Earthenware Pieces Manufactured for Roman Thermae

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ABSTRACT: This study focuses on Roman earthenware pieces manufactured specifically for bath construction. Considered are pieces for the hypocaust (to pave the area or to support the suspensura) and those for heating the hollow walls (concameratione) and the vaults. Special attention is paid to the construction properties of these pieces and hypotheses are suggested for the appearance of new types (setting aside variations in size.

The progressive development in the types of Roman lateres coctiles (Van Aken 1952) reaches its apogee in the earthenware pieces for bath use related to the heating system, quite apart from the employment of more general types used in both construction elements and in infrastructure. In fact, three peculiarities of these earthenware pieces make them particularly appropriate for heating-system use: ease of manufacture, ease of handling, and ease of producing new formats from a previous module, compatibility with humidity, and thermal inertia.

The basic concepts of the heating system, based on indirect heat transmission through flooring (hypocaust), walls, and vaults have been extensively studied due to the wide-ranging applications of this system. Publications on Roman baths, amongst which the works of Nielsen (1990) and Yegül (1992) stand out, tend to centre on their spatial distribution, paying no heed to the typology of the earthenware elements associated with heat transmission and, especially, to their construction properties.

Neither do works on earthenware production (McWhirr 1979) approach this issue. Although there do exist works broadly treating earthenware (especially Brodribb 1987; Bendala; Rico & Roldán 1999), the vast majority refer to specific sites, such as Walker’s (1985) on Settefinestre (Italy) and Roldán on the various sites in Baetica (Spain) (1987, 1988, 1994a, 1994b & 1999), some of the latter’s works actually focussing more on construction techniques (e.g. 1992 & 1993). There are very few indeed that centre on the heating systems themselves, amongst which mention should be made of Brodribb (1979) on the Beaufort Park Baths in Battle (UK) and on the works by Fernández, Morillo, and Zarzalejos (1996, 1997, 1999 & 2004) in the framework of a long-term research project (1993-2004) on Roman baths in Hispania (Fernández; García; Morillo & Zarzalejos 2004).

Archaeological publications show a wider range of solutions than those set forth by Vitruvius (De Architectura, V, X). In fact, in many cases, earthenware pieces manufactured in different localities are peculiar to the local area (with distinct sizes and types), although they may maintain the basic generic characteristics. These variations may have arisen in response to builders’ needs to speed up production, resolve perceived mechanical problems and/or heat transmission, or simply due to material availability or savings. The categorization of these earthenware elements here undertaken purely examines form, since variations in size can be endless and, often, merely an unintentional consequence of technical problems during firing or lack of accuracy during cutting (Brodribb 1987, p. 2).
EARTHENWARE PIECES FOR THE HYPOCAUST

Pieces for the area

As mentioned by Vitruvius (De Architectura, V, X), the best earthenware pieces for the area on which the hypocaust pilae are erected are sesquipedal bricks. Although he does not explain why, it is most likely for the same reason that pavements were made with similar-sized flagstones in the Near East: the greater speed in laying them, not only due to the large size of the bricks (a foot and a half per side), but also because the fact they are square made positioning the pilae quite easy. Nonetheless, other sizes were commonly used as well: smaller square bricks (pedales, one foot per side), rectangular ones (esp. lydios; 40 x 27-30 cm; 44-46 x 30-32 x 0.4-0.5 cm), and even irregular-sized ones. Also possible were pavements in opus signinum (very suitable due to its hydraulic characteristics), flagstones of dressed stone, shingles, and combined solutions. For instance, Fernández, Morillo & Zarralejos (1999, p. 292) report the use in Hispania of pedales (caldarium of the Augusteas Baths in Conimbriga), lydios (rooms 5, 6, and 11 of the West Baths in Mirobriga), and opus signinum. Andrés, Herras, Tirado, & Cabada (1997, p. 420) found pavement comprising small plaques of black and white dressed stone in Vareia; in Talavera de la Reina (Toledo) there are 16 large flagstones in the centre next to the furnace access (0.70 x 0.57 x 0.06 m) and the rest is opus signinum over a bed of shingle (Pacheco; Moraleda 1997, p. 431).

