**Univerzita Karlova v Praze**

**Filozofická fakulta**

**Ústav pro klasickou archeologii**

# DIPLOMOVÁ PRÁCE

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# Re-creation of a Roman bath complex in Pollena Trocchia

# Konstrukce římských lázní v obci Pollena Trocchia

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## Abstract

Roman baths were discovered in Pollena Trocchia on the northern side of Vesuvius. They can be labelled as private for their size and location and they probably belonged to a rich villa. This and the fact that they were built shortly after the A.D. 79 eruption makes them a rather rare specimen for study of development of Roman baths in the area. The baths are exceptionally well preserved and rare details of construction and functionality can be found, from the design phase, which can be seen in form of 1:1 plan carved on bricks forming the hypocaust floor, to the water and heating technologies. These details are followed in this thesis and the original form and modus operandi of the baths is reconstructed. The baths are also compared to selected published specimens from Campania and the rest of the Roman world.

## Keywords

Rome, baths, building, architecture, technology, Campania

# Abstrakt

V obci Pollena Trocchia na severní straně Vesuvu byly odkryty římské lázně, které lze díky jejich velikosti a poloze považovat za soukromé patřící k bohaté ville. Tato skutečnost a fakt, že byly postaveny krátce po erupci Vesuvu roku 79 n. l. z nich tvoří relativně vzácný exemplář pro studium vývoje lázeňské architektury v oblasti. Lázně jsou mimořádně dobře dochované a lze na nich pozorovat jinak vzácné detaily konstrukce a provozu lázní, počínaje již fází plánování, kterou lze pozorovat na vyrytém plánu v měřítku 1:1 na cihlách tvořících podlahu hypocausta, až po fungování technologického zařízení, tedy vytápění a rozvádění vody. Tyto detaily jsou v této práci sledovány a na jejich základě je rekonstruována původní podoba a funkce lázní. Lázně jsou také srovnávány s některými publikovanými exempláři z Kampánie i zbytku Římského světa.



# Klíčová slova

Řím, lázně, stavitelství, architektura, technologie, Kampánie

# Contents

## Baths in the Vesuvian region

Roman baths are often mentioned as one of the hallmarks of their civilization. They took a rather distinctive form and can be quite easily identified during excavations. They also seem to be almost omnipresent, as they used to be an essential part of the Roman lifestyle. They are found in various settings spread from Egypt to Scotland and in various forms from small private establishments in large cities and several one or more bathrooms adjoining the kitchen in private houses to the imperial thermae which represent some of the largest and most technologically advanced buildings of the Roman era. These establishments no matter what size form a group of buildings with certain common basic technological features, such as having a sequence of rooms with different temperatures, hot air heating and use of water. The public baths did not serve just the purpose of cleaning the body, but also as a place of meeting, recreation and sometimes possibly as a showcase of art. All of these functions are reflected on their architectural form. For archaeologist they form a numerous group of buildings spread through various social, special and temporal settings.

This being said, it is striking that study of this group was rather neglected until recently and for example the basic architectural typology still comes from Krencker's Die Trierer Kaiserthermen from 1929. Janet DeLaine addressed this issue of neglect in her article Recent research on Roman baths (DeLaine 1988) which is also rather outdated nowadays. The current issues and discussions in this field were more recently summed up by Sadi Maréchal (Maréchal 2012). Because of this long neglect of many crucial issues of Roman bathing, some of the most fundamental questions, such as naming conventions, intended interior temperature or meaning of the hollow elements in walls for heating, are still disputed, but several monographs present an invaluable resource for further research (de Haan 2010; DeLaine 1997; Manderscheid 2004; Nielsen 1990; Yegül 1992).

Greek origins of the bathing culture are not disputed, but its influence on development of Roman bathing culture is not yet completely explained. The difference can be simply summed up that while the Greeks preferred individual hip-baths and cold water, the Romans preferred communal immersion in larger pools and hot water. The rooms in Roman baths were heated by hot air flowing through a hollow space under the floor - a hypocaust system. Pliny the Elder attributes the invention to Sergius Orata, a wealthy Campanian merchant, probably in the 90's B.C. Archaeological records give us different data and the oldest primitive underfloor heating system can be found in Gela (310 - 280 B.C., Yegül 1992, 48) or Gortys (mid 3rd c. B.C., DeLaine 1988, 14) and even the oldest known true hypocaust with suspensurae (the floor is built from tiles laid between small pillars made of bricks) in Italy was recently found outside of Campania in Fregellae (Tsiolis 2013) and is dated before 125 B.C. Exclusive position of Campania in evolution of Roman baths is disputed nowadays, but G. Fagan presents convincing arguments putting Campania back to focus because of its wealth, obvious Greek connections and also presents the idea that the Roman style of bathing developed as a way of replicating the experience of local natural thermal springs (Fagan 2001). Local availability of volcanic deposits known as pozzolana and abundant sources of stone suitable for use as caementa and facing of the wall made it possible to create opus caementicium, which allowed the "Roman architectural revolution" (Ward-Perkins 2003, 100). The most important example are the Stabian baths in Pompeii. Based on them Nielsen creates seven periods of development from Greek model of palaestra with adjacent bathing facility to full Roman baths (Nielsen 1990, 26–35). The development did not stop and A. Jorio notices in his description of the heating systems in the baths in Pompeii (Jorio 1981) that when the baths were repaired and rebuilt between A.D. 63 and 79, new technologies were implemented, including tubuli, mostly to improve draft in the system and increase effectivity of air circulation. J. DeLaine notices that towards the 2$^{nd}$ century, the baths often took after the new type of imperial thermae and both the heated area and the area of various pools increased, but her research is limited to public baths (DeLaine 1992). They also became more open and better-lit because of the new trend of large windows which in combination of their correct placement on the southern side could also help the heating when glazed (Ring 1996)

The previous paragraph and literature cited deals almost exclusively with the public baths. Private baths present a rather different group, where the basic functionality is the same, but they often had to conform to more strict limitations such as expenses, size and shape of available space, availability of water and fuel, and owner's preferences in bathing. Once again, the habit of private bathing at home can be traced to Hellenistic times in Greece, Asia Minor and Sicily (Trümper 2010). In Campania, we can find examples of private baths in various sizes and contexts. The most basic system can be found in Pompeii in the House of the Bull (V.1.7) where there is a series of three rooms – apodyterium connected to caldarium with a caementicium bathtub, which was heated by a praefurnium in the third room which also served as a kitchen and had separate access. This is very simple arrangement, but presents the very essence of private bathing – a place where the user can undress and a place where he can immerse in hot water. More complicated way of heating water is uniquely preserved from the villa rustica in Boscoreale. Here the water was not heated directly in the tub, but rather in a large metal cylindrical boiler from which a pipe led through a wall to the tub (alveus) (de Haan 1996, 62). There could be more than one boiler vat, each supplied with cold water from a cistern to control temperature. They would also be interconnected with lead pipes, so water can be transferred and mixed between them (Yegül 1992, 374). Of course the private baths took many different forms with more rooms, advanced architectural forms and large consumption of fuel and water, imitating more and more luxury of the public baths. Such larger private baths can be found for example in villa San Marco in Stabia, where there are two pools of significant size. The pool with hot water is very large and because its floor collapsed, the heating channels and a round space for testudo alveorum (a large hemispherical metal fixture heated by hot air from the inside) are visible. The other pool is about half the size, was filled with cold water and was part of the frigidarium. In the urban context, the source of water can be either a private well or a very own branch of the public water network fed by the aqueduct. In the extra-urban context the baths must have relied on their own wells or when the amount of water was large on cisterns filled with rain water or possibly by redirecting some local stream. There is a significant group of private baths in Pompeii and Stabia, but their dating and often simplicity prevents them from being a good comparanda with the baths which are the topic of this thesis. The only specimen similar enough both in dating and in form present the Baths with a Blue Mosaic in Lauro.

## Baths in Pollena Trocchia

The bath complex examined in this thesis is located in Pollena Trocchia (NA), on the site known as Masseria De Carolis on Traversa Vasca Cozzolino (Figure 1). Traces of a Roman building were discovered on this site as soon as 1988 in place where builders decided to extract volcanic material to use in concrete for construction of the nearby apartment building. Mario Pagano identified the structures, already damaged by an excavator, as a storage building belonging to a large villa rustica and dated them to 2$^{nd}$ century AD. After this examination, the site was neglected for almost 20 years and the area was used as an illegal dump. Cleaning of the site began in 2005 and new excavations began in 2007 as a part of the Apolline Project (De Simone et al. 2009, 220–21). The excavation continues through 2016 with each season uncovering new area of the bath complex and adjacent structures, while fruitful cooperation with restorers allows better preservation of this rather exceptionally well preserved building (Figure 3). The project has a rather strong emphasis on public aspect of archaeology and the site is accessible by public even during the course of excavations. A small exposition of finds from the site was created in the premises in Pollena Trocchia, where is also a lab and accommodation for participants of the excavations. Good relationship with local mayors and schools make it possible to use the site not only to present the cultural heritage to local inhabitants, both on site, in the exposition and on various local festivals, but also for them to actively participate for example in form of programmes for local schoolchildren.

To preserve the site and make it safe for visitors, extensive restorations take place. The volcanic material both prevents certain parts of the building from collapsing, but also develops pressures which push the walls. This is especially problematic in the eastern corridor with preserved barrel vault supported by a heavily damaged outer wall. The vault and the wall were secured by a "sarcophagus" holding the vault together and by metal rods drilled into the fabric of the wall, forming a grid strengthening the wall. Unfortunately this was not enough and the unexcavated material still pushes on the outer walls and extensive scaffolding had to be put in place to support them. This situation was the main impulse which started the idea of a photogrammetric survey for time effective documentation of the current state of the structures before they are covered by the scaffolding.

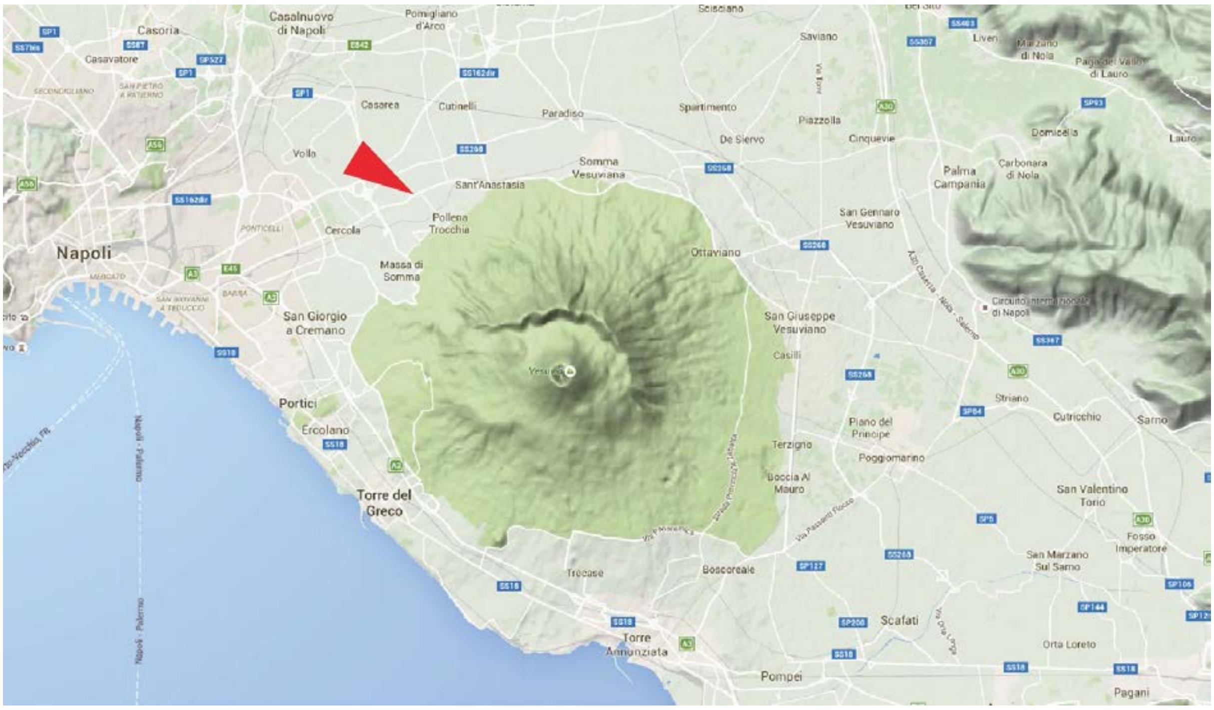


**Figure 1 Location of the villa with baths in Pollena Trocchia.**

As far as the current stratigraphic excavations tell us, the site has a rich history ranging from pre-79 to sometime after the 505-512? eruption. While the baths were built on top of the volcanic material brought there during the A.D. 79 eruption, excavations into that layer brought to light fragments of fresco and building material originating from an older villa, which was either on the same site, or slightly higher uphill. The site was re-occupied in a rather short time. Unfortunately dating of this re-occupation is rather difficult because of the fact that the baths were repurposed and partially disassembled in the late antiquity and they can be dated only by six brick stamps of the same type on the sesquipedales forming the floor of the hypocaust. The stamp has a form of shallow horse shoe and bears inscription DVO DOM (Duorum Domitiorum, CIL XV S.267 variant not in mirror writing). This stamp can be dated only vaguely to the Flavian era (Anderson 2002). This brings up the question of the time period in which the different areas around the Vesuvius recovered from the 79 eruption. The sesquipedales forming the floor of the hypocaust were almost certainly not locally produced. Though proper provenancing was not done, we know that the Domitii brothers had their kilns in the upper Tiber valley (Gasperoni 2003) and the bricks were probably imported, possibly as a substitute for local production interrupted by the catastrophe. G. Soricelli follows the activities of the Curatores Restituendae Campaniae and later related development of the areas to the south and east of the Vesuvius (Soricelli 1997). He notices repairs and rebuilding of various public monuments, reorganisation of their territories (new centuriation) and related building of new infrastructure. He concludes that this whole process must have been finished by the 120's. Dating of our brick stamps fits well within this time frame and it is possible that the villa with baths in question was part of the overall rebuilding of the area. Unfortunately it is not possible to recover more of the villa, as it extends below a modern road and an apartment building. The excavated part of the villa consists of several corridors, rooms and courtyards with traces of the original opulent decoration. Excavated contexts in this part of villa outside of the baths are often destruction layers and yield abundant amounts of frescos in various degrees of fragmentation, building materials, different types of marble and even several blue glass tesserae were found. The easternmost section of the excavated area yielded even a geometric black and white mosaic, heavily damaged by large chunks of caementicium, which possibly belonged to the original first floor. Room south from the room with mosaic has preserved imprints of the original geometric pattern of its floor in opus sectile. Small pieces of white marble were found in situ in the corner of the steps leading to the room with mosaic. The whole complex adjoining the baths (or better said vice versa) was built in several phases which are not subject of this thesis. Overally this building might have been part of the reorganised wine industry after the 79 eruption, similar to the near so called Villa of Augustus (sometimes called Dionysiac villa) in Somma Vesuviana. However, there is no architectural evidence of wine production in the villa in Pollena. This building probably served its purpose for several hundred years and then changed its purpose, probably in connection with larger socio-economic changes in the area. The baths fell into disuse, were stripped of the decorations and probably partially disassembled, several doors were blocked indicating a shift in use, more than 8 individuals[1] were buried there and the area was filled with building rubble and domestic waste. The decline is also marked by possible shift to a more agricultural use of the area. A new layer of a very rough cocciopesto was laid on the floor of for example room M, indicating some importance of that space, but later several significant roughly circular cuts were made in the floor and an orthogonal line of small round holes might indicate presence of some small structure, possibly a fence for small domestic animals, such as chicken. The larger holes might have served as a through for feeding them. Such re-use of former luxurious edifices is not rare in times of transition, such as the 4$^{th}$ and 5$^{th}$ century (Ripoll et al. 2000). This phase of habitation was interrupted by the eruption of 472, when the baths, at that time probably already partially disassembled through spoliation, were covered roughly up to two thirds of the original height by volcanic material. Thin layer of soil which formed on top of the volcanic material indicates that the site was not abandoned for a long time, before new

[1] 8 burials were published in (De Simone et al. 2012), since then several more were discovered

inhabitants arrived (De Simone et al. 2009, 224). These new occupants cleared out the material accumulated in the cistern above room H and covered its internal walls with a new layer of cocciopesto with inclusion of volcanic ash produced during the eruption. They also built a small furnace on top of room C, which was filled with volcanic material by then. The final habitation phase ends with the eruption of 505-512?.

