clear archaeological evidence, however, this suggestion remains only a theory. The earliest known examples of *tegulae mammatae* used in conjunction with a hypocaust system come from the late first century BC restorations of the Stabian Baths and Forum Baths in Pompeii (Yegül 2010: 86). This method for creating wall cavities enjoyed a long lasting usage throughout the Roman Empire. At least four sites in Britain have produced *tegulae mammatae*, all of which date to the late first century AD (Brodrigg 1987: 65). Despite the development of other techniques for creating wall cavities, *tegulae mammatae* were used in Athens possibly as late as the fourth century AD (Young 1951: 280-82), and perhaps even in the Umayyad period bathhouse in the Amman Citadel (Arce 2004: 250).

It is possible that Vitruvius may have referred to *tegulae mammatae* in his *De Architectura* (7.4.2). In his description on how to protect stucco from dampness, Vitruvius states that flanged tiles (*hamatae tegulae*) are to be fixed vertically to the walls, leaving a hollow space created by the flange. Vitruvius does not give a detailed description of these special tiles besides referring to them as *hamatae* (literally “hooked”). It is possible, however, that they were similar in design or identical to *tegulae mammatae*. In fact, some archaeologists have argued for an alternative reading of Vitruvius, suggesting that the word *mammata* is more likely to be correct than the traditionally accepted *hamata* (Brodrigg 1979: 400, note 24). Vitruvius recommended the use of these tiles not for heating, but for insulation and protection against dampness. Archaeological excavation in basement rooms of the House of Livia and the *domus Tiberiana* on the Palatine Hill have found *tegulae mammatae* used without hypocausts (Adam 1994: 269). The absence of a hypocaust suggests that these tiles were used to protect the walls from dampness in precisely the manner described by Vitruvius.

### **Terracotta Spacer Pins**

Another technique for creating wall cavities was the use of terracotta spacer pins. These conical or chisel-shaped ceramic pegs were driven into the structural wall and held vertical flat tiles in place with their specially designed heads (fig. 1.1c). In this arrangement, the terracotta spacer pins not only supported the tiles, but acted as separate *mammae*, being spacers between the vertical tiles and the structural wall.

The first examples of terracotta spacer pins date to the mid first century and come from Lydia, where they were used heavily in the second to third centuries AD and were

the preferred method for creating cavity walling (Gülşen 2007: 233-35). An example of their use in the region comes from a small private bath in Pergamon, which was built around AD 100 and subsequently abandoned in AD 250 (Radt 1999: 142-45). Although prevalent in Lydia, terracotta spacer pins were usually used only in smaller local baths rather than larger bath complexes (Farrington and Coulton 1990: 67). This distribution suggests that this technique was a local Lydian innovation (Gülşen 2007: 234-35). Nevertheless, there are examples of terracotta spacer pins that come from other regions of the Roman Empire. Numerous examples have been uncovered in Spain, many of which date to second and third centuries AD (Gamo 1987: figs. 2-4). Terracotta spacer pins have also been found at Timgad (Degbomont 1984: 137) and in Morocco that date to the early third century AD (Thouvenot and Luquet 1951: 18, fig. 3).

### **Spacer Bobbins**

Another method for creating wall cavities was the use of cylindrical ceramic spacers, often called “bobbins” due to their shape. In this technique, the spacer bobbins form the wall cavity by being placed in-between vertical hanging flat tiles and the structural wall. The tiles were then held in place by metal clamps or nails which ran through the spacer bobbins and into the wall (fig. 1.1d).

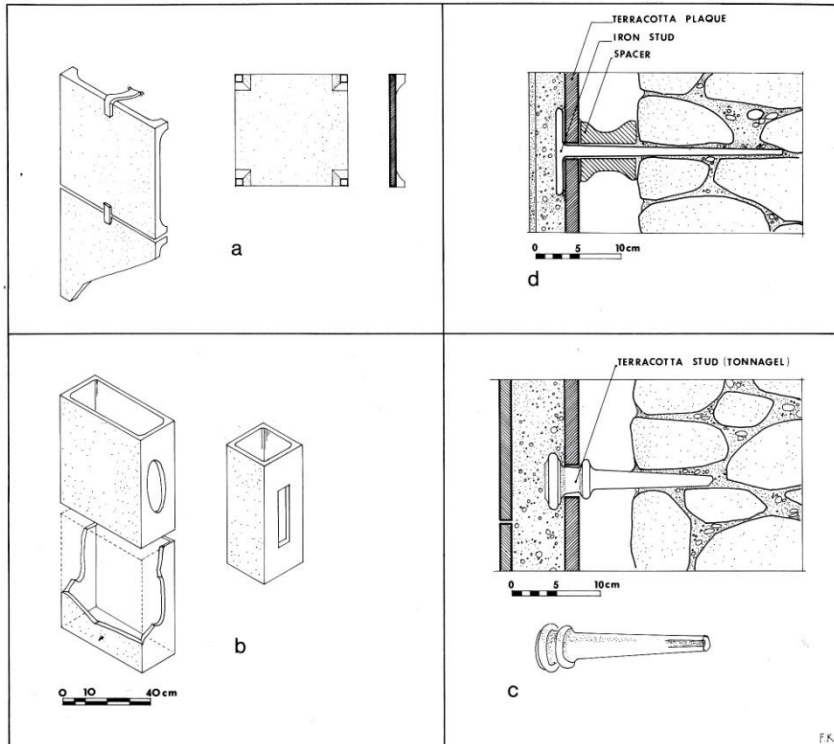
Spacer bobbins were widely used in Britain during the Roman period (Brodrigg 1987: 67-9). One example comes from a second century AD bath in Sussex (Money 1974). Elsewhere in the empire, spacer bobbins have been found in Spain (Gamo 1987: 226, fig. 5) and at Corinth (Biers 1985: 46, 78, fig. 4, pl 31.113). Although the exact date of these spacer bobbins is not known, it is possible that they come from the first half of

the third century AD (Biers 1985: 49). Excavation has also uncovered spacer bobbins in Romania, in baths dating to the early third century (Popilian 1971: 631, fig.4) and the fourth and fifth centuries (Barnea 1967: 242, fig. 15).

### **Half-box Tile**

A relatively uncommon method of creating wall-cavities was the half-box tile. These tiles are named for the fact that they resemble a *tubulus* (sometimes referred to as a box-tile) cut in half. They are characterized by deep flanges on their sides, which acted as spacers and create the wall cavity. In this way, the flanges fulfilled the same role as the projections on *tegulae mammatae*. Like the *tegulae mammatae*, half-box tiles were held in place by metal clamps or nails.

Half-box tiles have been uncovered at several sites in Britain, where some examples date to before the end of first century AD and others from the second half of the third century AD (Brodrigg 1987: 67). These tiles have also been found at Saalburg, in Germany, and may date to the second or third century AD (Batz 1970: 46, fig. 6). Due to their shape, half-box tiles have been suggested as transitional forms between *tegulae mammatae* and *tubuli* (Rook 2002: 14, fig. 7). Current archaeological evidence does not support this theory since *tubuli*, as will be shown in the section below, predate the half-box tile, and therefore could not have developed from them.



**Fig. 1.1** Wall-heating systems.

*a. tegula mammata.*

*b. tubuli.*

*c. terracotta spacer pins.*

*d. spacer bobbin.*

(After Yegül 1992: fig. 455, p. 366)

## Tubuli

A *tubulus* is a hollow tube, typically square or rectangular in profile. Stacked on top of one another, they formed vertical columns through which hot air and gases easily traveled. To increase circulation, vent holes were cut into the narrow sides of the *tubuli*, which allowed the lateral flow of air between adjacent columns (fig. 1.1b). *Tubuli* could be stacked securely, carried their own weight, and were easily mortared to the structural wall, making them far more stable and simpler to install than *tegulae mammatae* or the other methods mentioned above. Their stability also reduced the need for metal clamps or nails, although metal clamps were still sometimes used (Brodrribb 1987: 73; Yegül 1992: 363). Furthermore, the system of *tubuli* could create a wider void than that made by other methods. This larger space allowed the hot air and gases to circulate more freely and made the entire system more effective. For these reasons, *tubuli* were superior to the

other methods of creating cavity walling. Some scholars have seen the invention of the *tubulus* as a deliberate attempt to improve upon the shortcomings of the other methods (Rook 1979: 305; Adam 1994: 269). This theory, however, does not take into consideration the fact that, with the exception of *tegulae mammatae*, *tubuli* predate all other methods discussed above. This theory also does not explain why, despite the superiority of the *tubulus*, the other methods continued to be used throughout the Roman Empire. This contemporaneous use may have resulted from local habits or relative costs of the material (Farrington and Coulton 1990: 66-67)

*Tubuli* have also been referred to as box-tiles, flue-tiles, and even box-flue tiles; however, the use of the word “flue” is problematic. As will be discussed later, there is some debate as to whether or not *tubuli* formed part of the flue system, by which gases from the hypocaust escaped the building. The term “flue-tiles” is therefore somewhat of a misnomer, as it suggests that they were indeed part of the exhaust system. To avoid confusion, and in keeping with the majority of publications, the term *tubulus/tubuli* will be used to denote the ceramic tubes that were installed against walls to create vertical cavities through which hot air and gases could circulate.

Judging from its usage in graffiti from Roman Britain, the word “*tubulus*” also seems to have been the actual name used by the Romans for this material. One inscription, etched onto a tile found in Sussex, seems to be a record of work at a kiln. An entry in the list reads: TVBV(LI) N(VMERO) DLX, which has been interpreted as: “560 box-tiles” (Wright 1940: 188). Another tile from Dover has the inscription: TVBVLOS DL F(ECI) | QUASSIAVI LI, translating to: “I made 550 box-tiles, I shattered 51”

(Wilson 1973: 332). In addition to these inscriptions, a passage in the *Digest* of Justinian (8.2.13) also refers specifically to these pipes as *tubuli*.

Although they do not use the term *tubulus*, a few ancient authors describe walls being heated by hot air flowing through pipes, and it is almost certain that they are referring to *tubuli*. Pliny (*Ep.* 2.17.9) writes that his bedroom in his villa at Laurentum was *suspensus et tubulatus*. In this excerpt, it is clear that the word *tubulatus* is denoting a system of *tubuli*. Furthermore, it seems that the *tubuli* are working in conjunction with an under-floor hypocaust system. Seneca (*QNat.* 3.24.3) states that the walls of the baths in Baiae were heated with hot air flowing *per tubos*, just as if fire had been applied to them. In what is certainly the best reference to *tubuli* in ancient literature, Seneca (*Ep.* 90.25) recalls the development of the *tubuli* system and describes its benefits.

Quaedam nostra demum prodisse memoria scimus, ut speculariorum usum perlucente testa clarum transmittentium lumen, ut suspensas balneorum et inpressos parietibus tubos, per quos circumfunderetur calor, qui ima simul ac summa foveret aequaliter

We know that certain devices have come to light only within our own memory – such as the use of windows which admit the clear light through transparent tiles, and such as the vaulted baths, with pipes let into the walls for the purpose of diffusing the heat which maintains an even temperature in the lowest as well as in their highest spaces

Here, Seneca reveals that the system of wall-heating was most valued by the Romans for its ability to heat the rooms of the bath evenly, both high and low. He also states that wall-heating pipes were a rather new innovation, occurring in “his own memory”. This comment has been used by modern archaeologists to date the invention of the *tubulus*.

Despite the available evidence, the invention and development of the *tubulus* remains poorly understood. Based on Seneca’s comment mentioned above, some scholars have suggested that the *tubulus* was not invented until the first century AD (Rook 1979:

305-306). In actuality, the *tubulus* was developed earlier. The earliest example of heating pipes being embedded in bathhouse walls comes from Fregellae and dates to before 125 BC (Tsiolis 2013: 95, fig. 11). These pipes acted as flue vents as well as heating elements; however, they do not resemble the typical *tubulus* form with its characteristic rectangular cross-section and side vents. These pipes, therefore, likely represent an early forerunner to the *tubuli* covered in this study. During the reign of Augustus, Vitruvius made no mention of *tubuli* in his *De Architectura*. This absence, however, should not be taken as a sign that *tubuli* did not exist at that time. Vitruvius also did not mention baked brick despite their existence (Adam 1994: 270, note 93). Thus, the writings of Vitruvius cannot be used to help date the development of the *tubulus*. It is therefore necessary to turn to archaeological evidence. Excavation in a bathroom near the Forum Romanum has found evidence that the invention of *tubuli* could have occurred as early as the late first century BC (Nielsen 1990: 14). This early date is backed up by evidence from beyond the shores of Italy, as *tubuli* have been found in all but one of the Herodian bathhouses, which were likely built after King Herod's first visit to Rome in 40 BC (Netzer 1999: 45, 50). It seems, therefore, that the initial development of the *tubulus* occurred sometime in the late first-century BC. What then of Seneca's comment, discussed above, that the invention of *tubuli* occurred in "his own memory" (*Ep.* 90.25)? It is impossible that Seneca could have remembered the invention of *tubuli*, which occurred sometime in the century preceding his birth in 4 BC (Conte 1994: 408). This comment should, therefore, reflect not the invention of *tubuli*, but their proliferation in the first century AD. In fact, archeological evidence suggests that around this time *tubuli* began supplanting *tegulae mammatae* as the preferred technique for creating cavity walling in Italy. During repairs

to sections of the Stabian Baths after AD 62, *tegulae mammatae* were replaced with *tubuli*, and *tubuli* were being installed in the unfinished Central Baths when Vesuvius erupted in AD 79 (Adam 1994: 270). Even though the other methods continued to be employed, *tubuli* became the dominant means of creating wall cavities across the Roman world, being used from Britannia (Brodrigg 1987: 72-79) to Arabia (as will be examined in this study). The use of *tubuli* even out-lived the Roman Empire itself. In early Islamic *hammams*, tubular pipes were installed against the faces of walls for heating in the exact same manner as had been done during the Roman period (Dow 1996: 25). This long life is evidence of the efficacy and importance of *tubuli* within bathhouse architecture.

Although the *tubulus* was specifically designed to be used in a wall-heating system, *tubuli* have also been found being used to form the *pilae* that support the suspended floor in a hypocaust. One such example of this use of *tubuli* comes from Carthage (Rossiter 1998: 109). The discovery of *pilae* made from *tubuli* at Saalburg led to a scholarly debate on the reasons for this peculiar use or reuse. Some scholars hypothesized that the *tubuli* were made specifically for use as the *pilae*, while others argued that they were leftovers, purposely ordered as a contingency against breakage during transportation or construction (Degbomont 1984: 104).

The last argument brings up a good point about the fragility of *tubuli*. Being hollow, *tubuli* were very vulnerable to breakage, and contractors would have had to take this into consideration when building with them. As indicated on the tile from Dover previously mentioned, out of a batch of 550 *tubuli*, 51 (9%) were broken by the manufacturer alone (Wilson 1973: 332). One can assume that more would be broken during transportation, and even more during installation. It makes perfect sense,

therefore, that contractors ordered extra *tubuli* as a contingency against inevitable breakage.

In addition to being a headache for Roman contractors, the fragility of *tubuli* has also caused problems for modern archaeologists. One of the major problems with the study of *tubuli* systems, and indeed wall-heating systems in general, is their poor preservation. At many sites, the upper portions of walls do not survive, and in places where the walls are preserved, the fragile *tubuli* have fallen off. While many examples of *tubuli* have been found *in situ* against the lower courses of walls, almost nothing is known about *tubuli* and the heating system at the top of the walls.

### **Vault Heating**

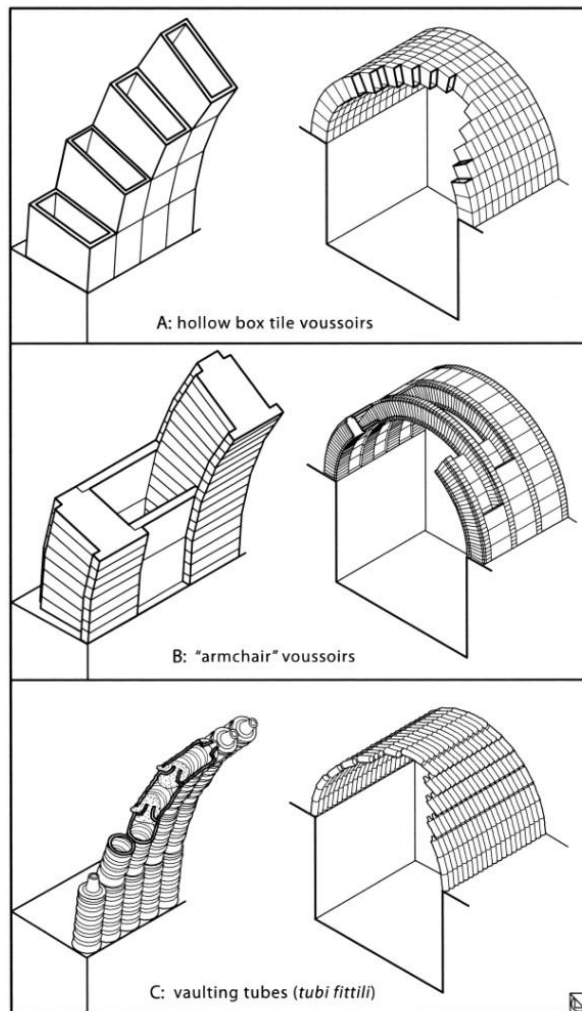
In some places, there is archaeological evidence that the Romans heated the vaults in addition to the walls. Just like wall-heating systems, heated vaults were usually constructed with ceramic building materials. Although not all of them were designed for heating purposes, the Romans had several different vaulting techniques using CBM, many of which were developed in the provinces (Lancaster 2008: 275-77). One of these methods, by which the vault could be heated, employed hollow voussoirs, called *tubuli cuneati* (fig. 1.2A). These tiles formed arches in the same way as stone voussoir blocks, but were ceramic and hollow, allowing hot air and gases to pass through them, just like *tubuli*. This method is found primarily in Britain, where the technique was developed (Lancaster 2012: 419). Another technique for creating a semi-hollowed vault used specially shaped voussoir blocks, called armchair voussoirs (fig. 1.2B). In this method, the voussoir blocks formed arched ribs which were spaced out from each other within the

vault. Between each arched rib, flat tiles were installed, supported by projections on the voussoir blocks. These flat tiles filled the gap between the arched ribs and formed the continuous vault. The hollow channels between the ribs served to lighten the load of the vault, and could function as flues for hot air (Brodribb 1983: 47).

A third method of employing CBM in the construction of vaults is the use of *tubi fittili*, or vaulting tubes (fig. 1.2C). Primarily found in North Africa and Italy, *tubi fittili* have been discovered as far away as Britain, Dura Europos, and Caesarea Maritima (Vann 1993: 32). These cylindrical tubes were open at one end and terminated in a tapered point at the other, allowing them to socket into one another. Cemented together with mortar, *tubi fittili* formed the curved intrados of an arch and allowed Roman builders to construct lightweight vaults quickly without the use of wooden centring. While they may have provided some insulation due to the nature of their hollow design, *tubi fittili* were not likely intended to be used as a conduit for hot air. This conclusion is based on several examples of *tubi fittili* that were produced with one end sealed, making it impossible for air to flow through them (Bound 1987: 191).

A final technique of vault construction is found in Vitruvius' *De Architectura* (5.10.3). Here, Vitruvius instructs how to build a vault using ceramic tiles suspended from the ceiling. When this method is used within bathhouses, he recommends building a double vault, thereby creating a void and protecting the wooden framework from moisture. Vitruvius does not, however, discuss the heating of vaults using this method, and it may be that this method was unsuitable for heating due to the risk of the wooden beams catching fire. While there are no extant examples of this construction technique, it seems to have been used in the baths at Fregellae (Tsiolis 2013: 90-93, fig. 6). There is

also evidence that something similar may have been employed in the bath vaults in Tivoli and even at the Baths of Caracalla in Rome (Yegül 1992: 366). Although the Romans developed several ways of creating a hollow vault, the only techniques proven by archaeology to have been used to heat the vault are the system of hollow voussoirs and the system of armchair voussoirs.



**Fig. 1.2** *CBM vault construction techniques.*

*A. tubuli cuneati*

*B. armchair voussoirs*

*C. tubi fittili*

(After Lancaster 2008: fig. 10.7, p. 276)

## Chimney Flues

Once the hot air and smoke rose to the top of the *tubuli*, or in some cases the top of the vault, it needed a way by which to exit the building. It did so through chimneys,

which often terminated in simple holes on the roof of the building (Yegül 2010: 87), although “chimney pots” have been found at several sites in Britain (Brodrigg 1987: 31-32). The exhaust of a bathhouse was an integral part of the hypocaust system. It was through these chimneys that the draught of the hypocaust was maintained, and the control of the draught was one of the ways the Romans regulated the temperature of the hypocaust (Webster 1979: 289). If the draught became too high, the heated rooms would grow unbearably hot. Proper management of the exhaust system, and thus the draught, was therefore very important.

Ceramic pipes were often used to convey the exhaust to the exterior of the building. Degbomont makes a clear distinction between chimney pipes and *tubuli*, since, though similar in shape to *tubuli*, chimney pipes are usually larger and do not have vents cut on their sides (Degbomont 1984: 138). Some of the earliest chimney pipes, found in association with hypocausts, come from the Central Baths in Herculaneum. These pipes are identical to typical water pipes (cylindrical with one end tapered); however, unlike water downpipes which have the tapered neck downwards, these pipes were set into the wall with their neck facing up (Rook 1979: 304). This reversal of orientation can be easily explained by the upward flow of smoke and hot air, as opposed to the downward flow of water.

Chimney flues from hypocausts were usually installed near the corners of rooms and can be classed into one of three categories: immured, where the chimney flue is built wholly within the wall; recessed, where the chimney flue is installed into a small niche; and advanced, where the chimney pipes are built against the wall and thus stick out into the room (Degbomont 1984: 138). The chimney flues were a necessary component of any

hypocaust system, and therefore were used with or without a *tubuli* system. In cases where separate chimney flues were used in a room containing a *tubuli* system, recessed chimney flues could be used behind the *tubuli* system (Degbomont 1984: 153, fig. 288).

In some cases, chimney flues were used as additional heating sources in the absence of a full *tubuli* system. Some heated rooms in houses were partially heated by hot air flowing through recessed chimney flues containing either box-tiles, or sealed by an upright piece of wood which was then plastered over (Webster 1979: 289). The dual function of heating the walls as well as venting away smoke and hot gases is more likely to be found with recessed chimney flues, since the pipes were closer to the wall surfaces. As mentioned above, it is possible that wall-heating developed from such spread-out chimney flues, when the heating potential of these flues was realized and the system was expanded across the face of the wall.

### **The Role of *Tubuli* in the Heating System**

As previously mentioned, the poor preservation of *tubuli* systems has led to an incomplete understanding of their role in the heating of hypocausted rooms. One major question is whether the *tubuli* played an active role in heating the room, or whether their role was passive and they acted more as insulation, preventing heat loss. Relating to this first unknown is the problem regarding the relationship between the *tubuli* and the exhaust flues. It is not fully known if all the *tubuli* were part of the exhaust system and carried draught, or if only some, or even none at all were connected to the chimney flues. With no complete *tubuli* system extant, both of these questions require practical experiments.

The first practical experiment to study the workings of an active hypocaust and *tubuli* system was set up by Fritz Kretzschmer in Saalburg in 1951 and in 1952 (Kretzschmer 1953). In this experiment, Kretzschmer built a complete hypocaust system, designed to heat a small, 5m by 4m, room. The data collected provided a great deal of information regarding the space heating requirements, fuel supply, and the efficiency of hypocausts. It also offered further insight into the function of the *tubuli* system.

Using his findings from the experiment, Kretzschmer suggested that the *tubuli* did not play an active role in heating the room (Kretzschmer 1953: 33). Instead, he argued that the *tubuli* acted as insulation, the air within them only being warm enough to prevent condensation. This theory, however, has recently been debunked by a more recent practical experiment.

In 1998, a team of archaeologists and engineers built a small, working Roman bathhouse for a TV documentary, using only techniques and materials available to the ancients (Yegül and Couch 2003). This experiment provided insight into many aspects of bathhouse construction and operation, including the unresolved relationship between the *tubuli* and the exhaust flues. To attempt to solve this mystery, the builders of the bath looked into different arrangements of the *tubuli* within the wider exhaust system, and several designs were entertained. One possibility was setting up the entire *tubuli* system to act as one giant flue, with each column of *tubuli* open at the very top. This design would create a strong draught, requiring a great deal of fuel, and creating a very hot hypocaust. A more economical design had the *tubuli* completely separate from the flue system. In this arrangement, each *tubuli* column would be blocked at the very top. The exhaust from the hypocaust, therefore, did not flow through the *tubuli*, but bypassing

them, the exhaust escaped through chimneys, which led directly from the hypocaust to the exterior of the building. In this method, the *tubuli* system was still open to the hypocaust below, but it carried no draught. Thanks to convection currents, however, air still would circulate within the *tubuli*, rising and falling as it was heated and cooled. The model chosen for the experiment was a hybrid of these two designs, where three out of every four *tubuli* columns were blocked off at the top and the remaining one was open to a horizontal header which in turn led to the exhaust pipe (Yegül and Couch 2003: 171). This design allowed for circulation within the *tubuli* system, as well as a steady draught, which was not so strong as to eat up excessive amounts of fuel.

After the bathhouse was completed and all the data had been collected, the engineers found that, while the method of blocking three out of every four *tubuli* columns and leaving the remaining one in four open did prove efficient, the *tubuli* were not completely effective at conveying smoke and gases out of the hypocaust. Despite the weak draught, circulation of hot air still took place within the *tubuli*, and the wall was sufficiently heated (Yegül and Couch 2003: 175). This discovery suggests that wall-heating systems could work efficiently without a direct connection to the exhaust flue.

This experimental construction of a Roman bathhouse also allowed the archaeologists to re-examine the role *tubuli* played in heating the bath. Using their recreated *tubuli* system, the archaeologists and engineers took thermal readings against the hollow walls, and discovered that the hot gases actively circulated within the *tubuli*. In addition, the *tubuli* system was found to make a significant contribution to the heating of the room (Yegül and Couch 2003: 175). If the walls of the bathhouse were not heated, the floor surface would have to be heated to an unbearable and even dangerous

temperature in order to offset heat loss. The author Pliny (*Ep* 3.14.2) alludes to how unbearably hot a hypocausted floor could be. Wall-heating, therefore, provided a more comfortable atmosphere within the bath and permitted a significant reduction in the fuel required to heat the structure. These findings disproved Kretzschmer's claim that *tubuli* acted solely as insulation. On the other hand, they agree with another experiment, which had argued that the use of *tubuli* with a hypocaust generated constant temperatures within the bathhouse which could be maintained with relatively little fuel (Hüser 1979: 30).

The fact that *tubuli* did indeed contribute to heating the bath agrees with ancient accounts of wall-heating in literature. As previously mentioned, Seneca (*QNat.* 3.24.3) described the walls of a bathhouse as being heated by hot air as if fire was applied. In another passage (*Ep.* 90.25), he attributed the comfortable climate within baths to the *tubuli*. Combining the evidence from practical experiments and literary accounts, it seems that *tubuli* most definitely played a significant role within the heating system.

### **Risks and Benefits of *Tubuli***

While the heat carried through the *tubuli* system helped to create a more comfortable and economical bath, it also posed serious risks. A passage from the *Digest* of Justinian (8.2.13) reveals just how dangerous *tubuli* could be. A law concerning the construction of wall-heating systems states: *non licet autem tubulos habere admotos ad parietem communem [...] quod per eos flamma torretur paries* "It is not permitted, however, to have *tubuli* placed against a common wall [...] because by means of them (*tubuli*) a wall is scorched by fire". Fire, of course, was a major concern in the ancient world, and laws such as this were necessary to prevent undue risk.

Despite the increased risk of fire, *tubuli* and wall-heating systems in general brought significant benefits to the design and architecture of Roman bathhouses. In addition to creating a more economical heating system and more comfortable temperatures within the bathhouse, wall-heating prevented condensation on walls, which was a great nuisance to bathers (Webster 1979: 289). *Tubuli* and wall-heating also contributed significantly to the successful function of the gigantic imperial *thermae*.

In one of his letters (*Ep.*86.4-10), Seneca compares the small and dark baths of the Roman Republic to the large and bright imperial *thermae*. This drastic change in bathhouse size in the first and early second century AD was in large part due to architectural developments during what Ward-Perkins termed the “Roman Architectural Revolution” (Ward-Perkins 1981: 105). The large open spaces of the imperial *thermae*, however, required much more energy to heat than could be provided by a simple under-floor hypocaust. Some of this additional heat came from solar energy through the large windows, which were glazed and oriented towards the afternoon sun (Ring 1996: 723). Seneca refers to these windows in his letter (*Ep.*86.8), stating:

At nunc blattaria vocant balnea, si qua non ita aptata sunt, ut totius diei solem fenestris amplissimis recipiant, nisi et lavantur simul et colorantur, nisi ex solio agros ac maria prospiciunt.

Nowadays, however, people call baths fit for moths if they have not been so arranged that they receive the sun all day long through the widest of windows, if men cannot bathe and get a coat of tan at the same time, and if they cannot look out from their bathtubs over land and sea.

While these windows could provide additional heat to the bathhouse, their poor insulation allowed heat to more easily escape from the bath (see discussion in Ring 1996).

The real technological innovation that enabled the heating of such large spaces was cavity-walled-heating (Rook 1979: 307). The heating of the walls meant that baths no longer had to rely on only their floors for heat. With the increase in the heated surfaces enormous spaces could be kept warm. So while it may have been the architectural developments of the “Roman Architectural Revolution” which made possible the building of the imperial *thermae*, it was the system of wall-heating and *tubuli* that heated these monumental structures and enabled them to be used as baths.

Although *tubuli* were essential to the construction of the large imperial *thermae* in Rome, this important technological innovation was used as well in modest bathhouses across the Roman world. *Tubuli* are found in great numbers even on the edges of the Roman Empire. Among these marginal areas is Roman Arabia.

### **Roman Arabia**

For the purposes of this study, the term Roman Arabia refers only to the geographic region that the Romans called Arabia and not specifically to this region during the Roman period. This area lies south and east of Palestine and Israel, between Egypt and Syria; it includes all of modern day Jordan, the Negev, southern Syria, and northwest Saudi Arabia (Bowersock 1983: 1). Initially known as Nabataea, this territory was annexed by Rome and, together with the region of the Decapolis cities, was formed into a province called *Provincia Arabia*. After Diocletian’s reorganization of the eastern provinces, this province was split into two provinces, *Palaestina Tertia* in the south, and *Arabia* in the north (Bowersock 1983: 143). This region was and still is characterized by a primarily desert climate, although it can be divided into several distinct geographic

zones. In the north, directly south of modern Syria, a Mediterranean climate supports evergreen forests and arable land. In the south, the Wadi Arabah runs from the Dead Sea to the Gulf of Aqaba. To the west of the Wadi Arabah lies the semi-arid Negev desert, while to the east a great escarpment rises up to form the western edge of the Shera'a, a long plateau ridge which separates the Wadi Arabah and the Dead Sea from the arid desert further east. The southern end of the Shera'a curves eastward, creating a high scarp and forming a barrier for traffic to and from the Red Sea, and between the Shera'a and the Gulf of Aqaba lies the arid Hisma Desert punctuated by craggy hills. This entire region, and especially the escarpment around the Shera'a, is characterized by sharply cut *wadis*, carved by seasonal runoff channels. These deep *wadis* and the high mountains create a jagged landscape.

### **Nabataean Kingdom**

Before the Roman annexation, this apparently inhospitable area was home to a semi-nomadic people, whom the Greeks called *Ναβαταῖοι* ("Nabataeans"), and whose origins are unknown and remain a debated issue (Parr 2003: 30). The first classical author to refer to the Nabataeans was Hieronymus of Cardia, whose work, although now lost, survives indirectly through the writings of Diodorus Siculus (2.48.1-9; 19.94.1-100.2). In his *Bibliotheca*, Diodorus Siculus describes the Nabataeans as an unsettled people and brigands, who collected water in deep cisterns, and grew wealthy from their control of the frankincense trade that passed through their territory. This portrayal stands in stark contrast to the accounts of Strabo (16.4.21), who, writing two hundred years after Hieronymus, described Nabataeans in the first century BC as being settled and well-

governed, with the city of Petra as their capital. The exact date of the settlement of the Nabataeans is debated among modern scholars. A sudden appearance of a rich material culture at the end of the second century and beginning of the first century BC has led to the argument that the Nabataeans became sedentary around 100 BC (Schmid 2001b: 368-71). On the other hand, excavation within Petra has uncovered evidence of what might be a permanent occupation dating back to the late third or early second centuries BC (Parr 2007: 278). This archaeological evidence along with early references to the Nabataeans in contemporary documents has supported arguments for an early date for the settlement of the Nabataeans (Graf 2007a: 333-35).

Long before becoming sedentary, the Nabataeans engaged in trade and profited greatly from it (Diod. Sic. 19.94.4-5). This wealth may have helped to make Nabataea so enticing to foreign invaders. In the late fourth century BC, Antigonus the One-Eyed tried twice to conquer the region (Diod. Sic. 19.94.1-100.2), and in the early first century BC, the Seleucid king Antiochus XII sent an army into Nabataea twice (Joseph. *AJ* 13.387-91; *BJ* 1.99-102). All of these attempts failed, and the Nabataeans remained independent, despite being bordered by powerful Hellenistic kingdoms. Periodic hostilities also erupted between the Nabataeans and the Hasmonaean Kingdom to the west (Hammond 1973: 16-18). Nabataea, however, maintained its autonomy and continued to grow in prestige.

### **Roman Annexation**

The independence of the Nabataean Kingdom came to an end during the reign of Trajan with its annexation in AD 106. This annexation, however, was not the first time

the Nabataeans encountered the Romans. During his campaign in the east, Pompey marched against Petra (Plut. *Vit. Pomp.* 41.1). This expedition was eventually called off, but Arabia nevertheless appeared in Pompey's triumphal parade as a newly conquered nation (Plut. *Vit. Pomp.* 45.2).

Drawing on numismatic evidence and a passage from Strabo (16.4.21), Bowersock made the interesting argument that the Kingdom of the Nabataeans had temporarily been annexed by Rome in the years 3/2 BC, before returning to the status of an independent client state (Bowersock 1983: 54-56). Scholars, however, have pointed out that there is not sufficient archaeological evidence to back up this argument, and the peculiar lack of Nabataean coins from the years in question may be due to only a distrust of the Nabataean king and a simple limitation of his powers (Fiema 1987: 25-26).

Whatever the case may be, the Nabataeans remained independent throughout the first century AD, and were even the targets of yet another abortive invasion in AD 37 (Joseph. *AJ* 14.120-126). These sporadic invasions of the Nabataean Kingdom were symptoms of what has been called the "comparatively tenuous and uncertain Roman control" of the region (Millar 1993: 55-56). During this time, although not directly controlled by the Romans, the Nabataean Kingdom was heavily influenced by them. With the Roman annexation of Nabataea in AD 106, this tenuous control ended, and the territory was incorporated into the Roman Empire as a separate province, called *Provincia Arabia*.

To the frustration of archaeologists and historians alike, there is a disappointing lack of literary sources for the annexation of the Kingdom of the Nabataeans. In his long history of Rome, Dio Cassius (68.4.5) devotes only one short sentence to this episode: κατὰ δὲ τὸν αὐτὸν τοῦτον χρόνον καὶ Πάλμας τῆς Συρίας ἄρχων τὴν Ἀραβίαν τὴν πρὸς

τῆ Πέτρα ἐχειρώσατο καὶ Ῥωμαίων ὑπήκοον ἐποιήσατο, “About this same time, Palma, the governor of Syria, subdued the part of Arabia around Petra and made it subject to the Romans”. Ammianus Marcellinus (14.8.13) also gives only a brief report of the annexation when describing the region of Arabia, and other sources give even less information (Eutr. 8.3; Festus 14.3; Jer. *Ab Abr.* 276b).

This lack of evidence has stimulated a tremendous amount of scholarship regarding the early history of Roman Arabia. Much ink has been spilt discussing the causes of the annexation. Scholars have suggested such reasons as the strategic importance of the area on the eve of Trajan’s Eastern campaigns (Bowersock 1983: 84; Sartre 1985: 72), the financial gain of direct control of the territory (Hammond 1973: 39; Fiema 1987: 30), the protection of trade routes from bandits (Isaac 1984: 187), and the maintenance of communication between Egypt and Syria (Préaux 1950-51: 135). The list goes on (Freeman 1996: 93-94; Fiema 2003: 43-44).

Scholars are much more like-minded in regards to the planning of the campaign. Some have argued that the invasion was not planned but was more of a reaction to immediate events (Fiema 1987: 35). The majority of scholars, however, agree that the annexation was premeditated (Kennedy 1980: 286-88; Bowersock 1983: 82; Freeman 1996: 94-95). There is even evidence that military units were transferred to Judea well ahead of the invasion in anticipation of it (Kennedy 2004: 39).