Pieces for supporting the suspensura: pilae, archwork bricks and bracket bricks

In traditional hypocausts —setting aside the “channel hypocaust” (Yegül, 1992, p. 361), the suspensura was made out of bipedales bricks and successive layers of opus signinum to better transmit heat. Save for occasional more “rustic” constructions enforced by the lack of suitable earthenware manufacturers, the elements supporting the suspensura (pilae, archwork bricks, and bracket bricks) were also made out of earthenware pieces. Adam (1996, p. 290), for instance, reports “rustic” pilae built out of solid blocks of dressed stone in SW Gaul in Vaison-la-Romaine and in Thuburbo Majus; Yegül (1992, pp. 357 and 232-234) refers to the masonry pilae of the Large South Baths in Timgad and to the small stone columns of Barbara Thermæ in Traer (Yegül, 1992, p. 360, Fig. 448).

Earthenware pilae pieces. The suspensura was generally supported by pilae, particularly in Italy and eastern regions of the Empire (Nielsen 1990, p. 14). Occasionally, this system was used in conjunction with archwork bricks (even in the same building), which was quite common in Hispania (Fernández; Morillo; Zarralejos 1999, p. 301). Although Vitruvius recommends pilae be two feet high and Faventinus (s. IV) recommends 2.5 feet in private baths and 3 feet in public ones, in fact the heights ranged from 0.45 to 1.00 m (and even up to 1.50 or 1.70 m). The pilae were usually made of earthenware pieces and very occasionally out of masonry (Chumillas; Ramírez, 1997, p. 333). The oldest pilae (e.g. the caldarium of the House of the Faun Baths, the baths in the House of Favius Rufus, and the Baia Baths) seem to have been hollow earthenware pieces crowned by one or several square bessalis bricks (2/3 of a foot per side). Likely due to lack of sturdiness (Adam 1996, p. 290), this type of pilae gave way to stacked bricks, which became the norm. However, in areas where ceramic production was more limited, less orthodox solutions could be used, such as: combining bricks with column shafts, using amphorae fragments as pilae bases, making pilae out of cuneati (wedge-shaped bricks; sing. later cuneatus), facing imbrices, or a combination of earthenware pieces and stone. Fernández, Morillo, & Zarralejos (1999, pp. 297 and 301) record some examples: column shafts and bricks in the three rooms of the second phase of the Braga baths, cunetali in Mirobriga and Braga-Maximinos, and a combination of brick pilae (square and circular bricks) with sandstone pilasters in the caldarium of Carthago Nova.

Following Vitruvius’ recommendation, the most common brick pilae used bessalis bricks (Brodribb 1987, 34), which are specifically for thermal use and occur in an innumerable list of hypocausts. In Pompeii, for instance, they occur in the men’s tepidarium of the Stabies Baths, where they are up to 80 cm in height. The team of Fernández Ochoa cites an important series of bath complexes in Hispania where they occur: room 5 of Mirobriga, the tepidaria of the Trojan Baths of Conimbriga, the caldarium and tepidarium of the Imperial Baths at Valentia, the caldarium of Arcabriga, the hypocaust at Hort de les Monges (Baetulo), the recessed bath on Montevideo Street of Lucus, and the tepidaria and caldaria of Gijón (Fernández; Morillo; Zarralejos 1999, p. 296; Hernández; Pujante 1999, p. 396). In Gaul they are found in the baths of Vaison-la-Romaine.

Bessalis were easy and economical to produce because they were made by cutting a sesquipedalis brick (Adam 1996, p. 158) and were square and small (2/3 of a foot); however, we must consider that, although a standard bessalis is 19.7 cm per side (equivalent to two-thirds of a foot), there are the expected local variations caused by the sizes of the larger bricks from which they are cut (ranging from 18 to 24 cm) (Brodribb 1987, p. 34; Fernández; Morillos; Zarralejos 1999, pp. 296 & 300).