The bath complex as excavated in 2015 is for purpose of this work composed of 5 excavated bath rooms (A – E), two service rooms with praefurnia (F – G), one completely preserved vaulted room with cistern in the upper storey (H – H1), a room with well (W), an open room with service access (L), courtyard (J), apse (K) and a corridor currently composed of room N and Q. Areas to the north of C and K are not yet excavated, but based on the visible traces in the upper parts of the walls, there are two rooms respectively. Unexcavated is also the underground cistern stretching in north – south direction west of the room with well. Outlet for waste water was realised through a channel going from the north-western corner of the unexcavated room north of K. The rooms are built on two different levels (Figure 5), with the unheated rooms on the upper level, heated rooms are founded on the lower level, thus compensating for height of the hypocaust (about 80 cm). The service rooms had their floor probably slightly lower, but it is difficult to identify the original level.

**Figure 2 Axonometry of the baths created by digital photogrammetry.**

**Figure 3 Overal view of the baths as excavated after 2014 season. (Apolline Project).**

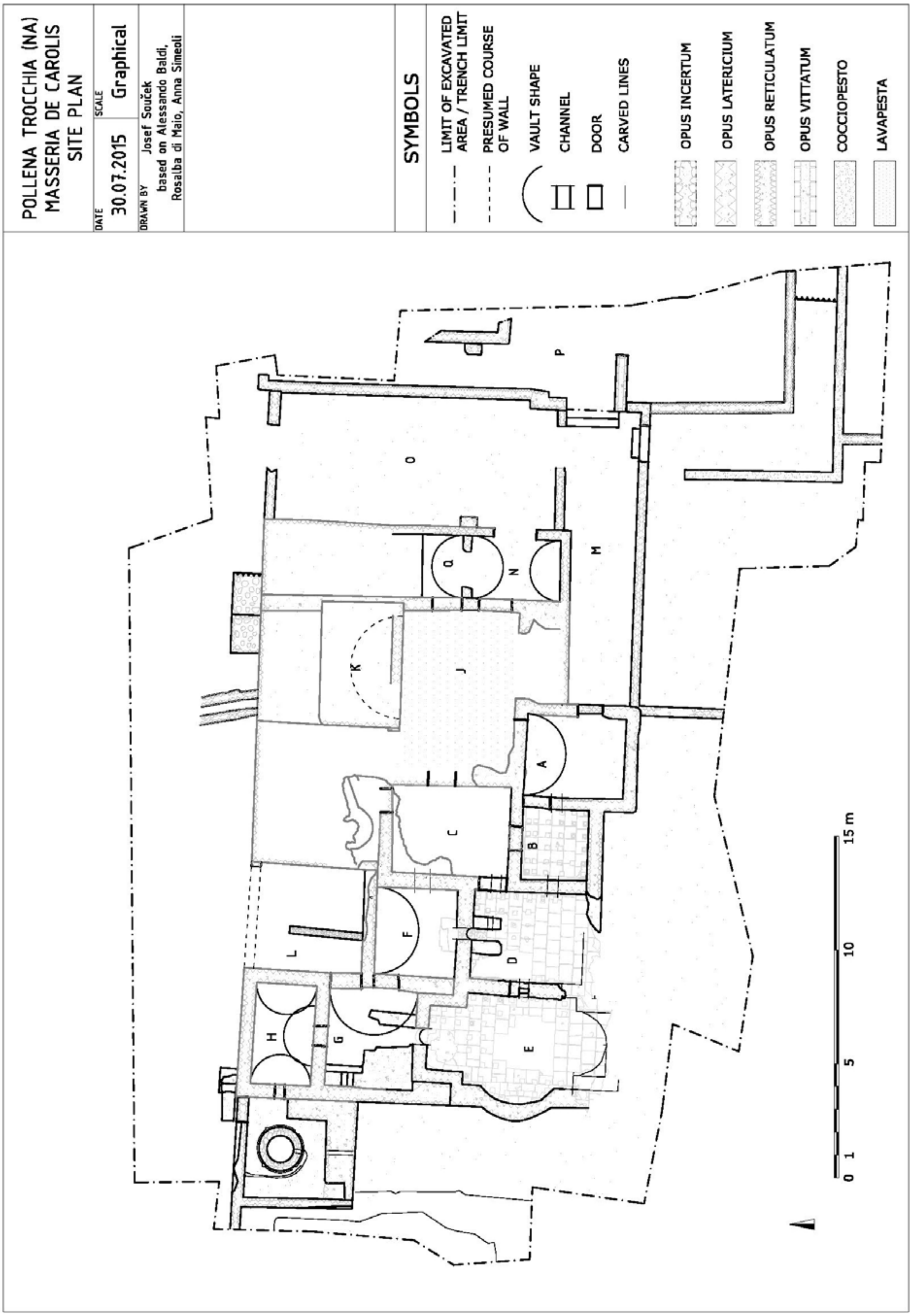


Figure 4 Overall plan of the site.

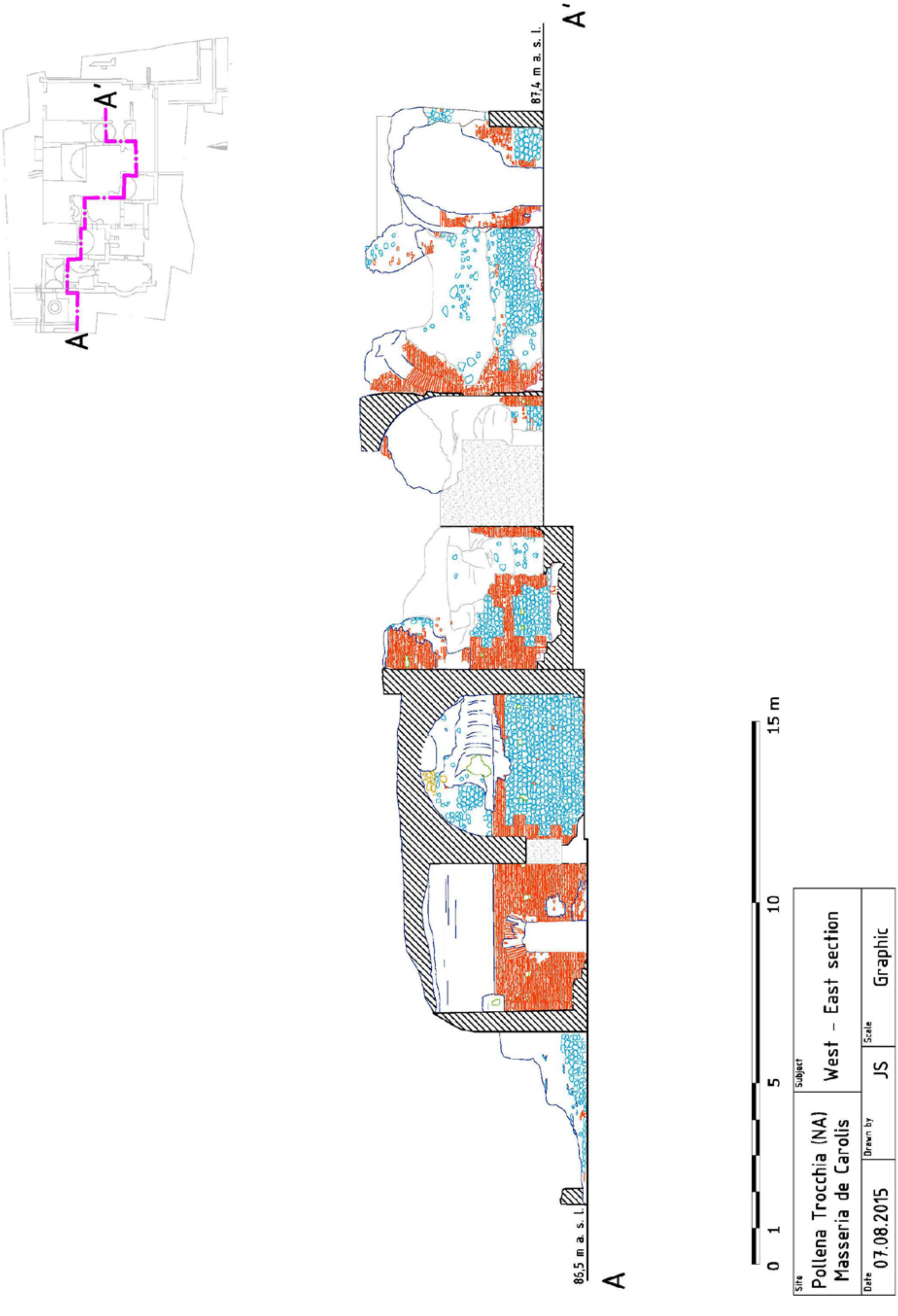


**Figure 5 Complete ection of the baths.**

# Non-interpretative description

## Room A

Dimensions / Area: 4,4 x 3,5 m / 15,39 $m^2$

Building technology: North: Only a small part was uncovered, otherwise the stability of the vault would be endangered. Wall is preserved to 4,5 m, almost the complete height of the room including the vault. The small area visible shows opus latericium. Facing from the end of the vault was massively spoliated, but several bricks remain in place in the very top.

South: Opus mixtum wall preserved to a maximum of 1,7 m. The middle part of incertum (lava stone) is preserved to only 0,6 m.

East: Preserved to full height of3,18 m in the northern end, 2 m in the southern end. Technology is opus mixtum with only a small part of opus incertum (lava stone). Pieces of bricks left in space and traces in the caementicium core reveal a relieving arch originally existing over the door.

West: Opus mixtum wall with the accessible part preserved to 1,8 m. Part of the latericium course tying the two latericium corners together is visible.

Floor: Rough cocciopesto made with larger pieces of terracotta. This is probably not the original pavement.

Ceiling: Preserved is a corner of a north – south oriented barrel vault that was about 30 cm lower than a perfect semi-cylinder would be. Material is caementicium with no facing, with a lot of local red pumice lightweight caementa. Traces of plaster covering the vault are visible.

Connectivity: Door in the eastern wall (1,1 m wide), connecting room A to room M, blocked with assorted building materials including bricks, tufa and lava blocks, during the re-use period.

Door in the northern wall, connecting room A to courtyard J, blocked using lava blocks and bricks during the re-use period. This door is not fully uncovered.

Door in the western wall (1,2 m wide), connecting room A to room B.

## Room B

Dimensions / Area: 2,8 x 3,2 m / 8,9 $m^2$

Building technology: North: Preserved from 1,5 to 2,5 m. Material is pure latericium.

South: Preserved to 2,5 m. Material is opus mixtum with a small panel of incertum (lava stone) below the door. Outer face of this wall is on the contrary almost all lava incertum.

East: Preserved from 2,5 to 3,4 m. Material is opus mixtum[2], with a very small panel of incertum (lava stone) between the rectangular opening and the door level. Pieces of bricks and traces in caementicium reveal a relieving arch over the door.

West: Preserved from 1,1 m to 2,5 m. Material is opus mixtum, showing three irregular incertum (lava stone) panels.[3] Channel connecting the hypocaust to the rest of the system is covered by a bipedalis carrying a very flat relieving arch made of 10 sesquipedales.

Floor: The room was heated by a hypocaust receiving secondary heat from room D. Pilae carrying the walk on floor were preserved in their original position. They were composed of several bessales followed by a circular tubulus with bessales on both ends.

Ceiling: No traces of the original ceiling were found.

Connectivity: Door in the eastern wall (1,2 m wide) connect the room to room A. They are visible, but blocked with unexcavated material from the other side.

Door in the northern wall (1,1 m wide) connect the room to room C. They were blocked during the re-use period with tufa and lava blocks with abundant mortar.

Other: The room is connected to the hypocaust system through a channel (58 cm high, 44 cm wide) in the eastern wall. A smaller rectangular

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[2] Different pattern than on the other side of the wall, see room A, western wall.

[3] Different pattern than on the other side of the wall, see room C, eastern wall.

opening (33 cm high, 44 cm wide) was built in the eastern wall, but ends with a standing brick, so the hollow space does not continue under room A.

Three burials were found in the south-eastern corner of the room and one in the south-western corner.

## Room C

Dimensions / Area: 5,1 x 4 m / 20,2 $m^2$

Building technology: North: Preserved from 1,3 to 4,5 m from the walk on floor. Technology is opus mixtum with regular panels of lava stones. Several tubuli heating the wall are visible in the lower part and even under the floor level.

South: Preserved from 1,2 to 2,6 m from the walk on floor. Technology is latericium, tubuli are visible in the lower parts.

East: Preserved to 2,8 m from the walk on floor. Material is almost completely latericium, with only a tiny rectangular panel (27 x 54 cm) of lava stones. Columns of tubuli are visible in the lower part of the wall. They are covered by a rather thick layer of plaster.

West: Preserved from 1,5 to 4,5 m from the walk on floor. Technology Is opus mixtum with one regular panel of lava stone. Tubuli are still in place in the lower area. Opening to the praefurnium is about 60 cm wide and arched.

Floor: The room was heated by a hypocaust floor, which was probably still in place during the 472 eruption and only collapsed under the weight of the volcanic material. It survives in a rather good state, because even the walk on surface is preserved next to the walls, while the central part is collapsed in situ and waits for restoration (Figure 8). The walk on surface visible was covered by smooth cocciopesto with decorative pieces of marble. This floor was carried by the same pilae from bessales and tubuli as in room B. Because of the preservation near the walls, we can observe the two rows of bipedales placed between the pilae on top of which a 9 cm thick layer of cocciopesto was poured.

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| Ceiling: | The only trace of the original ceiling survives in the north-western corner of the room, in form of a brick rectangle built separately from the rest of the wall, slightly curving to the east (Figure 9). |
| Connectivity: | The northern door (1 m wide) lead to the unexcavated area.<br>The eastern door (1,2 m wide) lead to the unexcavated courtyard J.<br>The southern door (1,1 m wide) lead to room B.<br>The western door (1,2 m wide) lead to room D. There is a channel connecting the hypocausts under this door. |
| Other: | The room was heated with its own fireplace from praefurnium F, with two baffles going inwards, separating the fire from the rest of the hypocaust. Because of the restoration works to be done on the floor, the hypocaust is not completely excavated.<br>Two burials were found in this room, but were not published at the time of writing this thesis. |

## Room D

| | |
|---|---|
| Dimensions / Area: | 4,9 x 3,9 m / 19,5 $m^2$ |
| Building technology: | North: Preserved from 0,6 to 3,4 m. Visible facing is just latericium. Original cocciopesto and plaster is visible to the height of the original walk on floor (70 cm). Central part of the wall is almost completely destroyed, possibly due to massive spoliation. Opening towards the praefurnium G was about 53 cm wide and is located in the middle of the wall.<br>South: Only a very small piece of this wall survived (0,8 m height, 2,2 m length). Building material in place is bricks, mostly covered by the original cocciopesto and plaster.<br>East: Preserved from 1,1 to 2,5 m. Facing is pure latericium[4] There are two openings of the hypocaust of roughly the same dimensions (44 x 60 cm). Cocciopesto and plaster covering of the wall is preserved to the height of the original walk on floor (80 cm).<br>West: |
| Floor: | The room was heated by a hypocaust receiving heat from its own |

[4] Pure latericium, unlike the other side, see room B, western wall.