There has also been debate on the method of annexation. Traditional thought held that the formation of *Provincia Arabia* was peaceful and more of a diplomatic achievement than a military one (Bowersock 1983: 81; Millar 1993: 414; Ball 2000: 64; Sartre 2005: 87). This argument stemmed from the lack of archaeological evidence for

destruction in the early second century which could be associated with a hostile invasion. The fact that Nabataean soldiers were recruited into the Roman army shortly after the annexation also suggests that there was no major conflict between the two sides (Graf 1994: 299-300). Further evidence for a peaceful annexation comes from numismatic evidence. Coins commemorating the annexation bear the legend *ARABIA ADQUISITA* (Arabia acquired), instead of using the typical word *CAPTA* (captured) (Mattingly and Sydenham 1926: 239).

On the other side, some scholars have suggested that the annexation was violent. Schmid has argued that a widespread destruction level dated to the early second century AD should be ascribed to the Roman annexation (Schmid 1997: 417-420). It is possible that the destruction that occurred in Humayma immediately before the construction of the Roman fort was due to violence associated with the annexation (Oleson 2004: 354). Although Parker attributes much of the destruction in the region to an undocumented earthquake, he does not reject the possibility of a violent takeover, saying that the two possible causes of the destruction are not mutually exclusive (Parker 2009: 1591). An annexation through the force of arms is also more in accord with the literary sources. Dio Cassius (68.4.5) uses the word *ἐχειρώσατο*, which suggests that some force was used. Ammianus Marcellinus (14.8.13) is even more explicit about the amount of fighting, writing:

Hanc provinciae imposito nomine, rectoreque adtributo, obtemperare legibus nostris Traianus compulit imperator, incolarum tumore saepe contunso, cum glorioso Marte mediam urgeret et Parthos.

It was given the name of a province, assigned a governor, and compelled to obey our laws by the emperor Trajan, who, by frequent victories crushed the arrogance of its inhabitants when he was waging glorious war with Media and the Parthians.

The arguments for a militaristic annexation are further supported by graffiti that refer to conflict with Romans, and by military honours handed out after the event (Freeman 1996:100-101). Bowersock himself admits that it took a curiously long time for Roman government to announce the annexation (Bowersock 1983: 82). It is possible that this delay resulted from ongoing resistance, which was stamped out only after several years of sporadic fighting.

The jury is still out regarding the reason for and the character of the annexation of the Nabataean Kingdom in AD 106. In all likelihood this will remain the case until concrete evidence is found. What is clear, however, is that there was some degree of planning for the campaign.

After the formation of *Provincia Arabia*, a full legion was stationed at Bostra, the new provincial capital. Other suggested sites of early, smaller Roman garrisons are Gerasa, Madaba, Petra, and Mampsis (Freeman 1996: 101). Humayma (ancient Haurra) deserves special mention as it was constructed immediately after the annexation and is the earliest large Roman fort in the region (Oleson 2009: 535). The identification of the initial garrison of the province has met with limited success. Epigraphic and papyrological evidence has suggested two likely possibilities: *Legio III Cyrenaica*, from Egypt, and *Legio VI Ferrata*, from Syria (Speidel 1977: 691-98; Oleson *et al.* 2002: 104)

### **Nabataea under the Romans**

With the arrival of Roman soldiers, one would also expect to see a transformation in Arabia to reflect the region's new status as a Province of Rome, or, to use an ambiguous and controversial term, Romanization. Like elsewhere in the empire, the

question of Romanization in Arabia is far from simple. On a local level, the existence of a Roman garrison at the settlement of Hauarra does not seem to have had much of a cultural effect on the local inhabitants (Oleson 2004: 358-59). Regionally, consequences of the annexation are more evident. Based on inscriptions, Greek language appears to have largely replaced the Nabataean language shortly after AD 106 (Graf 2007b: 180). Despite this adoption of language, Nabataean names written in their Hellenized forms remain common in inscriptions until the seventh century AD (Politis 2007: 188). In terms of religion, the Nabataeans maintained their dynastic and religious cults at least until the third century, albeit with Greco-Romanic influences (Graf 2007b: 183-84). Thus, while there is evidence that their language may have changed, the Nabataeans still clung onto a few ethnic markers.

Although it grew over time, the Romans also had a relatively limited immediate effect on the urban landscape of the major regional cities. In the years following the Roman annexation, there are surprisingly few building projects in Petra (Parr 2007: 293). Likewise, the majority of monuments in Bostra are not Roman but Nabataean in origin (Ball 2000:198). This lack of Roman monuments, however, is not a reflection of Arabia during the Roman period, but rather a reflection of Arabia before it became a Roman province. Starting from around 100 BC, Nabataea was a Hellenized kingdom (Schmid 2001a: 415-16). Influenced by their Hellenistic neighbours, Nabataean kings built their cities in the same fashion as those found in the Ptolemaic, Seleucid, and Hasmonaean kingdoms. Like other eastern cities, there was no need to construct large public buildings after the Romans arrived. In Petra and Bostra, they already existed.

Although limited, there is not a complete absence of Roman monuments in Petra. A Trajanic inscription found on the colonnaded street provides evidence for the existence of a monumental arch celebrating the emperor's conferring of the title 'metropolis' on the city (Parr 2007: 294). Furthermore, although traditionally the colonnaded street and the Temenos have been considered pre-annexation in date (McKenzie 1990: 35-36), recent excavations have suggested that these two features may actually date to after the Roman annexation (Fiema 2003: 47-49; Graf 2007a: 338).

In addition to these limited projects in Petra, the Romans were active elsewhere. Some structures, such as forts at Bostra and Humayma, were built soon after the annexation. Another consequence of the Roman presence, and the most conspicuous Roman building project in the years following the annexation, was the *Via Nova Traiana*, which stretched from the Syrian border in the north to Aila (modern Aqaba) on the Red Sea. It has been suggested, however, that this road may not have been a new creation, but rather a renovation of a pre-existing road (Freeman 2001: 433).

Although limited in the beginning, traces of the Roman presence increased with time. With prolonged Roman rule in Arabia, urbanization grew and construction of civic buildings continued across the region thanks to peace and prosperity (Freeman 2001: 444-45). Instead of undertaking any immediate monumental building projects to assert their dominance in Arabia, the Romans maintained, improved, and over time contributed to the urban and regional development begun by the Nabataean rulers before the annexation.

### **Byzantine and Early Islamic Periods**

As mentioned above, Roman Arabia saw profound administrative changes with Diocletian's reorganization of the eastern provinces, whereby *Provincia Arabia* was split into two separate provinces, *Palaestina Tertia* in the south, and *Arabia* in the north (Bowersock 1983: 143). These administrative changes also coincided with a massive reorganization of the eastern defences of the empire that included the construction of numerous forts and fortlets throughout Roman Arabia (Parker 2006: 541-52). During the Byzantine period, the region was troubled by frequent nomadic incursions and conflicts with the Sassanian Empire. Byzantine rule in Arabia finally came to an end with the Islamic conquest in the mid seventh century (Watson 2001: 466).

### **Bathhouses in Roman Arabia**

The history of bathhouses in Roman Arabia is likewise one of continuity stretching back well before the annexation in AD 106. While baths are regarded as quintessential Roman structures, the earliest bathhouses in the region are Hellenistic in origin. A second century BC example of one of these Hellenistic baths has been found at Tel Anafa, in the Upper Galilee (Herbert 1994: 67). Such bathhouses were not uncommon in Palestine during the Hellenistic period (Hoss 2005: 38-45). The introduction of Roman style bathhouses with Vitruvian hypocausts to the region is credited to Herod. Between the years 35 and 15 BC, Herod built a total of 11 Roman-style baths throughout his kingdom; however, unlike Roman bathhouses which were open to the public, the Herodian baths were all private, having been built within Herod's palaces (Netzer 1999: 45). These high-quality bathhouses were constructed with the latest

technological advancements in bathing architecture, including *tubuli*. Roman building techniques were also used, and it is likely that Herod contracted the work to Italian experts (Nielsen 1999: 42). Thus, from a very early time highly developed Roman-style bathhouses were introduced to the Near East.

One of these Herodian baths was at the palace-fortress, Machaerus, east of the Dead Sea and well within the borders of what became Roman Arabia. Originally built as a fort to guard the Hasmonaean eastern territories against the Nabataeans, the site became home to one of Herod's many palaces. The construction of the bathhouse at Machaerus dates to 30 BC, and its destruction seems to have taken place in AD 72 (Hoss 2005: 160). Like almost all Herodian bathhouses, the one at Machaerus featured *tubuli*.

Starting around the beginning of the first century AD, the practice of building baths seems to have been adopted by the Nabataeans. A villa containing a private bath suite was built in Wadi Musa in the early first century AD and renovated in the mid first century ('Amr *et al.* 1997: 470). Another domestic bathing installation with a hypocaust comes from Petra and dates to before the end of the first century AD (Stucky *et al.* 1994: 275). In Wadi Ramm, yet another early Nabataean villa has a bath with a hypocaust dating to the first century BC or first century AD (Dudley and Reeves 2007: 405-406). These bathhouses were obviously heavily influenced by Roman heating technology. Not only do they all contain Vitruvian hypocausts, but those from Wadi Musa and Wadi Ramm were also built with *tubuli*.

Except in military contexts, no Roman baths have been found in Egypt before the second century AD (Fournet and Redon 2013: 260). In Syria and the east, Roman bathing traditions, and thus Roman bathhouses, were also uncommon until the second century

AD (Fournet 2012: 331). It is therefore very unlikely that the Nabataean baths were influenced by those in Egypt or in Syria. The geographic locations and building techniques of the Nabataean baths suggest instead that they drew inspiration from the nearby Herodian baths. During this period the Nabataean kings were building their cities in the same fashion as the Hellenistic kingdoms next door. It makes sense that the kings and the nobility of Nabataea also adopted bathing facilities from their neighbours. After all, Nabataean domestic architecture and interior decoration at this time exhibit strong influences from its Hellenistic neighbours (Kolb 2001: 444). It is also not hard to imagine a scenario where the King of the Nabataeans, not wishing to be outdone by his rival to the west, built Roman-style baths in his palaces, which were then copied and built by the Nabataean elite. In Petra, plaster mouldings have been found that have exact parallels from Herodian bathhouses (Bellwald 2012: 43-5). There is also evidence to suggest that Nabataean masons were employed in Herodian construction projects in the first century BC, and could have learned and brought back to Nabataea the art of building bathhouses (Negev 1988: 180-81).

Before moving on to the Roman period, an important observation should be made about the contexts in which pre-annexation baths are found. Both the baths at Wadi Musa and those at Wadi Ramm were associated with private villas. Two other Nabataean baths, one at Khirbet edh-Dharih (al-Muheisen and Villeneuve 1994: 751) and another at Zantur in Petra (Stucky et al. 1994: 275), come from domestic complexes, where they functioned as private facilities. Based on evidence to date, it seems that before the Roman annexation, the only baths in the Nabataean Kingdom were private bath suites attached to the houses of the rich. There are two obvious explanations. One is that public bathhouses

did exist, but simply have not yet been found. Another possibility is that the use of bathhouses was a luxury enjoyed only by the elite, who imported the practice to serve as an indication of their prestige. If the latter is correct, yet another parallel can be drawn between the Herodian and Nabataean baths.

The annexation in AD 106 and the arrival of Roman soldiers marked the next chapter in the history of bathhouses in Arabia. In keeping with Roman practice elsewhere in the empire, the soldiers built bathhouses in areas where their garrisons were located. These bathhouses were used by the soldiers, who were accustomed to bathing in the Roman manner. One of the best examples of baths being built in association with a fort in early Roman Arabia is from Hauarra. Here, a bathhouse was built in the second century AD, following the construction of the nearby fort (Oleson 2010: 223). Although not located within the fort, but in the adjacent *vicus*, the bathhouse was intended for use primarily by the soldiers (Reeves 1996: 75-78).

Military bathhouses continued to be built in conjunction with forts throughout the Roman and Byzantine control of the region. When Diocletian reorganized the defence of the eastern frontier, many new forts were constructed throughout Roman Arabia. Many of these forts had their own bathhouses for the convenience of the troops. At the legionary fortress of Lejjun, there were baths inside the fort itself (de Vries and Lain 2006: 213-30). At smaller forts located at 'Ayn Gharandal (Darby and Darby 2012: 742) and Yotvata (Meshel 1989: 234-36), bathhouses were built adjacent to the forts.

In addition to private bath suites and military bathhouses, there existed a third type of bath complex in Roman Arabia, the public baths. These baths were open to the public and were similar in design and function to the imperial *thermae* found in Rome

and elsewhere in the empire. It is no surprise that in Roman Arabia, several public baths are found in the Decapolis cities where the populace was more accustomed to Greco-Roman culture. In Gerasa (modern Jarash), the recent discovery of the Central Baths has brought the total number of public baths in the city to three (Barnes *et al.* 2006: 300-305). In Petra, excavation has uncovered what is possibly a public bathhouse; however, the existence of this bath is no surprise given the affluence of the city (Joukowsky 2007: 101).

The history of bathhouses did not stop with the end of Roman and Byzantine rule in the region. After the Islamic conquest of the Near East, the tradition of bathing and constructing bathhouses continued. The Islamic baths, or *hammams*, are direct descendants of Roman baths, which were found throughout Roman Arabia (Dow 1996: 32-38).

From the earliest Herodian baths, to the Islamic *hammams*, *tubuli* are found in the majority of bathhouses in the region; however, as with all CBM, *tubuli* are seen as unglamorous, and those sites which do record the existence of *tubuli*, record them only in passing. At times, archaeologists will reference other sites as also having *tubuli*, but no attempt is made to discern whether *tubuli* from site “A” are the same as *tubuli* from site “B”. It is thought that one *tubulus* is the same as the next. To make such an assumption, however, is to rule out the possibility that anything can be discovered through the study of *tubuli*.

This study will prove this assumption incorrect and highlight the value of such mundane objects to the archaeology and history of Roman Arabia. Using collected samples and published reports, this study will examine the *tubuli* themselves, identifying

and describing typological differences in *tubuli* between sites and over time. Particular attention will be paid to comparing *tubuli* from before and after the annexation in AD 106. Differences and similarities in this respect will provide clues as to how the construction of Roman-style baths under the Nabataeans compared to the construction of baths by the Romans themselves. An attempt will also be made to fit the manufacture and supply of *tubuli* into the wider economy of the region by determining where the *tubuli* were produced and how far from the production site the *tubuli* were distributed. The primary goal of this study is to demonstrate that proper study of *tubuli* from Roman Arabia has the potential to answer many questions regarding the history and archaeology of this region.

The following chapter will present descriptions and analysis of *tubuli* collected from the site of Humayma (ancient Hauarra) in southern Jordan. Comparanda from neighbouring sites in the region will then be provided in the third chapter.

## **Chapter Two: The *Tubuli* from Humayma (Ancient Haurra)**

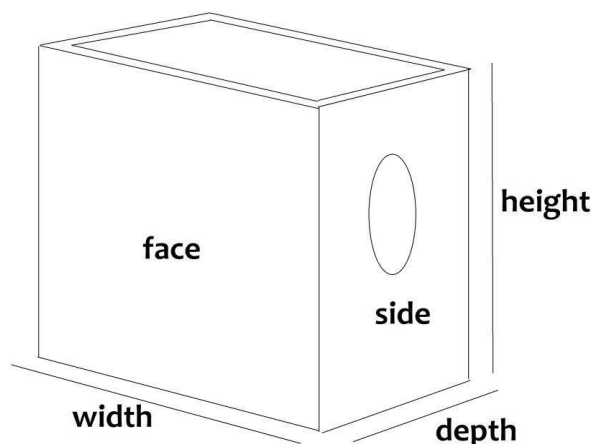
This chapter presents the findings and analysis from a study conducted in the summers of 2011 and 2012 of the entire Humayma *tubulus* corpus. The purpose of this study was to discern and describe types of *tubuli* and fit them into the chronological narrative of the site, thereby creating a *tubulus* typology for Humayma. At the same time, the study attempted to determine the source of the material, to gain a better understanding of their manufacture and use, and to fit them into a reconstructed pattern of trade in building materials in Roman Arabia.

For several reasons, the Humayma *tubulus* corpus provides an excellent starting point for the examination of *tubuli* in Roman Arabia. The material comes from structures or rooms that have been almost entirely excavated, and therefore a great deal of information on their context is available. The corpus also includes an assortment of *tubulus* forms, spanning several centuries. This variety has enabled a chronological typology to be compiled that can be compared to other sites in the region. Finally, thanks to the diligence of the excavators over the years, a large number of fragments were saved and available for study. The large size of the Humayma *tubulus* corpus has allowed this study to do much more analysis than would be possible at any other site where this material is rarely recorded or saved. For these reasons, the Humayma *tubulus* corpus will be the focus of this study and will be covered in this chapter.

## Terminology

Before proceeding to any descriptions or analysis of *tubuli*, it is necessary first to go over the terminology used throughout this study. As mentioned in the first chapter, the term *tubulus/tubuli* will be used to denote the hollow, box-shaped, ceramic tubes that were installed against walls in order to create vertical cavities through which hot air and gases could circulate. This term is consistent with the majority of scholarship on the material. At the same time, it avoids such problematic terms as “flue-pipes”, “box-tiles”, and “flue-tiles”, which erroneously suggest that these pipes were always part of the exhaust system of the hypocaust, or were always slab-made in the same fashion as bricks and tiles.

In regards to the labelling of the general features of a *tubulus*, this study follows the practice laid out by Brodribb (1987: 76 fig. 33), whereby the terms “height”, “width” and “depth” are used when referring to dimensions, and the terms “face” and “side” when referring to the walls of a *tubulus* (fig. 2.1). In this study, the depth is the measurement of the “sides” of the *tubulus* that contain the vents and are the narrower walls. The width is the measurement of the “faces”, which have no vents, and are the two wider of the four walls. As a result of the production process, the majority of *tubuli* from Roman Arabia have one end that is oval, while the other end is rectangular. This study uses the convention of referring to the rectangular end as the top, and the oval end as the bottom.



**Fig. 2.1** *Drawing of tubulus with features labelled.*

(Drawing by author, after Brodrigg 1987: fig. 33)

### **Cylindrical Flue Pipes**

Despite being the main focus of this study, *tubuli* were not the only type of ceramic pipe used within hypocaust systems. Chimney pipes, for example, have been identified at many sites in Western Europe. These box-shaped tubes are similar in form to *tubuli*, but are larger and lack vents (Degbomont 1984:146).

In Roman Arabia, excavations have found evidence that cylindrical pipes were at times used within hypocaust systems in addition to rectangular *tubuli*. These pipes, labeled here as cylindrical flue pipes, are found at many sites in the region, and while there is a great deal of variation in their forms, they almost always follow a similar design. In all cases, these pipes are wheel-made and cylindrical in shape. Both ends are either circular or slightly oval, yet typically one end (“male end”) is significantly smaller than the other end (“female end”). This design allowed the smaller end of one pipe to fit snugly into the larger end of an adjacent pipe. The difference in sizes between the two ends was formed by a sharp carination in the wall of the pipe closer to the smaller end. This carination is commonly referred to as the shoulder of the pipe.

The close-fitting joints formed by these pipes make them ideal for the transportation of water. More often than not they are used for such purposes, although this is not always the case. Regardless of this versatile use, when not found *in situ*, these pipes are typically referred to as “water pipes”. This identification is problematic as it does not take into consideration other possible uses for the pipe and encourages the erroneous belief that all pipes of this form are solely for the conveyance of water.

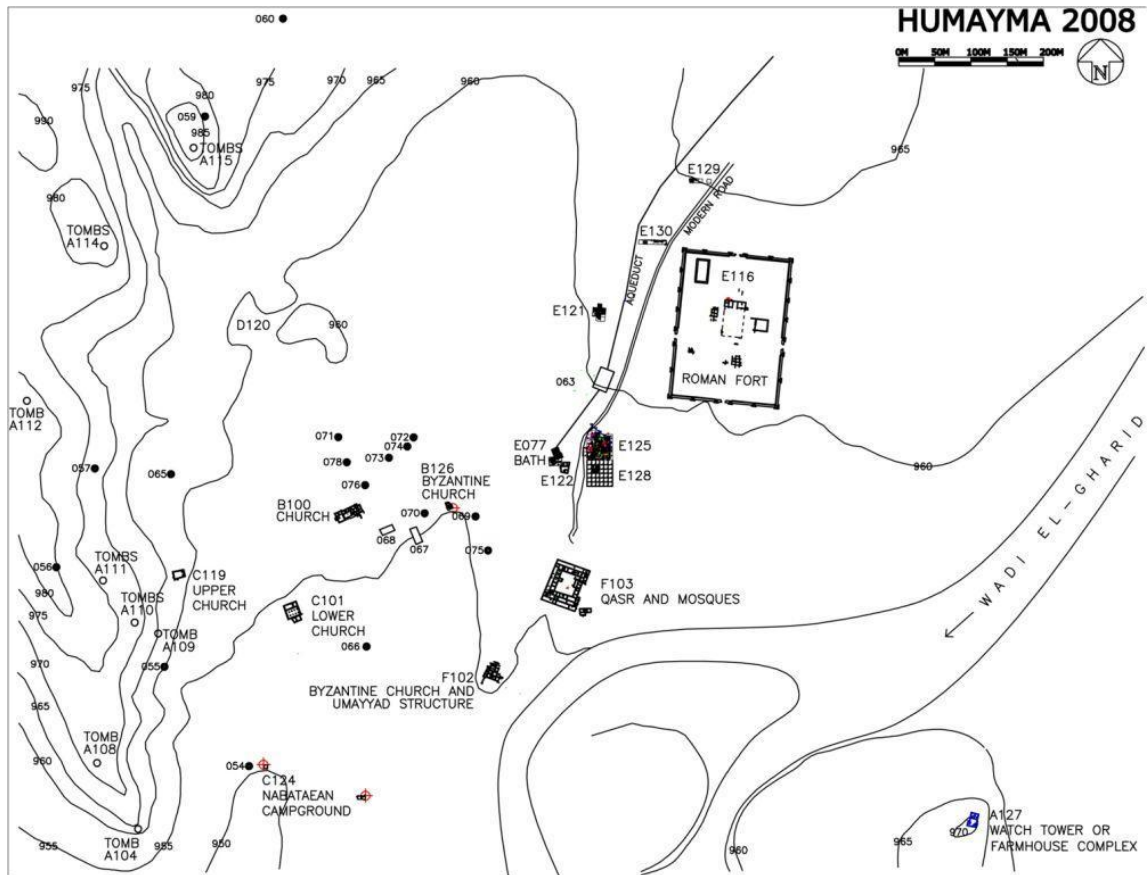
In addition to being used for water, these pipes were also used as downpipes in multistoried buildings, and conveyed both wastewater and sewage (Adam 1994: 259-60, figs. 608-610). Another function of these cylindrical pipes was as chimney flues. An early example of this use is found at the Central Baths in Herculaneum (Rook 1979: 304). Due to the similarity in form, the primary feature that distinguishes flue pipes from their hydraulic counterparts is the existence of soot staining or buildup on their interior surfaces.

Findings from this study have shown that cylindrical flue pipes were primarily used in the exhaust flues of the hypocaust. At a few sites, however, cylindrical flue pipes were used to line walls, in the same fashion as *tubuli*. An example of such use is found in the late third/early fourth century AD bathhouse at ‘Ayn Gharandal (Darby *et al.* in press). This use of cylindrical flue pipes will be discussed further in the third chapter.

*Tubuli* and cylindrical flue pipes together constitute the two types of wall-heating pipes examined in this study. At times, the term “rectangular *tubulus/tubuli*” is used, but only to emphasize the rectangular profile of the *tubuli*, or when contrasting them against cylindrical flue pipes.

## The Site of Humayma

Humayma is located in the Hisma Desert, 80km north of Aqaba and 50km south of Petra. According to the foundation myth recorded in Ouranios' *Arabika*, the settlement was founded by the Nabataean king Aretas III or IV in the first century BC (Jacoby 1958: 675 F1b). The site appears in several ancient sources and throughout its history has had numerous names, including "Hawara" (in Nabataean) and "Hauarra" (in Latin) (Oleson 2010: 50-57). During the Nabataean period, dozens of cisterns and a 27km aqueduct were built in order to supply the settlement with water. With the Roman annexation in 106 AD, Humayma became home to an auxiliary fort, built to the north of the settlement, and immediately after or during the fort's construction, a bathhouse was constructed overtop the levelled remains of the Nabataean town (Oleson *et al.* 2008: 309). The area surrounding the bathhouse soon developed into the *vicus* (a civilian community associated with a Roman fort). This bathhouse, although located outside the fort, is thought to have been built for and by the garrison (Reeves 1996: 75). For a brief period during the late third century AD, the fort (and presumably, by extension, the bathhouse) was abandoned, only to be reoccupied shortly afterwards (Oleson 2010: 59). The settlement of Humayma continued through the Byzantine period, and the construction of at least five churches in the fifth and sixth centuries suggests that the site even saw some degree of prosperity during this time. Humayma reached the height of its historical importance in the early Islamic period when the Abbasid family built a *qasr* and mosque on the site. It was from here that the Abbasids planned their successful overthrow of the Umayyad Caliphate, and went on to found their own dynasty (Oleson 2007: 454). After these events, Humayma's importance declined, and although the site was inhabited until the mid-twentieth century, the settlement never regained its former significance.



**Fig. 2.2** Site plan of Humayma.

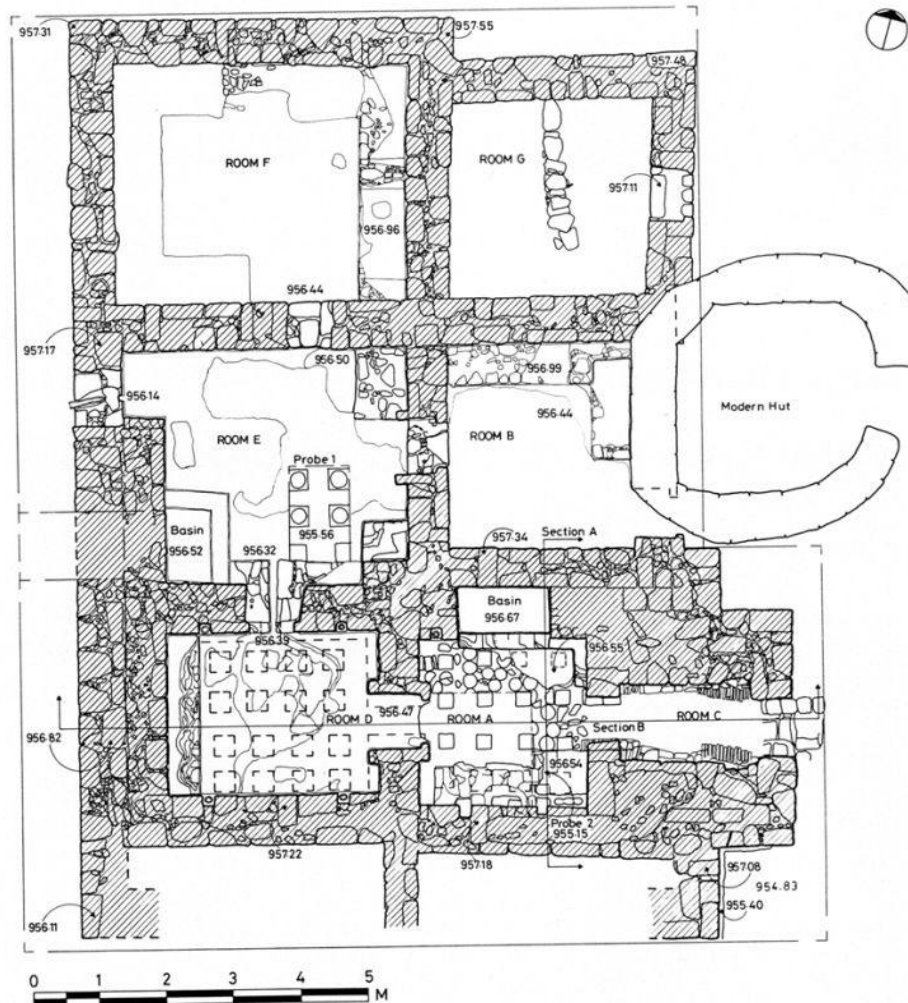
(Courtesy of M. B. Reeves)

In modern times, explorers and surveyors have made many visits to Humayma, but it was not until the 1980s that excavation began at the site (Oleson 2010: 9-20). Since then, excavation has largely been under the direction of Dr. John P. Oleson of the University of Victoria. In 2008, direction of the project was passed down to his former student, Dr. M. Barbara Reeves of Queen's University. Excavations at Humayma have largely concentrated on the hydraulic infrastructure, the churches, the fort, and the *vicus*.

*Tubuli* systems are known to have existed in at least two structures at Humayma: the bathhouse, and a small hypocausted room in the *Praetorium* of the fort. As of the 2012 season, excavation has been completed in both of these areas and a large corpus of *tubuli* exists for each. Analysis of the material found that the *tubuli* from the two areas are clearly distinct from each other. For purposes of clarity, the Humayma corpus will therefore be divided by area, with the bathhouse and its wall-heating pipes being discussed first.

### **Bathhouse (Structure E077)**

The bathhouse at Humayma is located in the *vicus* and was first excavated in 1989 as part of the site's hydraulic survey (Oleson 1990a: 294-306; 1990b: 152-61; 2010: 223-30). This excavation identified a modest sized building consisting of seven rooms (labelled A through G) (fig 2.3). Later excavations around the structure in 2008, 2010, and 2012 found that this modest sized bath was in fact built on top of a much larger bathhouse (fig. 2.4) (Reeves *et al.* 2009: 230-35; Reeves 2012a: 742-44). These excavations revealed that the original bathhouse had been reduced significantly in size during a remodeling/rebuilding of the structure (Reeves 2012a: 743). This later and smaller bathhouse corresponds for the most part with the structure initially excavated in 1989.



**Fig. 2.3** 1989 plan of bathhouse.

(After Oleson 2010: fig. 4.49 p. 224)

The phasing of the Humayma bathhouse remains very tentative. Complicated stratigraphy and a lack of datable finds have prevented a clear understanding of the history of the structure. In fact, the initial impetus of this study was to help resolve this issue by creating a datable typology of the *tubuli* that could then be used to help date the bathhouse phases. What follows is a very tentative phasing of the bathhouse and its heating system, based on the most recent excavations (Reeves 2012b). During the



**Fig. 2.4** 2012 plan of bathhouse.

(Courtesy of M. B. Reeves)

Nabataean phase (first century AD), a stone structure was built on this location and was subsequently destroyed. In the Roman phase of this structure (early second century to late third century), a bathhouse was constructed ovetop of the robbed-out walls of the earlier Nabataean structure. This construction likely took place at the same time or shortly after the construction of the nearby fort, which occurred immediately after AD 106. Over the next century, the Roman phase bathhouse slowly expanded through several additions,

until it was suddenly abandoned. This abandonment likely coincides with the withdrawal of the garrison from the fort in the late third century. The fort was later reoccupied in the fourth century with a much smaller garrison, and it is theorized that the reoccupation of the bathhouse dates from this time as well (Reeves *et al.* 2009: 235). The beginning of the Byzantine phase of the bathhouse is marked by a major renovation/rebuilding of the bathhouse, which saw a significant reduction in size of the building. Many of the original rooms were abandoned or walled-off. Some sections of the old hypocaust system were filled-in, while other parts, including the *tubuli* system, were removed and discarded. To replace these, a new hypocaust and *tubuli* system were installed. Later in the Byzantine phase of the bath, in the Late Byzantine period (AD 550-640), the furnace (*praefurnium*) was remodelled. It is not known exactly when the bathhouse finally fell out of use, but it is possible that the bathhouse may have continued to have been used during the early Islamic period (AD 640-750) by the elite residents of the nearby Abbasid *qasr* (Reeves 1996: 239-48).

Although almost completely excavated, the internal layout of the Roman phase bathhouse is still not fully known. This is partly because the findings from the 2012 field season are still being analyzed and partly because a large part of the Roman phase bath is covered by the subsequent Byzantine phase construction. It is possible, however, to say with some degree of certainty that the heated rooms in the Roman phase were located in the southern section of the structure, in Rooms A, D, and E and in the walled-off areas south of Rooms A and D.

On the other hand, the internal layout of the Byzantine phase bathhouse is well known since its walls were in relatively good condition at the time of excavation.

Unfortunately, the interior of the Byzantine phase bath had apparently been cleared out by a local inhabitant during the mid-twentieth century, and clandestine digging in 1988 had partially destroyed the floor of the *caldarium* (Oleson 1990a: 294). Most of the material removed from the bath during the excavation was therefore a secondary deposit and debris from the heavily damaged *caldarium* floor. Despite this disturbance, the excavators were able to identify the function of a majority of the rooms.

The heated rooms of the Byzantine phase bath are located in the southern section of the structure. The *praefurnium* (Room C) is located in the southeast corner, and directly to the west of this furnace is the *caldarium* (Room A). It was in this room that clandestine diggers had destroyed much of the *suspensurae*. In addition to the thousands of *tubuli* fragments found during the initial excavation of the bath, *tubuli* remained *in situ* against the south wall of Room A (the *caldarium*). Built into this same wall, were two recessed vertical vents. Two other recessed vents were built into the north wall of the *caldarium*. These recesses measure 0.15 by 0.15m, and held cylindrical flue pipes that acted as the exhaust flues for the hypocaust.

To the west of the *caldarium* is Room D, a proposed *laconium* (sweat room). This hypocausted room also contains four recessed, vertical flue vents (two in the north wall and two in the south wall). These recessed vents are the same size as those in Room A and likewise functioned as exhaust for the hypocaust. Within these recessed vents, cylindrical flue pipes were installed.

Directly north of Room D is Room E. A probe excavated in the south east corner of this room found evidence of a hypocaust system. The hypocaust in this room evidently comes from the earlier Roman phase of the bathhouse, and had been purposely filled in

during the major renovation/rebuilding of the bathhouse. Within the soil used for the fill, excavators found many fragments of *tubuli*. After the hypocaust of this room was filled in, this room was used as a *frigidarium*. Evidence of remodelling was also found in the *praefurnium* (Room C), which was last renovated late in the bathhouse's history.

The most recent excavations (2010 and 2012) located several concentrations of discarded CBM that contained many *tubulus* fragments, which were removed and thrown away during renovations. The excavations also unearthed a multitude of *tubulus* fragments scattered around the bath building. Thanks to these findings and the saving of every *tubulus* fragment found during the 2012 excavation, the Humayma *tubulus* corpus has grown greatly.

### ***Tubuli* from the Bathhouse**

The corpus of wall-heating pipes from the Humayma bathhouse is both large and diverse. In addition to containing fragments of both *tubuli* and cylindrical flue pipes, this corpus includes *tubuli* of different forms, *tubuli* made by different techniques, and *tubuli* from different phases of the bathhouse. The fragments of this corpus were collected over many seasons of excavation in and around the structure. Unfortunately, the manner in which these fragments were collected limits what can be done with their study.

Excavations of the Humayma bathhouse prior to the 2012 season did not record, collect, or save *tubuli* in any systematic manner due to a lack of specific interest. Between 1989 and the end of the 2010 season a total of 334 *tubulus* fragments had been saved and were available for the initial study in 2011. This initial collection was intended only to provide a representative sample of *tubulus* forms and fabrics and therefore did not

allow the opportunity for quantitative analysis. In an attempt to add to this corpus and increase our understanding of the Humayma *tubuli*, it was decided to save for study all of the 2500 *tubulus* fragments uncovered during the 2012 excavation. As a result of time constraints, however, not all of these fragments were able to be properly analyzed and recorded during the 2012 field season. Priority was given to both fragments from critical *loci* and reconstructible *tubuli*. The remaining fragments have been kept in storage for future study.

Working within these bounds, this study is unable to conduct useful quantitative analysis on the corpus, but instead seeks to identify and describe the material based on a typology designed specifically for this site. This *tubulus* typology is based primarily on form and not fabric. This decision was made on account of the clear distinctions in form that existed among the collected fragments. Variances in construction techniques, dimensions, and rim profiles were used to create this form-based typology. Furthermore, an inability at the time to conduct proper scientific analysis of the fabric excluded the possibility of basing this typology on fabric.

The 2012 *tubulus* study identified three distinct types of rectangular *tubulus* from the bathhouse at Humayma. Together these three groups encompass the majority of *tubulus* finds recovered from the bathhouse complex. Only a handful of fragments did not adhere to the present typology. The sections below provide detailed descriptions and analysis of each of the *tubulus* types and their use within the bathhouse. Descriptions of the cylindrical flue pipes found and a discussion of their use are also given.

### **Type 1 *Tubulus* (Slab-made *Tubulus*)**

One of the most distinctive types of *tubulus* found at Humayma is the Type 1 *Tubulus* (figs. 2.5-2.7). This type of *tubulus* was made not on a potter's wheel, but rather by bending and joining together slabs of clay. Only one reconstructed example exists for this type. This example (figs. 2.5 & 2.6) measures 19.6cm high, 16.4cm wide, and 14.5cm deep. Two other fragments have complete heights of about 20cm. It is interesting to note the relationship between these measurements and the Roman foot, which was 29.6cm (Oleson 2009: 540). Although the sample size is extremely small, these dimensions suggest that the Type 1 *Tubulus* was manufactured with the standard dimensions of  $\frac{2}{3}$  Roman foot high, by  $\frac{1}{2}$  Roman foot wide, by  $\frac{1}{2}$  Roman foot deep. Such standardization would help the *tubuli* function efficiently together. It has been theorized that the bathhouse was constructed by Roman soldiers (Reeves *et al.* 2009: 234). Perhaps these soldiers were also responsible for manufacturing the *tubuli*. It would not be surprising for the garrisoned troops at Humayma or in the region to have a role in the production of ceramic building materials, as this was the case in Jerusalem (Arubas and Goldfus 1995) and Bostra (Brulet 1984). If the Type 1 *Tubulus* was indeed made by Roman soldiers, it would make sense for them to use a Roman measurement.