Bessalis were appropriate not only for evenly distributing loads, but also for facilitating pilae positioning and the distribution of the suspensura bipedalis bricks. Fairly frequently, bessalis were substituted by the same lydios used in the walls to circumvent the use of special bricks; in Hispania, for instance, this occurs in some pilae of the Carteia hypocaust (Graciani 2007), in the rectangular sudatio of the Gijón baths, in the Exedra House at Itálica, in the caldarium of the Trojan Baths at Conimbriga, in a phase-one room of the Braga baths, in caldarium II of the Padre Blanc Baths at Astorga, and in the second tepidarium of Los Arcos II at Clunia (Fernández; Morillo; Zarralejos 1999, pp. 297 & 301).

Due to the rectangular shape (with many local variations; Brodribb 1987, p. 40) of the lydios, though, the areas then had to be paved with opus signinum or with irregularly distributed lydios. The standard bessalis pilae solu-
tion was fairly historically constant. However, observation has revealed drawbacks in the mechanical properties and pathologies deriving from the buckling to which bessals bricks were prone; moreover, these effects were magnified in large baths with higher hypocausts, whose pilae were therefore subjected to greater loads. One solution was to use larger earthenware pieces for the base of the pilae and/or as a capital for seating the suspensura. To this end, both square (pedalis or tetradoron bricks, 29.6 cm per side) and rectangular (lydios, 29.6 x 44.4 cm) bricks were used, with the scattered use of octogonal bricks; octogonal bricks were also used to make columns at the Pompeii Basilica (Van Aken 1952, p. 143), at the Fiésole baths (Italy) (Yegül 1992, p. 357), and in the bases and capitals of the rectangular sudatio at Gijón.

A second solution was the appearance, in the 2nd century CE, of circular pilae using annular earthenware bricks, often co-existing in the same baths with pilae made with polyedral bricks; for instance, in the two Albeiumendi hypocausts (San Román de San Millán, Álava) (Filloy; Gil 1997, pp. 392-394), in the Carteia caldarium (San Roque, Cádiz), and even mixed pilae comprising both types of pieces, such as in the San Martín de Santander hypocaust and in the Gijón circular sudatio. Fernández, Morillo, & Zarzalejos (1999, p. 289) refer to their use in Pompaelo, Complutum.

Circular pilae do not particularly improve the thermal inertia of the hypocaust; moreover, the circular earthenware bricks require more careful handling during manufacture, transportation, and laying. Consequently, the use of circular bricks for pilae construction must have been due to considerable mechanical advantages in balancing stresses and distributing loads by preventing buckling. An additional advantage conferred was the savings in raw material in the lack of edges, which bore no load in any case. The idea of building circular pilae spurred the appearance of new types of circular earthenware bricks, with clear precedents in Mesopotamian earthenware (Graciani 2007): on one hand, the circular or annular bricks for making pilae by simply stacking the bricks and, on the other hand, semi-circular or quarter-circle or third-circle bricks for making bonded pilae. In fact, despite being preferentially for thermal use, all of these brick types (save for the annular one) could be used in general support construction. The average diameter of these sections ranged from 12 to 23 cm, with occasional much larger ones (e.g. up to 32 cm in Carteia).