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| | praefurnium, communicating with hypocausts of rooms E, B and C. The sesquipedales forming the lower level of the hypocaust were put directly on top of the 79 volcanic layer and the room was built directly on top of these bricks, with no foundations. Several lines carved in these bricks can be found upon close examination. These were used as guidelines for construction and give us a precise idea about the original shape of rooms D and E. |
| Ceiling: | No traces of the original ceiling were found. |
| Connectivity: | Door in the eastern wall (1,2 m wide) connect the room to room C. In the middle of the western wall there was a door connecting the room to room E. This door is noticeable only as several lined up bricks on one side above the channel connecting the two hypocausts. |
| Other: | Two baffles lead from the fireplace of the praefurnium inwards to the hypocaust. They were built after the walls were lined with cocciopesto, as the layer is visible between the baffles and the northern wall. There are two semi-circular cuts in them, forming probably an elliptical fireplace. The eastern baffle has a small opening leading towards the channel to room C (Figure 6). The baffles themselves seem to have been built in two phases, the second being wider and including this small side opening.<br>Some of the bricks forming the hypocaust floor are stamped by DVO DOM that can be dated to a short time period after AD 90. Kilns of the Domitii brothers were mostly in the valley of Tiber and the bricks are made of very different material than the local bricks used elsewhere. |

## Room E

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| Dimensions / Area: | 5 x 4,1 m (central part), 7,9 x 4,7 m including the alveus and apses / 28,6 $m^2$ |
| Building technology: | North: Preserved from 0,7 to 2,5 m. Material is latericium with lower parts of the arch over the fireplace (75 cm wide) preserved. Lower part of the wall is lined with cocciopesto to the height of 75 |

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| | cm. The eastern part of the wall is pierced with a hole leading to the praefurnium G, some 1,5 m from the hypocaust floor. |
| | South: Nothing of this wall remains, but the carved lines show us an apse inscribed to rectangle, which was also the external shape of this part of the room. |
| | East: Preserved from 0 to 2,6 m. Technology is latericium, the lower part of the wall is lined with cocciopesto up to the height of 80 cm. |
| | West: Preserved from 0 to 0,6 m. Visible building material is bricks, but they are mostly covered with cocciopesto and plaster lining. There are also patches of mortar that used to connect the hypocaust pillar to the wall. Most of the wall (3,3 m) is curved to form a very shallow apse, which is also visible from the outside. |
| Floor: | The room was heated by a hypocaust receiving heat from its own praefurnium, communicating with hypocaust of D through a channel in the middle of the eastern wall. The sesquipedales forming the lower level of the hypocaust were put directly on top of the 79 volcanic layer and the room was built directly on top of them, with not foundations. Carved lines showing the original plan of the room with apse are visible in the southern part. |
| Ceiling: | No traces of the original ceiling were found. |
| Connectivity: | The eastern door, of which only a trace can be deduced from alignment of the bricks near the centre of the eastern wall, lead to room D. |
| Other: | Some of the bricks forming the hypocaust floor are stamped by DVO.DOM. |

## Room F

| | |
|---|---|
| Dimensions / Area: | 3,5 x 3,8 m / 13,7 $m^2$ |
| Building technology: | North: Preserved to 4,5 m from the excavated level. Lower part of the wall is opus mixtum with rather thing edge of bricks in the western end and large panel of lava stones incertum forming the majority of the wall. This construction is closed off with a course of |

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| | bipedales and the area under the vault is filled with incertum made of both lava stones and yellow tufa on the very top. The top part of the wall was damaged for the first time in antiquity through spoliation and for the second time in 1988 with a mechanical excavator. |
| | South: Preserved up to 3,7 m from the excavated level. All of the visible structure is made of bricks only, except part of the foundation made of stones. |
| | East: Preserved to 2,8 m, where the vault meets the wall. Technology is mixtum, where the panel of incertum starts rather high, only several rows of stone under the spring of the vault. Arch of the fireplace was mostly removed as a part of the spoliation process. There is a 80 cm high cut in the fabric of the wall, but it is not certain whether it was intentional or a result of spoliation as well. |
| | West: Preserved to 2,8 m from the excavated level. About one third of the wall is replaced by volcanic material and the rest is only bricks closed off by a course of bipedales. |
| Floor: | None of the original floor remains. Small podium made of bricks is at the southern side of the room, forming a platform for servicing the fireplace. |
| Ceiling: | Small part of the original barrel vault (north – south oriented) is preserved. Its shape is very slightly higher than perfect semi-circle. Material is caementicium with high number of local red pumice caementa. |
| Connectivity: | The only door (1,1 m wide) connects the room to praefurnium G. |
| Other: | One burial was found in the south-eastern corner of the room. |

## Room G

| | |
|---|---|
| Dimensions / Area: | 3,9 x 4,3 m / 16,7 $m^2$ |
| Building technology: | North: Preserved to 2,6 m, where the vault begins. The wall is pure latericium with a closing row of bipedales. The wall is pierced in the western end and the hole leads to the cistern above (Figure 7). |

| | |
|---|---|
| | The door is crowned by an arch of bipedales. |
| | <u>South:</u> Preserved to 2,8 m from the excavated level. Technology is opus mixtum, with just a small panel of lava incertum at the very top of the wall. Unlike the northern wall, it is not divided from the vault by a course of bipedales. |
| | <u>East:</u> Preserved to approximately 4,8 m from the excavated level. The lower part is built from bricks only, closed by a row of bipedales and then the area of the vault is built from lava incertum with three putlog holes for the centering of the vault. There is a part of a relieving arch above the door leading to L. Space under the arch was filled with bricks as well. Large part of this wall is missing and the area is filled with volcanic material hard enough to prevent collapse. |
| | <u>West:</u> Preserved to 3,9 m. Lower part of the wall is opus mixtum with a large panel of lava stone incertum. It is closed off by a course of bipedales and the upper part ending the vault is built mostly as incertum with a small panel of bricks. Two putlog holes for the vault centering are visible. |
| Floor: | None of the original floor remains. |
| Ceiling: | About half of the original barrel vault (east – west direction) is preserved. The shape is perfectly hemispherical, material is caementicium without facing and with a lot of local red pumice caementa. Imprints of the centering are visible, revealing the width of the boards being roughly 1 RF (29,5 cm). There are more traces of the original centering in form of holes in the eastern and western wall, where the beams of the centering were anchored. |
| Connectivity: | The room has two doors next to each other in the eastern wall, one leading to room L (1,3 m wide, circa 1,8 m high) and one leading to praefurnium F (1,1 m wide). Door on the northern side (0,8 m wide, circa 1,7 m high) lead to “storage room” H. |
| Other: | The baffles delimiting the fireplace of the praefurnium go inwards, unlike the other two cases. The western wall extends all the way to the western wall, forming a caementicium platform accessible via four steps from the north. |

## Room H

Dimensions / Area: 2,7 x 4,5 m / 11,8 $m^2$

Building technology: North: Preserved in complete height (0,6 m).Technology is opus mixtum with one long rectangular panel of lava incertum. From the outside, the wall includes the cistern and its height is 4,4 m. Technology is opus mixtum with three large panels of lava incertum. In the middle of the second panel is visible the external outlet of the cistern.

South: Preserved in complete height (0,6 m, 1,9 m to the top the door)

East: Preserved in complete height (2,1 m). Technology is opus mixtum with one panel of lava incertum and with one rectangular opening in the central top part (29,7 cm high, 21 cm wide)

West: Preserved in complete height (2,1 m). Technology is opus mixtum with one panel of lava incertum interrupted with three rows of bricks in the upper part. In the upper middle part of the wall is a small arched window (56 x 46 cm).

Floor: None of the original floor remains.

Ceiling: Barrel vault (east – west direction) made of un-faced caementicium, is intersected by a barrel vault (north – south direction) forming the crown of the door.

Connectivity: One door (0,8 m wide, circa 1,7 m high) in the southern wall connecting the room to praefurnium G.

Other:

## Room H1 (cistern)

Dimensions / Area: 2,7 x 4,5 m / 11,8 $m^2$

Building technology: North: Technology is opus mixtum with two panels of incertum divided by six courses of bricks. The walls are lined with different layers of cocciopesto and plaster.

South: Technology is opus mixtum with the incertum panel covering the whole central part of the wall. The cocciopesto lining

| | |
|---|---|
| | is partially in place. |
| | East: Technology is opus mixtum with just one brick corner visible. |
| | West: Technology is opus mixtum with just one brick corner visible. Patches of plaster and cocciopesto lining are in place. |
| Floor: | Cocciopesto. |
| Ceiling: | No traces of ceiling were found |
| Connectivity: | The cistern was connected with praefurnium G by a hole in the western lower corner of the southern wall. Another hole is in the central lower part of the northern wall and leads outside the baths. |
| Other: | |

## Room with well

| | |
|---|---|
| Dimensions / Area: | 3,5 x 4,4 m / 13,7 $m^2$ |
| Building technology: | North: Very little of this wall remains, up to height of circa 0,5 m. Technology is opus incertum. There is a hole near the north-western corner piercing through the wall. |
| | South: Southern wall of this room is formed by a very thick L shaped platform build in opus mixtum technique. A dent wide 0,7 m is in the western end, a channel going through the wall outwards is near the floor in the centre of the wall and a regular rectangular opening (30 x 20 cm) is in the eastern section of the platform. |
| | East: Behind the short side of the platform is the western external wall of room H, H1 and G. Its height is up to 3,9 m and technology is opus incertum with two visible wide panels of lava stone. There is a small (56 x 46 cm) arched window leading to room H. Patches of fine cocciopesto lining is visible on the wall. |
| | West: Not much remains of this wall (circa 0,5 m high). Technology is opus incertum. |
| Floor: | Floor is covered with coarse cocciopesto. |
| Ceiling: | There are no traces of ceiling. |
| Connectivity: | One door in the northern wall (1,1 m wide) lead outside the complex and continue in several steps going under the level of foundations. |

| | |
|---|---|
| Other: | There is a circular opening to the well in the centre of the room. The well is constructed from lava stones and there are four rectangular cuts around it, forming a basis for some construction of four posts. The body of the well is pierced with a hole from which a channel cut in the cocciopesto runs towards the hole in the northern wall.<br>The well itself has a cylindrical top which leads to roughly square space, which is connected to the neighbouring unexcavated underground cistern through a rectangular opening in its eastern wall. |

## Room J

| | |
|---|---|
| Dimensions / Area: | 5,1 x 7,1 m / 35,7 $m^2$ |
| Building technology: | The area is mostly unexcavated and the data available show brick facings. |
| Floor: | The uncovered south-eastern corner is paved with lavapesta (mortar with crushed lava stones) and decorated with small white marble pieces. |
| Ceiling: | Absence of chunks of caementicium in the excavated part can mean that the area had no roof. |
| Connectivity: | Two doors next to each other on the eastern side lead to rooms N and Q. The space was freely connected with the apse K.<br>On the southern side is a blocked entrance to room A.<br>On the western side is an entrance to room C. |
| Other: | It is very difficult to describe and interpret the true shape and meaning of the southern part of the courtyard across the apse. The other side of the southern wall is uncovered, but unfortunately most of it is destroyed and held in place only by the volcanic fill. Part of a large relieving arch spanning the whole width of the possible alcove inside is visible. |

## Room K

| | |
|---|---|
| Dimensions / Area: | Apse with 4,5 m diameter and approximately 2,2 m depth / 7,7 $m^2$ |

| | |
|---|---|
| Building technology: | The southern exterior wall is, as far as excavated, built from bricks and was subject to heavy spoliation. |
| Floor: | Unexcavated |
| Ceiling: | Caementicium semi-dome lined with plaster. |
| Connectivity: | Open towards the courtyard J. |
| Other: | Only the very top part of the apse was excavated. |

## Room L

| | |
|---|---|
| Dimensions / Area: | 4,8 x 4,7 m / 21,5 $m^2$ |
| Building technology: | North: Almost no visible remains, but its foundation and lower (underground) parts exist and traces of this wall can be seen in the eastern end.<br>South: Preserved to 5,5 m from the excavated level. About two thirds of the wall remained covered by volcanic material for static reasons. What shows is built in opus mixtum technique with two large panels of lava incertum. The row of bipedales dividing the wall from the vault on the other side of the wall is also visible.<br>East: Preserved to 2,8 m from the excavated level. This wall is built in opus mixtum with two visible panels of lava incertum divided by six courses of bricks. Well visible is a course of bipedales slightly protruding from the wall, which closes off the foundations and divides them from the wall itself. The wall retains several traces of plaster, one copying the north-eastern corner, running further south and the other is a rather large chunk of plaster lining the foundations.<br>West: Preserved to 5,4 m from the excavated level. Technology is opus mixtum with two large panels of lava incertum. Relieving arch above the door is completely preserved and underneath it are traces of filling, so the top of the door was originally flat. The wall shows massive signs of spoliation of the lava stones and bricks, resulting in large damage of the northern end and three large holes cut to the fabric of the incertum. |
| Floor: | None of the original floor remains. |

Ceiling: There are no traces of the original ceiling.

Connectivity: One door in the western wall (1,3 m wide, circa 1,8 m high) leading to room G. No other door was confirmed, but the room was probably accessible from the northern side.

Other: The room was at some point, probably in late antiquity, divided by a very coarse wall made of mortared rubble, creating a separated corridor some 1,5 m wide leading to the door.

## Room N

Dimensions / Area: Room N: 3,9 x 2,7 m / 10,5 $m^2$

Room Q (presumed): 8,4 x 2,7 / 23,4 $m^2$

Building technology: North: Wall is preserved in almost full height, so the joint with the vault is visible. The western end is constructed from bricks, closed off by one visible bipedalis and then continues in what seems to be incertum covered in mortar. The eastern end is in worse shape and the lower western corner is in fact a rectangular panel of lava incertum, maybe built as part of some restoration of the wall in antiquity.

South: A very small piece of wall remains in place (0,7 m high and 1,3 m long) and was originally connected to the southern wall of the courtyard J. Technology is opus mixtum and is partially covered with plaster.

East: Visible pieces of the wall disrupted by a passage are built only from bricks and partially covered with plaster.

West: The wall is preserved in its original height (2,8 m to the spring of the vault) and the material seems to be latericium, but it is currently very badly damaged by spoliation. Traces of a relieving arch above the door are visible as well as sections of the closing course of bipedales.

Floor: Covered by rather coarse cocciopesto.

Ceiling: Continuous barrel vault overlapping from room N.

Connectivity: Door in the western wall (1,4 m wide) lead to courtyard J.

Door in the northern wall (1,5 m wide) lead to room Q.

Door in the eastern wall (1,9 m wide) lead outside the bath complex to room O.

Other:

## Room Q

Dimensions / Area: Presumed 8,4 x 2,7 m / 23,4 $m^2$

Building technology: North: Unexcavated

South: The wall is damaged, but in its western part reaches all the way to the vault. Both of the parts of the wall are built from bricks, while the upper part used to fill the vault is incertum.

East: Preserved in its original height (2,8 m). The visible part of the wall is built from bricks, with small patches of stones, possibly created during maintenance or re-building of the space for other purposes.

From the outside, the wall is very badly damaged and had to be supported by scaffolding in 2015. Technology was  opus mixtum, there are traces of two large relieving arches spanning almost the whole length of the wall, but there is no material left inside them. Only the southern end of the wall was excavated all the way to the floor and it is partially covered by plaster, in some places even painted. There is also a low (5 courses of bricks) rectangular protrusion next to the door to N (74 x 44 cm) of unknown purpose.

West: Preserved in its original height (2,8 m). Almost all of the facing bricks were removed during the process of spoliation. There are traces of a relieving arch above the door.

Floor: Covered by rather coarse cocciopesto.

Ceiling: The original barrel vault is preserved over the whole length of the room and underwent an extensive restoration.