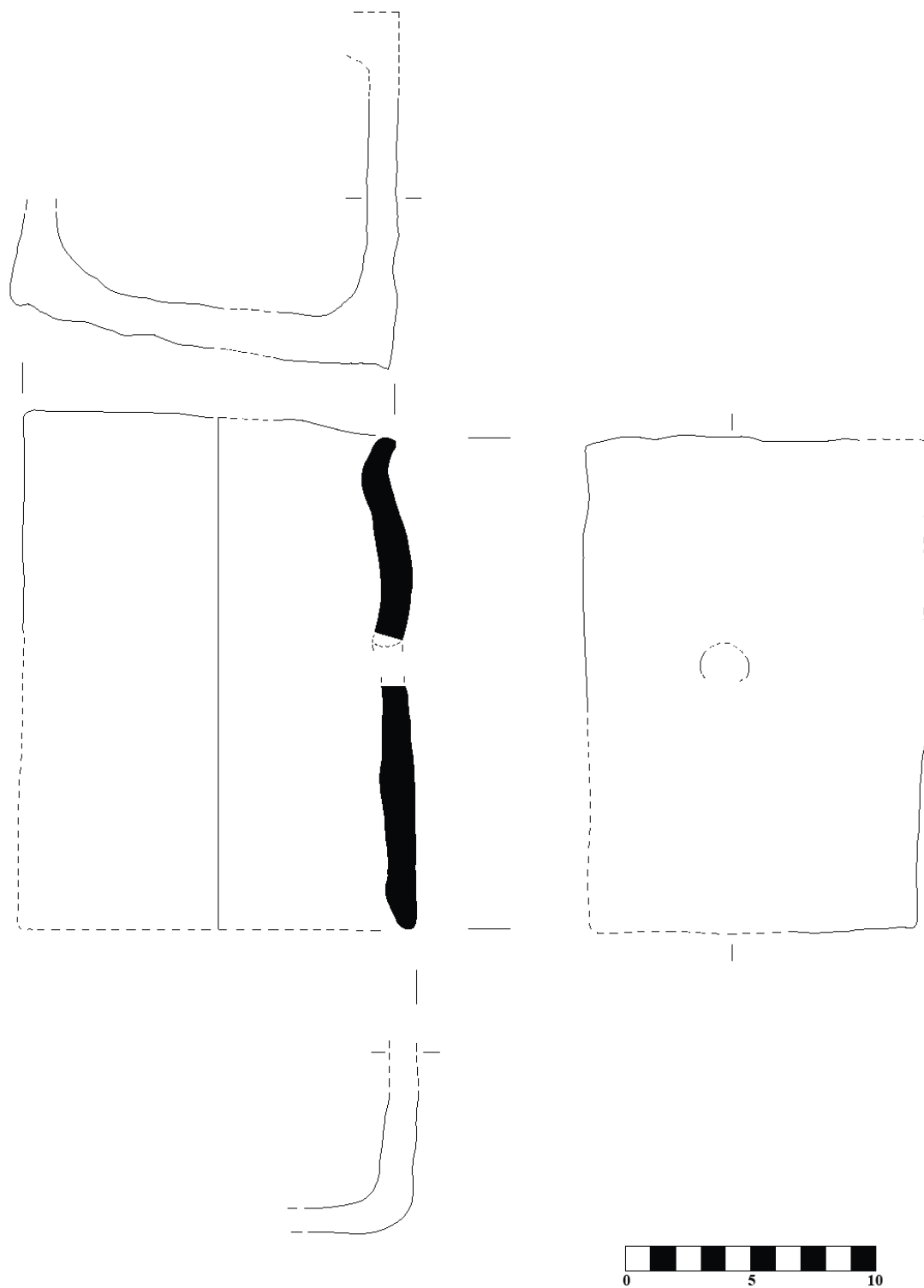
Turning back to the measurements of the *tubuli*, the walls of this *tubulus* type are usually 1.1 to 1.5cm thick, although they can be up to 3.0cm thick in the corners. This variation in thickness is due to the excess clay that was pushed into the interior corners to act as reinforcement and to help bond the seams of the slabs that were in the corners. Another result of this excess clay is that the interior corners of slab-made *tubuli* tend to be rounded, while the exterior corners often retain their 90° angles (fig. 2.6). Like all *tubuli*, this type has vents in its side walls to allow for the lateral flow of hot air. The best

preserved vent from this type measures only 1.1 by 1.6cm. The size and shape of the vents preserved suggest they were formed by piercing the side walls with a finger (fig. 2.7).



**Fig. 2.5** *Reconstructed Type 1 Tubulus.*

*H12.0009 T1.* (Photo by author with permission from M. B. Reeves)



**Fig. 2.6** Drawing of reconstructed Type 1 Tubulus.  
*H12.0009 T1.* (Drawing by author)



**Fig. 2.7** Fragments of Type 1 *Tubulus* with vents.

(Photo by author with permission from M. B. Reeves)

The Type 1 *Tubulus* exhibits an interesting range in its fabric. While some examples have a very coarse, sandy fabric, others have a fabric that is silty to the touch and contains numerous straw inclusions. Unfortunately, it is not possible to easily divide the Type 1 *Tubulus* into two distinct subgroups based on these different fabrics, because there is no clear division in the corpus. Many fragments seem to be a mix of these two fabrics, with varying degrees of sand or silt. Although this range prevents a clear division of the corpus, it is possible to describe in detail the two extremes.

The hard and sandy fabric can range in colour, but is predominantly reddish yellow, light brown, or very pale brown (Munsell: 5YR 6/6; 7.5YR 6/4; 10YR 7/3). Typical inclusions are well-sorted, medium, sub-rounded and sub-angular clear quartz sand, with some very coarse sand. This fabric also has some very small to medium voids, a few of which may be from straw temper.

The silty fabric is often pale brown in colour, although some fragments are pink (Munsell: 10YR 6/3; 7.5YR 7/4). This fabric is predominantly made up of fine silt, but

there is also well-sorted, medium, sub-rounded and sub-angular clear quartz sand.

Samples also have a few white flecks and many small to medium voids, many of which are from straw temper.

This variation in fabric does not have any correlation to how or where the *tubuli* were used within the bathhouse. Although the fragments are small, there also does not seem to be any difference in form between *tubuli* of these two fabrics. For these reasons and due to the difficulty of dividing the fabric into clearly defined groups, this study has not made any attempt to divide the Type 1 *Tubulus* into separate subtypes based on fabric.

Even without petrographic analysis, it is possible to make some comments on the silty and straw-tempered fabric found on some of the Type 1 *Tubuli*. This distinctive fabric is also found in the hypocaust bricks probably from the earliest phase of the Humayma bathhouse, but as of yet has not been identified at any neighbouring sites. It is possible that this fabric is similar to the “fired mudbrick” that was used to build pottery kilns and glass furnaces in late Roman and Medieval Israel (Tal *et al.* 2008: 81-83). This material was presumably used for its strong resistance to thermal stress. It may be the case that the silty and straw-tempered *tubuli* and hypocaust bricks were used in the Humayma bath for the same reason. The closest known parallel for this type of fabric comes from Egypt, where the local ceramics are well known for their silty and straw-tempered fabric made from Nile silt (Hayes 1997: 83). This recognizable fabric is also found in the amphorae produced in Egypt (Peacock and Williams 1986: 204-5). Although rare, these Egyptian amphorae do appear in the archaeological record at Humayma (Reeves *et al.* 2009: 253-54). Interestingly, one of the legions involved in the annexation

of Nabataea and potentially one of the first to be stationed at Humayma was the Legio III Cyrenaica from Alexandria (Oleson *et al.* 2002: 114). While it is not likely that Egyptian ceramic building materials traveled to Arabia with these troops, it is possible that the technique of using straw as temper did. It should be noted that Nabataean brick makers do not appear to have used straw as temper in their fired bricks. Hypocaust bricks from first century AD baths at Wadi Ramm do not have straw-tempered fabric (Reeves, personal communication, Jan. 2013). Perhaps it was the first legionaries stationed in Nabataea who introduced this technique to the region. Regardless, the location of the production site for these *tubuli* remains unknown and likely will remain so until petrographic analysis can elucidate its source.

In terms of its form, there is a great deal of comparanda for the Type 1 *Tubulus*. Using slabs of clay was the primary means of manufacturing *tubuli* across the Roman Empire. Slab-made *tubuli* were produced in Britain (Brodrigg 1987:75), France (Adam 1994: 269 fig.632) and Germany (Kretzschmer 1978: 42 fig. 58). In Rome, slab-made *tubuli* were used in the construction of the Baths of Caracalla (DeLaine 1997: 114-15).

Closer to Humayma, there are several sites that exhibit slab-made *tubuli*. In Israel, excavations have uncovered slab-made *tubuli* at Jalame (Weinberg 1988: 248-49) and Tel Tanninim, near Caesarea Maritima (Stieglitz 2006: 95-6, fig. 90). A slab-made *tubulus* fragment found in association with the Roman legionary kilns at Jerusalem (Rosenthal-Heginbottom 2005: 257, fig. 101) suggests that this was the method of production used by Roman soldiers in the region. These legionary kilns were in operation from the late first century AD to the late third century (Arubas and Goldfus 2005: 15-16). In Roman Arabia, examples of slab-made *tubuli* can be found by the bathhouse adjacent to the

Great Temple in Petra (see section in Appendix). Further north, slab-made *tubuli* have also been uncovered in the Decapolis City of Umm Qays, from the fourth century Byzantine bathhouse (Vriezen and Mulder 1997: 330; Nielson *et al.* 1993: 122, 265 fig. 294).

Slab-made *tubuli* were made in one of two ways. The first method, popular in Britain, was to wrap a clay sheet around a wooden frame, which was then removed before firing (Morgan 1979: 395-97). This method also seems to have been the preferred technique for producing *tubuli* in Rome (DeLaine 1997: 114-15). The second method for shaping slab-made *tubuli* was to place slabs of clay into a wooden mould and then to press additional clay into the corners to seal the joins and reinforce the *tubulus* (Vriezen and Mulder 1997: 330). This method was used for the *tubuli* from the Decapolis cities, and it seems to have been the one used for the slab-made *tubuli* from Humayma as well.

### **Use of the Type 1 *Tubulus***

Since only fragments of the Type 1 *Tubulus* were found, it is difficult to discern much about its use within the bathhouse. Nevertheless, heavy soot build-up on the interior of the fragments proves that this type was in fact used in the heating system. Analysis of its usage is hampered by the fact that this *tubulus* type was not found *in situ*, but rather in fragments scattered around the bath building complex. This distribution, however, suggests that the Type 1 *Tubulus* may have been employed in an early phase of the bathhouse and then discarded during one of the renovations.

Further information on the date of this *tubulus* type has been gained with a close examination of its fabric and stratigraphic context. As mentioned above, several

fragments of the Type 1 *Tubulus* have a distinctive silty, straw-tempered fabric. This straw-tempered fabric is also found in the bricks from the early hypocaust system in Room E, which has been dated to the Roman phase of the bathhouse (Reeves and Harvey 2013). The similarity of their fabric suggests that the Type 1 *Tubulus* may have been manufactured and used contemporaneously with the hypocaust bricks from Room E, and therefore dates to the Roman phase (early second century to late third century).

During the 2010 season, new excavations uncovered a *piscina* (small immersion pool) that had been abandoned and filled in during the major renovation of the bathhouse after its abandonment in the late third century (Reeves 2012a: 743). Within the *piscina*, a concentration of *tubulus* fragments, including many Type 1 *Tubuli*, were found. Also at the bottom of this installation were five straw-tempered hypocaust bricks, carefully stacked in piles. These bricks may have been removed from the hypocaust during the same renovations and stored in the immersion pool for reuse elsewhere. Before these bricks could be used, the *piscina* was filled in with soil containing numerous fragments of Type 1 *Tubulus*. Based on their existence in the fill, these *tubulus* fragments were removed from the bathhouse during or before the renovations after the abandonment of the bath in the late third century.

In summation, the similarity in fabric between the Type 1 *Tubulus* and the hypocaust bricks from Room E suggests that this *tubulus* type dates to the Roman phase of the bathhouse (early second century to late third century). This date is backed up by the Type 1 *Tubulus* fragments found in the *piscina*, which show that this type fell out of use by the end of the Roman phase. Therefore, although the dating is broad, it can be said

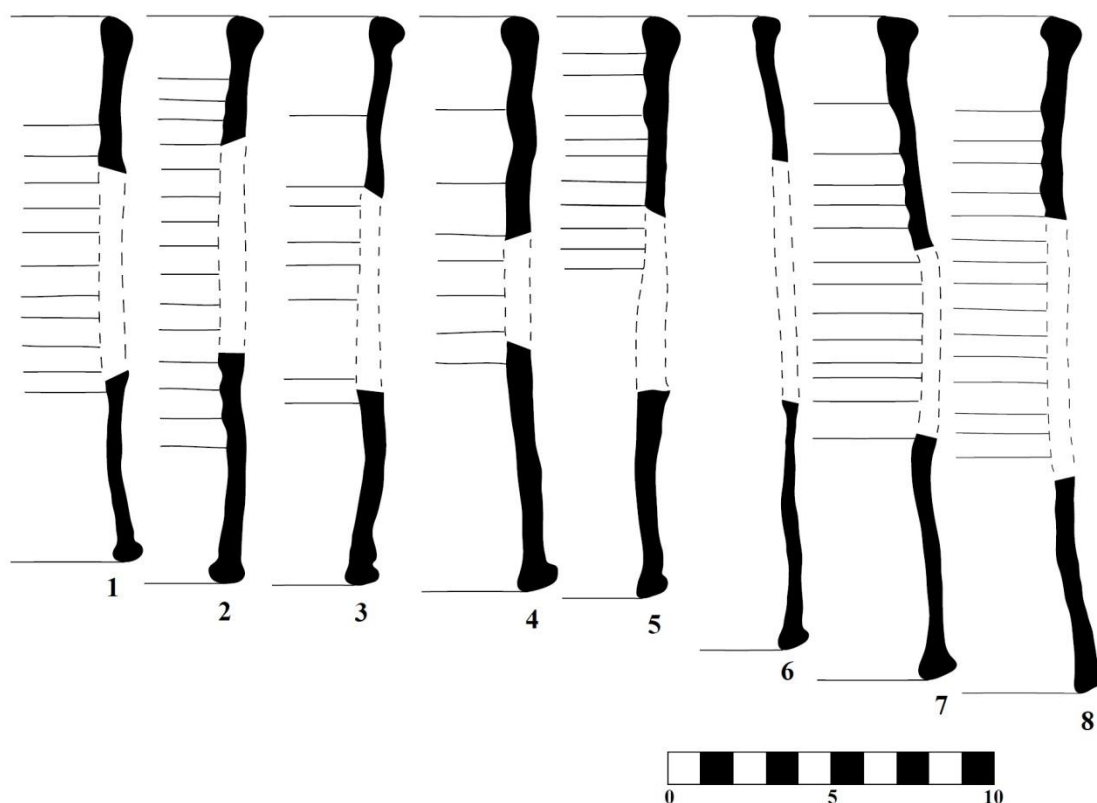
with some certainty that the Type 1 *Tubulus* was used at Humayma between the Roman annexation in AD 106 and the late third century abandonment of the bathhouse.

### **Type 2 *Tubulus* (Wheel-made Wide-depth *Tubulus*)**

The most abundant type of *tubulus* found at Humayma is the Type 2 *Tubulus* (figs. 2.8-2.13). This type is characterized by its wheel-made design and its relatively wide depth. Although a multitude of sherds of this type were found scattered around the bathhouse, excavation uncovered no examples of this type *in situ*. The Type 2 *Tubulus* was not made with slabs of clay, but was wheel-thrown. Nevertheless, the Type 2 *Tubulus* was rectangular in cross section, the final shaping done by hand. Typically, one end of the *tubulus* was rectangular in shape, while the other end was oval.

Despite the frequency of this form, its fragmented condition makes it difficult to determine the dimensions of this type of *tubulus*. Full heights exist for only eight large fragments and reconstructed examples, while just two samples have full depths and two have full widths. Interestingly, the Type 2 *Tubulus* varies in size to some degree. The eight fragments with full heights range from 16.9 to 20.8cm high and average 18.7cm high (fig. 2.8). The width and depth (from front to back) of the *tubuli* are more consistent. The two complete widths measure 17.6 and 17.8cm, while the two complete depths are 13.4 and 14.0cm. The heights of the Type 2 *Tubulus* range from about  $\frac{1}{2}$  to  $\frac{2}{3}$  of a Roman foot. While it is tempting to speculate that these measurements were indeed based on the Roman foot, the range in heights makes it difficult to say for certain whether there was meant to be any standardization of size.

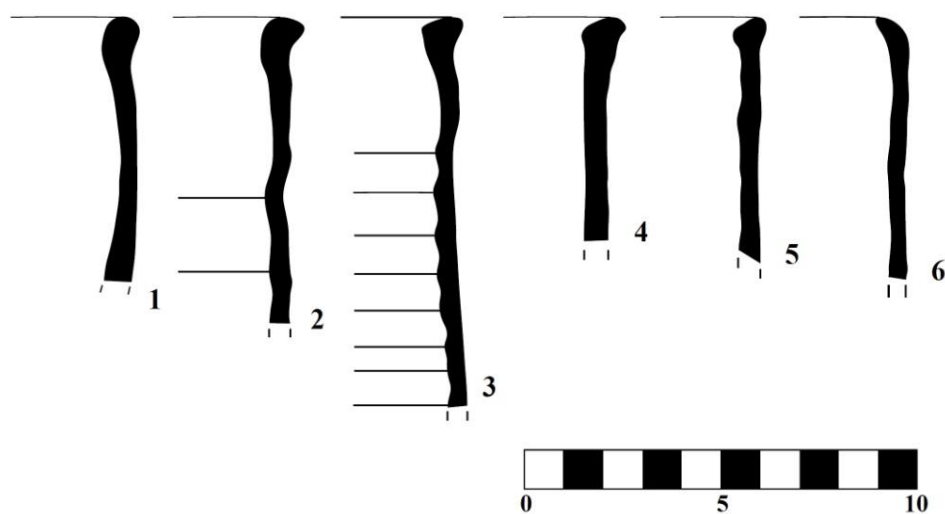
Wheel-made *tubuli* have two rims, one on the top end and one on the bottom. The rims for *tubuli* are not as standardized as they are for some ceramic vessels in the region, but there is some consistency within *tubulus* types. For instance, the vast majority of Type 2 *Tubuli* have thickened rims that overhang the exterior and, in some examples, slightly overhang the interior. The rims on the top (rectangular end) tend to differ slightly from the rims on the bottom (oval end). Judging from the eight samples that have complete heights (fig. 2.8), and therefore have rims preserved on both ends, the rims on the top are generally more rounded. Conversely, the rims on the bottom tend to have a more pronounced overhang on the exterior. Due to the small sample size it is not possible to tell if this was true for all *tubuli* of this type, or just a trend in the preserved samples.



**Fig. 2.8** Sections of the Type 2 Tubulus.

1. HEP 10.0151 C4256; 2. H12.100 T3; 3. H12.0056 T1; 4. HEP10.0161 C5018; 5. H12.0100 T1; 6. H12.0082 T1; 7. H12.0100 T2; 8. H12.0348 T1. (Drawing by author)

Out of a sample of 161 rim-sherds collected before the 2012 excavation season, over two-thirds are rims that fit the description above. The remaining 48 rim-sherds were classified as variants. Examples of these variant rim forms include rims with curved tops and rims coming to a point. Within these variations, it is possible to see a transition between different rim types (fig. 2.9), and a few sherds show that variation occurs even along the same rim. These variant rim forms are therefore not indicators of a new *tubulus* type, but are the results of inconsistent production. The lack of uniformity regarding rims is not surprising, given that *tubuli* were made for functional purposes, and no aesthetic value was required. There was no need to take the time to ensure the rims of the *tubuli* were uniform, as the production of *tubuli* was meant to be as quick and efficient as possible.



**Fig. 2.9** Selection of rim variants of the Type 2 Tubulus.

1. Hum89.128 T1; 2. HEP10.0110 T1; 3. HEP10.0121 C823; 4. HEP10.0038 C2619; 5. HEP10.0112 C547; 6. HEP10.0127 C1124. (Drawing by author)

There is also a lack of uniformity in regards to the shape and size of the vents on the Type 2 *Tubulus*. Once again this dissimilarity is likely due to the hasty production of *tubuli*, and the absence of any pressing need for uniformity. Vents for this *tubulus* type vary between being oval, pointed-oval, or tear-shaped. They can be up to 7.8cm long and 3.3cm wide.

The fabric of Type 2 *Tubuli* also varies to some degree, but not to an extent that suggests that the *tubuli* originated from more than one area. It is impossible to list the full range of colours here, but examples of common fabric colours include red and light red (Munsell: 2.5YR 5/6; 10R 6/8). Examples of common surface colours are red, reddish-yellow, and dark grey (Munsell: 2.5YR 5/6; 7.5YR 7/6; GLEY 4/N). Some examples have a dark grey core (Munsell: GLEY 4/N). The inclusions are typically well-sorted fine sub-rounded clear quartz sand with occasional small white inclusions and a few very small black flecks. The fabric also contains occasional small to medium voids. Based on macroscopic analysis of the fabric, I suggest that the Type 2 *Tubulus* was produced in the Petra region. This theory is based on similarities in fabric between these *tubuli* and ceramics known to have been produced near Petra, such as those found in association with the az-Zurraba kilns on the outskirts of the city (‘Amr and al- Momani 1999: 180-88). This source is not surprising given that the bulk of the ceramic material found at Humayma comes from Petra (Reeves *et al.* 2009: 252; Oleson 2010: 327; Oleson and Schick forthcoming). The slight variations in fabric colours and inclusions found within this *tubulus* type can be explained by various clay sources, changing kiln conditions, or the operation of several different workshops.

Wheel-made *tubuli* appear to be unique to Roman Arabia. Nevertheless they are found at many sites within the region. Among the sites with close parallels to the Type 2 *Tubulus* are 'Ayn Gharandal (fig. 3.10 & 3.11) (Darby *et al.* 2010: 198, fig. 20) and Lejjun (fig. 3.8 & 3.9) (Parker 2006: 361, figs. 16.76 – 16.79). The closest parallels, however, come from the Wadi Farasa (fig. 3.7), Petra, (Schmid 2002: 261, fig. 13) and Zantur IV (fig. 3.6), also in Petra (Kolb and Keller 2000: 361-62, fig. 9). This last parallel can be firmly dated to between the site's second phase of construction, tentatively set at the turn of the first to second century AD (Kolb and Keller 2001: 319), and AD 363, when an earthquake knocked the *tubuli* from the wall (Kolb and Keller 2000: 362).

The production of the Type 2 *Tubulus* involved several easily traced steps. A hollow ceramic tube was formed on a wheel, with a rim on the top and a partially made rim on the bottom. The *tubulus* was then cut off the wheel (likely using a string), and formed into its rectangular shape by hand, as shown by the finger impressions that often appear on the exterior sides of *tubuli* (fig. 2.24). Only the top was pressed into a rectangular shape, but this almost always resulted in the bottom losing its circular shape and becoming oval. In some examples, it is clear that the potter shaped the *tubulus* farther down the sides from the top than usual. In these examples, the bottom end, which is typically oval, also took on a rectangular shape, although it is never as rectangular as the top. The *tubulus* was then flipped over and the partially made rim that had been made on the wheel was quickly smoothed. This step accounts for why the bottom end (the circular end) sometimes feels rough or unfinished, having been only partially smoothed after having been cut from the wheel. After the *tubulus* was shaped, yet before it was fired, the vents on the sides had to be cut. Judging by the irregularity of the vent shapes and the

rough edges of the cuts, this step was done hastily. With the vents cut, the *tubulus* was ready for firing.

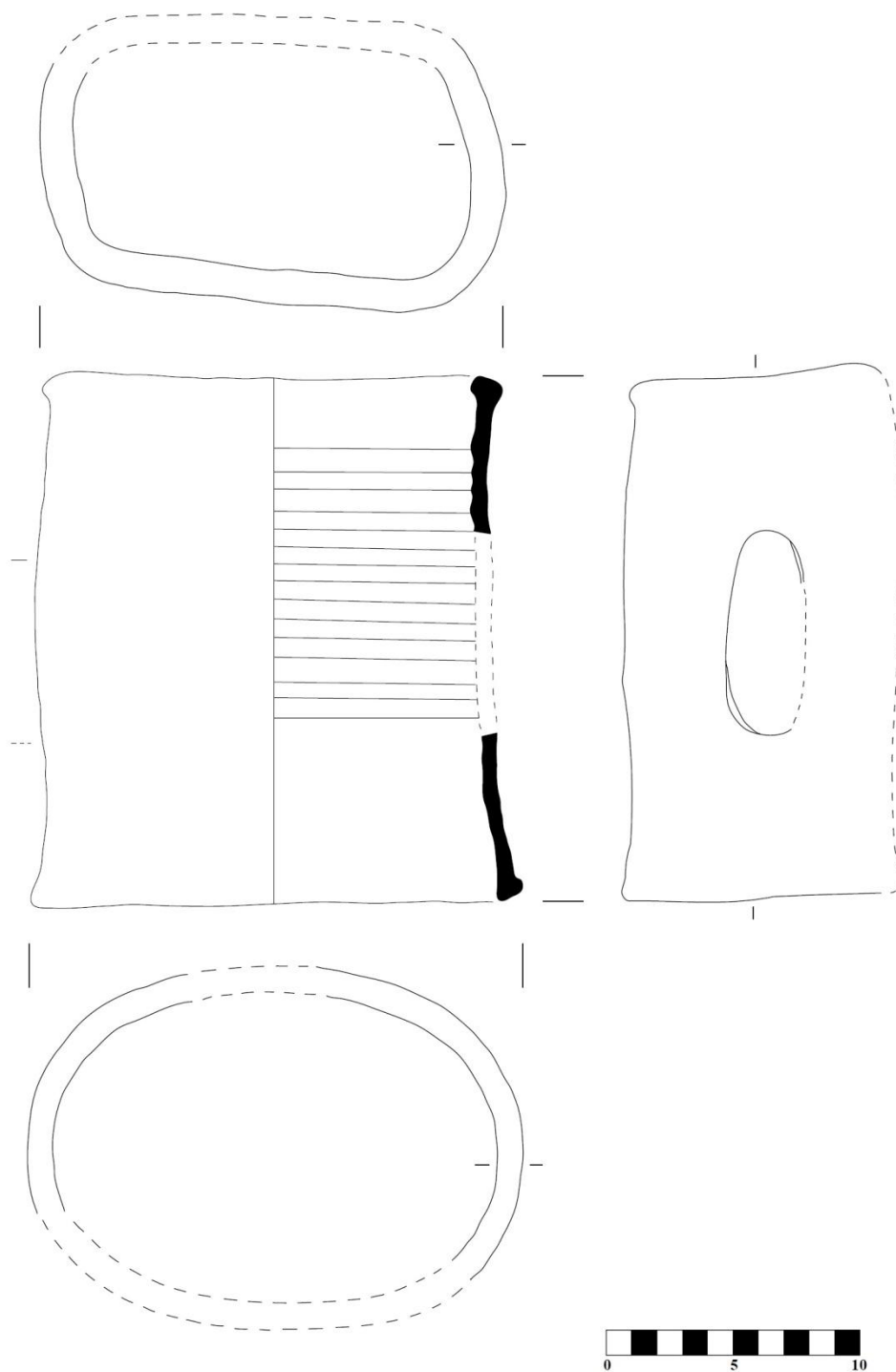
A peculiar characteristic of nearly every wheel-made *tubulus* examined in this study is the fact that they each have both a rectangular end and an oval end. The reasons for shaping the *tubulus* into a rectangular form are fairly obvious. This shaping flattened the faces and the sides, making the *tubuli* fit more closely together and more closely against the structural wall. This step also increased the surface area that the *tubulus* could cover and thus decreased the number of *tubuli* needed. The reasons for shaping only one end of the *tubulus* remain less clear. It is possible that the shaping of one end was sufficient enough, and any further shaping was considered a waste of time. Alternatively, it may have been the case that it was too difficult to properly shape the bottom end, and it was therefore left round. It is also possible that the bottom of the *tubulus* was purposely left round to help the *tubuli* stack on top of each other. As the saying goes, “a square peg cannot fit into a round hole”, and by fabricating the *tubuli* with different shaped ends, the builders could be sure that the *tubuli* would not fall into each other, but would stack neatly and securely, resting on the rim of the *tubulus* below.



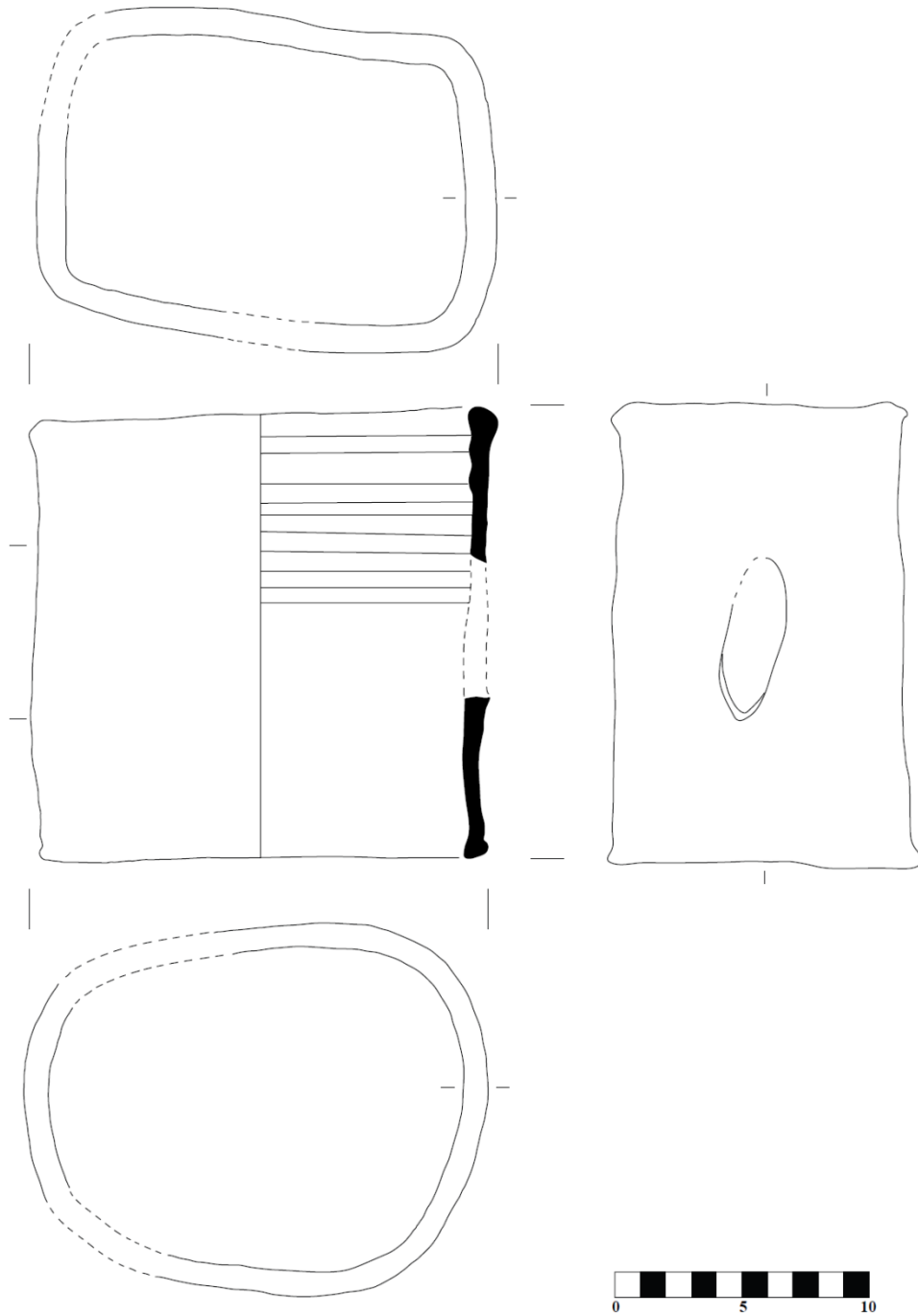
**Fig. 2.10** *Reconstructed Type 2 Tubulus.*  
*H12.348 T1.*  
 (Photo by author with permission from M.  
 B. Reeves)



**Fig. 2.11** *Reconstructed Type 2 Tubulus.*  
*H12.0100 T1.*  
 (Photo by author with permission from M.  
 B. Reeves)



**Fig. 2.12** *Drawing of reconstructed Type 2 Tubulus.*  
*H12.0348 T1.* (Drawing by author)



**Fig. 2.13** *Drawing of reconstructed Type 2 Tubulus.*  
*H12.0100 T1.* (Drawing by author)

### Use of the Type 2 *Tubulus*

Although it is the most abundant type of *tubulus* collected in and around the bathhouse, no examples of Type 2 *Tubuli* were found *in situ*. It is difficult therefore to document exactly how and where these *tubuli* were used, but careful examination of the samples provides useful clues. Soot buildup on the interior of the tubes attest to their heavy use, while mortar adhering to their exterior reveals exactly how the *tubuli* were installed against the walls. Thorough analysis of the soot and mortar patterns on the fragments can also shed light on how the *tubuli* worked together in the heating system.

One of the curiosities encountered during the study of the Type 2 *Tubulus* was the variation in height. As mentioned above, the heights of this *tubulus* type range from 16.9 to 20.8cm. This lack of uniformity is surprising, given that it would seemingly have a negative effect on the efficiency of the *tubuli* system. One of the defining characteristics of the *tubulus* is the side vents that allow for the lateral circulation of air between *tubuli*. Most illustrations of *tubuli* systems show the pipes closely stacked together with their vents side by side (Yegül 1992: 358, fig. 442). If not careful, the different heights of the *tubuli* could result in the horizontal rows of *tubuli* being staggered. The vent holes would no longer line up, and may even be blocked by the adjacent *tubulus*. In this scenario, the horizontal airflow within the system would be inhibited and the efficiency of the hypocaust diminished. Considering this potential problem, it is curious why the manufacturers did not make the *tubuli* more uniform. One solution to this potential problem would be to use *tubuli* of different heights in separate areas, but without samples *in situ*, it is impossible to determine whether this was done.

Examination of the soot and mortar on *tubuli* fragments has shown, however, that the height variation did not restrict lateral airflow between columns of *tubuli*.

Unsurprisingly, there is evidence that plaster once adhered to the faces of the *tubuli*. These surfaces were plastered either to hold the tube in place against the stone structural wall or to cover the *tubuli* and form the finished surface of the wall. The sides of the *tubuli*, on the other hand, do not have any sign of once having held plaster. Instead, the sides were left uncovered, and many fragments even have soot on their exterior surfaces near the vents. The lack of mortar and the soot on the sides of *tubuli* reveal that gaps were left between adjacent *tubuli*. This space, although narrow, was wide enough to allow for hot air to circulate from one *tubulus* into the void and then into the next *tubulus*. Even if the vents were not perfectly in line, the horizontal airflow would not be completely blocked. Thus the heights of the *tubuli* did not matter, and the vents did not need to line up in order for the *tubuli* system to function efficiently.

Thanks to the careful excavation of the bathhouse, it is possible to assign a general date to the Type 2 *Tubulus*. During the excavation of the fill within the purposely filled in hypocaust of Room E, a large number of *tubulus* fragments were uncovered (Oleson 1990b: 156; 1990a: 300). Although the preliminary excavation report states that these fragments were of the same type as those found *in situ* in Room A (Oleson 1990a: 303), the 2012 *tubuli* study found this not to be the case. Almost all of the *tubuli* collected from this probe were of the Type 2 *Tubulus*, revealing that their use predates the renovation in which the old hypocaust system was filled in. As mentioned above, this major renovation followed the abandonment of the bathhouse in the late third century. Further evidence comes from the large collection of Type 2 *Tubulus* fragments that were found along with broken Type 1 *Tubuli* in the filled in *piscina*, which was abandoned during these same renovations (Reeves 2012a: 743). Based on the findings from the filled

in hypocaust and the *piscina*, the use of the Type 2 *Tubulus* at Humayma can be dated to the Roman phase of the bathhouse, beginning in the early second century AD and ending with the bath's abandonment in the late third century AD. This broad date agrees with date of the parallel *tubuli* from Zantur IV, in Petra, and it also makes the Type 2 *Tubulus* an approximate contemporary of the Humayma *Tubulus* Type 1. Based on research to date, however, the exact chronological relationship between the Type 1 and the Type 2 *Tubulus* is not definitively known.