Unbonded pilae were usually built with circular pieces, commonly found in hypocausts and at pottery manufacturers; in Hispania, for instance, they have been documented in some earthenware manufacturers (Filloy; Gil 1997, p. 398) and hypocausts, including in Ilici, in Lancia, in the Santander Cathedral, in the Asturica Large Bath, in Diumium, and in Varea (Logroño) (Fernández; Morillo; Zarzalejos 1999, p. 296; Gisbert 1999, p. 85; Andrés; Heras; Tirado; Cabada 1997, pp. 420-422). In contrast, the annular ones (a true innovation in the History of Construction) are quite exceptional, with the most characteristic type found the Caracalla Baths in Ankara (Çankirikapi Baths) from the end of the 2nd century and beginning of the 3rd century CE. Among the bonded types, semi-circular pieces are the most abundant, occurring, for instance, in the Small Baths in Phaeselis (Turkey) (Yegül 1992, p. 358, Fig. 445) and having a much greater diameter than was usual (32 cm), and in the baths at Carteia (San Roque, Cádiz, Spain). Less common were the pilae made with radial pieces, which required much greater care in laying the brick, which may have been why, in some cases such as in Carteia (Graciani 2007), this method was abandoned in favour of recycling the radial pieces for mixed fabrics, placing the edge of the radius towards the wall face, as in pavements.

The choice of earthenware bricks for circular pilae must also have been influenced by mechanical properties. The use of semi-circular and radial pieces, which had to be bonded and therefore slowed down the laying, can only be accounted for if the builders believed this method served to prevent a possible load failure. They were evidently unaware that, in fact, pilae constructed with a single earthenware brick per course performed better mechanically because the earthenware brick itself has better cohesion than the mortar in the joints. The manufacture of semi-circular and radial bricks might also have been used at baths supplied by poorer-quality earthenware manufacturers in order to ensure that the pieces did not have any superficial unevenness that would hamper the laying. In fact, the manufacture of smaller bricks might prevent the occurrence of problems due to uneven firing, such as traction and compression that would buckle the smooth surface. This explanation might account for the fact that the circular pieces found at some earthenware manufacturers for the 2nd century CE disappeared from sequences corresponding to the 3rd century CE, during possible times of economic recession; for example, in the Almadrava earthenware manufacturer (Setla, Mirarosa-Miraflor) in the number 11 circular bricks, identified by Gisbert as type 9 from Saltètes d’Aude (Laubenheimer 1990, 103). The diameter and thickness of the bricks range from 19.5 to 22 cm and from 6 to 7.4 cm, respectively (Gisbert 1999, p. 85).

The annular bricks (exclusively made for baths) are spectacularly employed at the aforementioned Caracalla Baths in Ankara (Çankirikapi Baths), evidencing a clear improvement in design and illustrating that the builders were well aware that the central part of the pilae is an area of relative weakness. Consequently, hollowing out the interior of a brick does not affect its load-bearing capabilities since the load is borne by the outer curve in any case.

Archwork earthenware bricks. An alternative solution for supporting the suspensura, at times co-existing with pilae (e.g. in the Caracalla Baths in Turkey; Yegül 1992, p. 357 and 361, Fig. 451), consisted in constructing small arches and vaults. In some geographic areas, this method was used quite extensively; in Hispania, for instance, the research group of Fernández Ochoa has documented it in at least 25 baths; in Baetica in rooms 6, 7, and 9 of Baelo, Manigua, and the Trajan Baths at Italica; in Lusitania in rooms 5, 6, and 7 of the private baths of the Mérida Amphitheatre House, the Cantabfer House, and the baths next to the Conimbriga aqueduct; in Tarraconense in Águilas, in two tepidaria and the sudatio of the Padre Blanco Baths at Astorga, in the apodyterium and the possible rectangular sudatio of the second building phase at Gijón; in the baths under the León Ca-
In this method, specially designed bricks termed *cunetai* were laid in a radial position. These bricks are rectangular, with a tongue on one side and a wedge-shaped cross-section. Notwithstanding, on occasion general-use rectangular bricks were substituted, being of non-standard, extremely variable dimensions. Cases in Hispania include the *apodyterium* of Gijón (19.5 x 14 x 5.5 and 4.5 cm), Baelo Claudia (37 x 28.5 x 5.5-6.3 cm), and Munigua (14-15 x 5-6 x 3.5 cm) (Roldán 1999, p. 196; Étienne; Mayet 1971; Roldán 1994, p. 186).