Connectivity: One door in the southern wall (1,5 m wide) connecting the room with N. One door in the western wall (1,3 m wide), connecting the room with J. At least one more passage in the western wall is possible, but cannot be proven unless the room is excavated completely.

| | |
|---|---|
| Other: | For static reasons the excavation further to Q was not yet possible, so only a small trench was opened to reach the floor. |

## Northern exterior wall of the unexcavated rooms

| | |
|---|---|
| Building technology: | The wall is built in opus mixtum with four visible panels (or their remains) in lava incertum. It can be broken down to two parts. This division also follows the division of the one confirmed and two presumed rooms behind this wall.<br>The eastern part is preserved to a higher height (4,9 m from the foundation course) and has contains traces of two relieving arches. The eastern one marks the end of the barrel vault on the other side. The western one arches above a window, the original shape of which is nearly impossible to reconstruct because of massive spoliation. In the middle of this section is a door, cut in that wall during late antique re-use and there is a ramp built from spoliated material leading to it.<br>The western part is preserved to a lower height of 1,1 to 3,2 m from the foundation course, which is about 50 cm lower than the bipedales course of the eastern part. The foundations, made of lava stone, were uncovered to a greater depth and revealed the outlet channel for the waste water. It has rectangular shape with triangular top, created by leaning two sesquipedales against each other. Height of this outlet is about 75 cm and its width about 45. Bottom of the outlet is about 1,5 m below the upper foundation closing course. Right next to this outlet is another cut, probably made later, with unknown function, spanning the 50 cm between the upper and the lower foundation courses. The lower course of bipedales is sloping about 1°, which makes a difference of 7 cm at the end of the wall, while the upper foundation course is perfectly horizontal. |

**Figure 6 Baffles in room D with opening towards east.**

**Figure 7 Hole connecting room G with cistern H1.**

**Figure 8 Collapsed floor in room C, showing suspensurae and tubuli.**

**Figure 9 Springing of the probable cross vault in room C.**

# Methodology of research

The ultimate goal of the survey was to better understand the building phases, or stages of construction and their meaning. To achieve this goal, the following methods were used by the author.

## Photogrammetric survey

Firstly, it was the complex photogrammetric survey of the site and creation of a precise plan using total station. During the survey, each accessible wall surface of the baths was carefully observed, measured with total station and the source photos for photogrammetry were taken. The whole process was significantly sped up by using small group of assistants recruited from participants of the Apolline Project, who were offered the opportunity to learn this method, which is becoming a standard for the industry.

The tools and software used for the survey were:

- Canon 1100D 12 MPx DSLR with stock Canon 18-55 IS lens.
- Stonex R1 Plus reflectorless total station.
- Asus ROG G750 laptop (Intel Core i7 2,4 GHz, 16 GB RAM, GeForce GTX-870M, 3 GB VRAM)
- Lenovo ThinkPad E130 laptop (Intel Core i5 1,7 GHz, 8 GB RAM, Intel HD Graphics 4000
- Agisoft Photoscan 1.1.6.2038
- Autodesk AutoCAD 2014

The process was rather straightforward and effective. Once the surveyed wall was approached, it was cleaned and sketched. The wall was briefly described, including the building material, putlog holes, spoliation traces and its relationship to other walls.

At least three points in form of crosses were drawn on the surface using a coloured chalk. Normally a set of markers would be printed from Photoscan and attached to the surfaces, but this idea was abandoned, because of lack of good means of attaching them. Scotch tape was not effective enough, because the surfaces are too rough, dusty and even a slightest wind would blow them away. Nailing them to the surface would damage it permanently, so we also decided against.

Coordinates of the points were measured using reflectorless total station, while the assistants were learning about principles of measuring and basic total station operation.

A series of photos could then be captured for later use in Photoscan. The photos have to have at least 50% overlap in all directions and in this case and they should be more or less perpendicular to the surface. However, the main advantage of creating the orthophotos with Photoscan compared to a simple single-image photogrammetry is that the software can reconstruct shapes even from a set of rather oblique photos (Figure 10). Since the walls are sometimes preserved to a great height, single image photogrammetry would require a greater distance from the wall, which is unachievable in the rather small rooms of the baths, or some scaffolding or at least a ladder would have to be erected, which poses an unnecessary threat to the work safety. The data (measured coordinates and set of photos) were then checked using the smaller and less powerful “site laptop” (Lenovo), to see if the measurement was correct and the photos have sufficient quality (that they are not blurry, everything is in focus, there is no lens flare, there is enough overlap) and a preliminary processing was performed in Photoscan on low settings, to see if the desired area is covered completely.

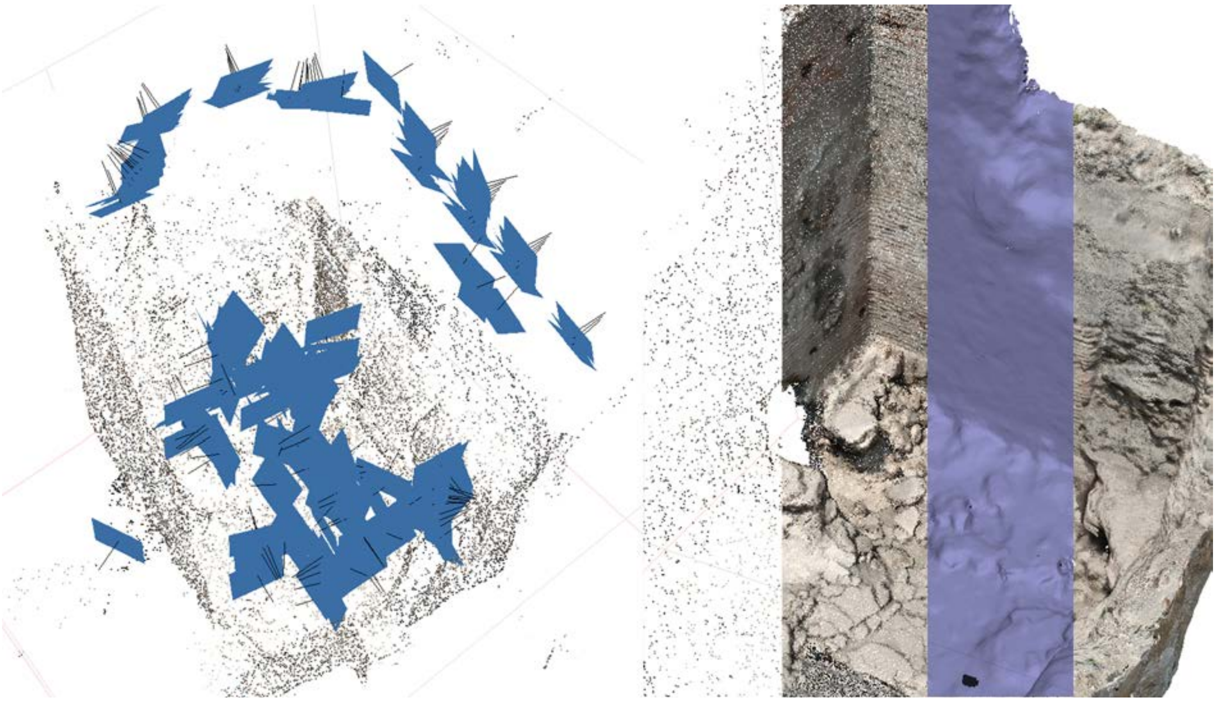


**Figure 10 Stages of processing the photos with Agisoft Photoscan.**

The off-site part of the survey was conducted with assistance of the same volunteers, who were notified beforehand to download and install the student version of AutoCAD 2015. The photo series were processed in Photoscan overnight as a batch on medium settings (Table 1), cleaned and orthographic projection of the model was exported. These orthophotos were distributed among the volunteers to be drawn in AutoCAD, which was also the second part of their training. Advantage was taken of the software’s ability to use layers with different properties and a different layer was assigned to each material – brick, lava stone, tufa, mortar, cocciopesto, plaster, painted plaster, unexcavated volcanic material and visible limits of the restoration works. In total, 49 surfaces were drawn this way during the 3 months long survey, covering most of the baths. The only surfaces not covered during the survey were the interior walls of room G, which was used as a storage and therefore inaccessible, and the area called "nymphaeum", which currently consists of the external face of the apse K and the two passages to the east of it. Since only very little changed in this area, since these surfaces were drawn in 2011, and the drawings were available in AutoCAD format, they could be incorporated to the corpus of plans.

| Operation | Settings |
|---|---|
| **Align photos (build a sparse cloud)** | Accuracy: medium<br>Pair preselection: generic |
| **Build dense cloud** | Quality: medium<br>Depth filtering: aggresive |
| **Build mesh** | Surface type: arbitrary<br>Source data: dense cloud<br>Face count: high<br>Interpolation: disabled |
| **Build texture** | Not necessary to perform, unless the model itself is to be used. |
| **Export orthophoto** | Projection type: planar<br>Blending mode: mosaic<br>Enable colour correction: on<br>Pixel size: 0,002 m for both X and Y |

**Table 1 Settings used for processing in Agisoft Photoscan.**

## Visual survey

Secondly, all the joints and building technology of the walls were examined visually to establish the relationship between the constructions and relative chronology. Because of the regular and highly standardised nature of Roman building, following courses of bricks can tell us a great deal about the structures. In this case, different phases can be observed by following the brick facing visible on the tops of the walls. Other indicator is courses of bipedales which are not present in all rooms. They were used as a bonding course to close off different stages of construction, in case of large scale construction even throughout the fabric of the wall (Lancaster 1998, 285), in small-scale construction like this only on top of foundations and on top of the walls, before the vault was built. It is also important to observe carefully the colour of mortar and look closely at the bricks, to see if the fabric is different.

## Metric analysis of brick facings

Thirdly, an attempt was made to carry out a metric analysis of the brick facing sample in different walls, in order to see whether the phases distinguished by following bricks in the wall sections were built in short or long time span. The method is the same as used by Maura Medri to examine the Aurelian walls in Rome, where it was employed to distinguish re-use of bricks from a long time period (Medri et al. 2015). The method is based on comparison of data from uniform 1 $m^2$ square samples of the brick facing from orthophotos. The vectorised orthophotos were used and the dimensions and areas were measured in AutoCAD using the built-in functions. The compared numbers are average length, thickness and area of the bricks uncut by the sample frame, ratio between the area covered by bricks and by mortar and finally the reconstructed total number of pieces used in 1 $m^2$.[5]

[5] Reconstructed total number of bricks is calculated as (area of cut pieces : average area of uncut pieces) + number of uncut pieces.

# Results of the examination

As was already stated, visual survey allows us to distinguish two separate structures forming the whole bath complex at its height – the bathrooms including the “representative” spaces not used for the process of bathing itself and the service rooms. The two parts can be distinguished by following the brick facing visible in the tops of the partially destroyed walls and also by following the courses of bipedales which close off the walls before the vault was built. We can see this course in all of the walls of the praefurnia, except the southern wall of G and eastern wall of F, where the vaults abutted on the already existing walls of rooms C and E.

## Design of the baths

Based on the precise plan created during the survey, a hypothesis about the planning process could be created to see how well the service rooms fit into a greater scheme. The building process inevitably started with reconnaissance of the terrain and drawing of a plan. Reconstruction of this plan is important, because it delimits the baths as an individual unit in context of the rest of the excavated building, which does not share the same modular system. In this case one version of the plan survives until today in form of the lines carved into the hypocaust floor which allow us to imagine the missing parts of rooms D and E. This 1:1 carved floor plan would not exist if the building had proper foundations, in which case only a system of posts and offset strings would be used (DeLaine 1997, 133–35). The ancient builders, however, deemed the hardened volcanic ashes from the AD 79 eruption hard enough to serve as a platform and to build directly on top of them. The outline of the baths was delimited and a floor of sesquipedales was laid. To explain the shape and organisation of the rooms, we can follow the work of Janet DeLaine (DeLaine 1997) and presume that the dimensions and arrangement of the rooms were guided by mathematical rules and could be drawn using simple geometry. To be able to reconstruct the way the ancient architect thought, all dimensions in Table 2 were converted to Roman feet where 1 RF = 0,296 m. I presume that the very first established number was the ratio between the sides of the rooms, similar to what Vitruvius prescribes (Vitruvius V.10). In this case the intended ratio for all of the excavated heated rooms except B was 1:1,25, and 1:1 for room B. Table 2 shows comparison between the ideal and real dimensions. It seems that the ideal dimensions could be drawn on “paper”, but then they were corrected so they did not contain fractions smaller than ½ RF. The final error was brought in during the construction itself.

I have demonstrated how the length to width ratio of the rooms influenced the final dimensions, but it does not tell us anything about the way the rooms were actually arranged. The baths are aligned along east – west axis, which has actually heading of approximately 285°. This slight deviation ensured that the afternoon and evening sun reaches and heats the southern side of the baths. I also argue that the placement of the rooms was a result of their inscription to a orthogonal grid with two repeating dimensions in each direction, here called major and minor offset. The horizontal major offset was derived from ratio 4:5, the same as the rooms would have, just turner 90°, resulting in rectangles 12 x 15 RF large. The minor horizontal offset was also based on the width of 15 RF, with ratio of 3:5. The resulting rectangle had dimensions of 15 x 25 RF. When the 12 x 15 RF rectangle was put in the middle, the resulting shape was the base of the grid. As is obvious now, 15 RF was the major vertical offset. The minor vertical offset was created as a golden rectangle based on 6,5 RF minor horizontal offset, creating a rectangle of 6,5 x 10,5 RF. Having these three basic rectangles, the architect could then arrange them in order to create the desired architectural effect. Through analysis of the floor plan I was able to reconstruct this basic grid into which the baths were designed, including some irregularities (Figure 11). Vertically, the major and minor horizontal offsets repeat themselves for three times. Such organisation of heated rooms, the service rooms and the rooms using larger volumes of water in separate rows can be seen elsewhere in the area, for example in the baths belonging to Hospitium dei Sulpicii excavated in Murecine and the baths in Lauro, where this organisation is related to the terracing. Horizontally, two major and one minor vertical offsets repeat themselves twice, in two different vertical stripes. Irregularities are present in form of the switched major and minor horizontal offset to create the possible alcove in the southern part of the courtyard J. Next to it are the rooms N and Q, the width of which is the minor vertical offset, which is irregular because it is second in row. The wall dividing these two rooms also respects the grid. An important revelation is that the service rooms, though technically separately built, respect the same grid as the bathrooms, even though less precisely, so they seem to be part of the original plan.

| Room | Side | Ideal | | Corrected | | Real | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | From ratio | Offset dimensions | Ratio | Dimensions | Ratio | Dimenions | Average | Difference of average from corrected |
| A | N | 1:1,25 | 11 | 1.26 | 11.5 | 1.24 | 11.93 | 11.78 | 0.27 |
| | S | | 11 | | 11.5 | | 11.62 | | |
| | E | | 14.75 | | 14.5 | | 14.51 | 14.58 | 0.08 |
| | W | | 14.75 | | 14.5 | | 14.65 | | |
| B | N | 1:1 | 10.5 | 1.05 | 10.5 | 0.93 | 10.72 | 10.47 | 0.04 |
| | S | | 10.5 | | 10.5 | | 10.21 | | |
| | E | | 10.5 | | 10 | | 9.72 | 9.71 | 0.29 |
| | W | | 10.5 | | 10 | | 9.7 | | |
| C | N | 1:1,25 | 13 | 1.27 | 13 | 1.27 | 13.46 | 13.38 | 0.38 |
| | S | | 13 | | 13 | | 13.3 | | |
| | E | | 16.75 | | 16.5 | | 16.95 | 16.99 | 0.49 |
| | W | | 16.75 | | 16.5 | | 17.03 | | |
| D | N | 1:1,25 | 13 | 1.27 | 13 | 1.26 | 12.96 | 13.15 | 0.15 |
| | S | | 13 | | 13 | | 13.34 | | |
| | E | | 16.75 | | 16.5 | | 16.34 | 16.58 | 0.08 |
| | W | | 16.75 | | 16.5 | | 16.82 | | |
| E | N | 1:1,25 | 13 | 1.27 | 13 | 1.24 | 13.42 | 13.23 | 0.23 |
| | S | | 13 | | 13 | | 13.04 | | |
| | E | | 16.75 | | 16.5 | | 16.2 | 16.40 | 0.10 |
| | W | | 16.75 | | 16.5 | | 16.6 | | |
| | | | | | | | | Average | 0.211 |