### **Slab-made *Tubuli* versus Wheel-made *Tubuli***

Before moving on to discuss the characteristics and use of the third type of *tubulus* commonly found at the Humayma bathhouse, let us first look more closely at the two types examined above. Although they are fabricated in completely different ways, the Type 1 *Tubulus* and the Type 2 *Tubulus* are often found in the same dump contexts, and while the dating is broad, both types appear to be rough contemporaries of each other. What then is their relationship, and why were both types produced?

One possible explanation requires another look at the parallels for these two types. As mentioned above, slab-made *tubuli* are found throughout the Roman Empire, from Britain all the way to Arabia. This method of production is also associated with Roman legionary kiln sites. In the west, legionary stamps are found on many slab-made *tubuli* from Germany (Degbomont 1984: 141, fig.253). In the east, the legionary kilns at Jerusalem also produced slab-made *tubuli* (Rosenthal-Heginbottom 2005: 257, fig. 101). These legionary kilns were in operation from the late first century AD to the late third century (Arubas and Goldfus 2005: 15-16). As suggested above, it is likely that the slab-

made Type 1 *Tubulus* was produced by Roman soldiers. This theory is based in part on the apparent use of the Roman foot as a unit of measurement for the dimensions of the Type 1 *Tubulus*.

In contrast to slab-made *tubuli*, all efforts by this study to find comparanda for wheel-made *tubuli* outside of Roman Arabia have thus far been unsuccessful. Though current analysis is in its early stages, it appears that wheel-made *tubuli* are exclusive to the region. This unique production technique seems to have been developed first by the Nabataeans. Wheel-made *tubuli* have been found in the bath complex at Wadi Ramm, which predates the Roman annexation (Dudley and Reeves 1997: 97-99). They have also been found at Wadi Musa, where a wheel-made *tubulus* has been dated based on its fabric to the mid-first century AD ('Amr, personal communication, July 2012). Chapter One has already presented the likelihood that Roman-style bathhouses were introduced to the Nabataean Kingdom through the influence of Herodian bathhouses. In their attempt to replicate *tubuli*, which were found in almost all Herodian baths (Netzer 1999: 50), the Nabataeans evidently chose to create them on a potter's wheel. This use of the potter's wheel is no surprise given the Nabataeans' skill at pottery production and the fact that they were making wheel-made ceramic water pipes from as early as the first century BC (Bellwald 2007: 322-23).

The existence of both slab-made and wheel-made *tubuli* at the Humayma bathhouse may be explained by the site's unique position in the history of Roman Arabia. Since the bathhouse at Humayma was built shortly after or at the same time as the nearby fort, which itself was the earliest Roman fort in the region, the bathhouse is very likely the first bathhouse in the region to be built by Roman soldiers. Roman construction was

known for its consistency in building techniques and materials. This was the case across the Roman Empire and even for the fort at Humayma (Oleson 2009). During the initial construction of the bathhouse, it would make sense for the Roman builders to use the slab-made *tubuli* since that was the manner of production to which they were accustomed. Eventually, perhaps as a result of contracts with local producers, the builders of the bathhouse began to use wheel-made *tubuli*, manufactured using local production techniques.

While the early use of slab-made *tubuli* may have stemmed from an initial preference of that design, or from ignorance of local production techniques, it may have also been the case that there was no alternative at that time. It is possible that the local production centres were out of commission shortly after the annexation, and thus the Romans were forced to use either temporary kilns or import their building ceramics (Reeves, personal communication, Jan. 2013). Destruction from this period is reported at many sites (Schmid 1997: 417-20), and it is possible that the kiln sites could have likewise been affected. Once the production centres were back in operation, wheel-made *tubuli* would have been once again available for use and could have replaced slab-made *tubuli*.

This switch to wheel-made *tubuli* was apparently permanent, as *tubuli* from later phases of the bathhouse and even those from within the fort were fabricated in this way (see section on *Tubulus* Type 4). Other bathhouses in the region associated with military garrisons, such as those at ‘Ayn Gharandal and Lejjun, constructed in the early fourth century AD, also used wheel-made *tubuli*.

This theory is a possible explanation for why both *tubulus* types are found at the Humayma bathhouse, and why Humayma is one of only two sites in the region once controlled by the Nabataeans that have slab-made *tubuli*. The only other exception is the bathhouse beside the Petra Great Temple (see section in Appendix). The Decapolis cities also have slab-made *tubuli*, but these settlements were more influenced by Greco-Roman culture than by Nabataean, and thus the existence of slab-made *tubuli* is understandable.

### **Type 3 *Tubulus* (Wheel-made Square-vent *Tubulus*)**

The third type of *tubulus* commonly found at the bathhouse is the Type 3 *Tubulus* (figs. 2.14-2.20). Although there are three distinct varieties of rims for this type, the heavily fragmented nature of the corpus prevented the creation of subtypes in anything other than rims. The Type 3 *Tubulus* is therefore typified by a similar relatively fine fabric and its characteristic square vent.

Despite being the only type of rectangular *tubulus* found *in situ* within the bathhouse, no full profiles have been recovered. Of the samples collected and examined for the 2012 study, the maximum preserved height was 22.1cm. The preliminary report of the excavation, however, records that impressions left in plaster suggest a full height of 23.5cm, a width of 15cm, and a depth of 8.5cm (Oleson 1990a: 303). These last measurements agree with the findings of the 2012 study, which noted only two full widths of 14.1cm and 14.6cm and only one full depth measuring 8.0cm. The walls of these wheel-made *tubuli* vary in thickness from about 0.6cm near their ends to a maximum of about 1.1cm thick in the centre.

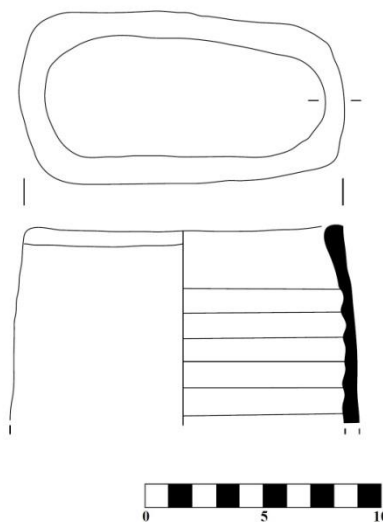
Determining the typical shape of the ends is made difficult by the poor condition of the corpus. Fortunately, a complete end of a tubulus, including its rim, was found *in situ* at floor level (figs. 2.14-2.16). The shape of the rim on this fragment is an elongated oval with straight edges along the width (face). Other smaller rim fragments show a similar shape.



**Fig. 2.15** *Humayma Tubulus Type 3 in situ against south wall of Room A. Note the recessed vent located behind the tubuli. (Courtesy of J. P. Oleson)*

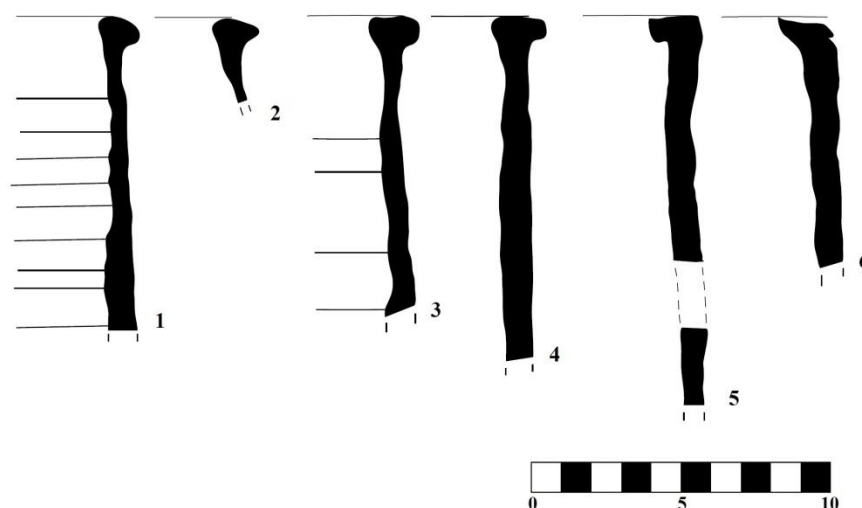


**Fig. 2.16** *Reconstructed Type 3 Tubulus found in situ. (Photo by author with permission from M. B. Reeves)*



**Fig. 2.14** *Drawing of reconstructed Type 3 Tubulus found in situ. (Drawing by author)*

There are three distinctive rims for the Type 3 *Tubulus*. Rim 3a, the most common of the rims with 25 samples, is a heavy rim that overhangs the exterior (fig. 2.17.1&2). The top of this rim can be either rounded or flattened, and the upper surface usually slopes downward towards the exterior. Rim 3b, found on 15 samples, has a more squared off profile with a slight projection on the interior and a more pronounced lip on the exterior, either flat or slightly rounded (fig. 2.17.3&4). The top surface is flat or slightly rounded and in some examples slopes downwards towards the exterior. A couple of examples have rims that lie in between rim 3a and rim 3b, and it may be that these types are variations of a common form. Rim 3c, found on only two examples, is quite distinct. This flat-faced rim overhangs the interior (fig. 2.17.5&6). In one of the examples the rim has been drawn up to a sharp ridge. The relationship among these rims remains unknown. They could be variations of the same type or may reflect different ends of the *tubulus*. The ratio of the rim types, however, especially given that only two examples of rim 3c were found, make this last explanation unlikely.



**Fig. 2.17** Variant rims of the Type 3 *Tubulus*.

Rim 3a: sherds 1&2; Rim 3b: sherds 3&4; Rim 3c: sherds 5&6.

1. Hum89.1.1 T5; 2. Hum89.11 T2; 3. Hum 89.21 T2; 4. Hum 89.20 T1; 5. Hum89.1.1 T7; 6. Hum 89.1.1 T12. (Drawing by author)

In some cases, the external overhangs of the rims are cut off by a knife. Judging from samples collected, this practice is only done on 3b rims, although not all of the rims of this type are trimmed. The peculiar technique appears to have been done haphazardly. In some places along the edge, the full rim remains, while in other areas the rim is completely cut down to the thickness of the wall (fig. 2.18). Usually the rims are trimmed along the edges of the faces and sides, leaving the original rim remaining in the corners. This step appears to occur before the *tubulus* is fired and presumably at the same time as the vents in the side walls are cut. The reason for cutting off the overhang is unknown, but may have been done to help the *tubuli* fit more closely together.

The vents that distinguish the Type 3 *Tubulus* are almost perfect squares and range from 2.4 – 3.4cm in height and 2.4 – 3.0cm in width (fig. 2.19). The vents are cut with a straight-edged blade, and over-cut marks sometimes appear in the corners.



**Fig. 2.18** Close up of Type 3 *Tubulus* rim that was partially trimmed.  
(Photo by author with permission from M. B. Reeves)



**Fig. 2.19** Sherd of Type 3 *Tubulus* with characteristic square vent.

(Photo by author with permission from M. B. Reeves)

The fabric of the Type 3 *Tubulus* is noticeably much finer than that of the Type 2 *Tubulus*. The fabric can range in colour from light red to light reddish brown to pale yellow (Munsell: 2.5YR 6/6; 5YR 6/4; 5Y 8/2). The surface colour can range from very pale brown to a reddish yellow (Munsell: 10YR 7/4; 7.5YR 6/6). The inclusions are typically well-sorted fine sub-rounded clear quartz sand. Some examples have occasional small white flecks, also most all have some small voids. Based on personal macroscopic analysis of the fabric, I suggest that this *tubulus* type also originates from the Petra region.

No clear parallels have thus far been found for the Type 3 *Tubulus*. The practice of trimming the rim appears unique to this type. In fact, the only comparanda for a similar technique is found on *tegulae* (roofing tiles), where sections were cut away before firing to allow the tiles to slot into each other (Brodrribb 1987: 16-17; Warry 2006: 20-28).

Parallels for rectangular vents are more numerous and were the most common shape for

vents on *tubuli* in Roman Britain (Brodribb 1987: 75). Closer to Humayma, rectangular vents were used for *tubuli* from the Roman phase at Jalame, in Israel (Weinberg 1988: 248, No. 149; fig. 8-15; Pl.8-10). They are also found on *tubuli* from the Umayyad bathhouse at Qasr al-Hayr East, in Syria (fig. 2.21) (Grabar *et al.* 1978: Vol. 2, fig. 28). The relationship between the Type 3 *Tubulus* and early Islamic *tubuli* will be discussed in a separate section below.

The method of production for the Type 3 *Tubulus* is almost exactly the same as that for the Type 2 *Tubulus*, with two major differences. The first and most obvious is the trimming of the rim, which took place before the *tubulus* was fired. The second difference concerns the method by which the *tubulus* was shaped. Unlike the Type 2 *Tubulus*, the Type 3 *Tubulus* does not have finger indentations caused by pressing the pipe into shape. Instead, one fragment has a clear finger groove running down the interior corner, and it seems that the pipes were shaped through a process of bending the clay around the finger as it moved up the interior wall.

### **Use of the Type 3 *Tubulus***

Since examples of the Type 3 *Tubulus* were found *in situ* (fig. 2.14), it is possible to gain a relatively firm understanding of its use within the bathhouse. The initial excavation of the bath found that this type was used only along the southern wall in Room A (Oleson 1990a: 302-3; 2010: 228). Here, the bottom of the *tubuli* system was left open to the hypocaust below enabling hot gases to enter the wall cavity. The pipes were also installed side by side to allow the air to flow horizontally through adjacent vents. Once imbedded in mortar, the *tubuli* were covered in layers of plaster. One *tubulus*

fragment, collected during excavation, has a large chunk of plaster adhering to it (fig. 2.20), and reveals how the plaster was applied to the wall of the installed *tubuli*. The first layer of plaster spread over the *tubuli* was a dark grey mortar with many carbon inclusions. This plaster had a dual function, as it helped to bond the *tubuli* together and to even out the surface of the wall. Based on this fragment, the thickness of this layer ranged from 0.6cm thick, when applied to the centre of the pipes, to 2.0cm thick when filling in the gaps between the pipes. Of particular note is the fact that neither this plaster, nor any other mortar or plaster was applied directly to the sides of the *tubuli*. Thus, just as was the case with the Type 2 *Tubuli*, hot air could flow freely into and out of the gap between adjacent *tubuli*, making the lateral flow of air less obstructed. On top of this layer of grey mortar, a thin (0.7cm) layer of hard pink plaster containing ground up pottery was applied. This layer was then smoothed and polished, and became the finished surface of the wall.



**Fig. 2.20** Sherd of Type 3 Tubulus with two layers of plaster adhering to its face.  
(Photo by author with permission from M. B. Reeves)

The initial excavation of the bathhouse uncovered Type 3 *Tubuli* remaining *in situ* against the south wall of Room A, the *caldarium* (fig. 2.14) (Oleson 1990a: 302-3; 2010: 228). The construction of this wall took place during the major renovation/reconstruction of the bathhouse after its abandonment in the late third century AD (Reeves *et al.* 2009: 235). The phasing of this wall definitively dates the Type 3 *Tubulus* to after this major renovation/reconstruction. This *tubulus* type is therefore considered to have been used during the Byzantine phase of the bathhouse (starting in the fourth century). This dating makes the Type 3 *Tubulus* the latest dated rectangular *tubulus* from Humayma. As will be discussed in the following section, it is possible that the Type 3 *Tubulus* may have an even later date.

### **An Islamic date for the Type 3 *Tubulus*?**

The Type 3 *Tubulus* has already been discussed in great detail. As mentioned above, there are thus far no clear parallels for this *tubulus* type. One theory that deserves further discussion is the possibility that these *tubuli* date to a much later period than originally thought. It is conceivable that the Humayma *Tubulus* Type 3 is in fact an example of an early Islamic *tubulus*.

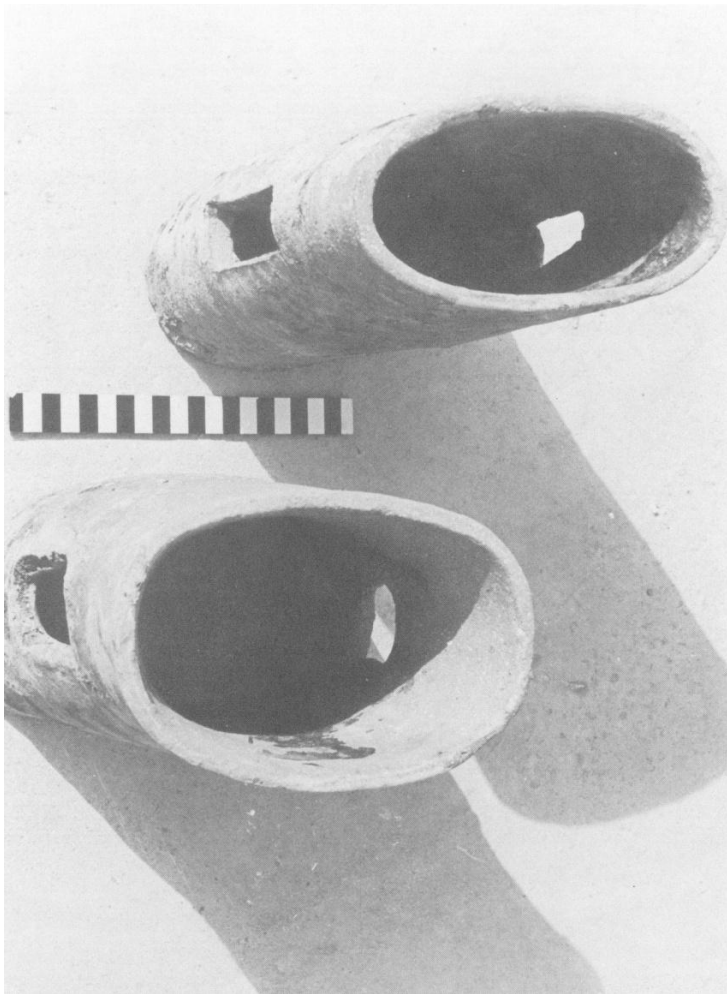
Like their Roman counterparts, Islamic *tubuli* are almost always overlooked and therefore rarely appear in excavation reports. Nevertheless, *tubuli* continued to be used into the Islamic period. While early Islamic *hammams* followed the Roman convention of using *tubuli* to heat the walls, later *hammams* used only a single flue in order to provide draught for the furnace (Dow 1996: 25). An example of this single flue system is found in the Ayyubid/Mamluk period bath at Tell Hesban, Jordan (de Vries 1986: 324). Within the

region of Roman Arabia, *tubuli* are mentioned as existing in several Umayyad *hammams*, including Hammam al-Sarah (Bisheh 1989: 228) and Qasr Amra (Almagro *et al.* 1975: 37-38). These publications, however, provide absolutely no descriptions of the *tubuli*, and it is therefore necessary to rely on photographs and drawings from sites further away in order to make typological comments. Based on a published photograph, Umayyad *tubuli* from Qasr al-Hayr East, in Syria, were wheel-made (fig. 2.21) (Grabar *et al.* 1978: vol. 2, 279, fig. 28). Those from Qasr Ain es-Sol, in Jordan, also appear to be wheel-made, although less convincingly so (Kennedy 1982: 321, fig. 41.87). The fact that these Umayyad *tubuli* are wheel-made reveals that the practice of fabricating *tubuli* on a potter's wheel continued into the Islamic period. It is not impossible then that the Humayma *Tubulus* Type 3, which is also wheel-made, dates to this period. Furthermore, as noted above, the characteristic rectangular vent of the Humayma *Tubulus* Type 3 is also found on the *tubuli* from Qasr al-Hayr East (fig. 2.21). This is the only other known example of square or rectangular shaped vents on wheel-made *tubuli*. Although this comparison is too tentative to prove definitively the date of the Humayma *Tubulus* Type 3, it does suggest that, typologically, there is no reason why these *tubuli* cannot be from the Islamic period.

This theory also does not conflict with evidence from the site itself. In fact, it has already been hypothesised that the Humayma bathhouse might have been used by the elite residents of the Abbasid *qasr* on the site (Reeves 1996: 239-48). Continued excavation of the bathhouse has found no evidence for when the bath fell out of use, only that the last dateable renovation occurred in or after the Late Byzantine period (Reeves 2012b). The evidence still remains inconclusive, and further research on early Islamic

*tubuli* is needed before the Humayma *Tubulus* Type 3 can be labelled as Islamic in date. Should, however, these *tubuli* prove to be Islamic, it would be definitive proof that the Humayma bathhouse continued to be used well after the Byzantine period.

This theory remains unconfirmed, and it is premature to definitively identify the Type 3 *Tubulus* as early Islamic in date. It is known without a doubt, however, that these *tubuli* date to after the major renovation/reconstruction of the bathhouse at the beginning of the Byzantine phase. Until there is concrete evidence to support a later date, the Type 3 *Tubulus* will be considered to date to the Byzantine phase of the Humayma bathhouse, which began in the fourth century.



**Fig. 2.21** *Tubuli* from the Umayyad bathhouse at Qasr al-Hayr.

(After Grabar *et al.* 1978: Vol. 2, fig. 28)

### **Cylindrical Flue Pipes from the Bathhouse**

Excavations have uncovered several types of cylindrical flue pipes from the bathhouse at Humayma. One likely cylindrical flue pipe found near the bathhouse came from a concentration of discarded and broken *tubuli*. The fragment's identification as a flue pipe is based on clear soot buildup on both its interior and on the exterior of the neck. This pattern of soot buildup is characteristic of cylindrical flue pipes. The fragment is a section of the male end, showing the pipe had an approximate diameter of 7.0cm along its rim and about 10.0cm at its shoulder. The pipe had a rounded carination at its shoulder, as well as a rounded rim. This pipe fragment was discovered within a concentration of Type 1 and Type 2 *Tubuli*, suggesting that it should be associated with these types and thus the Roman phase of the bathhouse (early second century to late third century). It is impossible to confirm this theory, however, since no other similar fragments of cylindrical flue pipe were found. The possibility that this pipe fragment is the result of displacement cannot be ruled out, and therefore its date cannot be definitively determined. Furthermore, the existence of only one small fragment makes it nearly impossible to discern much about its form or use.

While there may not be any concrete evidence for the use of cylindrical flue pipes during the Roman phase of the bathhouse, there is plenty of evidence for their use in the Byzantine phase. During the 1989 excavation, broken cylindrical flue pipes were found in association with the vertical vents in the walls of Rooms A and D, and were recorded as having a diameter of 11cm and a total length of 45cm (Oleson 1990b: 158). Several of these fragments were saved and were available for re-examination during the 2012 study. Upon close inspection, it became apparent the small collection of cylindrical flue pipe fragments was not completely homogenous, and contained two similar but separate pipe

forms. The corpus was too small and the differences were too slight, however, to determine whether this dissimilarity symbolized two separate types or simply two differing variations of the same type. For the purposes of this study, the differences will be tentatively considered to represent two distinct variations of a cylindrical flue pipe.

Since the fragments did not provide a full length, this separation was based solely on differences in diameter and rim design. The collection contained two different male ends and two different female ends. Although the fragments do not form a full profile, and thus the relationship between the ends cannot be known for sure, associations between male and female ends were made on the basis of wall thickness and diameter of the body. It is therefore possible to comment on both ends of the two variations with some degree of certainty.

The first variation (fig. 2.22.1-2) has a diameter of 12cm at its shoulder and that of 11cm at its neck (male end). The neck itself was somewhat thickened and was not sloped at all, being parallel to the walls of the pipe. The shoulder of this pipe is very narrow, and the rims on both the male and female ends were rounded. Not much remains of the body, but it does not seem to have deep wheel marks.

The second variation (fig. 2.22.3-4) has a diameter of 10.5cm at its shoulders and 9cm at its male end. At the female end, the diameter of the body widens to 11cm. Unlike the first variation, the neck of this pipe is not thickened, but it does remain parallel to the walls of the pipe. The shoulder of this pipe is also very narrow. The rim on the male end is rounded on the interior and comes to a point on the exterior. This is also true for the female end, which is rounded on the interior and comes to a point on the exterior. The walls of this variation are quite thick (about 1cm) and have deep and wide wheel marks.

One of the most distinguishing features of both these variations is their narrow shoulder and straight neck. Thus far no close parallels have been found for these pipes.



**Fig. 2.22** Cylindrical flue pipes from Byzantine phase of bathhouse.

*First variation: sherds 1&2; Second variation: sherds 4&5.*

*1. Hum89.34; 2. Hum89.34; 3. HEP10.0126 C2563; 4. Hum 89.13 T4 & Hum89.8 T5.*

(Drawing by author)

### **Use of Cylindrical Flue Pipe from the Bathhouse**

The fragments of cylindrical flue pipe described above were found in association with recessed vertical vents, which measure 15cm by 15cm (Oleson 1990b: 158). In the Byzantine phase of the bathhouse (starting in the fourth century), four of these vents were built into the south and north walls of Room D, and another four were built in the same configuration in Room A. Excavations in 2012 beneath the floor in Room D and at the base of one of these vents found fragments of cylindrical flue pipes and plaster chunks with impressions of these pipes. These findings confirmed that the recesses at one time held the cylindrical flue pipes that were collected during the initial excavation of the bath.

The cylindrical pipes were installed into these recesses and acted as the flues for the hypocaust. These recessed vents allowed smoke to escape and may have helped slightly to heat the room. The primary and most important function of these vents was to provide the draught necessary for the hypocaust system to function. Without the vents, the heat would not be drawn into the hypocaust under the floor and the rooms would not be heated.

The association of these cylindrical flue pipes with the recessed vertical vents dates the pipes to the Byzantine phase of the bathhouse. This date makes these cylindrical flue pipes contemporaneous with the Type 3 *Tubulus*.

### **Relationship between Cylindrical Flue Pipes and *Tubuli***

Excavation in and around the bathhouse has shown that both *tubuli* and cylindrical flue pipes were used together within the hypocaust system in the Byzantine phase. While the existence of cylindrical flue pipes in recessed vents in Room D is not

surprising, the placement of both these recessed vents and rectangular *tubuli* in Room A may seem redundant. This is especially true for the southern wall of Room A, which contains *tubuli* and vents together (fig. 2.14). If both *tubuli* and the flue pipes could carry away smoke and provide a draught, it does not make much sense to have them together.

There are two possibilities for why rectangular *tubuli* were installed against a wall that already had recessed vents holding cylindrical flue pipes. The first explanation is that the recessed vents predate the *tubuli*. This possibility is unlikely, however, since without the *tubuli* Room A would be only slightly hotter than Room D. It does not make sense for the bath to be designed this way, and therefore the *tubuli* system was most likely part of the original design of the renovated room.

If both types of pipe were installed at the same time, they were obviously designed to work efficiently in tandem. The second and more probable explanation for the existence of both the *tubuli* and the recessed flue vents along the same wall is that the *tubuli* system was a closed system and did not carry any draught. In this configuration, the draught was carried out through the cylindrical flue pipes in the vertical recesses. The *tubuli*, being closed at the top, heated the walls through convection currents.

Experimentation with reconstructed *tubuli* systems has shown that the *tubuli* did not need to be connected to a flue for them to work effectively (Yegül and Couch 2003: 175).

Thus in this system, the two types of pipes had very distinct and separate functions.

Whereas the *tubuli* were installed against the wall to help heat the room, the cylindrical flue pipes, on the other hand, were inserted into the recessed vertical vents to carry away smoke and provide a draught.

This design is not unique to Humayma. Several bathhouses in the region had *tubuli* systems installed overtop flue vents, which were recessed into the wall and connected directly to the hypocaust below. This arrangement has been found in the first century AD bath at Wadi Ramm (Dudley and Reeves 1997: 94-95) and at the large bathhouse in Masada (Netzer 1991: 92-93; Foerster 1995: 200). In the west, a bathhouse in Tongeren, Belgium, also has *tubuli* installed overtop a recessed flue vent (Degbomont 1984: 153, fig. 288).

Judging by the existence of cylindrical flue pipes and recessed flue vents, it seems likely that the wall-heating system in the Humayma bathhouse during the Byzantine phase was a closed system. What then of the wall-heating system in the Roman phase of the bathhouse? Only one fragment of cylindrical flue pipe was uncovered that was associated with this phase. It may appear therefore that the heating system of the first phase did not use cylindrical flue pipes in the same fashion as that of the later system.

Before concluding that the cylindrical flue pipes never existed in the first place, one must look at other explanations for their absence from the archaeological record. It is possible that the cylindrical flue pipes have yet to be found, or may have already been found, but misinterpreted as water pipes due to their disturbed context. Another possibility is that the cylindrical pipes were reused for drain pipes or wastewater.

Upon examination of the bathhouse walls from the Roman phase, it is apparent that they do not have the same type of vertical recesses that existed in the north and south walls of Rooms A and D during the Byzantine phase of the bath. The lack of recessed vertical vents suggests that a different flue system was used in the Roman phase (early second century to late third century). It is possible that an open system was used. In this

arrangement, either the entire *tubuli* system or only parts of it was left open to a horizontal header above (Yegül and Couch 2003: 170, fig.24; 172, fig.26). The draught was carried up through the *tubuli* themselves, into the horizontal header, and out of the hypocaust system. In this design, there was no need for separate flue pipes, or recessed vents. A likely parallel for the use of a horizontal header above a *tubuli* system is from the late third/early fourth century bathhouse at ‘Ayn Gharandal (Darby *et al.* in press: fig. 4).

### **Heating Pipes from the Bathhouse**

A very large variety and number of *tubulus* fragments have been found from the bathhouse at Humayma. Careful examination of these fragments and their context has provided a better understanding of when and how they were used. Thanks to this analysis, it is now possible to construct a rough and tentative history of their use.

When the Roman phase bathhouse was constructed in the second century AD, the wall-heating systems used either the Type 1 or the Type 2 *Tubulus*. At some point during the initial construction, or in an early unidentified renovation, the Type 2 *Tubulus* became the dominant type of *tubulus* in the bathhouse. This increased use of wheel-made *tubuli* is likely a result of the adoption of the local production method or the contracting of the production of the *tubuli* to local manufacturers, who had been making wheel-made *tubuli* well before the Roman annexation. The lack of cylindrical flue pipes and the absence of recessed vents in the walls from this phase suggest that the *tubuli* system was an open one, where the *tubuli* themselves both actively heated the walls and carried the draught as part of the flue system.

During renovations after the third century AD abandonment, the bathhouse was reduced in size and the Type 1 and Type 2 *Tubuli* were stripped from the walls. These *tubuli* were used to fill in the *piscina* and found their way into the fill of the hypocaust in Room E. The Byzantine phase bathhouse used only Type 3 *Tubuli*, which were installed along the south wall of Room A. In the south and north walls of both Rooms A and D, vertical recesses were built, and cylindrical flue pipes were installed into them. The *tubuli* system in this phase was a closed system. Independent from the flue system, the *tubuli* effectively heated the room, while the cylindrical flue pipes carried the draught. The Type 3 *Tubulus* was the last type of *tubulus* to be used in the bathhouse, fragments of which remained *in situ* until the building's excavation.

### **Hypocausted Room in the *Praetorium* (E116 Area I Room J)**

The second structure at Humayma that contained *tubuli* was a small hypocausted room in the *Praetorium* of the fort. The initial excavation of this room occurred in 2004, when only a small section along its eastern wall was cleared to floor level (Oleson *et al.* 2008: 323-24). Of the hypocaust, only the *pilae*, made from small rectangular bricks and circular *bessales*, remained *in situ*, although fragments of the covering tiles and chunks of plaster and mortar were uncovered from the fill. In 2012, the entire room (3.4 x 1.7m) was excavated to floor level (fig. 2.23). This excavation revealed the continuation of the *pilae* across the subfloor as well as vertical recesses, measuring about 0.08 by 0.12m, that were installed into each of the four corners to act as vents for the hypocaust. Fragments of the cylindrical flue pipes that were likely placed into these vertical recesses were recovered from the fill of the room. Excavation also unearthed hundreds of *tubuli* sherds,

indicating the existence of a wall-heating system. Although small, this hypocaust had all the features of larger systems. This room was initially theorized to be a private bath for officers, although the possibility of a heated dining room was also entertained (Oleson *et al.* 2008: 323). The 2012 excavation allowed for a better understanding of the room's function and confirmed that it was most likely a heated dining room (Reeves, personal communication, Oct. 2012). This hypocaust and *tubuli* system is thought to date from the second or early third century, and appears to have been destroyed by the beginning of the fourth century (Reeves and Harvey 2013). This dating places this *tubuli* system later than the initial construction of the Roman phase bathhouse, but before the Byzantine phase renovations of the structure.



**Fig. 2.23** *Hypocausted room in Praetorium, facing west.*

(Courtesy of M. B. Reeves)

### **Tubuli from the Praetorium**

The *tubulus* corpus from the hypocausted room within the *Praetorium* is very interesting in that it is a homogenous corpus with no other *tubulus* types present. Additionally, there is a great deal of uniformity among the *tubuli* in terms of their size. This uniformity is even more surprising given the quantity of fragments found. During the 2012 excavation season alone, this small room yielded over 1500 *tubulus* fragments, or 35kg of *tubuli*.

#### **Type 4 Tubulus (Wheel-made Narrow-depth Tubulus)**

Every single *tubulus* fragment from the hypocausted room within the *Praetorium* belonged to the fourth *tubulus* type (figs. 2.24-2.29). This type is wheel-made and is characterized by a narrow depth from front to back, which sets it apart from other *tubuli* at the site. Like the Type 2 *Tubulus*, the Type 4 *Tubulus* has a rectangular end and an oval end.

As previously mentioned, this *tubulus* type is remarkably uniform in terms of its dimensions. Full heights exist for eight reconstructed examples, all of which range from 17.4 to 18.3cm and average about 17.6cm. Six reconstructed examples with full widths (vent to vent) range between 15.5 and 16.5cm wide. The depths of only four samples could be measured, and these range from 8.0 to 10.0cm deep. The wall thickness of these *tubuli* varies from 0.4cm near the ends to 0.8cm in the middle.

There is a distinct difference between the rims on the top (rectangular end) of the *tubulus* and rims on the bottom (oval end). The vast majority of rims on the top end appear triangular in profile and overhang the exterior. Those rims that do not fit this

description tend to be thickened and rounded without an overhang. In all examples, the rims on the bottom end are flattened, while some have a projecting overhang on the interior. Practically all of these rims are rough to the touch. This roughness is likely from the *tubulus* being cut off the potter's wheel with a string.

The shape and size of the vents on this *tubulus* type lack uniformity. Typical shapes include irregular ovals, ovals pointed at both ends, and tear shapes. The vents range in size from 4.5 to 6.0cm long and 2.0 to 2.8cm wide. Interestingly, in all examples the vents are located closer to the top end of the tube.

The fabric of the Type 4 *Tubulus* is coarser than that of all the other *tubulus* types from Humayma. While this fabric is not found in any other *tubuli* from the site, it matches perfectly the fabric of the hypocaust bricks from the hypocausted room within the *Praetorium*, suggesting that the materials were manufactured in the same place. The fabric can range in colour from reddish yellow, to red, to reddish brown (Munsell: 5YR 6/6; 2.5YR 5/8; 2.5YR 4/3). The surface colour is usually darker such as light brownish grey or even dark grey (Munsell: 10YR 6/2; 5YR 4/1). Some examples have a dark grey core (Munsell: 5YR 4/1). Typical inclusions for this *tubulus* type are well-sorted medium sub-rounded clear quartz sand, with some coarse to very coarse sand and some small white flecks. The fabric also contains some small voids. Macroscopic analysis of the fabric by the author suggests that it originated from the Petra region, but petrographic analysis is needed to confirm this theory.

An interesting characteristic of the Type 4 *Tubulus* is a flaky or powdery white coating that covers the exterior surfaces of a majority of the fragments. This substance is likely efflorescence, a naturally occurring crystalline salt deposit (Rice 1987: 336). No

test has yet been done to confirm the identification of this substance, but if it is efflorescence, it would suggest the use of salt or brackish water in the production of the *tubuli*, or poorly levigated salty clay.

As previously listed, there are many sites in the region that have wheel-made *tubuli*; however, no close parallels have been found for the Type 4 *Tubulus*. A couple of sites have *tubuli* with depths of comparable narrowness. *Tubuli* from the Roman phase at Jalame, in Israel, have depths that average about 7.4cm (Weinberg 1988: 248), while *tubuli* from the Herodian baths at Machaerus are only 6cm deep (Loffreda 1981: 89). It is possible that the narrow depth of the Type 4 *Tubulus* may reflect the size of room it was designed to heat. Since the room was small to begin with, wider depth *tubuli*, such as those found in the bathhouse, would have only decreased the size of the room further. Moreover, since these pipes were not required to heat a large space, the effectiveness of the heating system was not drastically diminished by a narrower depth, and thus a more restricted airflow within the wall. The appropriateness of the Type 4 *Tubulus* for this space seems to suggest that it was designed specifically for this room. If this was the case, it would explain why there are no parallels for its narrow depth.