**Load-bearing bracket bricks.** A third type of piece specifically used in baths is bracket bricks for anchoring two elements of the heat-transmission system: the suspensura horizontally and, vertically, the plaques for enclosing the *concameratone* (when *tubuli* were not used). Some examples of such pieces are found in museums (e.g. the Archaeological Museum of Seville) and they have also been documented from the sites of some clay manufacturers. However, there are no specific studies on their method of placement or the construction purpose they form part of. The authors have approached this subject for the hypocaust at the Carteia Baths (Spain), where these bricks are fragmented and therefore had previously been interpreted as normal bricks. In fact, some of the bracket bricks are flush with the wall due to repairs to the concamerario enclosure system and the introduction of new bracket systems, whereas other breakages seem to be incidental. In any case, for whatever reason, the loss of the characteristic protrusion is most likely why the bracket system has previously gone unnoticed in this case and many others.

Unbroken pieces are easily identified as they have a prominent head (i.e. due to excessive length); in fact, they are set as headers and are longer than normal bricks since one part was embedded in the spine wall and the other jutted out the width of the *concameratio*. There are three types of these brackets and one of each type was laid in the wall along its axis, one on top of the other. The lowermost one was a flying bracket brick, which is a rectangular brick with a standard head, edge, and face. It has no protruding edges or grooves as its role is merely as a buttress to support the flight of the other brackets and thereby strengthen them against breakage. Above this piece is placed a suspensura *bracket brick*, which has a flat face and a longitudinal groove along its edge that continues onto the head. Two *bipedalis* bricks (with tongues) from the suspensura slot into these grooves. The top brick is a concameratio *bracket brick*, which has a slot in its face, a short slot in the edge near the head (smooth-faced itself); the veneer plaques of the concameratio slot in (with tongues and grooves to correspond with the next plaque) to these slots in the bracket brick.

**CONCAMERATIO PIECES**

The *concameratio* is the false chamber through which the flue gases circulate to heat the wall and facilitate the ascent of the air towards the vaults. In its lower part it is open to the hypocaust and with the underground systems of air circulation, whereas higher up there are vents to progressively allow the air to escape to the vaults. Seneca referred to these hollow walls as a recent invention, which, together with archaeological evidence, suggests they were introduced at the beginning of the 1st century BC; they are evident in the restorations to the tepidarium and caldarium of the Stabian Baths and in the caldarium of the Forum Baths in Pompeii. There are two earthenware elements related to heat transmission through the concameratio: the earthenware plaques (either *tegula mammatae* or rounded-off bricks with terra-cotta studs) and the *tubuli*. Both of these two elements would be covered by a 3-6 cm thick layer of mortar in which marble veneer or stucco was embedded.

The elements used to enclose the concameratio are among the most poorly preserved of those used in baths since, due to the air pressure and problems affixing these pieces, the chambers are more exposed to deterioration and, therefore, are more frequently renovated. Occasionally these renovations incorporate innovative solutions and brick pieces, thereby causing loss of any evidence of previous anchoring systems or, at most, the bare remnants of such systems in the spine wall. Moreover, since the above-ground portions of bath installations are not generally preserved, such pieces are not commonly found *in situ*, which makes it difficult to place these systems in a timeline. The most that usually remains of them are remnants at the base of the walls above the suspensura level. Instead, these pieces are usually fragmented and viewed out of context, either piled at the foot of the wall, in middens, or reused for other applications (e.g. emplaced in walls as standard bricks); many others are lost upon being crushed to make opus signinum. Since the disparity in types of these pieces and their common fragmentation make remains hard to identify, they are often catalogued simply as *tegula* fragments. Very few baths preserve concameratio pieces *in situ*; in fact, just a few highly significant Italian baths have been historically crucial to explaining how these applications worked in the different provinces of the Empire. Such is the case of the Ostia Antica Forum, where the bases of the *tubuli* sections are preserved with overlay remains and of the Stabiae Baths in Pompeii, which preserve their *tegula mammatae* (Adam 1996, pp. 292-293). In Hispania, for instance, only the baths at Astorga and Gijón have preserved the concameratio pieces *in situ*. 
Earthenware plaques: tegula mammatae and terra-cotta plaques with studs