**Table 2 Deviations from presumed ideal size and ratios of the rooms. All dimensions are converted to Roman feet (RF)**

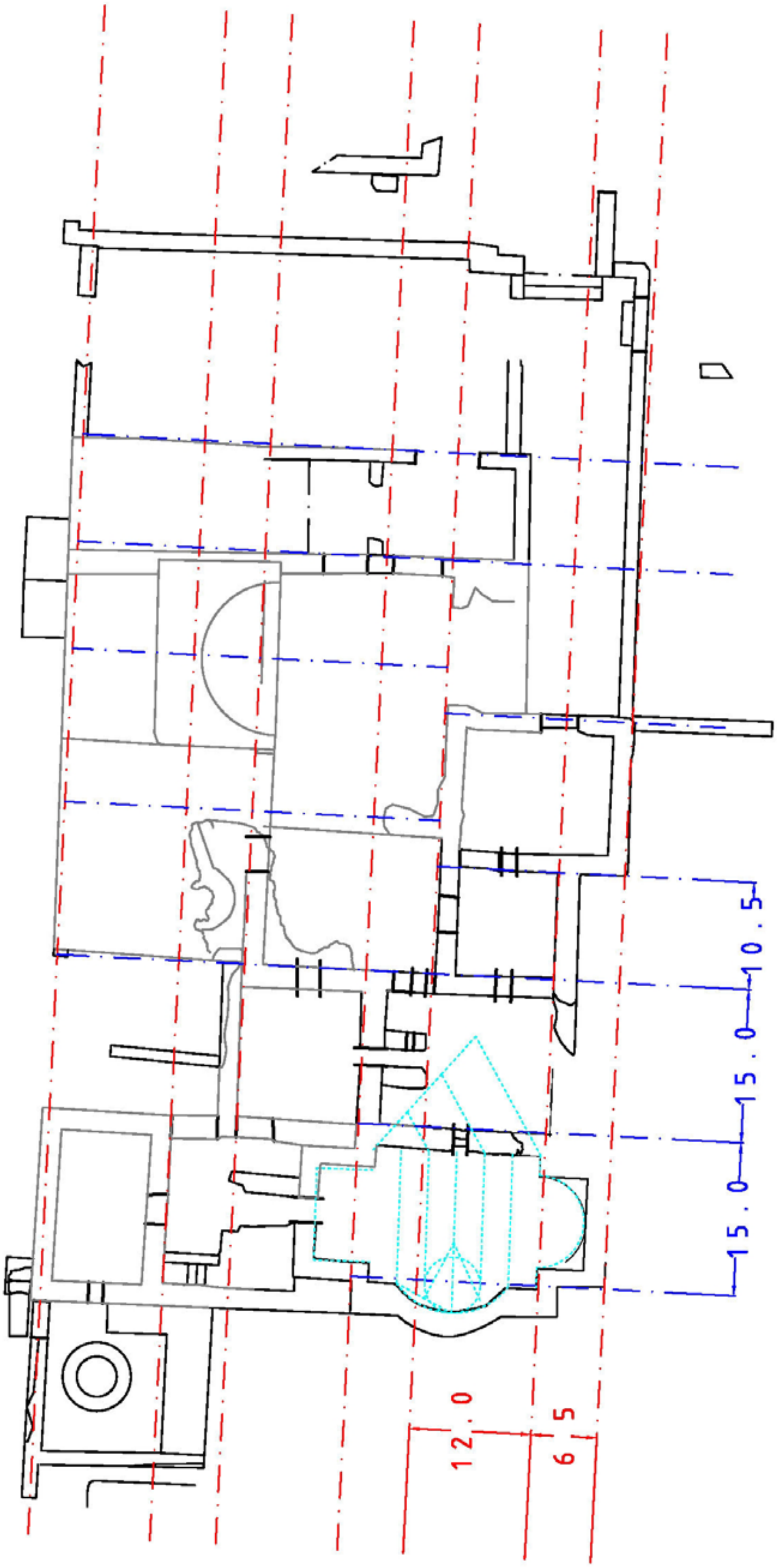



**Figure 11 Overlay of the site plan and the reconstructed planning grid. Cyan dashed lines show possible construction of the shallow apse.**

## Static problems

Second piece of evidence which can explain the disconnection of the service rooms was found during examination of the foundations. As was already mentioned, the rooms with hypocaust seem to have no foundations and the walls were built directly on a layer of sesquipedales. On the other hand, the service rooms and the unexcavated rooms in the north have very deep foundations built of stone with occasional brick reinforcements, such as in the north-western corner of the unexcavated area. The reason behind this is almost undoubtedly the original terrain. Based on the direction towards Vesuvius, the slope gradient would have azimuth of circa 320°. Solid foundations of the northern side of the baths might have actually served as a retention wall for a natural platform of volcanic ashes on which the heated rooms stood. Unfortunately, the eastern side of this platform was weakened by presence of an underground cistern, which is connected to the well. As much as its barrel vaults should have supported the volcanic ash platform from the eastern side, a linear feature in the cocciopesto paving where the cocciopesto layer cracked and folded over itself in the place where the cistern should end. The theory presented here is that this signifies a creep of the whole platform towards the east. This is further backed by the sloping of the course of bipedales closing off the foundations of the eastern part of the northern wall of the unexcavated area. This problem may have been anticipated, the corner of the foundations reinforced with bricks and the low wall connected this problematic area with the cistern block H.

## System of vaults

Roman structures often combined directions of the vaults to counteract the forces developed by them (Lancaster 2005, 133–34). Since only four of the vaults can be currently reconstructed with absolute certainty, this argument relies on a high degree of reconstruction (Figure 12). Rooms A, D, E and F would have barrel vaults with north – south orientation. Rooms N and Q have barrel vaults in that direction as well, but their forces are irrelevant to the bathrooms. Rooms G and H have barrel vaults with east – west orientation. A small brick rectangle detached from the rest of the wall and slightly curving inwards in the north-western corner of the room C is a remnant of a cross vault, allowing us to think about lighting through a clerestory. Room L was probably not vaulted at all and could have been covered by a simple shed roof, if the two large holes in the western wall were indeed putlog holes for the roof beams. There is no evidence of roof in the room with well. Finding the most probable vault for room B is a difficult task. Because the room is almost square, both barrel vault and cloister vault are possible. Cross vault is improbable and some sort of domical vault would need a transition from square to circle, most likely through pendentives which are a later invention. In context of the remaining vaults, a barrel vault with north – south orientation seems most possible from static point of view, because the lateral forces would be counteracted by vaults of A and D, while the forces developed by the cross vault of C are concentrated in the corners, so the vault does not need support from south. On the other hand, if the room was meant to be a sudatorium, for which there are no indices apart from its square shape which is very peculiar case, a cloister vault is a possibility, even though it would develop forces on all four sides, making the northern and southern unabutted.

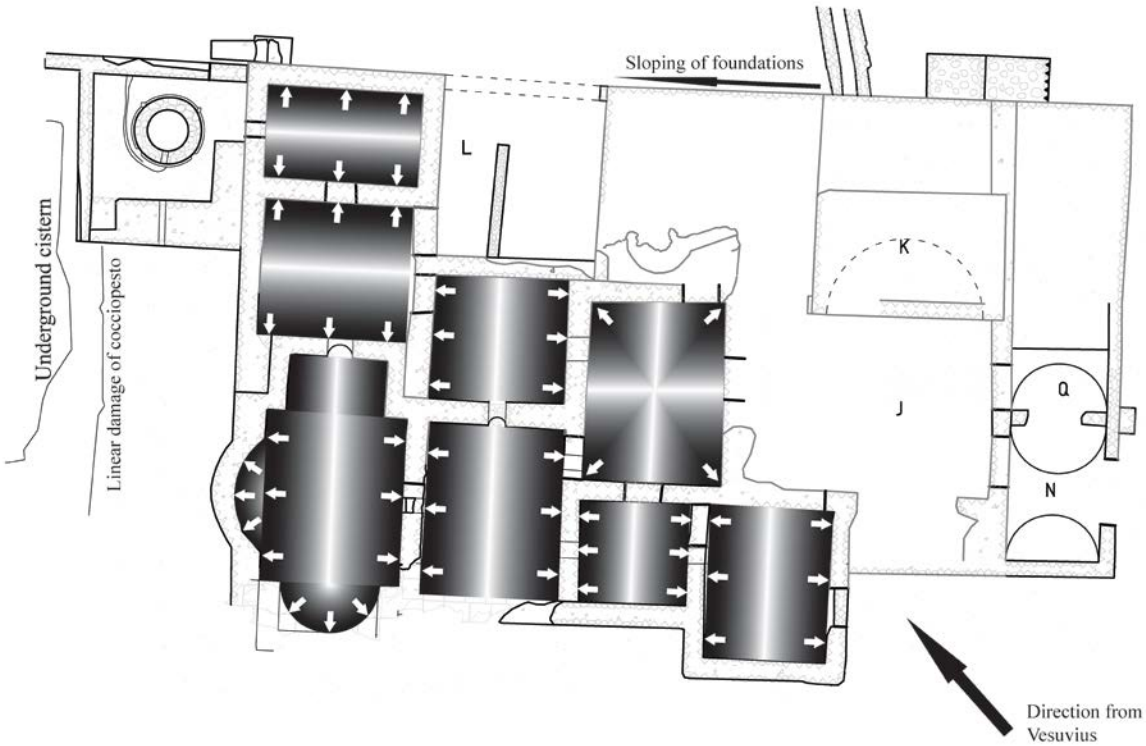


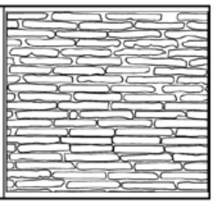

**Figure 12 Possible reconstruction of vaults and the forces developed by them.**

## Metric analysis of brick facings

Thirdly, the results of the metric analysis of the bricks showed very varied results (Table 3). Application of the method was problematic because of the area of the walls, where a 1 $m^2$ of uninterrupted and undamaged sample is difficult to find in the mostly opus mixtum walls heavily damaged by spoliation. The variability does not seem to correspond to the visually distinguished “phases”, even though the mortar used in the service rooms has a visibly different colour. This might have been done on purpose, maybe to strengthen the construction. All the indicators that were followed vary a lot even between samples from the same visually distinguished phase and can be actually closer to results from another phase. It has to be stated that this method was not employed with much success as the examined building would require a method with much higher resolution.

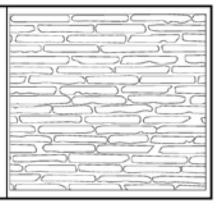
| Room B, southern internal wall | |
|---|---|
| Average length | 24.76 |
| Average thickness | 3.93 |
| Average area | 91.98 |
| Reconstructed number of bricks | 78.15 |
| Mortar / brick ratio | 2.56 |
| Phase 1 | |

Picture



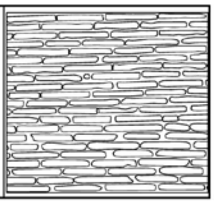
| Room F, western internal wall | |
|---|---|
| Average length | 27.38 |
| Average thickness | 4.02 |
| Average area | 105.20 |
| Reconstructed number of bricks | 61.54 |
| Mortar / brick ratio | 1.84 |
| Phase 2 | |

Picture



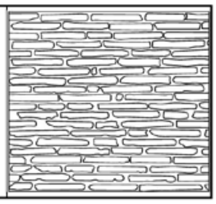
| Room F, eastern internal wall | |
|---|---|
| Average length | 21.45 |
| Average thickness | 3.51 |
| Average area | 70.79 |
| Reconstructed number of bricks | 88.09 |
| Mortar / brick ratio | 1.66 |
| Phase 1 | |

Picture



| Room G, northern internal wall | |
|---|---|
| Average length | 21.87 |
| Average thickness | 3.33 |
| Average area | 69.19 |
| Reconstructed number of bricks | 91.41 |
| Mortar / brick ratio | 1.72 |
| Phase 2 | |

Picture



| Room E, eastern internal wall | |
|---|---|
| Average length | 23.17 |
| Average thickness | 3.44 |
| Average area | 76.49 |
| Reconstructed number of bricks | 81.40 |
| Mortar / brick ratio | 1.65 |
| Phase 1 | |

Picture

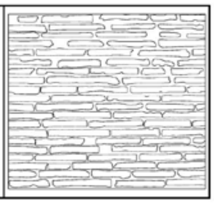


**Table 3 Results of the brick facing analysis.**

## Conclusions about the building phases

The presented evidence needs to be confronted with functionality of the baths (Figure 13). Service rooms with praefurnia and water heating and distribution system are inseparable part of any baths and should they be built in second phase, there would be traces of some previous heating and water arrangement, which there is not. The praefurnia could work without any dedicated rooms, but the underground cistern, top cistern and the well are all part of the complex of the service rooms and the baths could not operate without a source of water. I believe that by combining these operation necessities and the evidence already presented, we can conclude that the block of service rooms was built like this in attempt to support the heated rooms and prevent their sliding downhill. The area is also seismically active and it seems almost obvious that the architect tried to implement some kind of seismic protection into the design, especially such a short time after the events of 63 and 79. If the service rooms really had to support the rest of the baths, it seems logical that the walls are not physically connected with the heated rooms, so they allow slight movements in this seismically active area. The low connecting wall forming northern limit of the room L closes the shape of the building and freely ties the two parts together. From what is currently visible, the wall was also not joined with the wall at its eastern side, to allow slight movement.

Against this theory speaks the fact that even though the metric analysis did not show any sensible results, the service rooms are built using slightly different technology which is observable on presence or absence of the upper course of bipedales on top of the walls, which is not present in the heated rooms. It is also curious that the vaults of rooms F and G abutted directly on the walls of the heated rooms. Vault of room F is so well preserved that we can observe it has a slightly higher spring line on its eastern side, so it develops more outward pressure in that direction, against the room C.