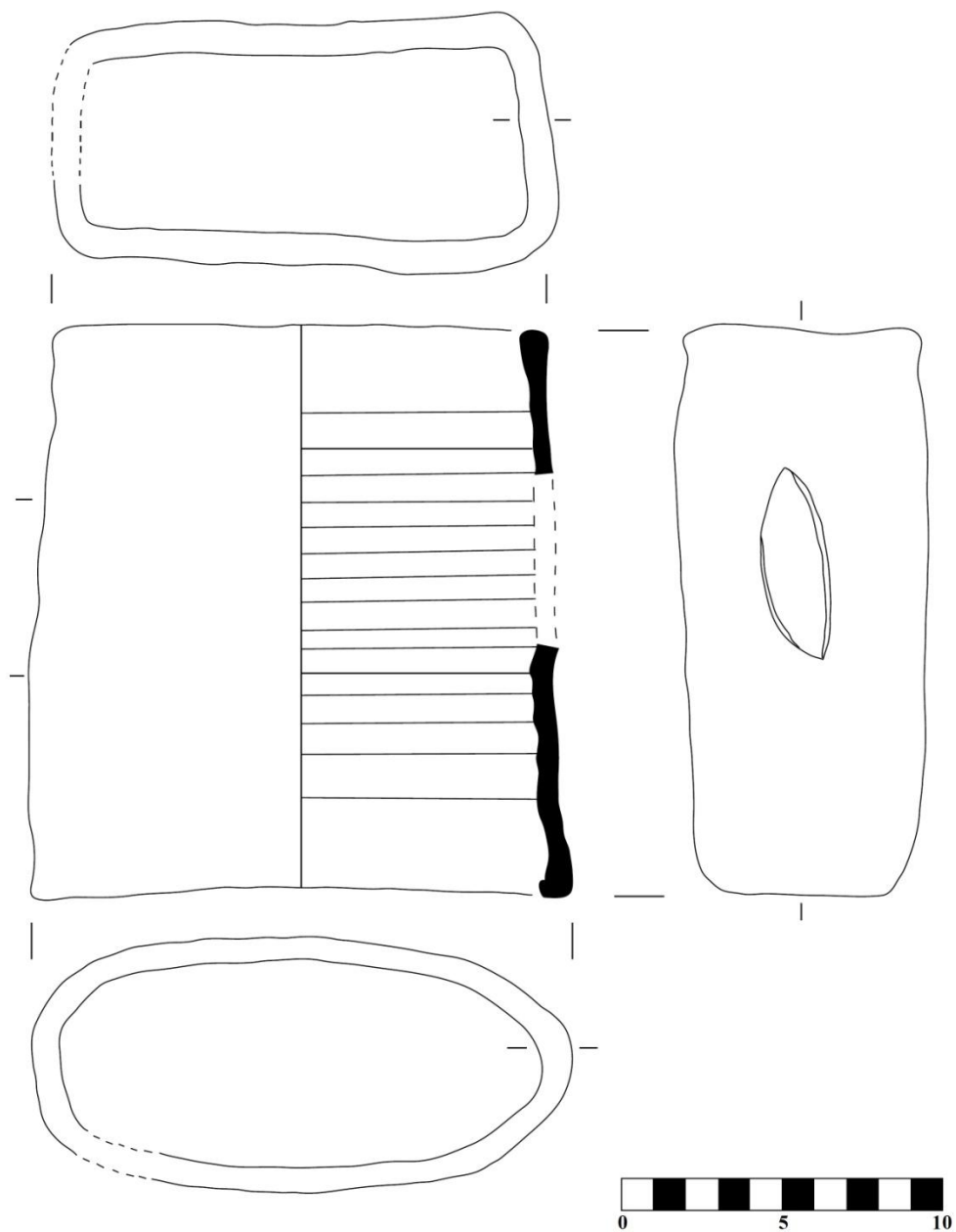
The Type 4 *Tubulus* was fabricated much in the same way as the Type 2 *Tubulus*. The *tubulus* was wheel thrown, and then shaped into its rectangular form by hand, as shown by the finger impressions that often appear on the exterior sides of *tubuli* (fig. 2.24). The side vents were cut, and the tube was left to dry before firing. One of the only differences between the fabrication of the Type 4 *Tubulus* and the Type 2 *Tubulus* is that no attempt was made to smooth out the bottom rim of the Type 4 *Tubulus* after it had been cut from the potter's wheel.



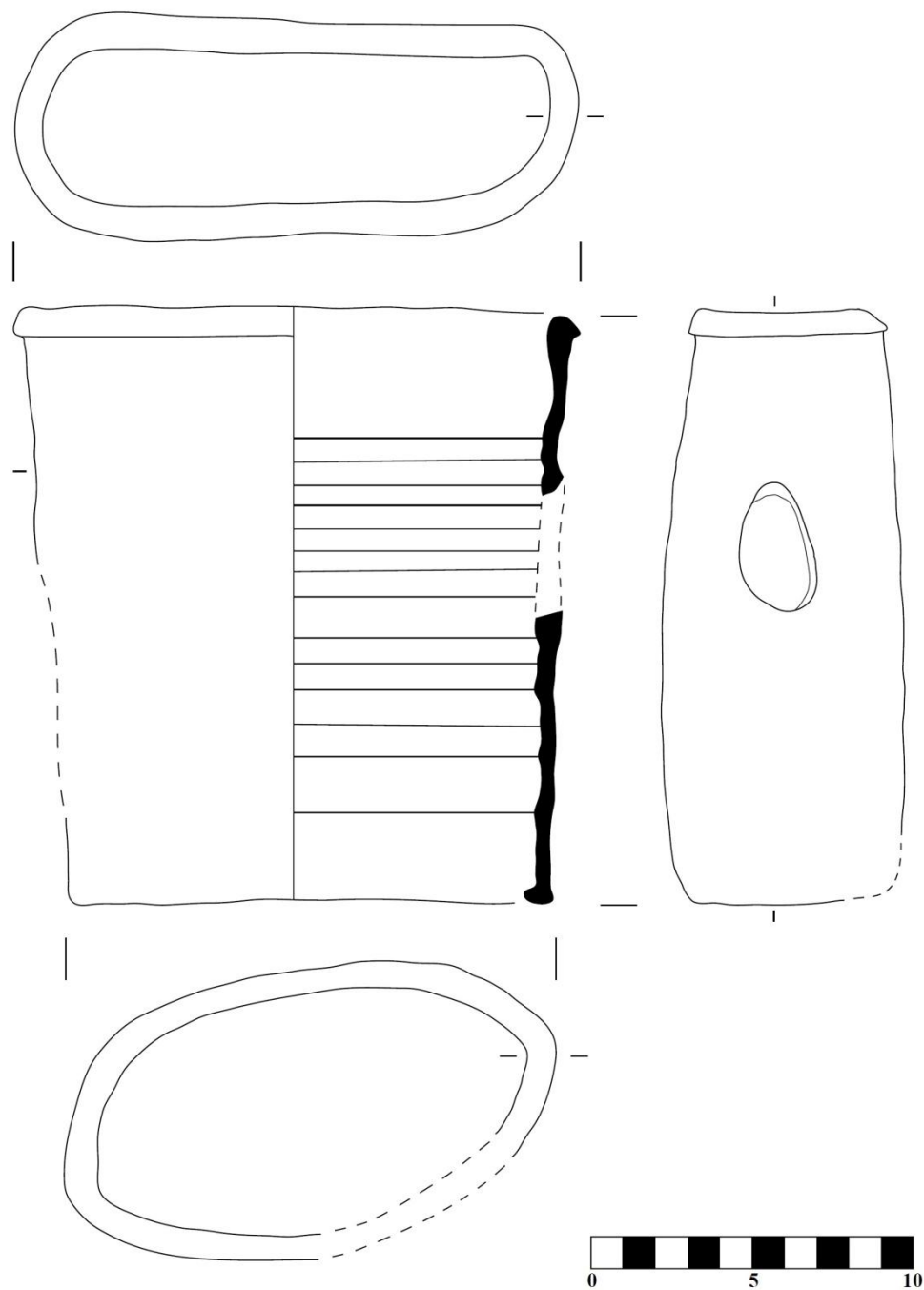
**Fig. 2.24** *Close up of Type 4 Tubulus side wall with finger impressions from shaping.*  
 (Photo by author with permission from M. B. Reeves)



**Fig. 2.25** *Three reconstructed Type 4 Tubuli.*  
 Left: H12.E116.Praetorium.Room J T1; Centre: H12.E116.Praetorium.Room J T2;  
 Right: H12.E116.Praetorium.Room J T3.  
 (Photo by author with permission from M. B. Reeves)



**Fig. 2.26** Drawing of reconstructed of Type 4 Tubulus.  
*H12.E116.Praetorium.RoomJ T1.* (Drawing by author)



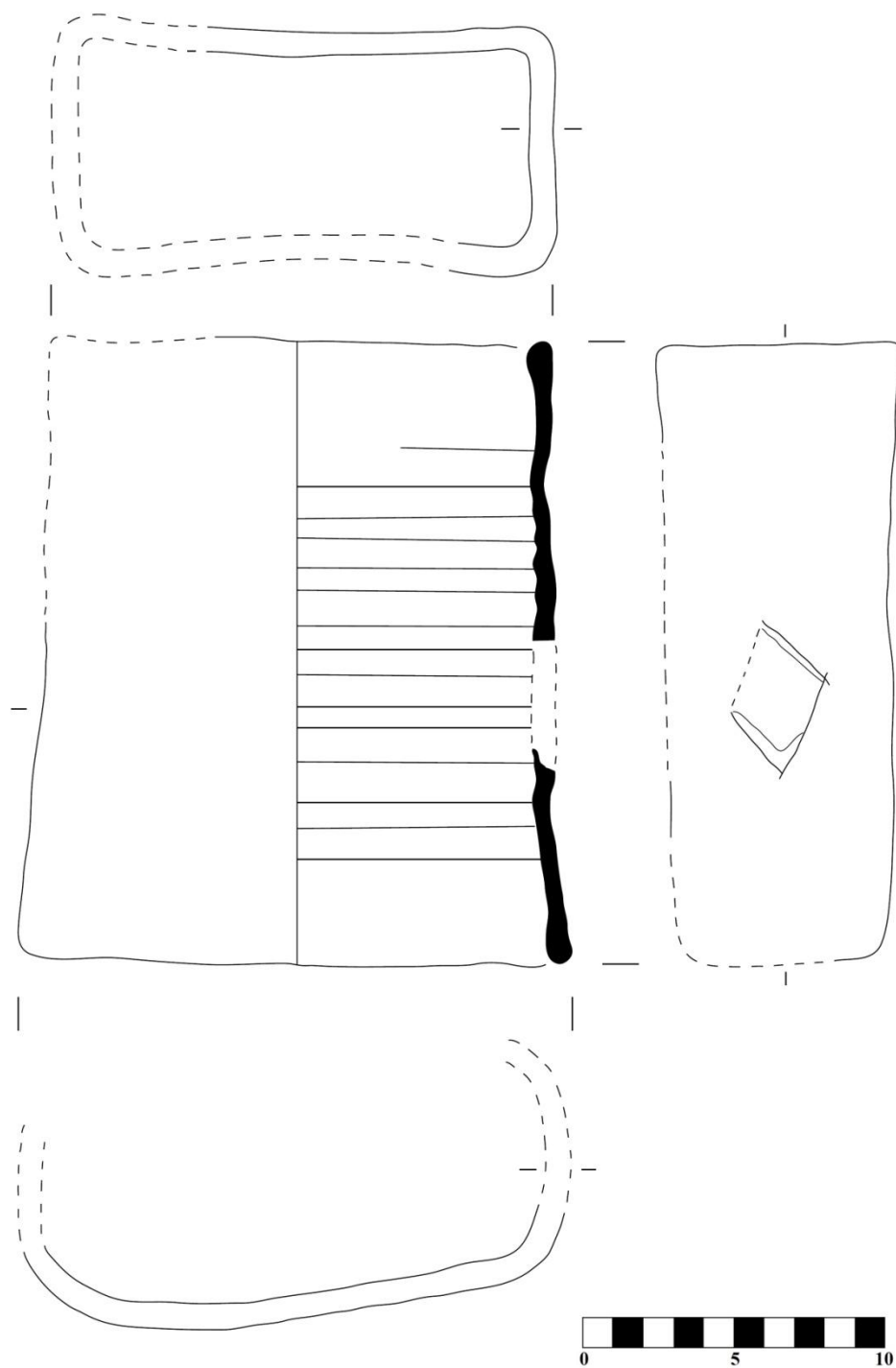
**Fig. 2.27** Drawing of reconstructed of Type 4 Tubulus.  
*H12.E116.Praetorium.RoomJ T2.* (Drawing by author)

### **Variant of the Type 4 *Tubulus***

Within the *tubulus* corpus from the hypocausted room of the *Praetorium*, there is a distinct variant form of the Type 4 *Tubulus* (figs. 2.28 and 2.29). This variant differs from the rest of the type in both its size and the shape of its vents. A close examination of all the fragments collected found a minimum number of two of these variant *tubuli*; however, it is very possible that more of them once existed. A large reconstructed example of this variant type is 20.6cm high, 17cm wide, and 10.5cm deep. While these measurements come from only one example, the fact that the only reconstructed variant *tubulus* differs so greatly from the uniform size of the regular Type 4 *Tubulus* is noteworthy. The other characteristic of this variant form is its diamond-shaped vents. Unlike the vents on the typical Type 4 *Tubulus*, which were cut with one stroke, those on the variant type were cut with four separate strokes of a knife, as clearly indicated by the over-cut marks in the corners. These same over-cut marks are present on the square vents of the Type 3 *Tubulus*.

In all other qualities this variant form is similar to the typical Type 4 *Tubulus* type. It has a similar overall design and is made from the exact same fabric. The identical fabric of this variant form reveals that it came from the same workshop as the others.

While it may be impossible to know for sure why a variant form of the Type 4 *Tubulus* exists, several potential explanations can be entertained. These variant *tubuli* could have been part of the first batch of tubes produced, or conversely, they may have been fabricated last, as replacements for *tubuli* broken during transportation or construction. Although the reason for the variant's existence is unknown, it is evident that they were produced at the same workshop and that they worked in conjunction with typical Type 4 *Tubuli* in the heating system.



**Fig. 2.28** Drawing of reconstructed of the variant Type 4 Tubulus.  
*H12.E116.Praetorium.RoomJ T10.* (Drawing by author)



**Fig. 2.29** Comparison of Type 4 Tubulus (left) and variant of Type 4 Tubulus (right).  
 Left: H12.E116.Praetorium.RoomJ T2; Right: H12.E116.Praetorium.RoomJ T10;  
 (Photo by author with permission from M. B. Reeves)

### **Use of the Type 4 Tubulus**

Although no Type 4 *Tubulus* was found *in situ*, the use of this type was clearly limited to the small hypocausted room. It is not clear which or how many walls were lined with *tubuli*, but a likely candidate is the northern wall. This wall has a narrow projecting ledge at the hypothesised height of the floor, and it is possible that this ledge served to support the bottom course of *tubuli*.

Several of the *tubuli* recovered from this room had chunks of plaster adhering to them. Excavation also found numerous chunks of plaster with impressions of *tubuli*. Careful examination of this plaster has provided detailed insight into how the Type 4 *Tubuli* were installed against the wall. Based on the analysis of the plaster, the Type 4 *Tubuli* were affixed to the stone wall with copious amounts of grey plaster. This grey plaster contained numerous carbon inclusions. On the other side of the *tubuli*, a different type of plaster was applied. This off-white, hard, and very sandy plaster was applied directly over top of the *tubuli* and also formed the finishing coat on the walls

Numerous chunks of plaster with impressions of two adjacent *tubuli* have revealed that the space between the Type 4 *Tubuli* ranged from as little as 0.6cm to as much as 2.7cm. Although this space allowed for the hot gases to circulate freely between adjacent tubes, the Type 4 *Tubuli* did not necessarily require such spaces since their uniformity ensured that their vents properly lined up and thus the lateral flow of air would not be inhibited.

The use of wheel-made *tubuli* within the Roman fort may seem surprising, especially given that this study has already argued that the Roman army produced slab-made and not wheel-made *tubuli*. The existence of wheel-made *tubuli* within the *Praetorium* exemplifies the extent to which this local production technique survived despite the introduction of Roman production methods. This cultural influence is also seen in the Humayma bathhouse with the supplanting of the slab-made Type 1 *Tubulus* with the wheel-made Type 2 and 3 *Tubulus*. Within the *Praetorium* itself, the mosaics that adorn its floors are thought to be the work of a Nabataean workshop (Oleson 2007: 452). The design of these mosaics and the production technique of the Type 4 *Tubulus*

suggest that Nabataean contractors may have had a significant role in the construction and renovation of the *Praetorium*.

As mentioned above, the construction of the heated room in the *Praetorium* is thought to have occurred sometime in the second or third century AD, while the destruction of the hypocaust had occurred by the beginning of the fourth century AD (Reeves and Harvey 2013). Based on these dates, the Type 4 *Tubulus* was likely in use at the same time as the Type 1 and 2 *Tubulus*, but before the Type 3 *Tubulus*.

### **Cylindrical Flue Pipes from the *Praetorium***

Excavation within the hypocausted room also uncovered many sherds of cylindrical flue pipe. These pipes, with heavy soot buildup on their interior, were of the typical design with male and female ends. No reconstructed pipes had full profiles, although one large one measured 23.2cm from its female end to the carination of its shoulder. Judging from this sample and a separate fragment of a male end rim, the full length of this pipe was around 27cm. The diameter of the pipe's body was 9.3cm. The male end was circular and 6.0cm in diameter, and the length of the neck was around 3.0cm. The female end could be slightly oval and ranged from 8.4 to 9.4cm in diameter. On the interior of the female end, just inside from the rim, a wide groove followed by a thick ledge was present on all samples. This feature was likely designed to grip the mortar that sealed the joint between two adjoining pipes.

Many parallels for this type of pipe exist, all of which come from hydraulic features at Humayma. Several similar pipes have been excavated from hydraulic features around the site (Oleson 2010: 331, Fig. 6.4). These water pipes are part of a pipeline laid

in either the second or third century (Oleson 2010: 330). The cylindrical flue pipes from the *Praetorium* likely come from a similar date and thus correspond with the dating of the Type 4 *Tubulus*. These parallels also reveal that the exact same pipe could be used as either a cylindrical flue pipe or a water pipe. The different functions did not require a different form.

### **Use of Cylindrical Flue Pipe in the *Praetorium***

The cylindrical flue pipes were likely installed into the four vertical recesses that existed in the corners of the room. The existence of recessed vents and cylindrical flue pipes suggest that the hypocausted room in the *Praetorium* had a closed *tubuli* system similar to that of the bathhouse after the Late Roman period renovations. These cylindrical flue pipes, therefore, had an important role to play within the heating system as they carried the draught necessary for the function of the hypocaust.

### **Heating Pipes from the Hypocausted Room in the *Praetorium***

Although small in size, the wall-heating system in the *Praetorium* was by no means modest. The quality of the materials and the construction of the entire system are in keeping with the lavish decoration of the *Praetorium*, which included mosaics and frescos (Oleson *et al.* 2003: 43-45). This homogenous corpus represents a single phase system and provides further information on *tubuli* systems while at the same time complementing the knowledge gained from the examination of the systems in the bathhouse.

### **The *Tubulus* Corpus from Humayma**

As far as sites in the region go, Humayma is very rich in *tubuli* and *tubuli* systems. The site has yielded four distinct *tubulus* types spanning over several centuries, in addition to examples of cylindrical flue pipes. These heating pipes come from two separate buildings, and careful examination has revealed that both open and closed *tubuli* systems once existed at Humayma. The wide diversity of the Humayma *tubulus* corpus represents a range of the *tubulus*' form and use.

Humayma is only one of many sites in Roman Arabia where excavations have unearthed *tubuli*. Although this small study cannot cover the large amount of material that exists, the following chapter will use evidence from a few selected sites in the region to examine some of the larger issues in relation to *tubuli* and their use in the region.

### **Chapter Three: *Tubuli* and their Use in Roman Arabia**

Far from being limited to Humayma, *tubuli* are ubiquitous in Nabataea and Roman Arabia, and are found in nearly every bathhouse or other hypocausted structure in the region. This chapter will use the data from many of these sites to look into some of the larger issues of *tubuli* and their use in Roman Arabia. The *tubuli* from Humayma will also be included in this analysis in order to better understand their place within the regional corpus. A catalogue of all the sites in Roman Arabia with *tubuli* that are known to this study, as well as detailed descriptions of these *tubuli* and their use, can be found in the Appendix. Although, at present, there are not enough data to establish a *tubulus* typology for Roman Arabia, it is possible to comment on several noticeable regional similarities. With further development and refinement, these similarities have the potential to be formed into a well-defined typology, similar to that established for Humayma. As will be discussed below, it is already possible to identify several supply centres for this material. This chapter will also touch on the trade and reuse of *tubuli*.

#### ***Tubuli* Systems**

Before focusing on the *tubuli* themselves, this chapter will examine the different *tubuli* systems found in Roman Arabia. In addition to discussing the *tubuli* systems, this chapter will postulate on the reasons why one system was chosen over another. This analysis is presented below.

### **Open versus Closed *Tubuli* Systems**

The first chapter has already introduced the two different configurations that could be used in the *tubuli* system. Depending on the relationship between the *tubuli* and the exhaust flue, *tubuli* systems can be either open or closed. In an open *tubuli* system, the columns of *tubuli* are left open at the top and lead to a horizontal header conduit that conducts the smoke and hot gases to the exterior of the building as exhaust. In this system the *tubuli* act as the flues providing the draught, and there is no need for a separate flue or chimney system. This system creates a strong draught, which leads to higher temperatures and greater fuel consumption.

In a closed *tubuli* system, each column of *tubuli* is blocked at the top. The *tubuli* are completely separate from the flue system and carry no draught. In this system, the draught is provided by a separate flue or chimney that leads directly from the hypocaust to the exterior. Despite not carrying any draught, the *tubuli* in a closed system still heat the walls effectively through convection currents. The hot air in the hypocaust rises, cools, and drops down to be reheated again (Yegül and Couch 2003:175).

A major difference between these two systems is that a closed *tubuli* system creates a low draught that consumes relatively less fuel, while an open system encourages stronger and hotter fires, but requires more fuel (Yegül 2010: 88). Since they are located in an arid climate with limited fuel resources, one would expect hypocausts in Roman Arabia to use the more economical of the two *tubuli* systems. There is evidence, however, that both open and closed systems were used in the region.

Unfortunately, due to the poor preservation of most of the *tubuli* systems, it is often difficult, if not impossible, to determine with certainty which system was used. The existence of recessed vertical vents in the walls and cylindrical flue pipes are signs of a

closed system, but not necessarily proof. Based on these signs, I speculate that closed *tubuli* systems were used in the first century AD bath at Wadi Ramm, at Mampsis, and at Humayma in both the Byzantine phase of the bathhouse and the hypocausted room in the *Praetorium*. It should be noted that these sites are the only ones with strong evidence for closed *tubuli* systems. Other sites in the region have recessed vertical vents in their walls, and therefore may have had a closed *tubuli* system, but there is not enough evidence to fully support the existence of one. These sites include Lejjun, in the *caldarium* of the early fourth century garrison bathhouse (de Vries and Lain 2006: fig. 7.1), the Byzantine bathhouse at Oboda (Negev 1997: 172, fig. 26), Rehovot-in-the-Negev (Musil 1908: 75, fig. 46), and a small bath within a Nabataean villa at Wadi Musa (‘Amr *et al.* 1997: fig. 5).

Despite their greater fuel consumption, I hypothesize the existence of open *tubuli* systems at a handful of sites in the region. As discussed in the second chapter, based on the lack of recessed vents in the walls and the absence of cylindrical flue pipes, the Roman phase of the Humayma bathhouse (early second century to late third century) is considered to have used an open *tubuli* system. At the Central Baths in Jarash, renovations in the heated rooms sometime after AD 660-680 resulted in the filling in of the original chimneys, and thus the *tubuli* system was altered to enable it to carry the draught (Blanke forthcoming). In the late first/early second century heated rooms of Zantur VI, in Petra, rectangular *tubuli* were placed in recessed vents and carried the draught of the hypocaust. These *tubuli*, however, acted more as flue pipes than wall-heating elements (Kolb and Keller 2000: 361-62). Therefore, since it did not have a true *tubuli* system with rows of adjacent *tubuli*, Zantur cannot really be considered to have

had an open *tubuli* system. Perhaps the best evidence for an open *tubuli* system in Roman Arabia comes from the late third/early fourth century baths at ‘Ayn Gharandal. Here, a photograph of the partially excavated *caldarium* shows *in situ tubuli* installed beneath an overhang of the wall (fig. 3.1). The soot-stained space between these *tubuli* and the overhang could have possibly held a horizontal header that conducted the hot air and smoke to a soot-stained chimney clearly visible in the corner of the room. Further excavation is needed to confirm the relationship between the *tubuli* and the chimney, but the available information suggests the *caldarium* in the ‘Ayn Gharandal bathhouse used an open *tubuli* system.



**Fig. 3.1** Caldarium in the bathhouse at ‘Ayn Gharandal, facing east.

*Note the horizontal space beneath the overhanging stones that may have formed a horizontal header for the tubuli below. Also note the soot stained chimney in the northeast corner (Courtesy of R. Darby)*

Judging from the sites mentioned above, there is neither an overarching chronological development from one system to another, nor a clear geographic pattern of distribution. As previously stated, closed systems use less fuel than open systems, and therefore it is puzzling why open systems were used at all in this desert region. Perhaps the Humayma bathhouse, being the first Roman-built bath in the region, was constructed without consideration of the available fuel supply. When the bathhouse was later renovated, the soldiers installed a closed *tubuli* system, having learned from their initial oversight. The existence of the open *tubuli* system at 'Ayn Gharandal is less easily explained. It is possible that the nearby oasis provided sufficient fuel, or that the higher temperatures provided by the open *tubuli* system were desired. Future excavation within the 'Ayn Gharandal bathhouse are sure to elucidate the use of the *tubuli* further.

### **Hypocaust Fuel**

It is necessary to interject here a very brief discussion on the types of fuel likely used in hypocausts of Roman Arabia. There is no need to cover this topic in depth, as hypocaust fuel for desert bathhouses has been discussed sufficiently elsewhere (Reeves 1996: 84-88). Typical fuels for hypocausts in the Roman world were wood, charcoal, and coal (Forbes 1966: 41). Since these resources were scarce in Roman Arabia, other fuels had to be used. One possibility is dung, which is known to have been an important fuel source in the region (Reeves 1996: 88). Excavations in a bath furnace at Umm Qays uncovered a large amount of charred olive pits, which were evidently used as fuel (Hoss 2005: 34). Another likely fuel source in this desert environment is brushwood. This resource is thought to have been the primary fuel used in the bathhouse at Mampsis

(Negev 1988: 169). At the Humayma bathhouse, excavation in the furnace recovered charred examples of jointed saltwood (*Haloxylon articulatum*), a common desert shrub that produces a very hot but quick burning fire (Oleson 2010: 229). These properties, however, make jointed saltwood a less than desirable fuel source. For one thing, the intense heat produced by this material could cause damage to the hypocaust system. Fragments of melted hypocaust bricks found in the Humayma bathhouse attest to this harm (Reeves and Harvey 2013). Secondly, the short lasting fire produced by this material necessitated large quantities of it to sustain the heating of the hypocaust. These characteristics make jointed saltwood poorly suited for use in a closed *tubuli* system, which drew its economic benefit from the fact that it encourages and works best with a slow-burning and low-temperature fire (Yegül 1992: 381). The use of jointed saltwood, therefore, did not at all take advantage of this efficient system. On the other hand, it may have been the case that the closed *tubuli* system slowed down the burning of fuel as much as possible and allowed the limited fuel supplies to last longer than they would otherwise.

### **Cylindrical Flue Pipes as Heating Pipes**

In some instances cylindrical flue pipes were installed against the faces of walls in the same fashion as *tubuli*. Like rectangular *tubuli*, these cylindrical flue pipes were intended to conduct hot air from the hypocaust and heat the walls. This peculiar use of cylindrical flue pipes is presently known to have existed at only three sites in Roman Arabia. It is found at ‘Ayn Gharandal, along the walls of the *tepidarium* (Darby *et al.* in press), and judging from details on the top plan of the bathhouse (Negev 1997: 172, fig. 26), cylindrical pipes may have been used in this fashion at Oboda. Finally, cylindrical

pipes were likely installed against the walls of the bathhouse at Mamphis. Although the pipes at Mamphis are not explicitly described as cylindrical, this shape is implied in their brief description (Negev 1988: 176). These bathhouses do not date to a common period, but instead range from the Late Nabataean to the Byzantine period. All three of these examples, however, are located in or near the Negev, and this raises the possibility that they represent a local technique.

The use of these cylindrical pipes in this way is puzzling since they are much less efficient as heating installations than typical rectangular *tubuli*. A photograph of one of these pipes from 'Ayn Gharandal reveals that the cylindrical pipes lack ventilation holes in their side walls (fig. 3.2). The absence of these vents severely restricted the circulation of hot gasses within the *tubuli* and limited the effectiveness of the wall-heating system.



**Fig. 3.2** Large cylindrical flue pipe used to heat the walls in the tepidarium of the 'Ayn Gharandal bathhouse. (Photo by author with permission from R. Darby)

The reason for this use of cylindrical pipes is not known. It is possible that, due to a lack of rectangular *tubuli*, the builders used water pipes intended for hydraulic installation instead. Although this theory explains the use of these pipes at Mampsis and Oboda, it does not account for their use at ‘Ayn Gharandal, where typical rectangular *tubuli* were used in the *caldarium* (Darby *et al.* in press). The conscious choice of installing cylindrical pipes instead of rectangular *tubuli* at ‘Ayn Gharandal may have actually been based on the restricted airflow created by these pipes. Since the pipes were used in the *tepidarium*, a room where only warm temperatures were desired, their limited heating capabilities may have been preferred. At Humayma, the cooler of the two heated rooms in the Byzantine period had no wall-heating pipes except for four recessed vents to carry the draught (Oleson 2010: 228). Nevertheless, this room was undoubtedly designed to be heated to an appropriate temperature. The cylindrical pipes in the *tepidarium* at ‘Ayn Gharandal may have therefore been designed to provide additional but not excessive heat. If this theory is correct, it would indicate that the ancient engineers both understood the limitations of cylindrical pipes without vents and used them as a means to control the temperature of the heated rooms.

### ***Tubulus* Form and Fabric**

Thus far, this chapter has concentrated on *tubuli* systems. The focus will now turn to the *tubuli* themselves and their variations in both form and fabric. Emphasis will be placed on what the form and fabric of the *tubuli* can reveal about regional forms and production centres.

In the following discussion of regional similarities, the form of the *tubuli* is prioritized over the fabric. This decision, like the one made for the Humayma *tubulus* typology, was made on account of the clear distinctions in form that existed among the studied *tubuli*. Also affecting this decision was the absence of proper scientific analysis of the fabric that would have been necessary for a fabric based typology.

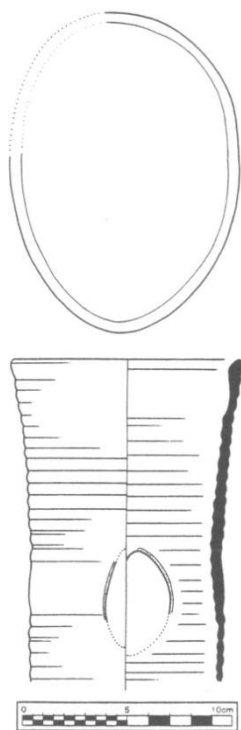
### **Regional Similarities in Form**

There is currently not enough information on *tubuli* to establish a well-defined regional typology. This lack of data is in large part due to the practice of not publishing *tubuli* in enough detail to allow for proper comparison among sites. Nevertheless, personal examination of *tubuli* from several sites in Roman Arabia, combined with the limited published material available, has elucidated several regional similarities in form. These similarities, with further development and refinement, can be used to establish a well-defined typology, which can then be used not only as a dating tool, but also as a means to further our understanding of the production and trade of ceramic building materials in the region.

One of these identified regional forms may represent the earliest *tubulus* used by the Nabataeans. This wheel-made *tubulus* form is characterized by unthickened rounded rims and wheel marks on both its interior and exterior surfaces heavy enough to resemble ribbing. This type is also very thin-walled relative to other *tubuli*. Its walls are typically less than 0.7cm thick, although they can be as thin as 0.4cm. These attributes are the defining characteristics that clearly differentiate this form from other wheel-made *tubuli* in the surrounding area. This study has identified this type of *tubulus* at only two sites:

Wadi Musa and Wadi Ramm. Of the examples from Wadi Musa, only two were available for study, neither of which have a datable context.

One fragment (fig. 3.3) comes from a pottery dump from kiln VI at az-Zurraba, Wadi Musa (‘Amr and al- Momani 1999: 185-86, fig 12.29). This dump contains material of a mixed date and was placed here some time after the abandonment of the kiln. It is therefore impossible to secure a date for the *tubulus* fragment based on its context. The other example from Wadi Musa (fig. 3.4) was uncovered with a backhoe during the Wadi Musa Water Supply and Wastewater Project (‘Amr and al- Momani 2001). This *tubulus* was not published in any report of the project, but was kept in storage where it was available for study with the permission of the excavator, Dr. Khairieh ‘Amr. Despite not having a clear context, the fabric of this *tubulus* suggests that it dates to the mid first century AD and was produced at the nearby az-Zurraba kilns (‘Amr, personal communication, July 2012).



**Fig. 3.3** Drawing of tubulus from fill of az-Zurraba kiln, Wadi Musa.  
(After ‘Amr and al- Momani 1999: fig 12.29, p. 185)



**Fig. 3.4** *Tubulus* uncovered with a backhoe, in Wadi Musa. (Courtesy of K. ‘Amr)



**Fig. 3.5** Broken *tubulus* from early excavations (1963) in bathhouse at Wadi Ramm.

(Photo by author with permission of Manal Basyouni, Aqaba Archaeological Museum Director)

At Wadi Ramm, many *tubuli* of this type were found, all of which came from a bathhouse that was constructed in the first century AD and destroyed sometime in the second century (Dudley and Reeves 2007: 407). Based on the fabric and context of the *tubuli* found at Wadi Musa and Wadi Ramm, this *tubulus* type dates to the first century AD. This date makes these *tubuli* some of the earliest in the region and certainly the earliest associated with the Nabataeans. It is therefore reasonable to assume that these *tubuli* represent the first *tubuli* made by the Nabataeans.

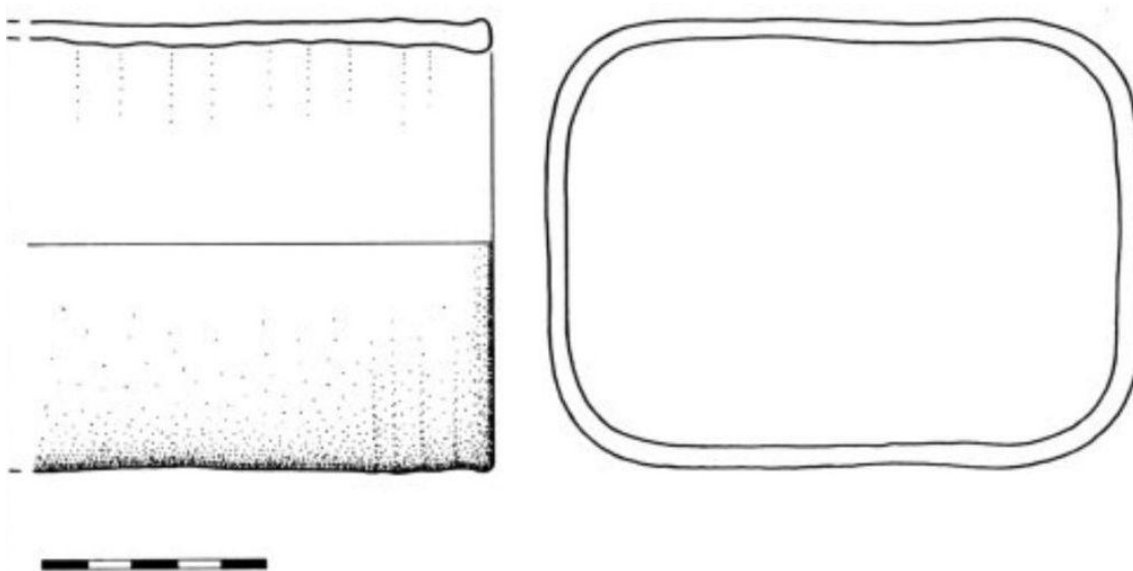
The most common form of *tubulus* in Roman Arabia is found at numerous sites, including Humayma (*Tubulus* Type 2), ‘Ayn Gharandal, Lejjun, and at several sites in Petra. Although similar in form overall, this group shows a great deal of diversity in certain features such as rims. The reasons for this variation will be discussed in detail in a subsequent section. To reflect the heterogeneity of this group, it is necessary to provide a purposefully ambiguous definition of this type, describing only the most common attributes. With this in mind, it can be said that this *tubulus* form is wheel-made with one end rectangular (in cross-section) and the other oval. The rims of this form vary greatly, but typically have some type of overhang, usually on the exterior. Future examination may be able to divide this group into better defined types, but until then a few general remarks can be made about its dating.