One of the first options is to create chambers for hot-air circulation with earthenware elements affixed to the spine wall. When there are no remains left of the concameratio elements, the traces of the anchoring systems to the spine wall can indicate the use of this method (although not which of the two variants was used). In fact, there are two generic types based on the piece characteristics: the tegula mammatae (which incorporate the anchoring systems themselves) and wire-cut bricks that use independent anchors (terra-cotta studs). In other cases, use is made of other earthenware pieces of uncertain function to make the chambers.

**Tegula mammatae.** The oldest method for enclosing the concameratio chambers seems to have been the tegula mammatae (earthenware plaques with bosses) that were in use up to the 1st century CE. In fact, they were used in various buildings at Pompeii at the start of the 1st century BCE, such as in the Forum Baths of Pompeii and the baths of several houses (including that of Julia Felix; II, 4). These earthenware plaques are about 2 cm thick with four nipples, usually truncated cones. They are anchored to the spine wall by studs or metal clamps piercing the nipples and leaving a space of about 3.5 to 5 cm between the wall and the plaques. They protruded 3.5 to 5 cm into the room near the corners of the plaques, producing a chamber about 5 to 8 cm deep.

Since there were no standards, there are abundant local variations, some rectangular and others (most) square, about a foot and a half long per side (around 45 cm). In fact, the men’s tepidarium at the Stabies Baths in Pompeii (beginning of the 1st century BCE) contains two different types: a square one 53 cm per side and a rectangular one also 53 cm high but narrower in width (Adam 1996, p. 292, Fig. 631).

Actually, there is no documentation confirming that this is the original term for this particular element. The word mammata is used by Pliny the Elder (35.159) in the passage the author wrote on baths. Vitruvius does not use this term, although in Chapter IV (IV, 2) of Book VII of De Architectura, he refers to a tegula hamata, amata, or ammata, with hooks (hamata is derived from hamus, meaning hook) used to separate the walls and thereby prevent the accumulation of humidity. Use of this method has been reported from various rooms of the Livia House and in the Tiberian Dome in the Palatine (Adam 1996, p. 292). It is probable that these pieces Vitruvius recommends (after water-proofing with pitch) are the same ones used to enclose the concameratione; Vitruvius may have neglected mentioning this use since, by his period, channeling via tubuli was already in use.

The tegula mammatae prevented a good draw in the chamber, causing wave turbulence that slowed the ascent of the flue gases and even sometimes caused a backdraft. The invention of the tubuli in the 1st century CE presented an alternative that solved this problem. Although it is commonly said that the tegula mammatae fell out of use with the invention of the tubuli, they did not disappear, so the presence of one type of piece cannot be used as a de-facto timeline.

**Terra-cotta plaques with studs.** Likely an older solution than the tegula mammatae was the use of plain terra-cotta plaques (without special corner bosses), such as simple roof tiles (even discarded ones) held in place by terra-cotta studs. (These plaques are referred to in Spanish publications as tegulas de orejeta or ladrillos con muescas; the studs are termed fijas, poleas, carretes, or clavijas in Spanish, Tonnägeln in German, and fiche en terre cuite in French.) The studs are generally cylindrical, with slightly diverging side walls and round heads. The stud heads have grooves for sloting in four enclosure plaques, and the other end of the stud is embedded in the spine wall (Fig.1).