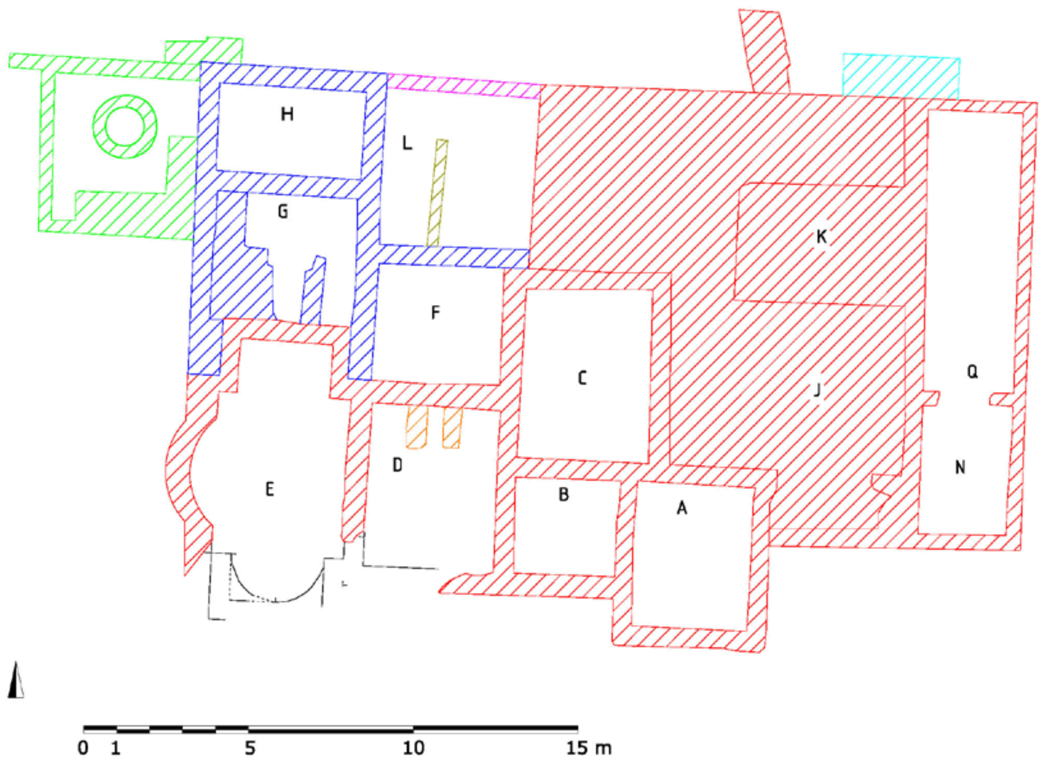



**Figure 13 Different parts of the building physically disconnected from each other, not necessarily meaning their building in different phases.**

# Interpretation of the baths

## The baths in Pollena Trocchia in context

The examined building is a rather rare example of almost fully excavated private baths in Campania after the Pompeian eruption, but certain trends and parallels can be found in several public and private baths both in the Vesuvian area and in wider context of the Roman empire (Figure 13). Comparable private baths can be found in Lauro about 20 km away. As was already stated, they were built and rebuilt in a short time span in the 1st half of the 1st century A.D. The whole villa is built on a slope of a steep hill and the rooms form three rows and the main axis of the baths respects the slope and therefore it is not perfectly aligned in east - west direction. The northernmost row contains the frigidarium which was supplied with fresh water from a cistern which lies still undiscovered more uphill. The second row is composed of the rest of the bathrooms, some of them on a slightly lower level because of the height difference required by suspensurae. The third row contains the praefurnia for heating the air for hypocausts. Unfortunately the heated rooms are filled with large chunks of vaults which fell there during the destruction, so the hypocaust system is not well known. On the other hand the water system was described by M. Statile rather well (Statile 2013). The phases as distinguished by her make it very difficult to reconstruct shape and order of the rooms from the 1st phase. On the other hand, the second phase as it can be seen nowadays is clearer, though I cannot agree with some of her identification. Entrance to the baths is through a frigidarium with a cold water pool (piscina) occupying about half of its area. The next room cannot be completely described because of the debris fill, but it was divided in two during the rebuilding. This room might have served as a combination of apodyterium and tepidarium and the two functions were later divided. To validate this theory it would be necessary to remove the large chunks of vault filling the rooms and excavating a trench under the floor to see if the room was indeed heated and if its hypocaust communicates with the one of the adjacent room. This heated room has rectangular shape, though slightly shorter than the original first. Statile identifies it as a caldarium and I have to agree. The next room is rather obviously another caldarium because of its heating and presence of an apse for labrum. From there it is possible to go back north and through a connecting rectangular room visit the circular room with four niches and a hypocaust, possibly supplied by hot air from the south. I find its interpretation as laconicum possible, but its dimensions are very large compared to the rest of the rooms and also its heating seems insufficient. To the south is also a comparatively small heated room accessible from both the laconicum and caldarium which is identified by Statile as a second tepidarium. Next to it she identifies a possible second praefurnium. From this room it is also possible to leave the baths in eastern direction and walk north through a corridor to stairs leading to the unexcavated upper levels. This complex is similar to the one in Pollena because of its size, distinctive strategically placed service areas, interconnected hypocausts using probably more praefurnia and possible duplication of tepidaria and caldaria. Further comparison between the two buildings is unfortunately beyond the scope of this thesis.

The Suburban baths both in Pompeii and Herculaneum also should also draw our attention. They represent a sample of rather small public baths and both of them were at the seaside just outside the town. Technology of the Suburban baths in Herculaneum was examined by U. Pappalardo and H. Manderscheid (Manderscheid et al. 1998), in Pompeii by H. Manderscheid (Manderscheid 2009). The baths in Pompeii were built around at the end of the 1$^{st}$ century B.C., in Herculaneum in the late augustan period, as attested by inscription of proconsul M. Nonnius Balbus. While the older baths in Pompeii can be still identified as the old row type, the baths in Herculaneum show a departure from this design and the layout seems more relaxed and aimed to support a more variable order of visit. Also the shape of the rooms is less prolonged than for example in the Stabian baths and the rooms with piscinae (and also the caldarium in Pompeii) have a more progressive shape with the walls decorated by combination of apsidal and rectangular niches which is a feature quite common in later public baths. Knowledge of the hypocaust system of these two baths is limited because of their exceptional state of preservation, so it is impossible to say how the rooms are connected under the floors. We can only see the preaefurnia which in both cases contained also the boilers and were placed immediately next to the alveus of caldarium. In the larger baths in Pompeii there are traces of two boiler vats, in Herculaneum of only one. An important trend is also observable regarding the windows. In both of the baths there is a common wall of the heated rooms, which is unobstructed from the outside and suited for windows. In case of Pompeii it is heading west, in Herculaneum almost perfectly south. In Pompeii, there are three rather large windows in the apse of the caldarium and the rest of the rooms seem to have at most one smaller window each. On the other hand the baths in Herculaneum have many large windows piercing its southern wall, letting in much more light and marking a new trend in design of the baths. The water system is described thoroughly in the publications. In both cases the main reservoir is on a higher terrace, taking advantage of the height difference between the seashore and the town. Water is channelled through pipes or channels to the areas of use, in Pompeii the water flows to the pool of frigidarium through a decorative cascade. Both of the baths also have a rather large pool with warm water heated by a testudo (sometimes called "samowar" in literature).

Some of the features in Pollena also call for more distant comparisons. Very interesting is the roughly square room B, identified in this thesis as a tepidarium possibly also used as unctorium. To find a comparable room in private baths, we have to focus our attention to Volubilis and Maison aux Traveaux d'Hercule. Unfortunately, the building was excavated in the 1st half of the 20th century and is not properly dated, so the only information available comes from N. De Haan's catalogue (de Haan 2010, 264–266). The roughly square room described has roughly the same size and connects frigidarium and tepidarium. Unfortunately no further explanation is given. Volubilis also gives us another set of private baths which bear even more similarities to the baths in Pollena than the geographically closer baths in Lauro. These baths are part of the Maison d'Orphée and unfortunately I can only evaluate the data presented by N. De Haan for the same reason as before (de Haan 2010, 274–275). Once again we are looking at a compact block of rooms which was impossible to build in ideal orientation because its incorporation in the insula. The service area with water and heating technology is packed together more tightly on the western side of the suite and the heated rooms do not have common orientation, possibly to make the overall shape more compact. The suite is entered through a long rectangular vestibulium through firigidarium with one larger (15,96 $m^2$) and one small (3,63 $m^2$) pool. This is yet another clue that the courtyard J in Pollena might be actually a frigidarium, but I will not make such conclusion unless the whole area is excavated. Apodyterium of a similar size as in Pollena is accessible from the western end of the frigidarium, so a visitor would have to pass through the frigidarium twice, before entering the heated rooms. The similarity continues there, because both the tepidaria and caldaria are doubled, all of them have hypocaust heating and traces of tubuli on the walls. The heat was generated by two praefurnia in one room, one for each caldarium. Water system was composed of a cistern between apodyterium and the service room, from which the water was led to a boiler above praefurnium and from there to an alveus in the caldarium, which is from the description the same short and efficient system as in Pollena. Unfortunately, there is no clue as to how the pools were supplied and from where was the water for the cistern taken.

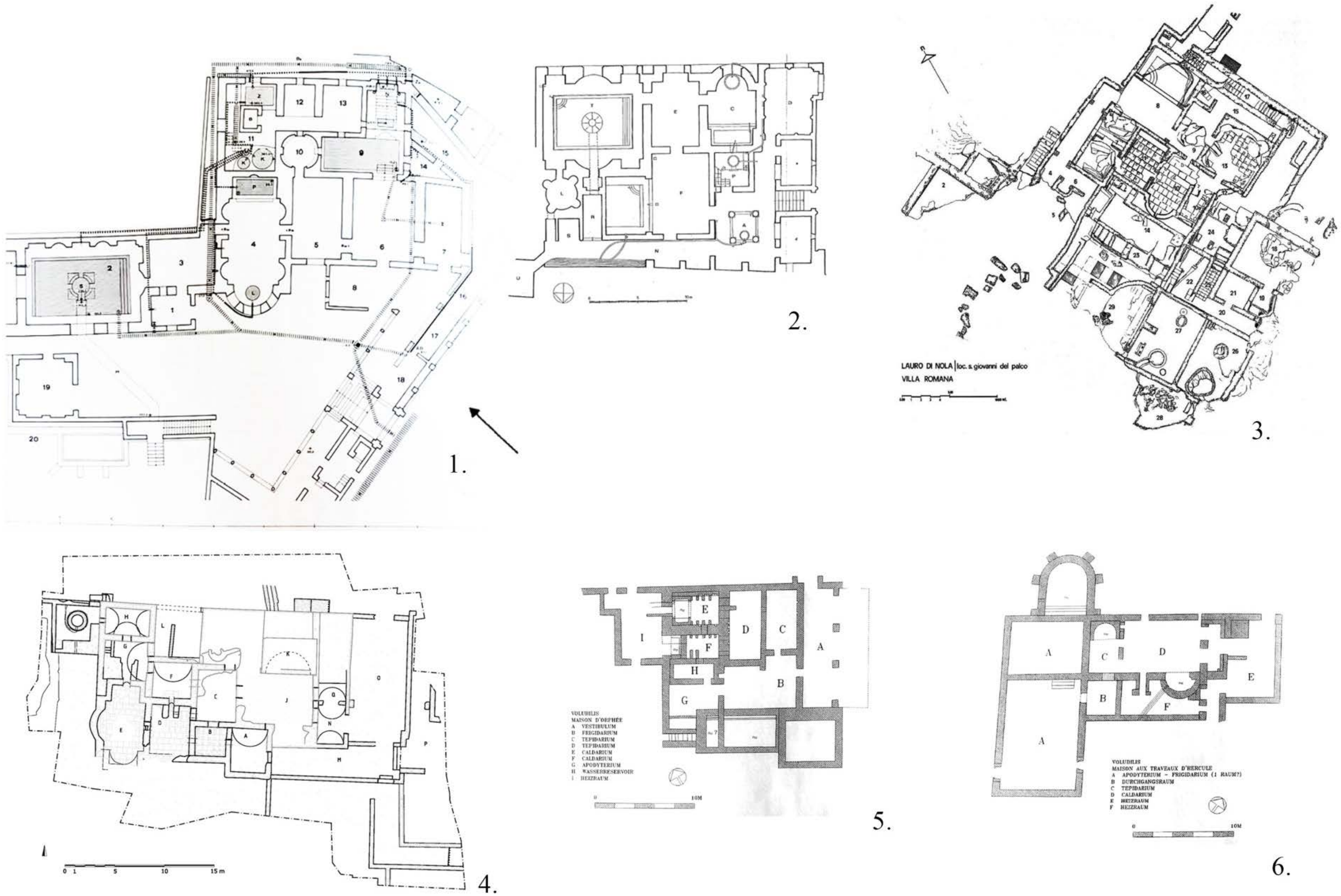



**Figure 14 The mentioned baths in the same scale. 1. Suburban baths in Pompeii (Manderscheid 2009), 2. Suburban baths in Herculaneum (Pappalardo 1998), 3. Baths in Lauro (Statile 2013), 4. Baths in Pollena Trocchia, 5. Baths in Maison aux Traveaux d´Hercule (De Haan 2010), 6. Baths in Maison d´Orphée (De Haan 2010)**

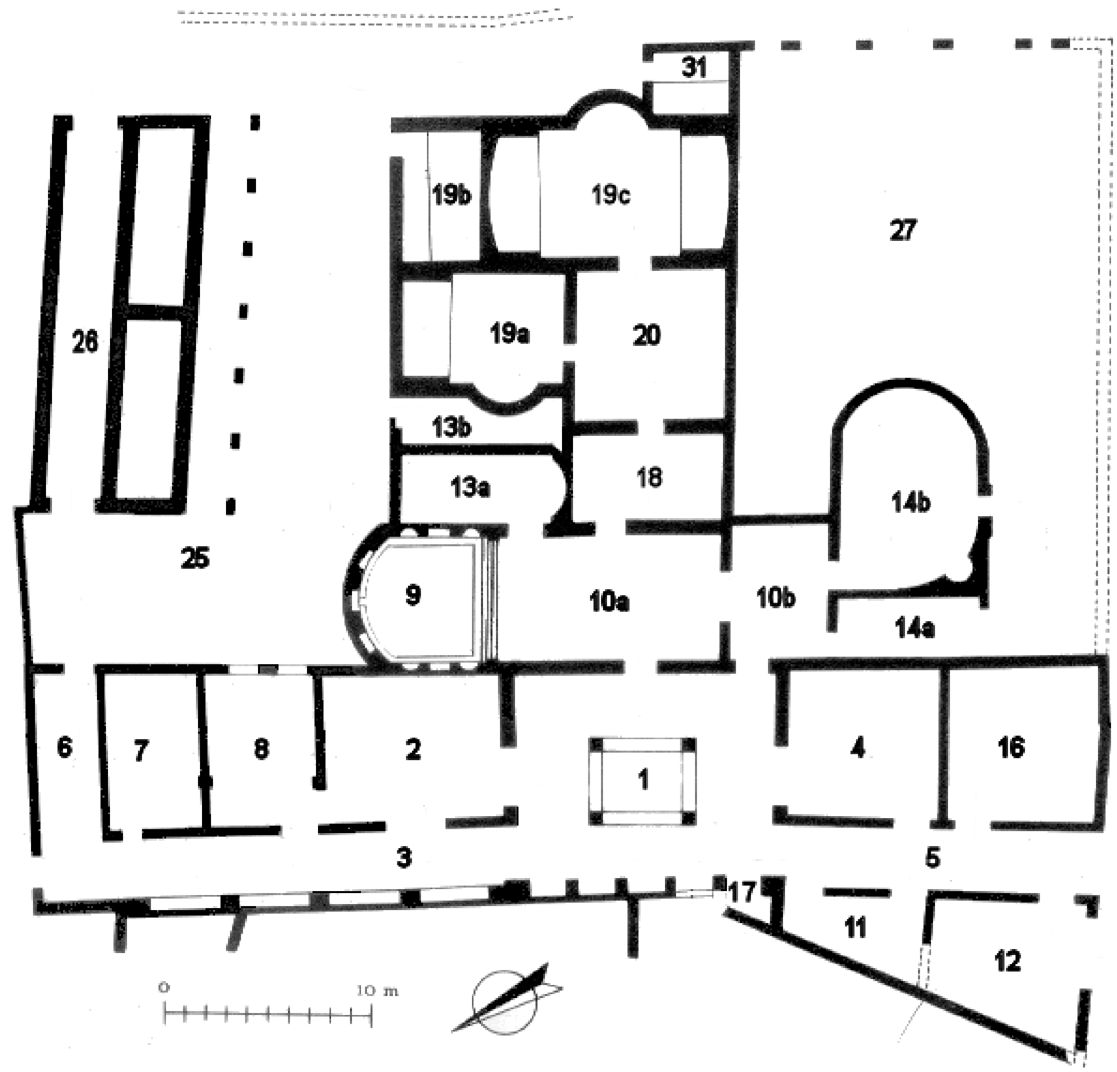



**Figure 15 Terme del Nuotatore.(jhtb 2005)**

## Heating system

Source of heat for the baths were with two praefurnia with three fireplaces located between a pair of baffles (Figure 15). The baths had several features to support the draft of the hot air through the hypocaust system and then out through the tubuli in the walls. Firstly, the baffles themselves create a narrow space where the air flows at higher speed. The floor of the hypocaust was supposed to be sloping towards the fire, and as far as the state of preservation allows, they do. Vitruvius also specifies the correct height of the hypocaust pilae to 2 RF (Vitruvius V.10). In our case, they are slightly taller and the preserved cocciopesto lining on the walls shows us height of 70 – 80 cm. The hypocausts were not closed systems for each room, but were connected to each other through openings of various sizes. The baffles of delimiting the fireplace between F and D seem to have been built in two phases, the first being much smaller. It is possible that they proved to provide insufficient draft and were enlarged. This larger second phase allowed part of the hot air to pass straight to hypocaust of C through a narrow cut in the eastern wall and then through the rectangular opening under the door. This seems to be a very practical solution to a problem that would emerge because of the new longer fireplace wall which created a very narrow space between itself and the opening to C. The airflow would become very turbulent in this area and the air flowing through this small cut would direct the flow towards the connection. This connection is so important because room C is the only one with preserved tubuli in the walls, thus probably serving as a ventilation for the fumes (Jorio 1981, 175). None of the other heated rooms has any traces of tubuli, but parts of tegulae mammatae are found in layers of rubble throughout the site. These would, however, be more effective for ventilation of the wet walls than for heating, because the hollow space would be too narrow to allow effective air flow. There are also no traces that would allow us to think about use of regular tiles with terracotta or metal spacers (Yegül 1992, 363–65). Room C is one of two ends of the hypocaust system, the other being room B, which does has no traces of tubuli or tegulae mammatae. The whole system was designed to effectively channel the hot air through all four heated rooms and out of the baths. Southern side of the baths was almost certainly pierced by windows. These could be glazed, though there is no evidence for it, as far as I know, and help the heating system by allowing the solar energy in and keeping the heat inside (Ring 1996). The windows were probably more similar to the ones in Suburban baths in Pompeii, one almost square window for each room. Since the apse of room E was rectangular from the outside, it is diffult to image a triad of windows as in Suburban baths in Pompeii and it is more likely that there was only one smaller window. Tha shallow apse on the other hand has a right shape and even good orientation to allow us to speculate about possible large windows there.