Archaeological evidence suggests that this variety of *tubulus* was first used in the second century AD. The earliest known use of these *tubuli* (fig. 3.5) comes from a heated room at Zantur IV in Petra (Kolb and Keller 2000: fig. 8). The construction of this room has been dated to the turn of the first to second century AD (Kolb and Keller 2001: 319), while its destruction dates to AD 363 (Kolb and Keller 2000: 362). Similar *tubuli* (fig. 3.6) have also been found in a dump context at Wadi Farasa, Petra (Schmid 2002: 261, fig. 13). As discussed in the second chapter, this *tubulus* form was also used in the second century AD at Humayma (*Tubulus* Types 2 and 4). This form appears to have remained the principle form of *tubulus* for several centuries. At the site of Lejjun, excavation uncovered many *tubuli* of this type (fig. 3.7) (Parker 2006: 361, figs. 16.76-16.79), which had been removed in antiquity from the garrison bathhouse. This bathhouse was functional from around AD 300 to the earthquake in AD 363 (de Vries and Lain 2006:

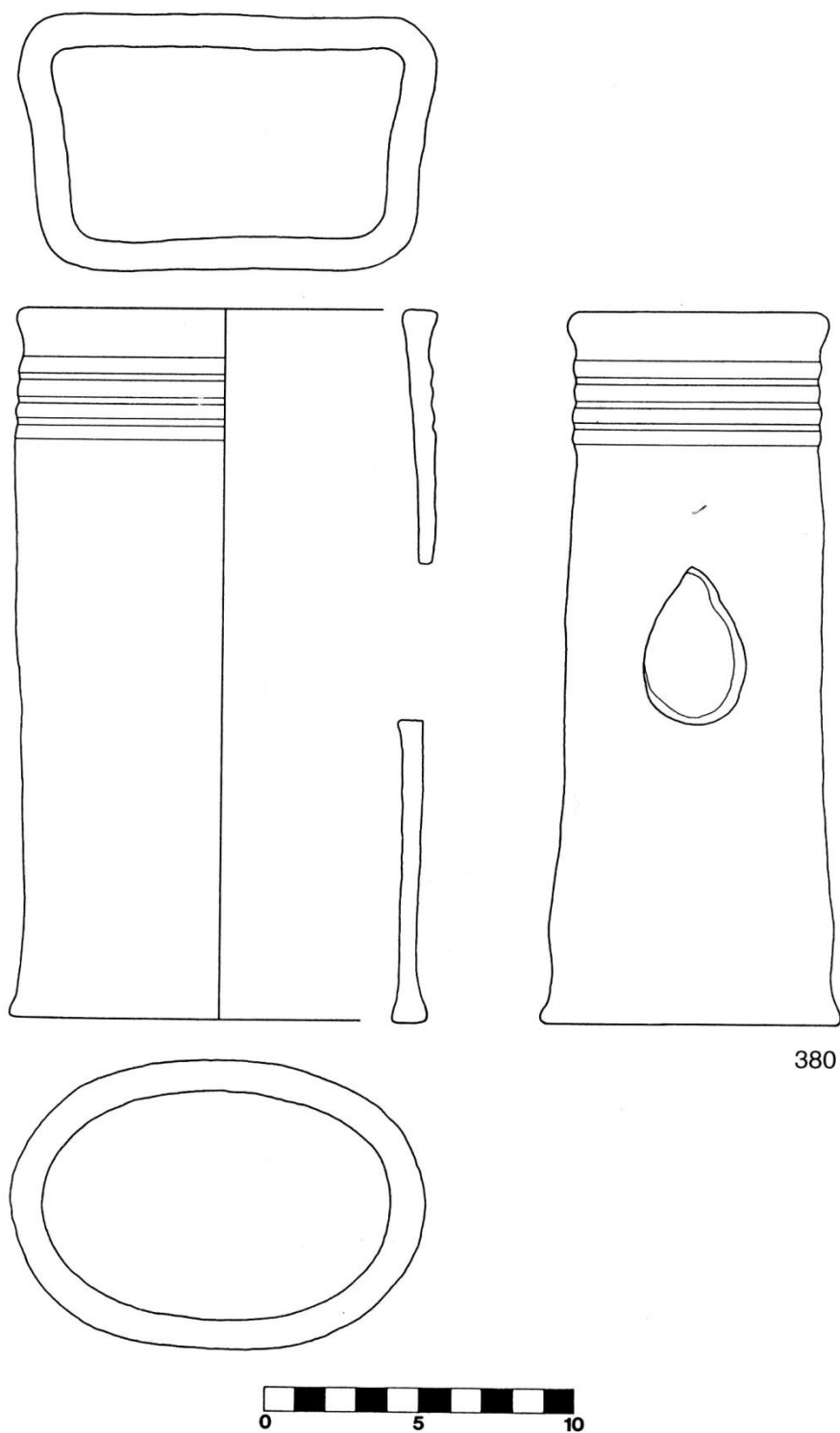
213). Likewise, similar *tubuli* found at Gharandal (figs. 3.10 & 3.11) (Darby *et al.* in press: fig. 11) come from a bathhouse associated with the nearby fort, occupied from around AD 300 to after the fifth century (Darby *et al.* in press). Based on the available evidence, this variety of *tubulus* was used from the beginning of the second century AD until sometime in the fourth century.



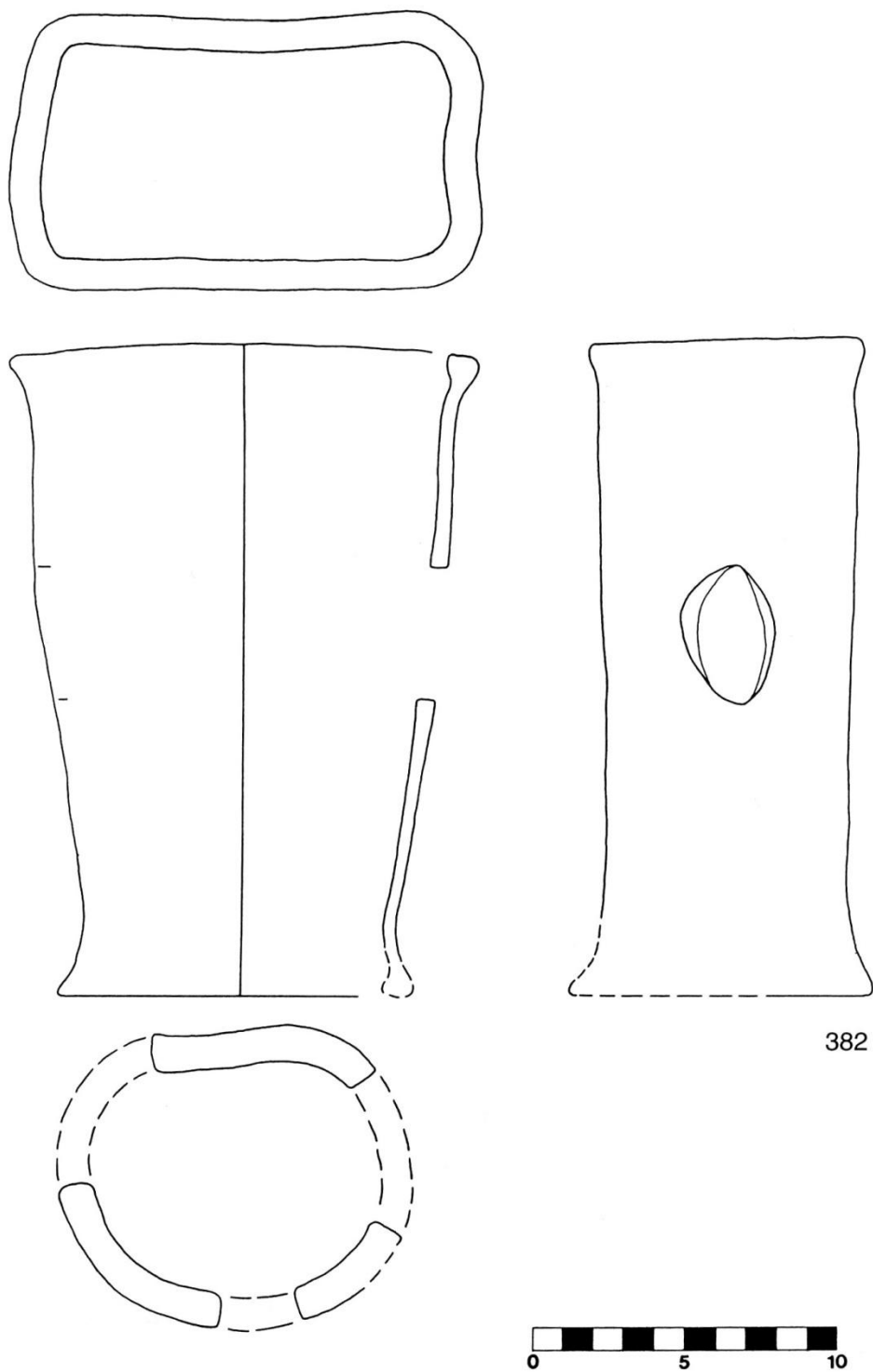
**Fig. 3.6** *Tubulus* uncovered from heated room of Zantur IV, Petra. (After Kolb and Keller 2000: fig. 8, p 362)



**Fig. 3.7** Drawing of *tubulus* from Wadi Farasa, Petra. (After Schmid 2002: fig. 13, p. 265)



**Fig. 3.8** *Drawing of tubulus from Lejjun.*  
(After Parker 2006 fig. 16.76)



**Fig. 3.9** Drawing of tubulus from Lejju.  
(After Parker 2006 fig. 16.78)



**Fig. 3.10** *Rectangular tubulus form 'Ayn Gharandal bathhouse (view of side).*  
(Photo by author with permission from R. Darby)



**Fig. 3.11** *Rectangular tubulus form 'Ayn Gharandal bathhouse (view of face).*  
(Photo by author with permission from R. Darby)

It is worth noting that the first *tubulus* form discussed, which is distinguished by its thin walls and rounded rims and found at Wadi Musa and Wadi Ramm, dates exclusively to before the Roman annexation in AD 106. On the other hand, the more common wheel-made *tubulus*, synonymous with the Humayma *Tubulus* Type 2, dates to after the annexation. A similar break in style at this time is found elsewhere in the ceramic record. For instance, there is a clear change in form and production of unguentaria at the turn of the first to second century AD (Johnson 1990: 237-40). Another contemporary ceramic change was the gradual decline in quality of Nabataean painted fine ware starting beginning after the first century AD (Schmid 2001b: 404). This

break in *tubulus* style is therefore not unparalleled, but may be part of a larger shift in the production of ceramics in the Nabataean world around the time of the Roman annexation. While it is possible that the production of ceramics was affected by the strife of the annexation, another explanation is that this shift reflects the mass production of these materials (Johnson 1990: 240).

The second chapter has already provided detailed discussion on slab-made *tubuli* in Roman Arabia, particularly on the slab-made *tubuli* from Humayma (*Tubulus* Type 1). Within this discussion, close parallels for the form of the Humayma *Tubulus* Type 1 were identified from the Central Baths in Jarash and the Byzantine Baths in Umm Qays. While the *tubuli* from these Decapolis cities are indeed similar in form to the Humayma *Tubulus* Type 1, they are nearly identical to each other in form, and may represent a regional style of *tubulus* specific to the Decapolis environs. Like those from Humayma, the slab-made *tubuli* from the Decapolis cities are formed within a wooden frame and exhibit excess clay and finger grooves on their interior corners. The main difference between the Humayma slab-made *tubuli* and the Decapolis slab-made *tubuli* is the treatment of their rims. On the Humayma *Tubulus* Type 1, the rims on both ends are simply squared off. In contrast, the rims of the Decapolis slab-made *tubuli* are folded inwards, creating an overhang and relatively narrow circular openings on both the top and bottom ends (Vriezen and Mulder 1997: 330, fig. 12).

Despite their similarity, there are differences in the size of the *tubuli* from Jarash and Umm Qays, but this varies even among *tubuli* from the same site. For example, the majority of slab-made *tubuli* from the Byzantine Baths in Umm Qays are stated as being 43cm high (Nielsen *et al.* 1993: 122); however, a registered and drawn *tubulus* measures

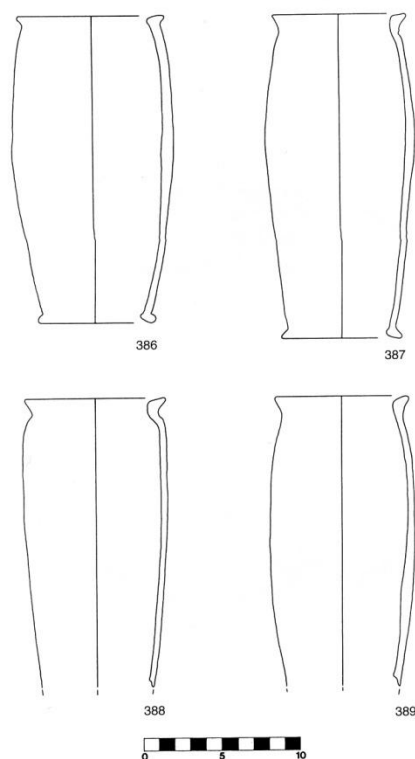
only 26cm high (Nielsen *et al.* 1993: 191, sherd 294; Pl.33.294). At the Central Baths in Jarash, on the other hand, a nearly complete *tubulus* measures 34.5cm high (Louise Blanke, personal communication, August 2012). It appears this form was therefore not limited to a particular size of *tubulus*.

The *tubuli* from the Central Baths at Jarash and the Byzantine Baths at Umm Qays are also contemporaneous with each other. The Central Baths in Jarash, from which the *tubuli* were recovered, were constructed in the late third century AD and destroyed in the early eighth century (Blanke forthcoming). At Umm Qays, the initial construction of the Byzantine Baths has been dated to the beginning of the fourth century AD (Holm-Nielsen *et al.* 1986: 220). By comparison, the Humayma *Tubulus* Type 1 is associated with the Roman phase (beginning in the early second century AD) of the Humayma bathhouse.

Based on the similar form and date of the *tubuli* from the Central Baths at Jarash and the Byzantine Baths at Umm Qays, it is evident that there is at least one distinct *tubulus* type for the Decapolis area. With further excavation and research, it will be possible to determine if this *tubulus* form was used in other Decapolis cities. Future research can also ascertain the full extent of this form's distribution. Slab-made *tubuli* from neighbouring Judea, from both a late third/early fourth century context at Jalame (Weinberg 1988: 248-49) and a Byzantine bathhouse at Tel Tanninim, near Caesarea Maritima (Stieglitz 2006: 95-6, fig. 90), show similarities to this form but do not appear to be of the same type.

The regional forms described above represent a majority of the various *tubuli* found in Nabataea and Roman Arabia, but they do not cover all of them. In addition to

these regional types, there are several unique forms that do not have regional parallels and require further excavation or research to determine their relation to other *tubuli* in Roman Arabia. One site with several of these unique *tubuli* is Lejjun. Here, several distinctive wheel-made cylindrical tubes were found (fig. 3.12) (sherds 386-89, Parker 2006: 361, fig. 16.81). These ceramic tubes were cylindrical, but have neither a carination in the side wall nor different sized ends, characteristic of typical cylindrical flue pipes. No parallels are known for these tubes, but their discovery in the early fourth century bathhouse and the heavy charring on their interior surfaces make it clear that they were used as some sort of flue pipe for the hypocaust. Also within the garrison bathhouse at Lejjun, a rectangular *tubulus* fragment was found with a full height of only 13.7cm. This previously unpublished *tubulus* is not only far shorter than the other *tubuli* from Lejjun, but is also shorter than any *tubulus* encountered in this study.



**Fig. 3.12** Drawing of unique *tubuli* from Lejjun garrison bathhouse. (After Parker 2006 fig. 16.81)

Another site with distinctive *tubuli* is Khirbet al-Khalde south of Humayma. Excavation here uncovered a hypocausted room, labelled a bath, but no *tubuli* were mentioned or described in its publication (Waheeb 1996: 364). A visit to the site by the author found several fragments of *tubuli* on the surface. One of these *tubuli* was made with two clear vents on one side. While this feature is unique for the region, parallels do exist elsewhere. In Britain there are a few sites that have produced *tubuli* with two vents per side (Brodribb 1987: 75-76, fig. 33).

### **Variation in *Tubulus* Form**

Throughout this study, it has been apparent that there is a considerable lack of uniformity in form among *tubuli*, both between separate sites and even among *tubuli* within the same site. The absence of uniformity in form among *tubuli* from a single site likely stems from the fact that *tubuli* were made for a functional role and were intended to be covered with plaster and completely out of sight. There was therefore no need to take the time to make them aesthetically pleasing or perfectly identical to each other. Furthermore, there is evidence that uniformity was not even needed for the *tubuli* to function properly. It has already been argued that the varying heights of the Humayma *Tubulus* Type 2 did not diminish their ability to work efficiently together. Another factor that likely contributed to the variation in *tubulus* size is shrinkage, which results from the evaporation of water during drying and firing (Rice 1987: 63, 87). The effects of shrinkage vary based on the amount of water in the clay and firing temperature. Although

it does not account for differences in rim forms or large differences in sizes, shrinkage likely had some effect on the varying dimensions of the *tubuli*.

Complicating efforts to create a regional *tubulus* typology is the variation in form between sites. While significant differences in form can be attributed to separate production centres, smaller variations between sites may have resulted from other factors. These inconsistencies in form were likely caused by a lack of continuous production. Unlike other ceramic material that was produced year after year, *tubuli* were required and produced much less frequently. The periodic orders for *tubuli* likely resulted in slightly different designs being produced with each new contract.

It is not only in Roman Arabia that such disparities exist among *tubuli* from different sites. In Britain, there are substantial differences in *tubulus* form and sizes from site to site (Brodribb 1987: 74-79). *Tubuli* from Herodian bathhouses, despite being produced in a relatively short period of time, also display a great deal of variety in their sizes. For instance, at Machaerus *tubuli* measure 6 x 12 x 31cm (Loffreda 1981: 89). While in the Herodian palace at Cypros, *tubuli* measure 10 x 16 x 34cm (Netzer 2004: 270), and at Jericho, *tubuli* from the First Winter Baths measure up to 37.5cm in height (Pritchard 1958: 11). Although the reasons for these variations outside of Roman Arabia have not been explored, it is evident that the absence of uniform *tubuli* within Roman Arabia is not abnormal.

### **Fabric and Production Centres**

It is not only the form of the *tubuli* that varies, but also their fabric. This variation in fabric suggests the existence of multiple production centres in the region. Thus far, the only *tubuli* from Roman Arabia that have undergone petrographic analysis are those from Umm Qays (Vriezen and Mulder 1997: 328-30). In order to determine definitively the location of regionally *tubulus* production centres, further petrographic analysis is needed. In the absence of petrology, I suggest a few likely sources based on personal macroscopic analysis of the fabric.

Although they were not the only production centres in Roman Arabia, the two primary sources for *tubuli* in the south seem to be Petra and Aqaba. It is no surprise that these sites were prominent production centres for *tubuli*, since both Petra (‘Amr and al-Momani 1999) and Aqaba (Parker 2007: 361-63) had kilns that were used for the production of other ceramic material. Additionally, Petra was the commercial heart of Nabataea and southern *Provincia Arabia* (Fiema 2003: 49-50), and recent excavation at Aqaba has revealed that this port city was likewise a centre of regional trade and industry (Parker 2007).

In theory, the difficulty of transporting building materials (see section below) would encourage the fabrication of ceramic building materials at smaller local centres as opposed to larger centralized sites. In an ethnoarchaeological study of brickworks (1979: 7), Peacock suggested that such centralized production centres only exist if one of three conditions holds. These conditions are that adequate clays are available in only one area, the products are able to be easily transported and widely distributed, and the production centre is located in a densely populated area that provides a high demand. In the case of Petra, almost all three of these conditions were met.

Although clay belts do exist elsewhere in the region, a large clay source is located just east of Petra near the town of Wadi Musa (Khairy 1982: 275). Traditionally, Petra was thought to have been connected to the *Via Nova Traiana* only by a secondary road. It has been suggested, however, that the *Via Nova Traiana* may have passed through Petra (Graf 1995: 242-44), giving it much easier access to regional markets. Petra was also a large settlement in its own right and represented a considerable consumer of building ceramics. It makes sense therefore that Petra was a major producer of *tubuli*.

Indeed, this study has found that the vast majority of *tubuli* from southern Roman Arabia appear to come from the Petra region. Sites with *tubuli* coming from this region seem to include: Humayma, Wadi Ramm, ‘Ayn Gharandal, Petra, Wadi Musa, and possibly even Lejjun. The fabric of the *tubuli* from these sites vary in colour and inclusions due to different clay sources, changing kiln conditions, or the operation of several different workshops, but these *tubuli* typically show a reddish/pinkish coloured fabric. Common inclusions for these *tubuli* are well-sorted fine/medium sub-rounded/sub-angular clear quartz sand with occasional small white inclusions and occasional very small black flecks. This fabric is consistent with that of ceramics known to have been produced in the Petra region, such as those found in association with the az-Zurraba kilns on the outskirts of the city (‘Amr and al- Momani 1999: 180-88).

It should be no surprise that the *tubuli* found at Petra and Wadi Musa were manufactured at these nearby pottery kilns. For the sites further away, one would expect to see a correlation between the source of *tubuli* and the primary source of other ceramic material, but this is not always the case. At Humayma, for instance, the *tubuli* seem to have been produced at Petra (see Chapter Two), which was also the source for the bulk of

other ceramic material (Reeves *et al.* 2009: 252; Oleson 2010: 327; Oleson and Schick forthcoming). At 'Ayn Gharandal, on the other hand, the *tubuli* appear to have come from Petra, while the primary source of ceramic vessels was Aqaba (Darby *et al.* in press).

Although Aqaba did not supply 'Ayn Gharandal with *tubuli*, it seems to have been the source of this material for a couple of sites in the south. The *tubuli* from Khirbet al-Khalde and Qasr el-Kithara have fabric that is heavily micaceous. This distinctive inclusion is characteristic of ceramics produced in Aqaba (Dolinka 2003: 63). Despite an uphill climb through the Wadi Yitm, both Khirbet al-Khalde and Qasr el-Kithara are within 40km of Aqaba. Given the close proximity of these sites to Aqaba and their distance to Petra, it makes sense that the *tubuli* from these southern sites were produced in Aqaba. At Khirbet al-Khalde, the presence of other ceramic material made in Aqaba, supports the argument that Aqaba was a major supplier of these southern sites (Dolinka 2003: 84).

In some cases, a site has *tubuli* that come from two production centres. At Lejjun, a majority of the *tubuli* appear to have come from Petra, with at least one strange exception. A previously unpublished *tubulus* fragment has fabric matching the coarse ware pottery produced in the local region, which suggests that it too was produced locally and not in Petra. Despite having a different fabric and coming from elsewhere, this *tubulus* is of the exact same form as the other rectangular *tubuli* from the site (Parker 2006: 361, figs. 16.76-16.79). Although no kiln sites have yet been found near the fort of Lejjun, there clearly was a local ceramic industry, and it has been theorized that the legionary soldiers themselves produced ceramic building materials found in the fort (Parker 2006: 362). As previously mentioned in the second chapter, it seems to have been

common practice for legionary soldiers in the area to produce their own ceramic building material. Such legionary production centres are known to have existed at Bostra (Brulet 1984), Jerusalem (Arubas and Goldfus 1995), and at Legio in Israel (Tepper 2007: 68).

The two different fabrics found at Lejjun suggest that there were two production centres supplying the *tubuli* for the garrison bathhouse at Lejjun. It is puzzling, however, that *tubuli* should have been shipped from Petra all the way north to Lejjun, when there was a functioning *tubulus* production centre near the site. It is possible, perhaps, that this locally made *tubulus* was only made as a replacement for broken *tubuli* or to make up a shortfall in the supply. In Roman Britain, sites were often supplied with *tubuli* from multiple production centres, and at times these were transported over long distances (Black 1996: 67). Whether a similar supply system existed for Lejjun remains unknown, but this apparent locally made *tubulus* demonstrates that the technique of making wheel-made *tubuli* was not confined to Petra and Aqaba. Future excavations and analysis of *tubuli* from other sites in the region may identify other production sites for this material.

Macroscopic analysis of fabric has suggested the existence of at least two major supply centres, Petra and Aqaba, for *tubuli* in southern Roman Arabia. A third production centre may have existed near Lejjun. All three of these centres are too far south to have supplied the *tubuli* found at both Jarash and Umm Qays. As mentioned above, the *tubuli* from the Central Baths at Jarash and the Byzantine Baths at Umm Qays are almost identical to each other in form. Although this similarity suggests a shared production centre, there is not enough evidence from their fabric to confirm this theory.

Umm Qays is the only site in Roman Arabia where the fabric of *tubuli* has been examined using petrology. This analysis found that the *tubuli* were of a common ware

and were most likely made from local clay (Vriezen and Mulder 1997: 330). A specific kiln site has not been identified.

Unfortunately, the fabric of the *tubuli* from the Central Baths at Jarash is not described in enough detail to speculate on their source based on their ware. Since Jarash and Umm Qays are so close in proximity, it is conceivable that the *tubuli* from the Central Baths at Jarash were produced at the same place as the *tubuli* from Umm Qays. This theory is supported but not proven by their similar form. Another possible source for the *tubuli* from the Central Baths at Jarash is Jarash itself.

Excavations in the Jarash Hippodrome have revealed a large number of pottery workshops, which are thought to have played a major part in the supply of ceramic material to the region (Kehrberg 2007). A wide variety of ceramics were made here, including ceramic building materials. This site is known to have produced hypocaust tiles and cylindrical pipes in great numbers, and exact parallels of these pipes have been found in water systems throughout the city (Kehrberg 2009: 509-10, fig. 10). Although there is no mention of *tubuli* coming from these kilns, it is quite possible that they were indeed the source of the *tubuli* found in the Central Baths at Jarash. Not only did these workshops produce ceramic building material that was used in the city itself, but they were in operation at the time of the Central Baths' construction. These baths, constructed in the late third century AD, could have been supplied by the local workshop, which began in the third century and soon developed into what was potentially the biggest ceramic production centre of the Decapolis cities (Kehrberg 2009: 493). The large size of this production centre leads to the possibility that these kilns supplied the *tubuli* found elsewhere in the region. Again, no *tubuli* have been found to prove this hypothesis, but it

is supported by the fact that ceramic building materials found at other Decapolis cities were produced in Jarash, such as roof tiles found in Pella (Barnes *et al.* 2006: 306).

The discussion above has outlined the likely sources of *tubuli* in Roman Arabia. Despite being based in archeological evidence, this examination is hampered by the lack of scientific petrologic analysis of the ceramic fabric. With future research, it may be possible to confirm the sources of this material and to reconstruct the supply and trade of *tubuli* and other ceramic building material in the region.

### **The Trade in *Tubuli***

Trade was vital to the economy and thus the success of the Roman Empire. Far from being limited to luxury items and necessities such as grain, the Roman world supported trade networks of items not frequently associated with economic value. Among these less celebrated commodities was ceramic building material, including *tubuli*.

Despite the existence of a large trade network of this material, modern scholars are faced with many questions regarding the different scales of trade (local or regional), the routes and modes of transportation used, and the commercial dynamics of the industry (Gliozzo 2007: 59). In Roman Arabia, there is a glaring lack of research on the production and distribution of ceramic building materials, with the exception of a few site specific studies for Umm Qays (Vriezen and Mulder 1997), Jarash (Kehrberg 2009: 509-10), and Jabal Harun (Hamari 2008). This paucity is unfortunate given that the examination of this industry has the potential to reveal much about the regional economy and the organization of construction projects in Roman Arabia. Since the production of *tubuli* has already been discussed in this chapter, the focus will turn to the trade and

transportation of the material. While a comprehensive and definitive examination of the trade of *tubuli* in Roman Arabia is beyond the scope of this study, this section will seek to highlight some of the major issues associated with its study and suggest a few theories on the mode of its transportation.

Since relatively little is known about the trade of *tubuli* and other ceramic building materials in Roman Arabia, it is necessary to examine first its trade in other parts of the Roman Empire. One of the major factors affecting the mode of transportation was cost. This was especially true for ceramic building material, which was more expensive to transport due to its weight. The cost of transporting goods in antiquity varied widely and could be very expensive if done by land. In one of his many letters to the Emperor Trajan, Pliny bemoaned the exorbitant cost of transporting goods (including building materials) by road compared to the relatively cheap cost of their transportation by sea (*Ep.* 10.41.2). A comparison of figures in Diocletian's *Price Edict* also reveals just how much more expensive land-transport was in relation to other methods. Using the *Edict*, the cost ratio of transportation by sea : inland river : road is 1 : 4.9 : 34-42 (Duncan-Jones 1974: 368). Given these relative prices, it is no surprise that the sea was the preferred means of transportation for bulky goods such as ceramic building materials.

Taking advantage of the relatively cheap cost of shipping goods by sea, an intense and extensive seaborne trade of this material developed throughout the Roman Empire. In a comprehensive study of shipwrecks in the Mediterranean and Roman provinces, forty-five were found to have carried brick or tile, and two of these were carrying a cargo consisting entirely of tile (Parker 1992: 18-20). The existence of ships carrying only tile suggest that the trade of ceramic building material could be profitable in its own right. A

majority of the shipwrecks with tiles are from the Roman period (Mills 2005: 27-28, Tables 1.1 -1.2). Although the number of wrecks may seem small, when looking at data from shipwrecks, it is important to understand that the data represent only a small fraction of the maritime trade in building ceramics that occurred in the Roman world.

Based on evidence throughout the Mediterranean, the seaborne trade of ceramic building materials was very extensive. For example, the identification of Italian brick stamps in North Africa has revealed that, during the Severan period, this area was partially supplied with bricks from Campania (Mills 2005: 232). Conversely, underwater archaeology has uncovered numerous examples of *tubi fittili* that were being shipped from North Africa to Sicily and Italy in the third and the fourth centuries AD (Bound 1987: 194-97). Italian-made bricks were also shipped across the Adriatic Sea, and have been found in settlements along the Dalmatian coast (Wilkes 1979: 68). In the east, petrographic analysis of roof tiles found in Beirut has shown that they were fabricated in Cilicia (Mills 2005: 234). In fact, between first and third centuries AD, Eastern Cilicia seems to have been the primary source for roof tiles for most communities along the Syrian coast (Butcher 2003: 200).

For inland sites where transportation by sea was not an option, river transport was preferred over land transport. In central Italy, major brick kilns likely transported their goods both up and down the Tiber River and its tributaries (DeLaine 1997: 90; Gliozzo 2007: 69). River transport has also been suggested as a possible means of shipping roof tiles in Roman Britain (Warry 2006a: 124).

When not even river transport was an option, it was necessary to resort to land transport. Due to its slowness and expense, the transportation of ceramic building

material by land was likely done only over short distances or as a last resort. While it can be assumed that moving ceramic building material by road happened throughout the empire, this method is known to have been used in Dalmatia (Wilkes 1979: 68) and in Britain (Warry 2012: 55). Transporting bricks by road is also suggested to have been used by suppliers in central Italy (Gliozzo 2007: 69-70).

The range of distribution for ceramic building materials depended on a number of factors, and especially on the means of transportation. Evidence from Britain suggests that tiles were regularly transported up to 40km, and at times up to 80km, while *tubuli* are thought to have been transported even further (Warry 2006a: 124).

In Roman Arabia, the transportation of ceramic building materials including *tubuli* was severely hindered by the geography and topology of the region. Although the region had access to the Red Sea, it was almost completely devoid of inland waterways. The one exception is the Dead Sea, via which the Roman army besieging Masada may have been supplied with water from the springs at Ein Gedi (Magness 2009: 84). Nevertheless, there is no evidence that this body of water was used for transporting ceramic building materials or *tubuli*. Further obstructing transportation are the many mountain ranges, *wadis*, and plateaus that divide the region. Despite these obstacles, *tubuli* apparently made in Petra were transported over this difficult terrain to Humayma, ‘Ayn Gharandal, and several other sites. As previously mentioned, ceramic production centres in Petra and Aqaba were connected by the *Via Nova Traiana*, and it is mostly likely that their goods were transported by this route. Regrettably, land transport in Roman Arabia is a neglected subject, and there is not much information on how this necessary task was carried out.

Packsaddles, carts, and wagons were commonly used throughout the ancient world for land transportation; however, the manner in which goods were transported depended largely on the terrain and the character of the material being transported (Raepsaet 2008: 589-92). Harnessed carts and wagons were able to carry heavier loads, while the use of draft animals with packsaddles was more suitable for mountainous terrain. In difficult terrain without well constructed roads, pack animals with packsaddles had an obvious advantage over wheeled carts. The existence of well built roads such as the *Via Nova Traiana*, may have enabled the transportation of ceramic building materials including *tubuli* by cart or wagon.

Wheeled vehicles were certainly used in the region, as indicated by wheel ruts found in the paving stones of the Petra *Siq* (Bellwald *et al.* 2003: 33). Whether these carts, and particularly carts loaded with ceramic building materials, were easily able to travel along roads further afield remains unknown. As previously mentioned, it has been suggested that Petra was connected to the *Via Nova Traiana*, the primary commercial artery in Arabia (Graf 1995: 242-44). In addition to the *Via Nova Traiana*, and in contrast to the mistaken idea that Petra was an inaccessible stronghold, several passable roadways led to and from the city. These roads followed ascents gentle enough for camel traffic (Roll 2007: 122). It is possible that these roads were not too steep for wheeled vehicles to use. In the Eastern Desert of Egypt, large wagons carrying monumental stone columns were used with success despite the mountainous terrain (Adams 2007: 66-68). It is therefore conceivable, but not definitively known, that wagons and carts were used to transport ceramic building materials including *tubuli* in Roman Arabia. While the use of

wheeled carts is a possibility, a more reasonable assumption is that transport in this area was achieved by beasts of burden with packsaddles.

When considering the type of animal used in the transport of ceramic building materials, a few species can be immediately ruled out. As a result of the arid climate, oxen, which require much food and water, were not the optimal choice for desert transportation (Adams 2007: 63). Excavations at Humayma have uncovered faunal remains of bovines; however, these animals seem to have been bred for consumption as evidenced from bone cuts (Oleson 2010: 46-47).

Horses and mules are also unlikely candidates for the overland transport of bulky commodities in Arabia. Although used elsewhere in the Roman Empire for transport, these species were not often used for economic purposes in Roman Egypt (Adams 2007: 58-62). Despite being noted in antiquity as a superb pack animal (Columella *Rust.* 6.37.11), faunal remains of mules are surprisingly absent from several sites in central Jordan (Toplyn 2006: 292). The reason for this absence may in part be due to the cost and difficulty in their breeding (Adams 2007: 61-62). Compared to mules, there is even less faunal evidence for horses in the region (Toplyn 2006: 294).

With the elimination of these animals, only the camel and donkey remain. At Lejjun, these two species represent the vast majority of transport animals (Toplyn fig. 22.8). These beasts of burden were also heavily used for transportation in Roman Egypt (Adams 2007: 55).

Camels have a long history of domestication by humans in ancient Arabia for both military and transport purposes (Ripinsky 1975). Classical authors were keenly aware of the camel's aptitude for desert travel and use in these regions (Diod. Sic. 2.54.6-7; Pliny

HN 8.26). Due to their tolerance of arid climates, camels were and are frequently used as pack animals. In addition to being able to travel long distances without food or water, camels can also transport heavy loads. One estimate suggests a typical camel load in the incense trade at around 400 pounds (181kg) (Groom 1981: 160). A drawback to using camels, however, is the difficulty they face in traversing uneven and steep terrain (Borstad 2008: 63). Nevertheless, if the roads were indeed built with a gentle gradient, as suggested above, transportation by camels with packsaddles would not have been problematic. In Roman Egypt, camels were used for carrying various materials including hay and clay (Adams 2007: 72-73). In addition to being used as pack animals, camels could also be harnessed to carts. Evidence from the Eastern Desert suggests that teams of camels were used to haul monumental columns from the stone quarries (Adams 2007: 204-5). Assuming that carts or wagons were used on the *Via Nova Traiana*, it is possible that harnessed camels were used to transport *tubuli* and other ceramic building material to sites in Roman Arabia.

Donkeys, although not typically associated with deserts, can work without water for up to 60 hours and can carry loads of up to 150kg (Adams 2007: 57-58). These abilities, combined with their docility and surefootedness, made the donkey an excellent transport animal. Papyrological evidence reveals that donkeys were used in antiquity for transporting bricks (*P. Lond.* I 131 R, 73 and *P. Cair. Zen.* 3 59480). It can easily be assumed that donkeys were also used to carry other building materials, such as *tubuli*. Even today, donkeys are still used as pack animals at brick kilns in Egypt (Burn *et al.* 2010: 389).

In conclusion, it seems most likely that *tubuli* and other ceramic building material were transported in Roman Arabia using camels and donkeys. Whether the transportation of this material used wheeled carts or packsaddles remains undetermined.

Assuming the use of packsaddles, it is possible to estimate the number of pack animals needed for supplying a site with *tubuli*. As mentioned above a donkey can transport up to 150kg of goods, while a camel load is estimated at 181kg. These figures are somewhat misleading as the carrying capacity of donkeys, camels or any other animal is greatly dependant on the distance traveled and topographical factors (Adams 2007: 78-81). While it may be impossible to reach an accurate figure, a few calculations give a basic understanding of the number of pack animals that might have been needed.