This combination was widely used in the Mediterranean, being reported from North Africa, Turkey (e.g. the Small Baths in the Middle City in Pergamon; Yegül 1992, p. 363), and Hispania. The first studies on the topic were done by Fincker (1986) and, for Hispania, Sanz (1987 & 1987b), with a number of subsequent reports on findings of these types of pieces in different manufacturers and sites (Gisbert 1999, p. 89; Filloy; Gil 1997, p. 397;...
Galve; Valero 1980; Andrés; Heras; Tirado; Cabada 1997, p. 420 & 424). Yegül considers it may be an earlier method than the tegula mammatae, although this, again, does not mean they only appear in buildings constructed before the appearance of tegula mammatae at the start of the 1st century BCE. In fact, their use did persist at less specialized earthenware manufacturers as these plaques are easier to make (simply by cutting off the four corners of the brick); moreover, they are easy to transport and can be stacked with less risk of breakage. There are even cases in which the method is further simplified by anchoring simple rectangular files or tegulae (without the nipples) to the spine wall with iron studs. Although the first Hispanic examples reported (e.g. from Baelo Claudia) were thought to be a result of a North African influence, further research has indicated that the use was far more extensive than a local influence would imply.

**Vertical-Transmission Pieces: Tubuli latericii**

One alternative to hot-air transmission through the concameratione was to vertically channel the air up to the vaults by means of tubuli latericii; these were earthenware ‘pipes’ placed vertically end-to-end and side-by-side. Some tubuli also had side cut-outs (circular, square, or rectangular) allowing the lateral flow of hot air and thereby reducing breakage. These tubuli latericii were affixed to the wall with a layer of mortar, due to which some have their faces scored or incised with rectangular or diamond motifs made by a finger, a sharp object, or even by a comb (Brodribb 1979, p. 149). At times the tubuli were anchored to the wall two by two with iron T-cramps. The overlay was then applied on top of them. Curiously, in some cases the tubuli are even scored on the inner wall (Hernández; Pujante 1999, p. 396). As mentioned, this innovation is believed to have arisen in the first half of the 1st century CE, accounting for Vitruvius’s failure to mention it. Tubuli can be found, for instance, in two buildings in Pompeii that underwent renovations in the second half of the 1st century; in the caldarium of the Stabies Baths (undergoing renovations in 62 BCE) and in the new town centre baths.

There are two shapes of tubuli, hollow tubuli and half tubuli (U-shaped in cross-section). The complete tubuli latericii could be oval or polyhedral (rectangular or square) in cross-section, with the side cut-outs occurring as straight lines or circles (regardless of the shape in cross-section).

Tubuli with a flat outer surface are easier to overlay as the outer faces of the tubuli provide the support for the overlay material, whereas as curved tubuli first require the hollows between them to be filled before the overlay can go on. In the Forum Baths of Ostia Antica are polyhedral tubuli affixed to the wall with mortar and overlaid with marble veneer, also affixed to the tubuli with mortar (Severan period, end of the 2nd century CE to the start of the 3rd). An alternative to the whole tubuli was the half-tubuli, which channelled the hot air through the hollow formed by two facing pieces (examples found in the Carteia Baths; Graciani 2007); there are more rudimentary alternatives, such as lining up bricks to create channels. For instance, in the Murobriga West Baths, the wall is made out of bricks 36-37 x 7 cm separated from the spine wall by bricks of the same type placed transversally (Fernández; Morillo; Zarzalejos 1999, p. 299). A similar, more rudimentary, method did not use specialised ceramic pieces, simply facing imbrices, which were also sometimes used for making pilae and, more commonly, chimneys. For instance, in Britannia, this pilae solution has been reported in Binchester and in Rockbourne, and in Hispania it has been noted in the second phase of the Caldarium 1 of the Padre Blanco Baths at Astorga (Fernández; Morillo; Zarzalejos 1999, pp. 181 –cfr. Bedoyere 199, p. 299-).