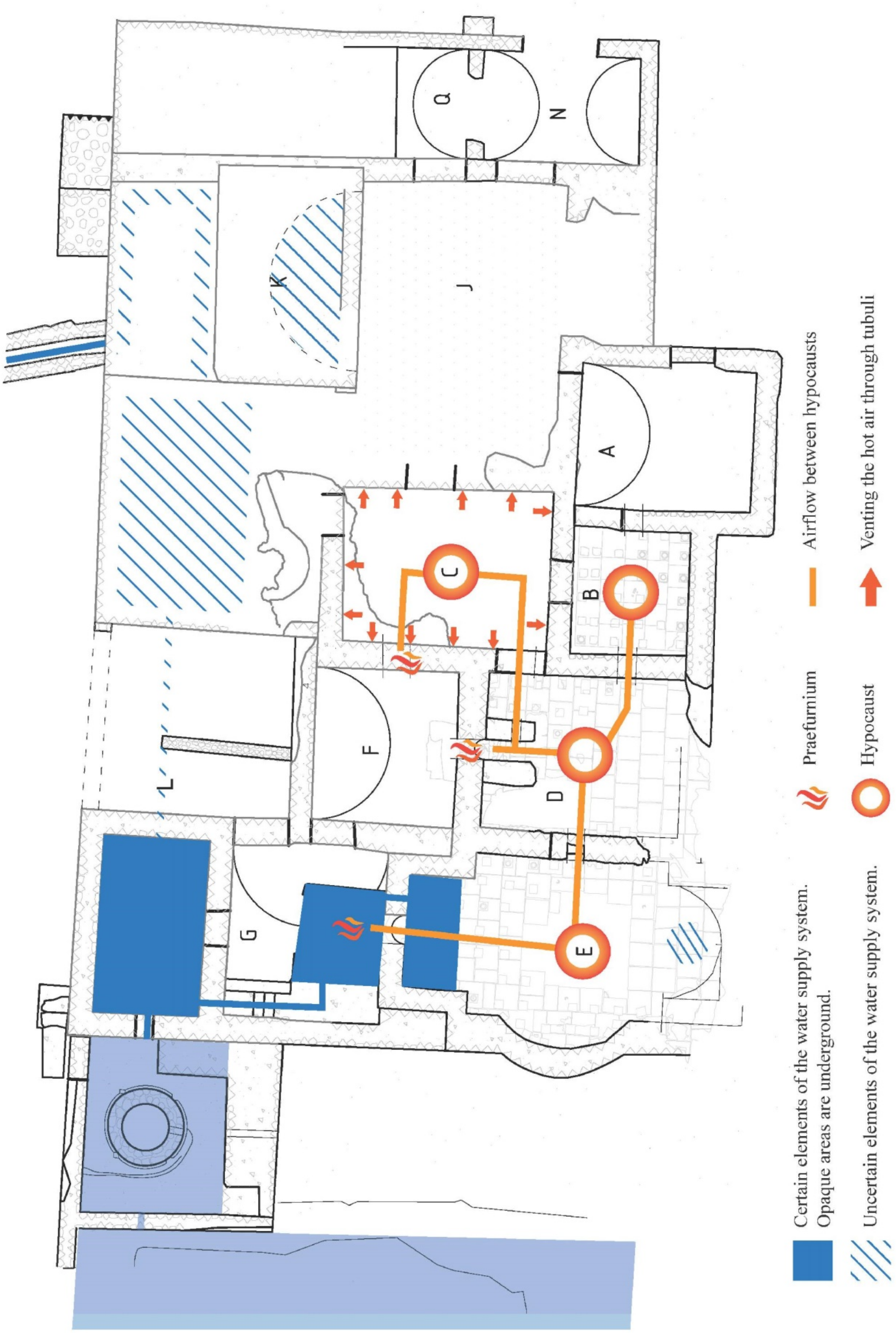



**Figure 16 Scheme of the water supply and heating system.**

## Water supply system

Similarly ingenious system can be at least partially reconstructed for water supply (Figure 15). Source of the water for the baths is unknown and the first link of the supply chain we know of is the underground cistern. It is unexcavated and we can only assume that it was one or more barrel vaulted long rooms. Since the Aqua Augusta was rather far away and to my knowledge no traces of some smaller regional aqueduct were found nearby, I think the baths relied on natural sources of water, which are still plentiful on Mount Somma in form of many streams. This underground cistern was connected to a well about 4 m deep. The well room had to contain a water-lifting mechanism of unknown type which I will attempt to reconstruct. Shape of the room and traces in it allow us for a reconstruction of a bucket chain powered by a wheel operated by one man from the platform on the east (Figure 16). Space between the thick southern wall and the cylinder of the well would accommodate a wheel with radius of 1,73 m mounted on a fixed axle going through the wall, rotating on metal bearings. Unfortunately this cannot be proved because of the state of preservation of the wall and all the following calculations are very rough, rely on a very high degree of reconstruction and should only show whether or not such system would be feasible within some margins. The wheel in the presented reconstruction is loosely based on Vitruvius (Vitruvius X.4) and other existing reconstructions of similar devices in Pompeii (Stabian baths, (Eschebach 1979, 27–39), Ostia (Ricciardi et al. 1996) and Cosa (McCann et al. 1987). As a material for weight calculation of the wheel itself was chosen an Austrian pine (Pinus nigra), which was not in favour of ancient authors, but its high content of resin has makes it perfect for use in wet or humid place (Ulrich 2007, 256). In the model (Table 4), the wheel has 36 steps about 30 cm apart, 8 crossbeams and side desks tying the whole construction together. A volume of wood necessary for this reconstruction is 1,53 $m^3$ and using the average dry weight of Pinus nigra of 475 $kg/m^3$ we get the weight of 725 kg, not including the tar and metal fixtures, which the axle in the wall could support, maybe with additional diagonal beams standing on the ground inside the room. The bucket chain itself could be supported by a construction of four beams rising from the cuts forming a square around the cylinder of the well. These beams could be simply connected on top and both the axle of the bucket chain and the trough to carry the water into the cistern H1 could be placed on top of this construction. The buckets themselves are of course a complete mystery. They could be made of bronze or of wood, as attested in Cosa. For this model a bronze semi-conical buckets with volume of 1 conginus (3,5 l) are used. My reconstructed bucket has diameter of 0,29 m and height of 0,175 m. If it was made of bronze with density of 8770 $kg/m^3$, its empty weight would be 2,76 kg. Given the necessary length of the bucket chain of some 5 m and distance between the bronze buckets of 0,6 m, the chain would accommodate some 28 buckets weighing 77 kg plus some weigh of the chain itself (however, the chain could be made of rope). When operating, half of these buckets were full, so the total weight of the chain in operation would be approximately 126 kg, 88 kg out of which had to be pulled up. Power of the wheel could be transmitted by a simple rope or chain from gear on the same axle as the wheel to a gear on the axle of the bucket chain. If both of these gears had diameter of 0,148 m, the toque transmitted would be 5727 Nm, which is more than enough to lift the water easily. More calculations can be done with different transmission ratios, but this one should be enough to confirm feasibility of the concept.

| Device | Properties | | Notes |
|---|---|---|---|
| Wheel | Diameter | 1.73 m | Pinewood |
| | Weight | 725 kg | |
| Half-conical buckets | Volume | 3.5 l | If made of 3 mm thick bronze with density of 8770 kg/m$^3$ |
| | Diameter | 0.145 m | |
| | Height | 0.175 m | |
| | Empty weight | 2.76 kg | |
| Bucket chain | Nr. of buckets | 28 | 60 cm apart |
| Operator | Weight | 50 kg | |
| | Torque on 0.148 m gear | 5727 Nm | |

**Table 4 Reconstructed properties of the water lifting device**

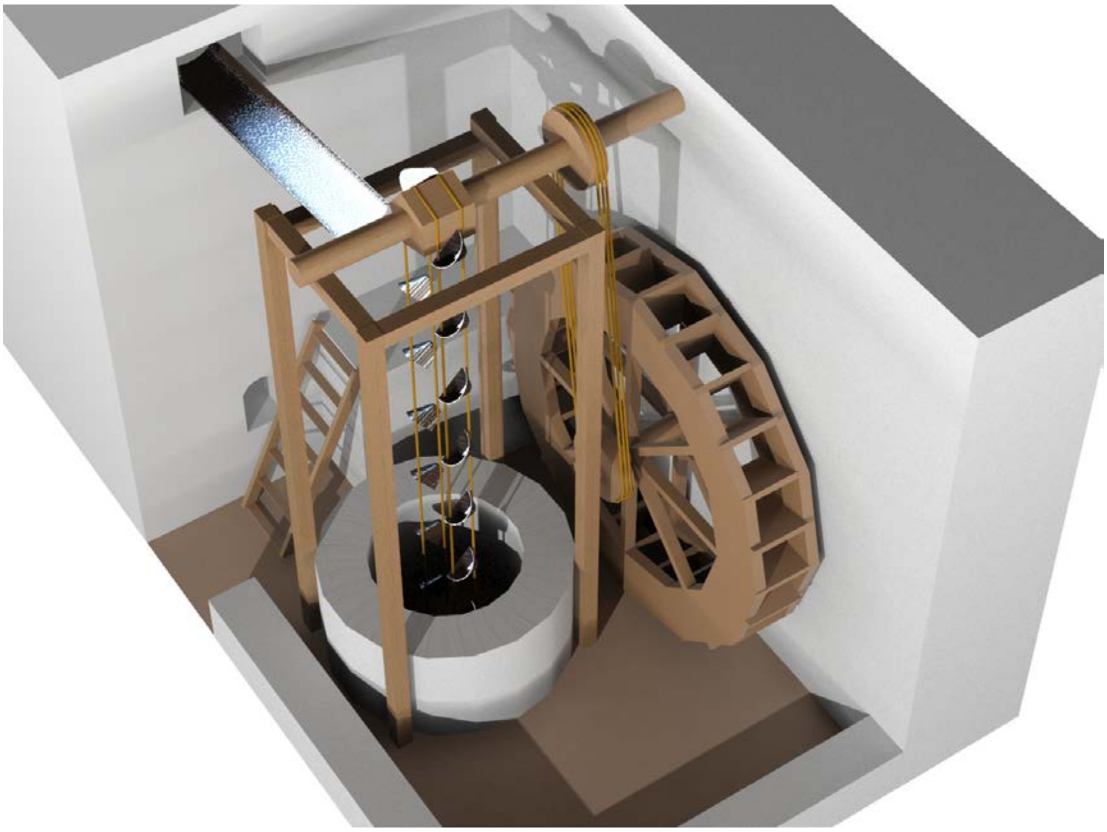


**Figure 17 Reconstruction of the water lifting system.**

This reconstruction fills most of the volume of the room with the lifting device and only allows access to the platform for the man operating the wheel via wooden steps, possibly removable, because no holes in the wall remain from such construction. The architect predicted significant splashing and solved the maintenance problem by fitting the room with a small channel leading through the wide wall carrying the wheel out to the open area outside. Another shallow channel was later cut in the floor leading from the hole in the body of the well out of the room through the northern wall. The water lifting mechanism would allow lifting sufficient volume of water to fill the upper cistern H1. Unfortunately it is impossible to reconstruct the original volume of the tank, but in current state of preservation the cistern has volume of about 25 $m^3$. The cistern has a visible hole in its south-western corner through which a lead pipe led to a boiler which was placed on top of the caementicium platform of room G. This explains the fireplace being inside the room, not technically in the room it was supposed to heat. There is one obvious outlet for the hot water from the boiler in form of a hole for a lead pipe in the wall that belongs actually to room E and led to an alveus in the northern alcove. If we suppose that the water pipe was slightly above the water level and that the bottom of the alveus was at the floor level, we get a very shallow hot bath about 0,6 m deep with volume of about 2,4 $m^3$. There is no evidence of a drain. The opposite side of room

E might have had another fixture using water – the labrum. There is no proof of an actual labrum, only the possible reconstruction of an apse in the southern part of the room, which would be a normal architectural setting for a round labrum. Since there is no evidence of this, we can only imagine that if there was no direct connection to a source of water, labrum was filled and emptied simply by buckets with water from alveus. Unfortunately, a large part of the water system is missing or unexcavated and the next element being the drainage channel emerging from the foundations in the north-western corner of the presumed unexcavated room north of K. There is no evidence of water supply for this area of the baths, but the dimensions of the water outlet (0,35 m wide and 0,22 m high near the wall) and its rather steep decline outwards (11°) suggest a rather large use of water, leading to thoughts about a frigidarium with large pool supplied directly from the H1 cistern in the unexcavated area north of C with possible secondary use for the waste water in the unexcavated room north to K (possibly a latrine, (Nielsen 1990, 163).