For this calculation, the Humayma *Tubulus* Type 4 will be used. This choice is based on the fact that *tubuli* of this type are relatively uniform in size, and several nearly complete examples provide a good idea about the weight of a *tubulus* (about 805g). Furthermore, the dimensions of the heated room from which they come are known, and thus it is possible to calculate the approximate number of *tubuli* that would have been required to furnish it. One of the unknowns concerning the number of these *tubuli* is the number of walls that were covered with *tubuli*. The following calculations will therefore assume that only the north wall held *tubuli*.

Since the north wall was 3.4m across and the average width of a *tubulus* was 16cm, there would have been 21 *tubuli* on each row. Estimating the number of *tubuli* per column is more difficult, given the dilapidated state of the walls. At the Lejjun bathhouse, wall heights are 2.08m from floor to the base of the lowest vault springer, and 3.41m from floor to the apex of the vault (de Vries and Lain 2006: 215). Based on these figures,

it is reasonable to assume that the height of the walls in the non-vaulted heated room in the *Praetorium* were about 2.5m. At 18cm in average height, there would have been about 14 rows of *tubuli*. At approximately 21 *tubuli* across and 14 *tubuli* high, this one wall would have contained 294 *tubuli*. With a weight of about 805g per *tubulus*, a total of 237kg of *tubuli* would have been required. According to the above carrying capacities, the weight alone of these *tubuli* would have required fewer than two donkey loads, or slightly more than one camel load.

Although the weight of these *tubuli* could have been carried by two donkeys or camels, their bulk may have been too unmanageable for only two pack animals. Furthermore, due to the fragility of the *tubuli*, extra care would have had to be taken to ensure that as many *tubuli* as possible made it to the site intact. With sufficient cushioning, the risk of breakage would be mitigated. This extra weight, however, would increase the number of pack animals needed. It is also important to remember that the figures above represent the minimum number of *tubuli* needed for only one wall, and it does not take into consideration the extra *tubuli* needed in case of breakage.

Although the number of pack animals needed for the shipment of *tubuli* for the *Praetorium* is not large, a great many more would have been needed for the more numerous *tubuli* used in the nearby bathhouse. An even greater number of beasts of burden were needed for the transportation of other ceramic building materials such as the brick and tile used at the site. Based on the estimated existence of 18,000 *imbrex* tiles reused in the aqueduct at Humayma, approximately 18,000 *tegulae* (pan tiles) are thought to have existed as well (Oleson 2010: 329). With an individual weight of about 8.43kg,

these 18,000 *tegulae* would have had a total weight of 151,740kg. This number represents about 1011 donkey loads, or 838 camel loads, not including the 18,000 *imbrex* tiles.

Although it is difficult to determine the exact number of animals needed for the transportation of *tubuli* and other ceramic building materials, it is clear that the transportation of this material required an established system of land transportation in the region. The use of wheeled carts would have decreased the number of transport animals needed, but only if these vehicles could be used effectively in the region. The topic of land transportation in Roman Arabia remains poorly understood, but its continued study is vital to the understanding of the regional economy.

### **The Reuse of *Tubuli***

Ceramic building material was often reused in the Roman world, and this practice is even recommended by Vitruvius in his *De Architectura* (2.8.19). The reuse of old brick was much more economical than the production and transportation of new material. This economic benefit was especially true in urban centres where there was a large supply of previously used building materials (DeLaine 2001: 241-46). In Roman Arabia, there is ample evidence for the reuse of ceramic building material. Excavation of a water channel at Humayma revealed that the conduit was formed by reused and inverted *imbrices* (Oleson 2010: 328-30, figs. 6.1-6.3). While the *imbrices* were reused in the aqueduct, the corresponding *tegulae* (pan tiles) are surprisingly scarce in the archaeological record of the site. This notable absence has led to the theory that the tiles were exported for reuse at other neighbouring sites (Oleson 2010: 329). Reuse of ceramic building materials is evident elsewhere on site. In the Humayma bathhouse, the subfloor of the hypocaust in

the Byzantine phase *caldarium* was paved with circular *bessales* taken from the *pilae* of the Roman phase of the bathhouse (Oleson 2010: 228, fig. 4.52). This reuse is paralleled exactly at Lejjun, where the floor of a barrack room was paved with circular *bessales* removed from the nearby bathhouse (Groot *et al.* 2006: 176).

As of yet, there is no definitive proof that *tubuli* were removed from the walls and reused elsewhere. One possible reason for this may be that the removal of *tubuli* from their plaster encasement was too difficult or time consuming to be of much benefit. The fragile *tubuli* were simply too prone to breaking, and thus no attempt was made at salvaging them.

In most cases, it seems that used *tubuli* were merely discarded when removed from the wall. A pottery dump in Wadi Farasa, Petra, contained large quantities of broken *tubuli* likely thrown there from a nearby heating installation (Schmid 2002: 261). At Humayma, recent excavations around the bathhouse have uncovered multiple dumps of broken *tubuli* and hypocaust bricks. This ceramic building material was removed from the bathhouse during one of its renovations and thrown away.

Despite the possible complications, there is some evidence that *tubuli* were in fact removed for reuse elsewhere. A large assemblage of *tubulus* fragments from a kitchen in the Lejjun fortress has been hypothesised to represent either the temporary storage of *tubuli* or that their fragments were used in the fill of installations (Lain and Parker 2006: 138). At the Central Baths in Jarash, the absence of any complete *tubuli* has led to the theory that they were removed for use elsewhere (Blanke forthcoming). It is not known whether or not the remaining fragments were removed from the bath as complete *tubuli*, and only then were subsequently broken. Either way, neither of these examples is

definitive proof of the material's reuse. Until they are found in secondary use, it will not be possible to say with certainty that *tubuli* were in fact reused. As with almost all aspects of this material, further research is needed in order to fully understand how *tubuli* were used in Roman Arabia.

This chapter has provided discussions on *tubuli* systems, the form and fabric of *tubuli*, and the trade and reuse of this material in Roman Arabia. The purpose of these discussions has been to place the Humayma *tubulus* corpus in its wider context. Further research must be done on *tubuli* and their use in Roman Arabia in order to properly understand this material. It is hoped that this study has provided a strong basis for future work on this material.

## **Conclusion**

This study began with the goal of learning as much as possible about *tubuli* and their use at Humayma and in Roman Arabia as a whole. It was anticipated that such an investigation would demonstrate the potential of studying ceramic building material on a larger scale and elsewhere in the Roman Empire. Through a detailed and thorough examination of the *tubuli* from Humayma and a number of sites in the region, this once overlooked material is now much better understood. In addition to discovering more about *tubuli* themselves, this study was able to use *tubuli* to gain insight into economic and cultural aspects related to their use.

Among the many results of this study was the identification and description of four distinct types of *tubuli* used at Humayma, and using these types, a well-defined chronological *tubulus* typology has been established for the site. This typology has also been used to help guide an initial examination of regional *tubulus* forms. The identification of several regional forms has proven the potential for a well-defined regional *tubulus* typology. One of the most significant findings of this project is the identification of the wheel-made *tubulus*. This form, apparently unique to the region, was first created by the Nabataeans in the course of their importation of Roman bathing technology, most likely via the Herodian bathhouses. The existence of the wheel-made *tubulus* highlights the ingenuity of the Nabataeans, their skill with ceramics, and their desire to adopt the most advanced form of central heating for themselves, even before the Roman annexation in AD 106. At the same time, the longevity of this local *tubulus* production method, despite the arrival of the Roman technique of making slab-made *tubuli*, provides insights into the cultural exchange between the Nabataeans and the

Romans in the period following the annexation. The continual production of wheel-made *tubuli* suggests that the local Nabataeans retained some level of control over the supply of ceramic building material, even to the point of supplying the ceramic building material for Roman forts, just as they supplied fine wares. Perhaps this local control accounts for the apparent lack of legionary brick stamps in south and central Roman Arabia (c.f. Parker 2006: 361). Although not proven, this study has also suggested that the majority of *tubuli* in south and central Roman Arabia were manufactured in the Petra region. Aqaba also seems to have been a source for this material. Through the tentative identification of these production centres and the sites that they supplied, this study has demonstrated that *tubuli*, and presumably other ceramic building material, were traded in large quantities and over long distances in the region. The ability and willingness of the ancients to transport such bulky material over such difficult terrain suggests the existence of a well organized system of internal trade and the necessary infrastructure to support it. The extent of this trade shows the importance placed on ceramic building material in antiquity, both in Roman Arabia and throughout the Roman Empire. This study has also shown that even marginalized areas on the edge of the Roman Empire could support a ceramic building material industry, despite a paucity of resources and the difficulty of its transportation. These findings have the potential to be used by other studies on the trade of ceramic building material elsewhere in the Roman Empire.

The initial impetus of this study was the need to document the phases of the Humayma bathhouse better by dating previously un-datable *loci*. It will be interesting to see whether the chronological Humayma *tubulus* typology will be of any assistance. If so, the creation of a regional *tubulus* typology may likewise be used to help date structures

throughout the region. It is also hoped that this study will act as a starting point for future studies on *tubuli* in Roman Arabia or other regions of the Roman Empire.

This study represents the very first specific examination of *tubuli* in Roman Arabia, although it is far from being the definitive work on the subject. There are several issues that must be examined further to understand fully *tubuli* and their use in Roman Arabia. One of the most important future projects for the study of *tubuli* in Roman Arabia will be petrographic analysis of their fabric, which will help identify their source. It is also important to investigate and collect further data from known bathhouses in the area in order to help support the establishment of a well defined regional typology. With the creation of such a typology, it will be possible to comprehend the distribution of the material and how this distribution changed over time. Another future endeavor will be to examine early Islamic *tubuli* in an attempt to understand how they evolved from earlier forms. Since the Islamic *hammam* developed in this general region, it is conceivable that it was the *tubuli* from Roman Arabia that influenced the early Islamic *tubuli*. Such a study will further the understanding of how Islamic *hammams* developed and the cultural exchange that occurred during the beginning of the Islamic period. Although this study has looked at comparanda from Israel and Syria, so far there has been no intensive research on *tubuli* from these areas, and as a result it is difficult to compare the corpus from Roman Arabia to *tubuli* from the wider region. Such studies will be necessary in order to properly understand how the *tubuli* from Roman Arabia relate to those in the surrounding territories.

If nothing else, this study has shown just how much can be learned from studying such seemingly unremarkable objects in great detail. The continued study of *tubuli* and

other ceramic building material in Roman Arabia is sure to reveal even more about not only these objects but also their role in the regional economy and cultural exchange. In summation, this work has shown the importance of overlooked artefacts to the archaeological record and how so much information about ancient economy and even culture can come from the study of something as unremarkable as the *tubulus*.

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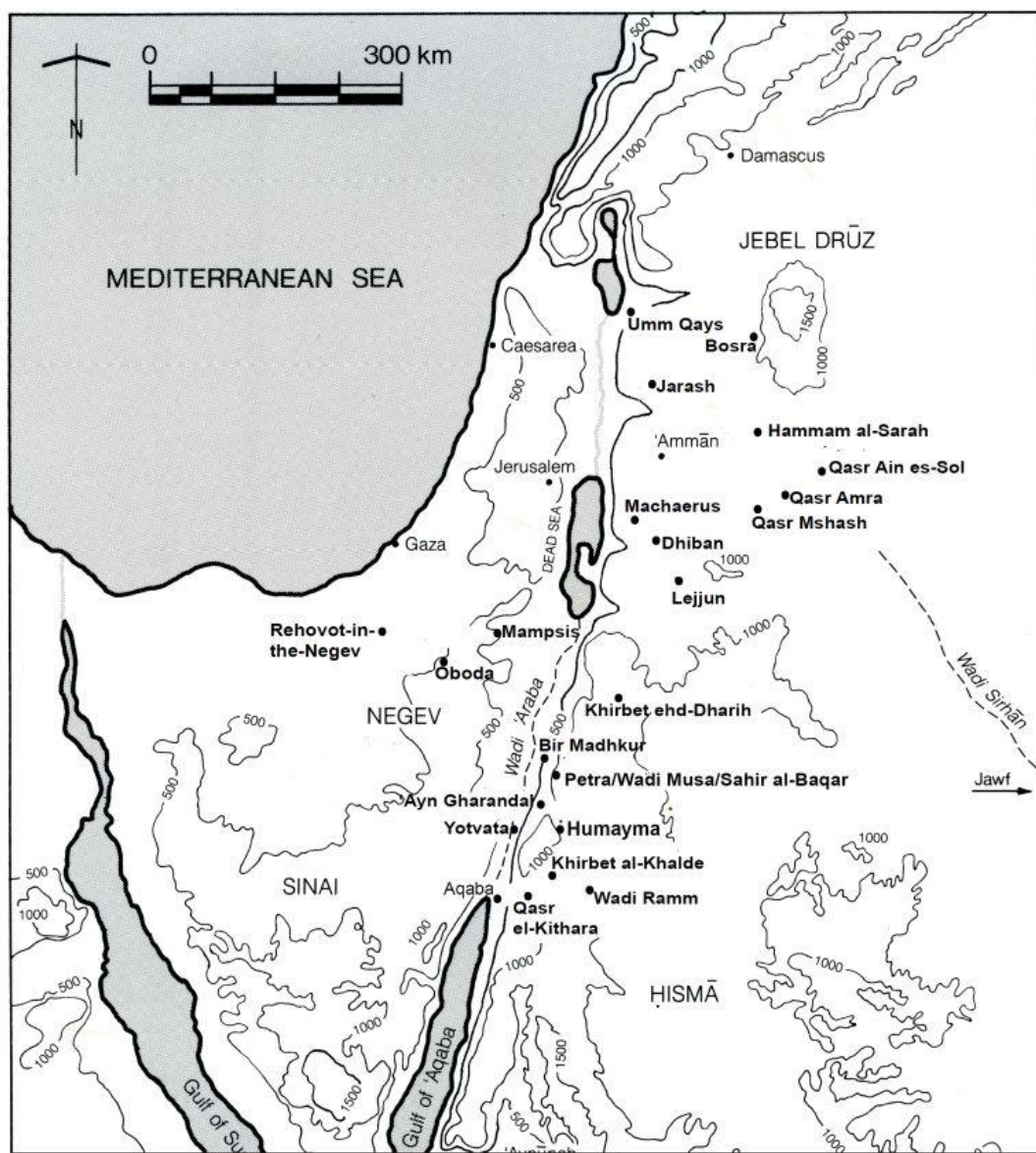
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## Appendix: Catalogue of Sites in Roman Arabia with *Tubuli*

This catalogue provides descriptions of the *tubuli* and their use from all sites in Roman Arabia where *tubuli* are known to have been found at the time of the completion of this thesis (April, 2013). The sites are listed in alphabetical order and include on those sites within the borders of Roman Arabia, as defined in the first chapter.



**Fig. Appendix.1** Map showing sites in Roman Arabia with *tubuli* in bold.

(Map by author, after Oleson 2010: fig. 2.1, p. 22.)

## Herodian, Nabataean, Roman, and Byzantine Structures with

### *Tubuli*

**SITE NAME:** ‘AYN GHARANDAL.

**Site location:** E side of Wadi ‘Arabah, ca. 100km N of Aqaba, 40km SW of Petra. (30° 5'11.47"N 35°12'12.19"E)

**Type of structure:** Bathhouse associated with nearby *castellum*.

**Excavation:** Excavation is ongoing.

**Dating:** Associated fort occupied from the late 3<sup>rd</sup>/early 4<sup>th</sup> century AD throughout the 5<sup>th</sup> century.

**Preservation of structure and *tubuli*:** The bathhouse is extremely well preserved, and full batteries of *tubuli* exist *in situ*. Several perfectly preserved *tubuli* and cylindrical flue pipes have been uncovered.

**Description of *tubuli*:** (From personal examination.) Both rectangular *tubuli* and cylindrical flue pipes exist at Gharandal, and there are two clearly different types of cylindrical flue pipe.

- **Rectangular *tubulus*:** These tubes are similar in form to Humayma *Tubulus* Type 2. They are wheel-made, and then pressed into final shape by hand. One end is typically rectangular, and the other is oval. One perfectly preserved example has measurements of 16.5cm high, 14.5cm wide and 12.5cm deep. Other examples show that the height varied from 16.5 to 19cm, and the width

varied from 14.5 to 16cm. Rim forms vary greatly. Some are thickened with an exterior overhang; others display a more rounded or flattened rim with no overhang. Typically, the rim on the oval end (bottom) is rough possibly from being cut off the potter's wheel by a string. Typical vent shapes include irregular ovals, ovals pointed at both ends, and tear shapes. The fabric ranges in colour but is usually reddish or pink. Typical inclusions are well-sorted, fine and medium sub-rounded clear quartz sand, a few very coarse sand, some white flecks, and some small voids.

- **Small cylindrical flue pipe:** This hollow pipe has both a small (male) end and a large (female) end thanks to a carination in its side wall near the male end. One complete example is 26.7cm long, and has a diameter of 11.8cm at its shoulder. The male rim is rounded and has a diameter of 8cm. The female rim is also rounded and has a diameter of 11-11.8cm. The length of the neck is 3.1cm.
- **Large cylindrical flue pipe:** This hollow pipe has both a small (male) end and a large (female) end thanks to a carination in its side wall near the male end. Several complete or nearly complete examples exhibit a range in lengths from 33.5 to 37.5cm. The diameter at the shoulder ranges from 13.5 to 15cm, and the length of the neck varies from 2.5 to 3.8cm. The male rim typically is rounded and can vary from 9 to 11cm in diameter. The female end is usually thickened and some examples present an exterior rounded overhang. The diameter of the female end can range from 14 to 16cm.

**Description of *tubuli* use:** *Tubuli* exist *in situ* in two heated rooms, which are labelled the *tepidarium* and the *caldarium*. In the *tepidarium*, cylindrical flue pipes line the

walls in the manner typically associated with rectangular *tubuli*. The *caldarium* contains typical rectangular *tubuli*. Close examination of a photograph of the partially excavated *caldarium* suggests that the *tubuli* terminated in a horizontal header. This arrangement implies an open *tubuli* system.

**References:** Darby *et al.* 2010: 191-94, 198; Darby *et al.* in press.

**Images:** (Pipe fragments) Darby *et al.* 2010: 198, figs. 19 and 20; (Whole pipes and pipes *in situ*) Darby *et al.* in press. In this work: figs. 3.1, 3.2, 3.10, and 3.11.

**Drawings:** None.

**Comments:** Permission to study the *tubuli* from Gharandal was generously provided by directors Robert Darby and Dr. Erin Darby.

**SITE NAME:** BIR MADHKUR.

**Site location:** E side of Wadi ‘Arabah, about 10km NW of Petra. (30°23’45.26"N 35°20’37.63"E)

**Type of structure:** Presumed bathhouse associated with nearby *castellum*.

**Excavation:** Several trenches opened in structure.

**Dating:** Presumed bath complex is contemporary with nearby fort, which was constructed in the 4<sup>th</sup> century AD.

**Preservation of structure and *tubuli*:** Not known. Only fragments of *tubuli* found.

**Description of *tubuli*:** No description is given.

**Description of *tubuli* use:** Not known. Fragments of *tubuli* not found *in situ*.

**References:** Smith 2010: 147-48.

**Images:** None.

**Drawings:** None.

**Comments:** None.

**SITE NAME:** BOSRA (Syria).

**Site location:** 140km S of Damascus. (32°31'12.75"N 36°28'56.70"E)

**Type of structure:** Large public baths (the Central Baths).

**Excavation:** Partially excavated.

**Dating:** The bathhouse was constructed in the 2<sup>nd</sup> century AD, with additions and renovations in the 3<sup>rd</sup> and 4<sup>th</sup> centuries.

**Preservation of structure and *tubuli*:** The monumental structure lies in ruins, although many walls remain standing. The preservation of the *tubuli* is unknown.

**Description of *tubuli*:** No description of *tubuli* provided.

**Description of *tubuli* use:** *Tubuli* are mentioned to have existed in the heated rooms.

Artist's drawing shows *tubuli* against wall with recessed chimney behind them.

**References:** Fournet 2007: 245, 253.

**Images:** (Artist's reconstruction of bath showing *tubuli*) Fournet 2007: 253.

**Drawings:** None.

**Comments:** None.

**SITE NAME:** DHIBAN.

**Site location:** 64km S of Amman. (31°30'5.79"N 35°46'38.41"E)

**Type of structure:** Bathhouse

**Excavation:** Only one room (*caldarium*) excavated.

**Dating:** Roman or Byzantine.

**Preservation of structure and *tubuli*:** Not known.

**Description of *tubuli*:** No *tubuli* or cylindrical flue pipes are mentioned specifically, but the hypocaust is said to have a “pottery chimney”.

**Description of *tubuli* use:** Vertical recesses in each of the room’s four corners are said to have held a “pottery chimney”.

**References:** Winnett 1952: 14-15.

**Images:** None.

**Drawings:** None.

**Comments:** None.

**SITE NAME:** HUMAYMA.

**Site location:** Hisma Desert, 80km north of Aqaba and 50km south of Petra.

(29°57'5.59"N 35°20'43.84"E)

**Type of structure:** Bathhouse associated with nearby fort.

**Excavation:** Excavation has been completed.

**Dating:** Constructed in early-mid 2<sup>nd</sup> century AD, renovated sometime after a brief abandonment in the late 3<sup>rd</sup> century, in use until throughout Late Byzantine period (AD 550-640). It is possible that this bathhouse was still in use during the early Islamic period (AD 640-750).

**Preservation of structure and *tubuli*:** Much of the Roman phase bathhouse from the 2<sup>nd</sup> century was built over or robbed out to foundation levels by the major renovation/reconstruction of the baths after its abandonment in the late 3<sup>rd</sup> century. The Byzantine phase structure is partially preserved, while the hypocaust system from this phase is largely intact. The central part of the structure was built over and cleared out for a house in the mid 20<sup>th</sup> century. In 1988, a year before excavation began, the hypocaust in the *caldarium* was partially destroyed by clandestine digging. The *tubuli* are fragmented and not *in situ*. Only one half of a *tubulus* remained *in situ* at time of excavation.

**Description of *tubuli*:** (For the full description see Chapter 2) Personal examination identified three clear types of *tubulus*:

- **Humayma *Tubulus* Type 1:** This is a slab-made *tubulus*. The samples collected are very fragmentary, but one example measures 19.6cm high, 16.4cm wide, and 14.5cm deep. The wall thickness ranged from 1 to 1.5cm, but could be up to 3cm

in the corners, thanks to the production method. A small circular hole (about 1.1 by 1.6cm) formed the vent in the side wall, and was likely made by a finger. The fabric ranged from a hard sandy fabric to a silty straw-tempered fabric. The hard and sandy fabric can range in colour, but is predominantly reddish yellow, light brown, or very pale brown (Munsell: 5YR 6/6; 7.5YR 6/4; 10YR 7/3). Typical inclusions are well-sorted, medium, sub-rounded and sub-angular clear quartz sand, with some very coarse sand. This fabric also has some very small to medium voids, a few of which may be from straw temper. The silty fabric is often pale brown in colour, although some fragments are pink (Munsell: 10YR 6/3; 7.5YR 7/4). This fabric is predominantly made up of fine silt, but there is also well-sorted, medium, sub-rounded and sub-angular clear quartz sand. Samples also have a few white flecks and many small to medium voids, many of which are from straw temper.

- **Humayma Tubulus Type 2:** This *tubulus* is wheel-made and is distinguished by its relatively wide depth. Once removed from the wheel, it is pressed into final shape by hand. One end is typically rectangular, and the other is oval. Eight full heights range from 16.9 to 20.8cm, while two complete widths measure 17.6 and 17.8cm, and two full depths are 13.4 and 14.0cm. The rims vary, but most commonly are thickened, either with an exterior overhang, or a more rounded profile. The lateral vents vary between being oval, oval with points on both ends, and tear shaped. These vents were cut out using an unknown tool. The common fabric colours include red and light red (Munsell: 2.5YR 5/6; 10R 6/8). Examples of common surface colours are red, reddish-yellow, and dark grey (Munsell:

2.5YR 5/6; 7.5YR 7/6; GLEY 4/N). Some examples have a dark grey core (Munsell: GLEY 4/N). The inclusions are typically well-sorted fine sub-rounded clear quartz sand with occasional small white inclusions and a few very small black flecks. The fabric also contains occasional small to medium voids.

- **Humayma *Tubulus* Type 3:** This *tubulus* is wheel-made and is distinguished by its square vent. Excavation reports record a full height of 23.5cm. Two collected fragments show an average width of 14.4cm and a depth of 8.5cm. The wall thickness ranges from 0.6cm near the ends to 1.1cm in the centre. This *tubulus* type has three distinct rim types (see Chapter 2 for full description). In some cases these rims are trimmed off. This *tubulus* has square vents, which were cut out with a knife. The fabric is much finer than that of the Type 2 *Tubulus* and can range in colour from light red to light reddish brown to pale yellow (Munsell: 2.5YR 6/6; 5YR 6/4; 5Y 8/2). The surface colour can range from very pale brown to a reddish yellow (Munsell: 10YR 7/4; 7.5YR 6/6). The inclusions are typically well-sorted fine sub-rounded clear quartz sand. Some examples have occasional small white flecks, and all have some small voids.

Personal examination also identified cylindrical flue pipes from the bathhouse. Many cylindrical flue pipe fragments were uncovered, which were once placed into the vertical recesses of the heated rooms in the Byzantine phase. These pipes can be grouped into two variations. The first kind has a shoulder diameter of 12cm and a diameter of 11cm at the male end. The second type has a shoulder diameter of 10.5cm, a diameter of 9cm at the male end, and thick wheel marks on its walls. Both types are distinguished by a narrow

shoulder. These cylindrical pipes were used in conjunction with the Humayma *Tubulus* Type 3.

**Description of *tubuli* use:** (For the full description see Chapter 2.) Due to their fragmented nature and successive remodelling of the bathhouse, not much is known about the use of Humayma *Tubulus* Types 1 and 2, although they are theorized to have been part of an open *tubuli* system. Examples of Humayma *Tubulus* Types 3 were found *in situ* along the S wall of the *caldarium*, and the later phase cylindrical flue pipes were found associated with recessed vertical vents. The Byzantine phase *tubuli* system was most likely a closed system.

**References:** Oleson 1990a: 300, 302-303; Oleson 1990b: 152, 156-58; Oleson 2010: 223-24, 228; Reeves 2012b; Reeves and Harvey 2013.

**Images:** In this work: Type 1: figs. 2.6-2.7; Type 2: figs. 2.10-2.11; Type 3: figs 2.14-2.15, 2.18-2.20.

**Drawings:** In this work: Type 1: fig. 2.6; Type 2: figs.2.8-2.9, 2.12-2.13; Type 3: figs. 2.16-2.17; Cylindrical flue pipe: fig. 2.22.

**Comments:** Permission to study the *tubuli* from Humayma was generously provided by director Dr. M. Barbara Reeves and former director Dr. John P. Oleson.

**Type of structure:** Heated room in *Praetorium* of fort.

**Excavation:** Excavation has been completed.

**Dating:** Construction of hypocaust dated to the 2<sup>nd</sup> or 3<sup>rd</sup> century AD, while its destruction has been dated to the late 3<sup>rd</sup> or early 4<sup>th</sup> century.

**Preservation of structure and *tubuli*:** The walls of the room are fairly well preserved. The hypocaust and the *tubuli*, however, are heavily damaged. Only *pilae* remain *in situ*.

**Description of *tubuli*:** (For the full description see Chapter 2) Personal examination found that the corpus was homogenous, containing only one type of *tubulus*:

- **Humayma *Tubulus* Type 4:** This *tubulus* is wheel-made and is distinguished by its relatively narrow depth. Once removed from the wheel, it is pressed into final shape by hand. One end is typically rectangular, and the other is oval. Eight full heights range from 17.4 to 18.3cm, six full widths range from 15.5 to 16.5cm and four full depths range from 8.0 to 10.0cm. The wall thickness varies from 0.4 to 0.8cm. Rims on the top end tend to have an exterior overhang, while those on the bottom are flattened. Its vents are typically an irregular oval, oval with points on both ends, or tear shaped. The fabric can range in colour from reddish yellow, to red, to reddish brown (Munsell: 5YR 6/6; 2.5YR 5/8; 2.5YR 4/3). The surface colour is usually darker such as light brownish grey or even dark grey (Munsell: 10YR 6/2; 5YR 4/1). Some examples have a dark grey core (Munsell: 5YR 4/1). Typical inclusions for this *tubulus* type are well-sorted medium sub-rounded clear quartz sand, with some course to very coarse sand and some small white flecks. The fabric also contains some small voids. Many fragments have what appears to be efflorescence on their surfaces. A clear variant of the Humayma *Tubulus* Type 4 exists, which is characterized by its larger size and diamond-shaped vents.

Personal examination also identified the cylindrical flue pipe used in this system. This hollow pipe has both a small (male) end and a large (female) end thanks to a carination in its side wall near the male end. Its full height is around 27cm; the diameter of its body is

9.3cm; the diameter of the male end is 6.0cm; and the diameter of the female end ranges from 8.4 to 9.4cm. On the interior of the female end, a wide groove followed by a thick ledge was present on all samples. These pipes are exactly the same in form as water pipes from some hydraulic features at Humayma, which date to the 2<sup>nd</sup> or 3<sup>rd</sup> century AD (Oleson 2010: 330-31).

**Description of *tubuli* use:** (For the full description see Chapter 2.) No heating pipes were found *in situ*, but *tubuli* most definitely lined at least one of the walls of the room.

Cylindrical flue pipes were installed in vertical recesses in each of the four corners, and thus the system was likely a closed *tubuli* system.

**References:** Oleson 2008: 323-24; Reeves 2012b; Reeves and Harvey 2013.

**Images:** In this work: Type 4: figs. 2.24-2.25, 2.29.

**Drawings:** In this work: Type 4: figs. 2.26-2.28.

**Comments:** Permission to study the *tubuli* from Humayma was generously provided by director Dr. M. Barbara Reeves and former director Dr. John P. Oleson.

**SITE NAME:** JARASH.

**Site location:** 36.5km N of Amman. (32°16'45.07"N 35°53'28.53"E)

**Type of structure:** Bathhouse (this is the recently discovered Central Baths located near the southern *tetrakonia* and under the ruins of an Umayyad mosque).

**Excavation:** Excavation is ongoing.

**Dating:** Construction dated to late 3<sup>rd</sup> century AD; destruction dated to the early 8<sup>th</sup> century.

**Preservation of structure and *tubuli*:** Fairly well preserved. Many of the *pilae* remain in place. Large quantities of broken *tubuli* were found, but no intact ones.

**Description of *tubuli*:** (From personal communication with Louise Blanke, August 2012.) One nearly complete *tubulus* is slab-made and measures 34.5 x 19.5 x 21.5cm. Both ends have a circular opening (about 13 cm in diameter). Each side had a circular vent. One of these vents is about 6.5cm in diameter, while the other is partially damaged. On one face there is a layer of plaster (0.5-2.5 cm.). The other side has no visible features. The inside of the *tubulus* is blackened from use and has many finger lines.

**Description of *tubuli* use:** Although *tubulus* fragments were uncovered in many areas of the bathhouse, only a few *tubuli* were found *in situ*. These *tubuli* were installed against three sides of four columns. Several chimneys were found recessed into the walls. These, however, were filled in during a renovation sometime after AD 660-680 and were no longer functional. In order to provide a draught for the hypocaust, the *tubuli* were connected to chimneys, thus making an open *tubuli* system.

**References:** Barnes *et al.* 2006: 300-305; Blanke forthcoming.

**Images:** None.

**Drawings:** None.

**Comments:** This information was kindly provided by Louis Blanke, excavator of the Central Baths, under the direction of Dr. Alan Walmsley.

**SITE NAME:** KHIRBET AL-KHALDE.

**Site location:** 33km S of Humayma. (29°39'22.51"N 35°13'49.58"E)

**Type of structure:** Heated room in *castellum*.

**Excavation:** A sounding within the fort came down upon a “bath” (Waheeb 1996: 364).

Personal examination of the site found no evidence of water installations, thus it is more likely a heated room.

**Dating:** Excavation suggested the structure dates to the Nabataean period. Surface sharding supports an occupation into the Roman period (Kennedy 2004: 201).

**Preservation of structure and *tubuli*:** The structure is in a poor state of preservation, while the hypocaust system is partly intact. Much of the partially excavated structure seems to be in a poor state, but there is evidence that part of the hypocaust remains intact. The *tubuli* are fragmented.

**Description of *tubuli*:** (From personal examination of surface sherds.) Since the corpus is not large enough to establish a typology for the site, the information presented here will focus on general observations and distinguishing features of the *tubuli* from the site. The *tubuli* are very fragmented, with the largest fragment having a maximum preserved height of 16.5cm, a maximum preserved width of 10.0cm, and a maximum preserved depth of 8.0cm. Of the examples studied, all are wheel-made. The shape of the fragments suggests that the *tubuli* could be either oval or rectangular in profile. Most fragments were relatively thick, with most ranging from 0.5 to 1.6cm thick. The rims varied to some degree, but all had an overhang on the exterior. Most vents were oval with points on both ends. These were cut with two strokes of a knife, leaving over-cut marks at each point of

the oval. One example had a vent in the shape of an irregular oval. A unique example was fabricated with two vents on one side, 5.7cm apart, one above the other. The fabric ranges in colour but is usually reddish yellow, light red, or greyish brown. Typical inclusions are well-sorted, medium sub-rounded clear quartz sand, biotite (mica), a few white flecks, and some small voids. This mica is found in the sediment surrounding the site and is also characteristic of ceramics produced in Aqaba (Aila).

**Description of *tubuli* use:** (From personal examination.) Nothing specific is known about their use. Charring on the interior of the *tubuli* proves that they were indeed used for heating.

**References:** No publications mentioning *tubuli*.

**Images:** None.

**Drawings:** None.

**Comments:** None.

**SITE NAME:** KHIRBET EHD-DHARIH.

**Site location:** SE of Dead Sea, 70km NW of Petra. (30°54'26.34"N 35°42'10.26"E)

**Type of structure:** Room within domestic complex. Room labeled as *caldarium*, but could be heated room not associated with bath.

**Excavation:** Excavation of heated room and hypocaust has been completed.

**Dating:** Occupation lasted from the 1<sup>st</sup> century AD to beginning of Byzantine period.

**Preservation of structure and *tubuli*:** Room and hypocaust are well preserved.

**Description of *tubuli*:** No *tubuli* or flue pipes mentioned.

**Description of *tubuli* use:** Images clearly show recessed vertical vents in the wall. It is likely that these recessed vents held flue pipes.

**References:** al-Muheisen and Villeneuve 1994: 751-52; el-Muheisen and Villeneuve 1995: 522.

**Images:** (showing recessed vents) al-Muheisen and Villeneuve 1994: 752, fig. 8; el-Muheisen and Villeneuve 1995: 522, fig. 14.

**Drawings:** None.

**Comments:** None.

**Type of structure:** Bath for community or bath associated with nearby church.

**Excavation:** Excavation has been completed.

**Dating:** Built in Byzantine period, ceased functioning around AD 640.

**Preservation of structure and *tubuli*:** Well preserved.

**Description of *tubuli*:** No description given.

**Description of *tubuli* use:** Used for heating. Plan of bath shows what could be *tubuli* installed along west wall in the south (Villeneuve 2011: 324, fig. 11).

**References:** Villeneuve 2011: 324-25.

**Images:** None.

**Drawings:** None.

**Comments:** None.

**SITE NAME:** LEJJUN.

**Site location:** 67km E of Dead Sea, 17km NE of Karak. (31°14'16.19"N 35°52'5.47"E)

**Type of structure:** Bathhouse within legionary fortress.

**Excavation:** Partially excavated.

**Dating:** Bath was functional from around AD 300 to the earthquake in 363.

**Preservation of structure and *tubuli*:** Bathhouse is well preserved. *Tubuli* are mostly fragmented, some were found *in situ*.

**Description of *tubuli*:** (From publication and personal examination.) The corpus of wall-heating pipes collected from the garrison bathhouse contains several very interesting examples.

- **Large cylindrical flue pipe:** This description is based on two reconstructed examples, both of them published (sherds 384-85, Parker 2006: 361, fig. 16.80). This hollow pipe has both a small (male) end and a large (female) end. Only one example has a full length, which measures 31.9cm. The two examples have diameters of 13.0 and 13.5cm at their shoulders and diameters of 6.7 and 7.0cm at the male end. The more complete of the two has a diameter of 12.0cm at the female end. Wall thickness in both ranges from 0.4 to 1.3cm. Both examples have a sharp carination at their shoulders, and a curved neck. The male rim on both examples is rounded, but on one it appears slightly everted.