The use of half-tubuli is most likely related to the lack of a quality manufacturer of ceramics in the area surrounding the baths under construction as it is much easier to produce straight, open pieces than hollow ones (which also require greater care in firing). Moreover, the openings for cross-ventilation are much more easily made in the half-tubuli, simply by cutting out a section in each piece where it comes into contact with contiguous tubuli. Despite the evident manufacturing advantages, this solution does allow more heat loss and, consequently, failures of the system requiring repairs. The studies performed on ceramic fragments from the Carteia Baths (San Roque, Cádiz, Spain) reveal two variants of the half-tubuli based on whether the pieces were designed to be placed facing each other upright or facing each other on their sides (Graciani 2007), in addition to variations in size (Fig. 2). The first model most probably allowed more flute gases to escape since the joints were longer, and so the second type may be a better, more perfected solution.

![Figure 2: The two variants of the half-tubuli at the Carteia Baths (Spain): (Graciani 2007, drawn by Núñez Arce)](image)
Vault pieces: Tubuli lingulati and tubuli cuneati

Some baths not only had a system for heated walls, but also for heated vaulting. In such cases, there were two heating methods: via tubuli lingulati or via tubuli cuneati. The simplest method was to place a line of interconnecting earthenware tubes on the vault intrados (Yegül 1992, p. 365) termed tubuli lingulati that, in addition to distributing the heat through the vaults, also (because they are hollow) diminish its weight. The use of earthenware tubes in Roman vault construction was extensive in North Africa from at least the end of the 2nd century CE, with examples also reported from Great Britain and Sicily. These tubes also lightened the weight of the vaults and they are, in fact, similar to those commonly used in the apses and cupolas of Ravenna constructions at the end of the 4th century CE.

The other option was to use hollow box-shaped earthenware pieces termed tubuli cuneati (hollow box tiles) or hollow voussoir tiles (Brodribb 1987, pp. 79-83). These pieces were employed as voussoirs in the series of ribs of barrel vaults of opus caementium as an internal framework, allowing the passage of hot air that ascended through the walls from the hypocaust. They are very characteristic pieces due to the boxiness of their faces, their wedge-shaped edges, and the finger impressions common on the faces to improve mortar adherence. The vault was clad externally with a protective tile roof of conventional form.

Hollow voussoir tiles are not very often found, perhaps due to loss or fragmentation upon falling from the ceiling or perhaps because this system was not widely spread. In fact, Brodribb (1979) indicates it was uncommon to find complete pieces, although examples had been found at various localities (e.g. Chedworth, Bath, Darenth, Eastbourne, Godmanchester, Silchester, Rockbourne, Reculver, Colchester, Corinium, and London) and that “…examples of tapering sides only (Part B) are recorded from some 15 different sites—not a large number. There are 6 other sites with reports of voussoirs…” but details are not given (Brodribb 1979, p. 148). An extremely interesting methodological analysis has been carried out by Brodribb in which, based on tile dimensions, he calculated the possible span of the vault and, consequently, its possible height. Tubuli cuneati were occasionally used as a substitute for tubuli cuneati to construct the ribs. Mason cites an example of such a substitution in his study on the earthenware tubes at the baths of the legionary fortress at Chester in the third century. Tube length ranged from 18.5 to 22.5 cm, the external diameter at the open end ranged from 6.5 to 8.1 cm, and that at the nozzle varied from 2.2 to 3.0 cm (Mason 1990, p. 218).

CONCLUSIONS

In contrast to the standards set forth by Vitruvius, the hypocaust system in fact shows the use of diverse methods and multiple types of earthenware pieces used in baths based on geographic location and, especially, on the size of the works, the budget and materials available, and the quality of the earthenware industry and of the manufacturer supplying the building site. Some methods evidently arose as a response to material scarcity, such as the substitution of area sesquipedalis by general-use pieces. Even more ingenious solutions can arise (not therefore problem-free, though), such as the use of the half-tubuli or the innovation of the bracket system.

Changes in the types of earthenware pieces therefore seem to arise from reflections on how to prevent the drawbacks and construction pathologies inherent in previous types by manufacturing new types of pieces, even at the cost of demanding diversification in the earthenware production.

REFERENCES