- **Cylindrical flue pipe without carination:** This description is based on four nearly complete or fully complete examples, all of them published (sherds 386-89, Parker 2006: 361, fig. 16.81). This type of wheel-made cylindrical flue pipe lacks the carination in its side walls that is associated with most cylindrical flue pipes in the region, and thus this pipe was not designed to fit into and join with an adjacent pipe. Rather, they were likely stacked and mortared together similar to rectangular *tubuli*. Two full lengths measure 19.7 and 20.4cm. The diameter of these pipes at their widest part ranges from 9.0 to 10.3cm. The walls, which are typically 0.4 to 0.5cm in thickness, have a curved profile, making both ends of the pipe smaller in diameter than the middle. The ends, slightly oval in shape, range in diameter from 7.9 to 9.0cm. The rims can be curved or flattened, and while they always have an exterior overhang, some examples have a slight overhang on the interior as well. This type of pipe does not have any side vents. No parallels yet exist for this type of pipe.
- **Very short rectangular *tubulus*:** Also found within the garrison bathhouse is a previously unpublished fragment of an unknown type of pipe. This fragment shows the full profile of a wheel-made pipe that measures only 13.7cm high. The wall thickness ranges from 0.5 to 1.0cm. Interestingly, the fragment contains what appears to be a partial vent in the middle of its wall. This vent is too small to measure or determine its shape. The walls of the pipe turn inwards near each end, making the rims not as wide as the body of the pipe. The rims are thickened, flattened and have an overhang on the exterior. This pipe appears to

be a very short rectangular *tubulus* complete with a vent. No parallels yet exist for a *tubulus* this size.

Interestingly, with the exception of the possible very short *tubulus* described above, there does not seem to be clear evidence of typical rectangular *tubuli* being used within the bathhouse. It is possible, however, that the *tubuli* were stripped off the walls and used or dumped elsewhere (see sections on the barrack and kitchen at Lejjun).

**Description of *tubuli* use:** (From publication and personal examination.) Excavation within the bathhouse found fragments of *tubuli* still *in situ* against the walls. In the *tepidarium*, impressions in the wall plaster also attest to their presence. A top plan of the bathhouse (Parker 2006: fig. 7.1) shows vertical recesses in the walls of the *caldarium*. These may be evidence for separate flue pipes, and thus a closed *tubuli* system. Two cylindrical pipes (sherds 384-85) were initially thought to have been used for water (Parker 2006: 361). Personal examination of these pipes with director, S. Thomas Parker, found that they in fact had a charred interior surface, and thus were used as flue pipes.

**References:** Parker 1990: 364; Parker 2006: 361; and de Vries and Lain 2006: 216-17.

**Images:** None.

**Drawings:** Parker 2006: figs. 16.80 and 16.81. In this work: fig. 3.12.

**Comments:** Permission to study the *tubuli* from Lejjun was generously provided by director Dr. S. Thomas Parker.

**Type of structure:** Barracks building (*tubuli* are likely a secondary deposit).

**Excavation:** Partially excavated.

**Dating:** The *tubulus* fragments come from a stratum dated to 284-324 AD.

**Preservation of structure and *tubuli*:** Structure poorly preserved. *Tubuli* are in fragments, but several nearly complete reconstructs were uncovered.

**Description of *tubuli*:** (From publication and personal examination.) This description is based on five nearly complete rectangular *tubuli*, four of them published (sherds 380-83, Parker 2006: figs. 16.76-16.79), and one of them previously unpublished. Although all the *tubuli* are slightly different from each other, they are wheel-made, and then pressed into final shape by hand. One end is typically rectangular, and the other is oval. The lengths of the five examples range from 21.0 to 23.1cm; the widths range from 12.5 to 13.6cm; and the depths range from 8.6 to 10.0cm. The thickness of the walls tends to be between 0.4 and 0.6cm. The rims can be thickened and flattened with slight exterior overhang, or rounded and everted. There is a range of vent shapes including: oval, circular, irregular-circular, and tear shaped. These *tubuli* are similar in form to the Humayma *Tubulus* Type 2, but are higher and not as deep. The fabric ranges in colour but is usually red or pink. Typical inclusions are well-sorted, fine or medium sub-rounded or sub-angular clear quartz sand, a few white flecks, and a few small voids.

**Description of *tubuli* use:** (From publication and personal examination.) These *tubulus* fragments come from a bench within a barrack. There is no mention of any heating system, yet the charring on the interior of the *tubuli* clearly indicates that they were used for this purpose. It is possible that the *tubulus* fragments were deposited here from the legionary bathhouse or another hypocausted structure. In an adjacent barrack, a floor was paved with reused round *bessalis* tiles from the bathhouse (Groot *et al.* 2006: 176). It is possible that the *tubulus* fragments were also brought over for reuse. A similar

concentration of *tubulus* fragments from the kitchen in the *principia* of legionary fortress is theorized to have been used to construct installations (Lain and Parker 2006: 138).

**References:** Parker 2006: 361. For information on the context of the finds see Groot *et al.* 2006: 171-73.

**Images:** None.

**Drawings:** Parker 2006: figs. 16.76-16.79. In this work: figs. 3.8 & 3.9.

**Comments:** Permission to study the *tubuli* from Lejjun was generously provided by director Dr. S. Thomas Parker.

**Type of structure:** Kitchen within *principia* (*tubuli* are likely a secondary deposit).

**Excavation:** Partially excavated.

**Dating:** The *tubulus* fragments come from a stratum dated to 284-363 AD.

**Preservation of structure and *tubuli*:** Structure fairly well preserved. *Tubuli* are in fragments, but several nearly complete reconstructs were uncovered.

**Description of *tubuli*:** (From personal examination.) This description is based on five partially reconstructed rectangular *tubuli*, none of them published. The *tubuli* are wheel-made, then pressed into final shape by hand. One end is typically rectangular, and the other is oval. These tubes are smaller than those found in the barracks at Lejjun. Three of them measure between 17.6 and 18.2cm in height, while one relatively larger tube is 22.5cm high. Of the five examples only two have full widths and depths. One is 15.5cm wide and 11.0cm deep, and the other is 15.7cm wide and 9.0cm deep. The rims are typically flattened and have an exterior overhang. There is a range of vent shapes including: oval, circular, and irregular-circular. Although many of them are shorter, these

*tubuli* are of the same type as those described above, which were found within the barrack at Lejjun. These *tubuli* are also similar in form to Humayma *Tubulus* Type 2. The fabric ranges in colour but is usually red or pink. Typical inclusions are well-sorted, fine or medium sub-rounded or sub-angular clear quartz sand, a few white flecks, and a few small voids. The fabric of one partially reconstructed *tubulus* is unlike that of the others and is similar to the fabric found on ceramics produced in the surrounding region, suggesting that this *tubulus* was made locally. In terms of its form, however, this *tubulus* is exactly similar to the others from Lejjun.

**Description of *tubuli* use:** (From personal examination.) Charring on the interior of the *tubuli* clearly indicates that they were used for heating. No *tubuli*, however, were found *in situ*, nor is there any sign that they were once installed against the walls of this room. It is thought that they were either stored here or were used in the fill of the installations in the room (Lain and Parker 2006: 138). It may be that these *tubulus* fragments originally were used in the garrison bathhouse.

**References:** Parker 2006: 361; Lain and Parker 2006: 137-38.

**Images:** None.

**Drawings:** None.

**Comments:** Permission to study the *tubuli* from Lejjun was generously provided by director Dr. S. Thomas Parker.

**SITE NAME:** MACHAERUS.

**Site location:** E of Dead Sea. (31°34'1.98"N 35°37'26.73"E).

**Type of structure:** Private bath.

**Excavation:** Excavation has been completed.

**Dating:** Herodian, constructed after 30 BC, destroyed in AD 72.

**Preservation of structure and *tubuli*:** Poor.

**Description of *tubuli*:** Described as having vents on their sides. Standard size of *tubuli* given as: 31cm high, 12cm wide, and 6cm deep.

**Description of *tubuli* use:** Installed against wall in the *laconicum*.

**References:** Loffreda 1981a: 89; Loffreda 1981b: 111.

**Images:** None.

**Drawings:** None.

**Comments:** None.

**SITE NAME:** MAMPSIS (Israel).

**Site location:** In the Negev, SW of Dead Sea. (31°1'30.16"N 35°3'50.57"E).

**Type of structure:** Bathhouse.

**Excavation:** Excavation has been completed.

**Dating:** The construction is dated to the Late Nabataean period, but it was used until Late Roman and Byzantine periods.

**Preservation of structure and *tubuli*:** The structure is fairly well preserved. There is not much information given on the preservation of the *tubuli*.

**Description of *tubuli*:** The heating pipes are described as 10cm in diameter. This measurement suggests that the tubes were cylindrical, not rectangular.

**Description of *tubuli* use:** Impressions in mortar show that these round heating pipes lined the walls of the *caldarium*. A gap of 10-12cm was left between the *suspensurae* and the walls to allow for hot air to enter the heating pipes. On the W wall of one of the heated rooms, two recessed vertical vents exist. A burnt brick chimney also was installed into the N wall. The fact that these vents began at a level below the *suspensurae* suggest that they were the flue system for the hypocaust. The *tubuli* system at Mamphis was therefore likely a closed system, and the round heating pipes installed against the walls did not carry any draught.

**References:** Negev 1988: 174-76; Negev 1993a: 887; also briefly mentioned in Negev 1997: 176.

**Images:** (showing recessed vertical vents) Negev 1988: 175, photo 184; (showing gap for *tubuli* between *suspensurae* and wall) Negev 1988: 176, photo 186.

**Drawings:** None.

**Comments:** None.

**SITE NAME:** OBODA (AVDAT) (Israel).

**Site location:** In the Negev, SW of Dead Sea. (30°47'38.14"N 34°46'23.20"E)

**Type of structure:** Bathhouse.

**Excavation:** Excavation has been completed.

**Dating:** Not accurately dated, usually dated to Byzantine period.

**Preservation of structure and *tubuli*:** The structure is fairly well preserved. Although much of the hypocaust has not survived, in some areas *tubuli* remain *in situ*.

**Description of *tubuli*:** No description is provided.

**Description of *tubuli* use:** Many *tubuli* remain *in situ* along the W wall of the *laconicum*.

*Tubuli* also are preserved behind bathtubs against the N and S walls of *caldarium*. The plan of the bathhouse also shows many recesses that could have been used as flue vents for the hypocaust (Negev 1997: 172, fig. 26).

**References:** Negev 1993b: 1165; Negev 1997: 174-76.

**Images:** None.

**Drawings:** None.

**Comments:** None.

**SITE NAME:** PETRA – BATHHOUSE NEXT TO PETRA GREAT TEMPLE.

**Site location:** next to Petra Great Temple, near the monumental gateway. (30°19'45.20"N 35°26'31.03"E)

**Type of structure:** Bathhouse with possible connection to neighbouring temple.

**Excavation:** Excavation has been completed.

**Dating:** Based on lamp fragments, the first phase of the bath dates to around AD 70. The heated rooms were constructed sometime around the annexation in AD 106. After the earthquake in 363, some alterations were made to the heated rooms. The building was finally destroyed in the earthquake of AD 512.

**Preservation of structure and *tubuli*:** The building is fairly well preserved, and in some small areas the hypocaust is intact. Some fragments of *tubuli* remain *in situ*.

**Description of *tubuli*:** (From personal examination.) Examination of *tubulus* dump pile next to site identified two distinct types of *tubulus* from the structure.

- **Slab-made *tubulus*:** This *tubulus* seems to be slab-made, as it does not exhibit the wheel-marks associated with wheel-made *tubuli*. It is possible, however, that this type is in fact wheel-made and belongs with the type described below. Only three fragments of these possible slab-made *tubuli* were examined. By far the largest fragment has a full depth of 14.5cm, and a wall thickness that ranges from 1.5 to 1.7cm. The corners are slightly curved. A finger groove running along the inside corner reveals that the *tubuli* were shaped by bending the clay around the finger as it moved up the interior wall. The side walls have a very large vent cut out in the shape of a diamond. The vent measures 7.1cm wide, and while the maximum

preserved height of the vent is 7.9cm. The fabric is usually light red. Typical inclusions are poorly-sorted, medium to very coarse sub-rounded clear quartz sand, a few small pebbles, a few white flecks, and some small to medium voids.

- **Thick-walled wheel-made *tubulus*:** These *tubuli* are very similar in form to the possible slab-made *tubulus* described above, but they display clear wheel-marks from their production. Several *tubuli* of this type are found *in situ* within the *caldarium*. They measure approximately 39cm high, 29cm wide, and 16cm deep. Their wall thickness ranges from 1.7 to 1.9cm. The *tubuli* are squared on both ends, the shaping was completed by bending the clay around a finger as it moved up the interior wall. The rims are flattened and rounded with a slight interior overhang. The side walls have a very large vent cut out in the shape of a diamond. The vent is about 17cm high and 7cm wide. The fabric of this type was not able to be examined.
- **Thin-walled wheel-made *tubulus*:** Only two fragments of this type were examined. Neither example was large enough to provide useful data for the full dimensions of the *tubulus*. The thickness of the fragments varied from 0.5 to 0.9cm. Both exhibited heavy wheel-marks on their interior surfaces. At least one of the ends was squared. The rim of this type is slightly thickened, with a flattened top that slopes towards exterior and a slight rounded interior overhang. Although vents are present, not enough of one remains extant for detailed comment. The fabric ranges in colour but is usually red or light red. Typical inclusions are well-sorted, medium to coarse sub-rounded clear quartz sand, some white flecks, and a few small voids.

This corpus remains understudied, and further work must be done to gain a firm understanding of the types of *tubuli* used within this bath.

**Description of *tubuli* use:** A total of 1200 *tubulus* fragments were recorded from the excavation. Many of these came from the *caldarium*. The preliminary report also notes a number of interconnecting cylindrical flue pipes that were imbedded within the walls to serve as exhaust for gases.

**References:** Joukowsky 2007: 91, 93-94.

**Images:** None.

**Drawings:** None.

**Comments:** Permission to study the *tubuli* from the bathhouse in Petra was generously provided by director Dr. Martha Sharp Joukowsky.

**SITE NAME:** PETRA – UMM AL-BIYARA.

**Site location:** On Jebel Umm al-Biyara, W of the city centre. (30°19'36.96"N  
35°26'5.86"E)

**Type of structure:** Private bathhouse, associated with Nabataean Palace.

**Excavation:** Partially excavated.

**Dating:** The bathhouse was built in the second half of the 1<sup>st</sup> century AD (Schmid *et al.* 2012: 84).

**Preservation of structure and *tubuli*:** *Tubuli* are broken. The hypocaust is poorly preserved.

**Description of *tubuli*:** No description given. Based on published photograph, they are wheel-made.

**Description of *tubuli* use:** No description given.

**References:** Schmid *et al.* 2012: 79-81.

**Images:** (Image of *tubulus* fragments) Schmid *et al.* 2012: 79-81, fig. 9.

**Drawings:** None.

**Comments:** None.

**SITE NAME:** PETRA – WADI FARASA.

**Site location:** Located S of the city centre. (30°19'15.32"N 35°26'41.91"E)

**Type of structure:** No structure. Found at the Lower Terrace near the “Soldier Tomb”.

**Excavation:** Many fragments of *tubuli* were found in a dump context.

**Dating:** Not known.

**Preservation of structure and *tubuli*:** *Tubuli* are fragmented.

**Description of *tubuli*:** (From published drawing.) The drawn *tubulus* is wheel-made, and rectangular in profile. Its full length is not available. It is about 13cm wide and about 10cm deep. The rim is flattened with a slight overhang on the interior. The fragmented *tubuli* are recorded as being very similar to those found at Zantur (described below).

They also seem to be similar to Humayma *Tubulus* Type 2.

**Description of *tubuli* use:** Since the fragments were found out of context, their use is unknown.

**References:** Schmid 2002: 261, 265.

**Images:** None.

**Drawings:** Schmid 2002: 265, fig. 13. In this work: fig. 3.7.

**Comments:** None.

**SITE NAME:** PETRA – ZANTUR IV.

**Site location:** On ridge south of *decumanus maximus*. (30°19'38.98"N 35°26'34.95"E)

**Type of structure:** Heated room in domestic structure, “winter living room”.

**Excavation:** Excavation of heated room and hypocaust has been completed.

**Dating:** Function of hypocaust dated from late 1<sup>st</sup>/early of 2<sup>nd</sup> century to AD 363.

**Preservation of structure and *tubuli*:** Well preserved hypocaust. *Tubuli* are broken and not *in situ*. The *tubuli* appear to have been knocked out of the recessed vents during the AD 363 earthquake.

**Description of *tubuli*:** (From published photograph) Wheel-made, pressed into rectangular form by hand, irregular oval-shaped vent on side, very similar to Humayma Type 2. The measurements are given as 18 x 14 x 11cm.

**Description of *tubuli* use:** They are thought to have been imbedded in three vertical recessed vents in northern wall. If this was their use, their primary function would have been to carry the draught. Their heating ability would have been diminished.

**References:** Kolb and Keller 2000: 361-63; Kolb and Keller 2001: 319.

**Images:** (Image of room with recessed vertical vents) Kolb and Keller 2000: 361, fig. 6;

(Image of reconstructed *tubulus*) Kolb and Keller 2000: 362, fig. 8. In this work:  
fig. 3.6.

**Drawings:** None.

**Comments:** None.

**SITE NAME:** QASR EL-KITHARA.

**Site location:** About 20km north of Aqaba, in the Wadi Yutm. (29°32'38.00"N 35°  
8'0.57"E)

**Type of structure:** Suggested to be a small bath within fort. Based on personal examination at the nearby site of Khirbet al-Khalde, another perhaps more likely possibility is a simple heated room.

**Excavation:** Partially excavated.

**Dating:** Unknown. Surface sherding has collected pottery from the Early Roman/Nabataean period to the Late Byzantine period.

**Preservation of structure and *tubuli*:** Unknown.

**Description of *tubuli*:** (From personal examination.) Only a few fragments of this wheel-made *tubulus* type were available for examination. The largest of these has a maximum preserved height of 22.7cm, a maximum preserved width of 8.9cm, and a maximum preserved depth of 5.5cm. The wall thicknesses of all examples vary from 0.7 to 1.1cm. Most fragments have heavy wheel-marks, and one has clear impressions from shaping, after it was removed from the potter's wheel. The rims of these *tubuli* have an exterior

overhang and a flattened rim that slopes towards the interior. These *tubuli* have side vents, but none are preserved enough for detailed comment. The fabric ranges in colour but is usually reddish yellow. Typical inclusions are well-sorted, medium sub-rounded clear quartz sand, biotite (mica), some white flecks, and a few small voids.

**Description of *tubuli* use:** Evidence of *tubuli* was found against the walls of a plastered installation. No further details are given.

**References:** Parker 2003: 330.

**Images:** None.

**Drawings:** None.

**Comments:** Permission to study the *tubuli* from Qasr el-Kithara was generously provided by director Dr. S. Thomas Parker.

**SITE NAME:** REHOVOT-IN-THE-NEGEV (Israel).

**Site location:** In the Negev, W of Mampsis. (31° 1'36.25"N 34°33'54.86"E)

**Type of structure:** Bathhouse.

**Excavation:** Not known.

**Dating:** Not known.

**Preservation of structure and *tubuli*:** The structure is very well preserved.

**Description of *tubuli*:** Rectangular (15 x 10cm) clay pipes are labeled as rainwater downpipes. These may in fact be *tubuli*.

**Description of *tubuli* use:** The pipes are installed into recessed vertical vents in the walls, which are clearly visible on the top plan (Musil 1908: 75, fig. 46).

**References:** Musil 1908: 80; Tsafirir 1988: 17-20

**Images:** None.

**Drawings:** None.

**Comments:** None.

**SITE NAME:** SAHIR AL-BAQAR.

**Site location:** Near Petra, NW of city centre. (Near: 30°21'15.83"N 35°24'52.38"E)

**Type of structure:** Hypothesised to be baths, associated with house and Nabataean temple (Pond Temple).

**Excavation:** Unexcavated, survey of site.

**Dating:** Associated temple is dated to 1<sup>st</sup> century AD and was destroyed in the 3<sup>rd</sup> or 4<sup>th</sup> century.

**Preservation of structure and *tubuli*:** Preservation of structure unknown, *tubuli* in fragments.

**Description of *tubuli*:** No description given. Photograph of bathhouse remnants appear to depict wheel-made *tubuli*.

**Description of *tubuli* use:** Unknown.

**References:** Lindner and Gunsam 1995: 211.

**Images:** (Photo of *tubulus* fragments) Lindner and Gunsam 1995: 211, fig. 19.

**Drawings:** None.

**Comments:** None.

**SITE NAME:** UMM QAYS (GADARA).

**Site location:** SE of the Sea of Galilee. (32°39'24.54"N 35°40'38.34"E)

**Type of structure:** Byzantine Baths, large public bathhouse.

**Excavation:** Mostly excavated.

**Dating:** The initial construction of the bathhouse is dated to the beginning of the 4<sup>th</sup> century AD. About a century later, the bathhouse was partially destroyed, but was soon rebuilt and continued to be used as a bath. The bath fell out of use at some point between the Late Byzantine and Umayyad periods.

**Preservation of structure and *tubuli*:** The structure is fairly well preserved with many *pilae* still in place. In several areas, *tubuli* remain *in situ*.

**Description of *tubuli*:** The publications on this site contain a great deal of information and several different types of wall-heating pipes.

- **Slab-made *tubulus*:** These are described as rectangular in shape with vents in their sides. Most are said to be 43cm high, 25cm wide, and 14.5cm deep. A drawn *tubulus* (Nielsen *et al.* 1993: 191, sherd 294; Pl.33.294) is 26cm high, 16.5cm wide, and 14.5cm deep. It has a circular vent in its side. Based on the drawing, this *tubulus* was made in the manner described for other *tubuli* from this site (Vriezen and Mulder 1997: 330, fig. 12). The tube was given its shape by being formed in a wooden mould. The rims were folded back inwards, creating a round interior overhang, which can be seen in the drawing (Nielsen *et al.* 1993: Pl.33.294). Petrology on fabric from *tubuli* of a similar form also found in Umm

Qays has shown that they were produced from local clay (Vriezen and Mulder 1997: 330).

- **Possible wheel-made *tubulus*:** There is not much information to confirm the existence of wheel-made *tubuli* at this site, but one *tubulus* is recorded as being oval (Nielsen *et al.* 1993: 192, sherd 295). The drawing of this fragment *tubulus* (Nielsen *et al.* 1993: Pl.33.295) appears to depict a wheel-thrown *tubulus*.
- **Cylindrical flue pipe:** Many cylindrical flue pipes were recorded from the excavation. These hollow pipes have both a small (male) end and a large (female) end thanks to a carination in its side wall near the male end. The pipes could be 20cm in diameter, and one fragment found *in situ* was 46cm in length (Nielsen *et al.* 1993: Pl.34.297). These cylindrical flue pipes were nearly identical to the drainpipes found in the bathhouse (see Nielsen *et al.* 1993: Pl.34 for clear comparison).

**Description of *tubuli* use:** Rectangular *tubuli* were found mainly in the *caldarium*. Here they remain *in situ* in the NE corner of the room, and there are traces of *tubuli* up the walls to a height between 213 and 230cm. In several places, cylindrical flue pipes were imbedded in recesses of the walls. These pipes were used as exhaust. Interestingly, these recessed flue pipes were never found together with batteries of rectangular *tubuli*.

**References:** Holm-Nielsen *et al.* 1986: 220-25; Nielsen *et al.* 1993: 122-25, 191-92; Vriezen and Mulder 1997: 330

**Images:** (Image of *tubuli in situ*) Holm-Nielsen *et al.* 1986: Pl. XXXIX.1; Nielsen *et al.* 1993: Pl. 9.C, 9.D, 10.A. (Depiction of *tubulus* manufacture) Vriezen and Mulder 1997: 330, fig. 12

**Drawings:** (Rectangular *tubulus*) Nielsen *et al.* 1993: Pl.33.294-95; (cylindrical flue pipes) Nielsen *et al.* 1993: Pl.34.296-300.

**Comments:** None.

**SITE NAME:** WADI MUSA.

**Site location:** In the modern settlement of Wadi Musa, E of Petra. (30°19'16.78"N 35°28'47.66"E)

**Type of structure:** Small bath within Nabataean villa, located in the centre of town.

**Excavation:** Partially excavated.

**Dating:** The villa was constructed in the early 1<sup>st</sup> century AD, renovated in the middle of the 1<sup>st</sup> century, and abandoned in the late 1<sup>st</sup> to early 2<sup>nd</sup> century AD.

**Preservation of structure and *tubuli*:** Structure was poorly preserved at time of excavation. Shortly afterwards the excavated portion of the site was demolished for development.

**Description of *tubuli*:** No description is available.

**Description of *tubuli* use:** A photograph of the excavated *caldarium* shows clear impressions of *tubuli* in the plaster of a wall. There also appears to be a recessed vertical flue vent in the wall holding the *tubuli*.

**References:** ‘Amr *et al.* 1997: 472, fig. 5.

**Images:** (Photo of *tubulus* impressions in plaster) ‘Amr *et al.* 1997: 472, fig. 5.

**Drawings:** None.

**Comments:** None.

**Type of structure:** Possible bath or heated room, located about 250m S of bath described above.

**Excavation:** Unexcavated, surveyed.

**Dating:** Unknown.

**Preservation of structure and *tubuli*:** Unknown. A *tubulus* remains *in situ*.

**Description of *tubuli*:** No description given.

**Description of *tubuli* use:** A ceramic pipe was found plastered against the face of a wall.

A later publication identified this pipe as a *tubulus*.

**References:** ‘Amr *et al.* 1998: 524-25, fig 13; ‘Amr and al- Momani 2001: 267.

**Images:** (Photo of *tubulus* against wall face) ‘Amr *et al.* 1998: 525, fig 13.

**Drawings:** None.

**Comments:** None.

**Type of structure:** Pottery kiln at az-Zurraba (Kiln VI)

**Excavation:** The kiln was completely excavated.

**Dating:** Kiln VI dates to between the 2<sup>nd</sup> and early 4<sup>th</sup> centuries AD. The ceramics including the *tubulus* fragment, however, were dumped in the kilns after they fell out of use. The date of the *tubulus* fragment therefore is unknown.

**Preservation of structure and *tubuli*:** The kiln was in a poor state of preservation at the time of excavation.

**Description of *tubuli*:** (From published drawing.) The *tubulus* is wheel-made. Only one oval end remains extant, but the other end was likely rectangular. The width of the

*tubulus* is about 15cm and its depth is about 11cm. The walls are about 0.5 to 0.7cm thick and have very pronounced wheel-marks on both their interior and exterior surfaces. Its rim is rounded with no overhangs, and its vents are oval. The fabric is reddish yellow and has many sand, white and grog brown inclusions (‘Amr and al- Momani 1999: 186). This *tubulus* seems to be very similar to the previously unpublished *tubulus* described below. Additionally, the rectangular *tubuli* from Wadi Musa are most similar in form to those from Wadi Ramm.

**Description of *tubuli* use:** Since the fragment was found out of context, its use is unknown.

**References:** ‘Amr and al- Momani 1999: 185-86, fig 12.29.

**Images:** None.

**Drawings:** ‘Amr and al- Momani 1999: 185, fig 12.29. In this work: fig. 3.3.

**Comments:** None.

**Type of structure:** Out of context. No known structure.

**Excavation:** During excavations for The Wadi Musa Water Supply and Wastewater Project (‘Amr and al- Momani 2001), a single *tubulus* was unearthed with a backhoe in Area W18 (‘Amr, personal communication, July 2012).

**Dating:** Based on its fabric the *tubulus* likely dates from the mid 1<sup>st</sup> century AD (‘Amr, personal communication, July 2012).

**Preservation of structure and *tubuli*:** *Tubulus* is fragmented, but has been restored.

**Description of *tubuli*:** (From personal examination and consultation with Dr. Khairieh ‘Amr.) This previously unpublished *tubulus* is wheel-made and then pressed into final

shape by hand. One end is rectangular, and the other is oval. The dimensions of the *tubulus* are 17 x 14 x 10cm, and its wall thickness is 0.4cm. The walls have very pronounced wheel-marks on both their interior and exterior surfaces. Both its rims are rounded with no overhangs. The tube has one completely preserved vent that is a rounded diamond shape. This *tubulus* is very similar to the *tubulus* described above from the published drawing (‘Amr and al- Momani 1999: 185, fig 12.29). Additionally, the rectangular *tubuli* from Wadi Musa are most similar in form to those from Wadi Ramm. The fabric of this *tubulus* is typical of the ceramics from the az-Zarraba kilns (‘Amr, personal communication, July 2012).

**Description of *tubuli* use:** Since the fragment was found out of context, its use is unknown.

**References:** None. The *tubulus* was previously unpublished.

**Images:** In this work: fig. 3.4

**Drawings:** None.

**Comments:** Access to this *tubulus* and information on it was generously provided by Dr. Khairieh ‘Amr.

**SITE NAME:** WADI RAMM.

**Site location:** In the Hisma, 60km E of Aqaba. (29°34'41.24"N 35°24'57.61"E)

**Type of structure:** Small bath within a villa.

**Excavation:** Excavation has been completed. Much of the structure was cleared out by the Department of Antiquities in the 1960s. Limited excavation was conducted in 1996 and 1997.

**Dating:** Bath possibly constructed in the 1<sup>st</sup> century BC, more likely to be from the 1<sup>st</sup> century AD.

**Preservation of structure and *tubuli*:** Parts of the hypocaust remain intact. One *tubulus* fragment was found *in situ*.

**Description of *tubuli*:** (From personal examination.) Several *tubulus* fragments were saved from the 1996 excavation and made available for examination. An unexpected source of information was a nearly complete and previously unpublished rectangular *tubulus* from the Aqaba Museum, which was kindly made available for study. This *tubulus* came from clearings of the site in 1963, and was mislabelled as an incense burner. Although the exact provenance of this *tubulus* is not known, it matches the *tubuli* collected from the *caldarium* in nearly every way, and therefore is very likely to have come from the same system.

- **Rectangular *tubulus*:** These are wheel-made, and then pressed into final shape by hand. One end is typically rectangular, and the other is oval. Based on fragments, the excavators record the dimensions of a typical *tubulus* as 29 x 14 x 10cm, with a wall thickness of 0.7cm. Although the publication states that the full height was

about 29cm, the excavator, Dr. M. B. Reeves (personal communication, May 2013), says that this is a typo and photographic evidence suggests a height closer to 19cm. This height matches the height of the nearly complete *tubulus* from the museum, which measures 19.5 x 13 x 10cm, and has a wall thickness that varies from 0.5 to 0.9cm. The walls have very pronounced wheel-marks on both their interior and exterior surfaces. Both rims are rounded with no overhangs. On some examples they are slightly thickened. The rims on the bottom end can at times be rough possibly from being cut off the potter's wheel by a string. The vents on these *tubuli* are typically oval or oval with points on both ends. The rectangular *tubuli* from Wadi Ramm are most similar in form to those from Wadi Musa. The fabric ranges in colour but is usually reddish or pink. Typical inclusions are well-sorted, fine and medium rounded or sub-rounded clear quartz sand, a few very coarse sand, some white flecks, and a few very small voids.

- **Cylindrical flue pipe:** Several small fragments of cylindrical flue pipes were also uncovered during excavation. These hollow pipes have both a small (male) end and a large (female) end. No full length remains, but all examples have a body diameter of 8.0cm. On the interior of the female end, a wide groove followed by a thick ledge was present on all samples. The fabric of these flue pipes appears to be the same as that of the *tubuli* from Wadi Ramm, and it suggests a source in the Petra region.

**Description of *tubuli* use:** A large *tubulus* fragment was found *in situ* against the E wall of the *caldarium*. Along this wall, the suspended floor stopped 10 to 12cm short of the wall to allow hot air from the hypocaust to enter and circulate within the *tubuli* that lined

the wall. It is theorized that *tubuli* also lined the N and S walls. Vertical grooves were cut into the E, N, and S walls. Although the dimensions of these grooves vary, the best preserved one measures 15 by 8cm, and could have easily held the cylindrical flue pipes found during excavation. The grooves extend 54cm below floor surface and were covered by vertical slabs of rock. These recessed vertical grooves were the flue vents that provided draught for the hypocaust. The existence of these flue vents coupled with batteries of *tubuli* suggest that the *tubuli* system was a closed system where the *tubuli* did not carry any draught.

**References:** Dudley and Reeves 1997: 94-96; Dudley and Reeves 2007: 405.

**Images:** (Showing vertical rock slab covering recessed vent) Dudley and Reeves 1997: 97, Pl.10; Dudley and Reeves 2007: 406, fig. 3. In this work: fig. 3.5

**Drawings:** None.

**Comments:** Permission to study the *tubuli* from Wadi Ramm was generously provided by co-director Dr. M. Barbara Reeves. Permission to examine the *tubulus* stored at the Aqaba Museum was generously granted by Manal Basyouni, Museum Director – Aqaba Archaeological Museum.

**SITE NAME:** YOTVATA (Israel).

**Site location:** Western edge of Wadi 'Arabah, ca. 40km N of Aqaba. (29°53'9.96"N 35°3'9.23"E)

**Type of structure:** Bathhouse associated with nearby *castellum*.

**Excavation:** Mostly excavated.

**Dating:** The construction of the associated fort has been dated to around AD 297, and its final destruction to the late 4<sup>th</sup> century (Meshel 1989: 238). Subsequent excavation has put forward a later foundation date, likely between AD 360 and 370 (Davies and Magness 2011: 476).

**Preservation of structure and *tubuli*:** The structure is poorly preserved. Some *tubuli* remained *in situ* at time of excavation.

**Description of *tubuli*:** A *tubulus* from this site was described as ceramic and square in shape. Image is too poor to infer any other details.

**Description of *tubuli* use:** One *tubulus* was preserved *in situ* against one of the walls of the heated rooms. A plan of the structure (Meshel 1989: fig. 4) shows what appear to be *tubuli* in a second room (labelled the *caldarium*).

**References:** Meshel 1989: 234-36.

**Images:** (*Tubulus in situ*) Meshel 1989: pl. 32 D.

**Drawings:** None.

**Comments:** None.

## Islamic Hammams with Tubuli

**SITE NAME:** HAMMAM AL-SARAH.

**Site location:** About 55km SE of Amman, and 45km NW of Qasr Amra. (32° 5'0.57"N  
36°21'46.86"E)

**Type of structure:** Islamic *hammam*.

**Excavation:** Excavation has been completed.

**Dating:** Umayyad. Constructed in AD 705-15.

**Preservation of structure and *tubuli*:** The structure is very well preserved, although the hypocaust is much less so.

**Description of *tubuli*:** No description is provided.

**Description of *tubuli* use:** In each corner of the heated room, rectangular *tubuli* were installed to heat the walls. These *tubuli* did not extend up the entire wall but stopped at a height where there was an overhang in the side walls. In the upper part of the S wall, 2.45m above the floor, there are three vertical recessed grooves that extend through the roof to the exterior. These grooves were designed to hold cylindrical flue pipes.

**References:** Bisheh 1989: 228, al-Asad and Bisheh 2000: 128

**Images:** None.

**Drawings:** None.

**Comments:** None.

**SITE NAME:** QASR AIN ES-SOL (EL-SIL).

**Site location:** The Azraq Oasis, 1.75km NE of Azraq Castle. (Near: 31°53'6.33"N  
36°50'11.80"E)

**Type of structure:** Islamic *hammam*.

**Excavation:** Excavation has been completed.

**Dating:** Umayyad. Specific date unknown.

**Preservation of structure and *tubuli*:** The structure is somewhat well preserved. Much of the hypocaust is destroyed.

**Description of *tubuli*:** Pipes described as having “a rectangular section with rounded corners” are clearly rectangular *tubuli*. A drawing of one of these pipes (Kennedy 1982: 121, fig. 41.87) confirms this identification. Unfortunately, not much is discernible from the drawing. The walls appear relatively thick, and the rims do not have much of an overhang. The drawing does not depict the *tubulus* as having a side vent.

**Description of *tubuli* use:** No description is provided.

**References:** Kennedy 1982: 131, 320-21; Bisheh 1982: 154; Bisheh 1989: 92.

**Images:** None.

**Drawings:** Kennedy 1982: 321, fig. 41.87

**Comments:** None.

**SITE NAME:** QASR AMRA.

**Site location:** 80km E of Amman. (31°48'11.11"N 36°35'17.94"E)

**Type of structure:** Islamic *hammam*.

**Excavation:** Excavation has been completed.

**Dating:** Umayyad. Constructed in AD 705-15.

**Preservation of structure and *tubuli*:** The structure is extremely well preserved.

**Description of *tubuli*:** No description is provided.

**Description of *tubuli* use:** In both of the hypocausted rooms, flue pipes exist in all four corners. These pipes led directly to the outside and carried the draught of the hypocaust system.

**References:** Almagro *et al.* 1975: 37-38.

**Images:** None.

**Drawings:** None.

**Comments:** None.

**Site name:** QASR MSHASH

**Site location:** 19km E of al-Muwaqqar and 21km NW of Qasr al-Kharana.

**Type of structure:** Islamic *hammam*.

**Excavation:** “Almost completely excavated”.

**Dating:** Umayyad.

**Preservation of structure and *tubuli*:** Somewhat well preserved. Hypocaust remains well preserved in only some areas.

**Description of *tubuli*:** No description given.

**Description of *tubuli* use:** Flue pipes were located in SW and SE corners of *caldarium*.

**References:** Bisheh 1989: 86.

**Images:** (Photo of pipes *in situ*) Bisheh 1989: pl. 4c.

**Drawings:** None.

**Comments:** None.