## The bath rooms

Now when the heat and water supply system was reconstructed and described, we can attempt to reconstruct the purpose of the individual bathrooms and the representative area as excavated. There are two possible entrances to the baths - one through the representative area, through the room N and the other directly to room A. We can only guess to where the corridor Q led, but possibly to the room behind the apse K. Two passages led from N and Q to the courtyard J which was centre of the representative area. Unfortunately since the courtyard was excavated only just behind the passage from N, we do not have sufficient data to reconstruct this so called nymphaeum. It can be also interpreted as a frigidarium, but further excavations of the room to the north of C would be necessary to establish whether or not it is a separate cold pool (piscina). From the courtyard there were at least two passages, one already mentioned to A and one directly to C. Even though the passage to room C is located in the centre of the wall, leading the eye of the visitor towards that room, which was probably higher than the surrounding rooms, the two possibilities of entrance to the unheated room A lead me to think that it was meant to be visited first, thus we can identify the room as apodyterium. Passage leads from A to B, a roughly square room where one branch of the hypocaust ends. Its square shape suggests a possible sudatorium (Nielsen 1990, 159–60), but it does not have a praefurnium on its own and most of the necessary heat would have to be produced by a metal brazier placed in the room. Its location is also unusual for a sudatorium, usually inserted between tepidarium and caldarium, not immediately after apodyterium. It is also possible to abandon the attempt to give a Latin name for the heated rooms and to adopt Krencker's system (Krencker et al. 1929, 177) and label the room simply as I. Nielsen also describes a so called unctorium, a room used for anointing and possibly for massages. Even indirect hypocaust heating would be enough for this room which would function as a tepidarium with lower temperature and the only definitely known example from Villa Casale in Piazza Armerina, where the purpose of the room is depicted on a mosaic, is also square in shape (Nielsen 1990, 161). For covering the room, possibility of either a barrel vault or a cloister vault was already presented. A cloister vault would be more likely in case the room was indeed equipped with a brazier and the heat was to be regulated as Vitruvius suggested (Vitruvius V.10), by a movable metal plate in the oculus of the vault. Either way, the smaller dimensions of the room suggest that the room was not meant for a prolonged stay. Passage on the northern side leads to room C which seems to be a central hub for the bathing activities because it has passages on all four sides. It is also the best preserved room so far and gives us many indices to its original form and function. Crucial place for reconstruction of the vault is the north-western corner, where several bricks form a slightly curved rectangle detached from the rest of the wall. This is almost certainly a very humble relic of the cross vault covering the room. If the haunches of the vault were roughly semi-circular and we take the height of room A as the standard height for the rest of the heated rooms, we find that room C was higher than the rest of the baths. This would support the theory that the room was the most important and that the tubuli in the walls were meant to let the fumes out of the heating system. The preserved floor is covered with cocciopesto with pieces of white marble in it. Unfortunately nothing remains of the hypothetical wall paintings and other decorations. The eastern passage in the centre of the wall allowed visitor to go back to the courtyard, which may have also served as a small palaestra. The northern passage leads to the unexcavated area, where a frigidarium with a rather large pool can be predicted. The western passage leads to room D. Identification of rooms D and E is rather difficult as both of them seem to have been designed to have similar temperature and the main differences are in advanced architectural shape of room D and its use of water. Passage existed between the rooms, one side of which is observable in the wall 1,85 m from the northern corner, but the other is not preserved. I believe that one carved line going across the wall outline 0,85 m from the southern corner of room D may be clue to the planned width of the door. This would make the passage 2,3 m wide, twice as much as the others. Because it is not in the middle of the wall, it was possibly designed to lead the visitor and emphasize the labrum. Such a wide connection may indicate closer relationship between these two rooms and I believe that both of the rooms can be labelled as caldaria. Room D was the final room which the visitor would see and has the most complex shape which would be common if it were not for the shallow apse, which makes the shape unique. The most obvious non-standard feature is the shallow apse on the western side, for which there is currently no explanation that can be confirmed. One of the possibilities is that the space was created to accommodate some piece of art. The semi-circular apse for labrum and the rectangular alveus on the other side are on the other hand typical features of a caldarium (Nielsen 1990, 156–57). Architectonically and functionally similar room seems to be the caldarium of Terme del Nuotatore in Ostia, which is also entered through a slightly off-centre passage and features alvei on two sides and an apse, in that case with labrum directly against the passage. The room is also directly connected to hot water and air supply, in this case from two different rooms.

## Order of visit

The presented description of the rooms allows us to reconstruct the most probable order in which a visitor would pass through the rooms (Figure 17). Using Krencker's typology (Krencker et al. 1929, 177–181), the baths are functionally, not architecturally, very close to a simple ring type where the visitor goes from apodyterium through a series of several increasingly heated rooms to caldarium and then back through tepidarium and frigidarium to apodyterium. It is the position of frigidarium in the scheme which prevent me from assigning these baths to a simple row type, as the schemes of this type usually start with frigidarium. The row type with more creative modifications, was persistent in Campania of the late 1$^{st}$ century (Nielsen 1990, 48). This example only further proves that attempts to create a universal typology of Roman baths, though useful for very basic description, cannot truthfully capture the diverse reality. Earlier baths had quite rigid design, but with increasing creativity and luxury, it became dependent rather on arrangement of functional units in an aesthetically pleasing way, than a certain traditional scheme.

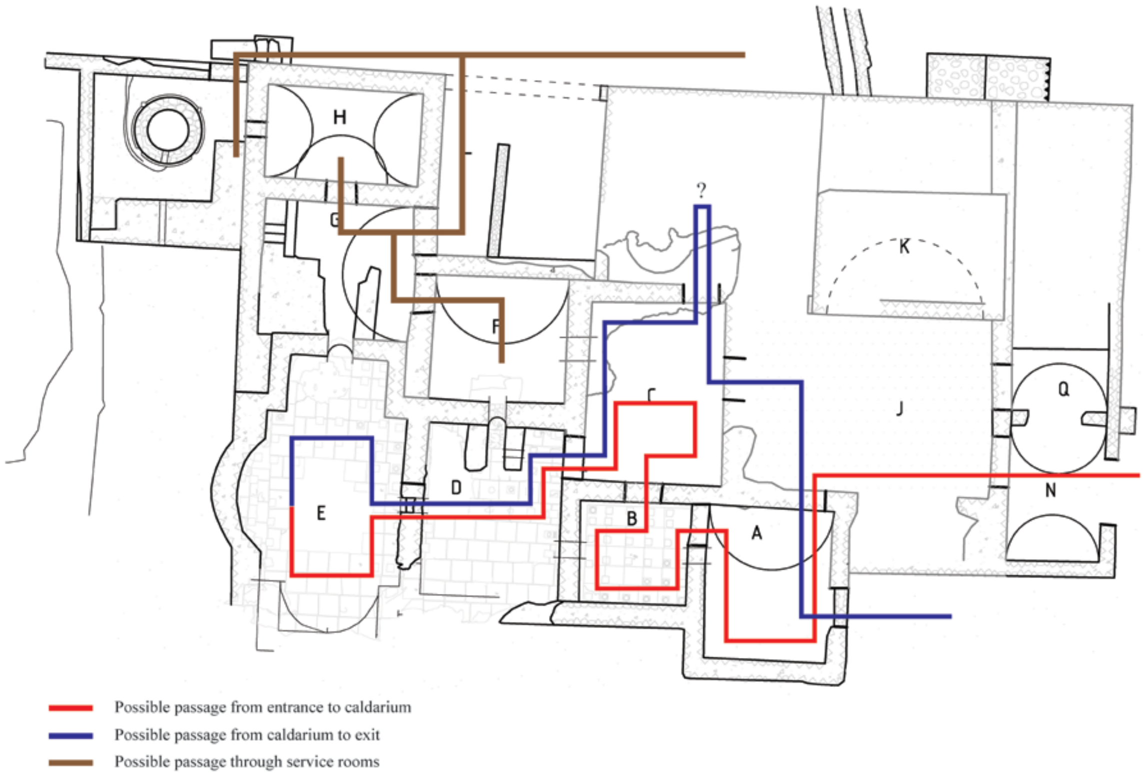



**Figure 18 Scheme of possible passage through the baths.**

The presented scheme relies on room A as the first in order of the visit. It was possible to enter both from the courtyard and from corridor M and the entrance as reconstructed is arbitrary as both options are possible. The visit continued through the rooms with increasing heat and returns in through the same rooms to the tepidarium C and most probably diverts the possible frigidarium or pool to the north. The visit logically continues across the courtyard back to the apodyterium, where the visitor could get dressed again and leave the complex.

## Roofs

Last problem of reconstruction presented in this thesis concerns the original roofs. Apse K and corridor N-Q have their original upper surface preserved and it shows traces of superstructures. It is possible that there was another room above the corridor N-Q and at least a low wall on top of K facing the courtyard is almost certain. Though the upper surface of the apse K is damaged, possibly by later exploitation of the surface, it is clear that the surface was originally flat and possibly covered by cocciopesto.  For the rest of the baths two possibilities exist. Based on Eschebach's plans of the Stabian baths (Eschebach 1979), extrados of the vaults might have been admitted, covered by waterproof cocciopesto, and the space between the vaults might have been filled with more concrete to stabilise the vaults. The other option is that the vaults were hidden and the roof was completely flat from the outside, but possibly not at the same height through the complex. Numerical model (Tang et al. 2006) shows that the more the roof is curved, the more heat it dissipates and that showing the whole extrados is suitable for hot and dry areas, while flat roofs are better suited for hot and humid regions. Because the very purpose of the baths was to keep the heat inside as effectively as possible, flat roofs would be more effective, but would require more material and would be heavier. By combination of these two approaches, it is possible that the space between the vaults was filled to a significant height, but the top of the vault was still showing. There is no evidence of using roof tiles to cover the extrados.

## Conclusions

To produce a credible reconstruction of a building and to study the building process and technology, it is necessary for two circumstances to come together. Firstly it is the researcher who has to have enough time to scrutinize even the smallest details. Secondly it is the building itself, which has to be preserved enough to allow such scrutiny. Fortunately enough, these two circumstances met and this thesis was their product. I was lucky enough to spend sixth months over three years on the site, which was enough time to establish my interpretation as presented in this thesis. The technology which allowed me to scrutinize the details of the building was mostly the digital photogrammetry, which was used to produce models and plans of the extant structures. The results are both rather precise and visually appealing, so they can be used both for analyses and later presentation to public. The opportunity was also taken to teach other participants of the program about this technology. The baths in Pollena Trocchia are not really exceptional in the area. There are numerous better preserved baths, both larger and smaller, but the examined complex stands out in several ways. First of all, it was founded at the end of the 1$^{st}$ or the very beginning of the 2$^{nd}$ century, rather short time after the A.D. 79 eruption and the site was occupied until the 472 eruption, with small scale reoccupation until the next eruption in 505 or 512. Also the fact that it is a private bath complex belonging to a large villa makes it rather unique among the known baths in the area. While the very well preserved private and public baths in Pompeii and Herculaneum give us a snapshot of situation in 79, when they were destroyed abruptly, the baths in Pollena were already disused for a rather long time at the time of the 472 eruption, so they present a rare and valuable image of a building which was already in ruinous state in antiquity. The second circumstance mentioned in the beginning of the paragraph is met to a certain degree as we can see the whole life cycle of the building, including its demise.

This traceable life cycle begins with the rather rare clues to the early stages of building in form of the carved lines on the hypocaust floor which shows us the layout of the walls that were to be built. The complex was supplied with warm water from a metal boiler and through metal pipes, which were not found and were probably spoiled during the late antiquity when the baths fell out of use. However, the pipes and other technologies left traces in the fabric of the building, so the system can be reconstructed to a certain degree, including the bucket chain powered by a thread wheel, pumping water from the underground cistern to a smaller cistern on the first floor. Unfortunately the current knowledge is limited because some of the crucial areas were not excavated. The baths were heated by a hypocaust system with three praefurnia and the excavated remains show us that the original system was probably not efficient enough and had to be modified at some time to ensure a proper air flow. A computer model of the air flow can be done in the future to prove this hypothesis.

Traces of failure in Roman buildings can be very difficult to find, because of state of preservation of many monuments. Fortunately this is not the case in Pollena and I believe that several clues on site point to a possible attempt to prevent a collapse of the building using the whole system of service rooms and their vaults as a support which ought to prevent sliding and collapse of the rest of the baths.

Despite this effort, life of the baths ended probably rather soon as they fell into disuse probably sometimes during the 3rd or 4th century. The decoration of the walls was removed and large volumes of bricks and stones were removed from the walls of the complex which then served as a garbage dump and occasional burial place. There are only humble traces of habitation for this period, including several nails found still in the walls and cuts in floor possibly related to presence of animals.

The building technology itself can be labelled as standard. The walls are built in opus mixtum technique utilising local volcanic stones and probably also local bricks. One of the details which require further investigation is the hypocaust floor which is formed by sesquipedales from kilns of the Domitii brothers which were located in the upper Tiber valley and it was uncommon for bricks to be transported over such a long distance.

The architecture of the baths seems to be somewhere between modern and conservative. The unusual and creative order and layout of the rooms can be attributed to the fact that the baths belonged to a large mostly unexcavated private villa. However, unlike in the older villae, for example in Stabiae, the rooms respect more the proportions established by older public baths and do not exhibit such a flair and luxury as for example the Hadrian's baths in his villa in Tivoli. However, the layout can be viewed as more progressive. Unfortunately, we cannot reconstruct the windows accurately enough. In case they were small and few, it would be a very conservative element for its period when larger glazed windows were becoming standard.

Further research of the building materials would be useful. Testing of its physical strength would make it possible to verify the hypothesis of failure by computer simulation. Analysing its chemical composition would be useful for finding out its provenance. Though the excavations are nearing completion, there is still a lot we can learn from further examination of the baths, not to mention the material found within, which was almost completely and knowingly omitted in this work.

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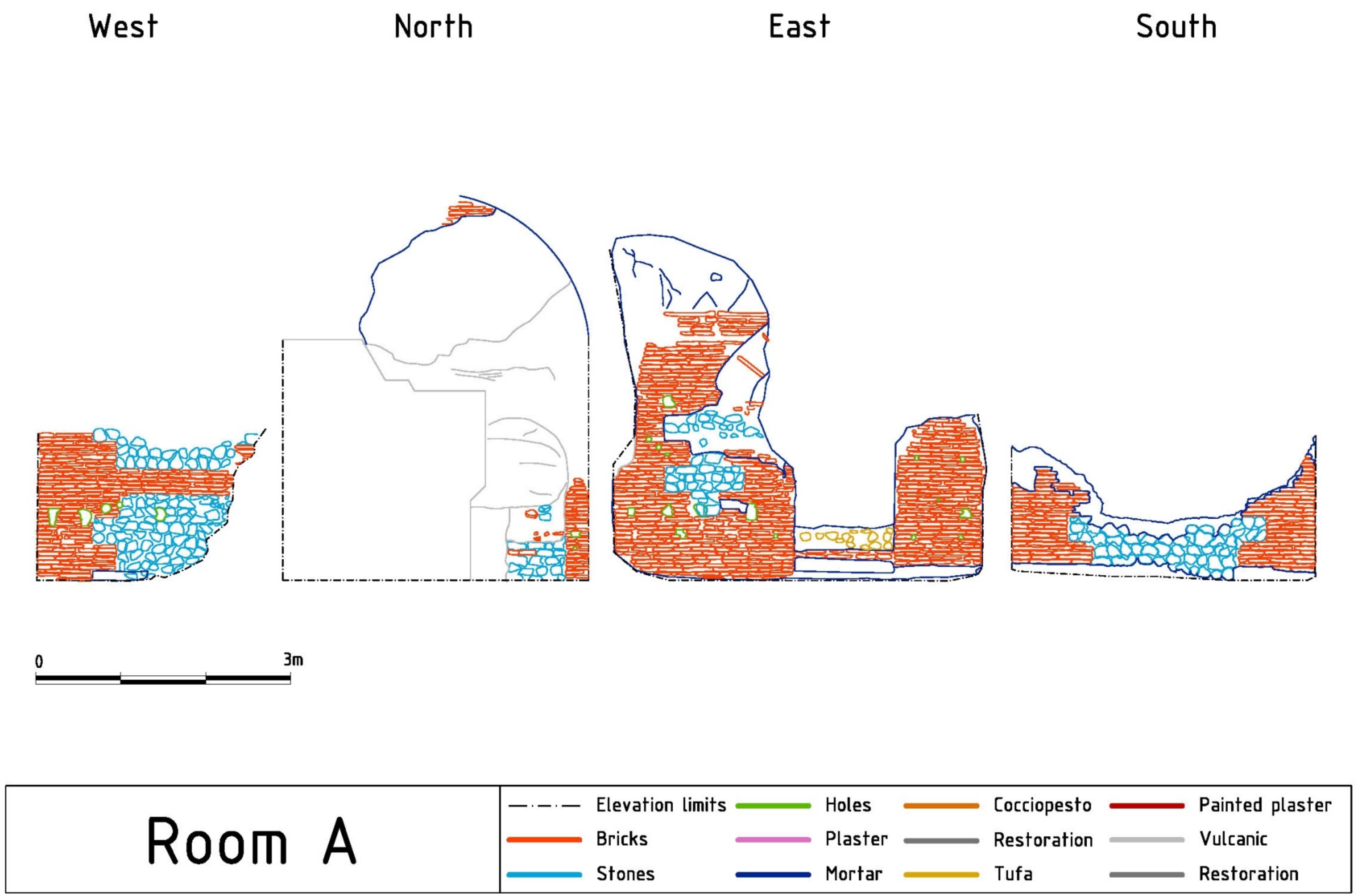
# List of illustrations



# List of tables

# Appendix 1: Elevations of the walls

All of the following drawings were created as a part of the 2015 photogrammetric survey project, except for rooms H and K, which were adapted from plans created in 2011 by Alessandro Baldi, Rosalba Di Maio and Anna Simeoli.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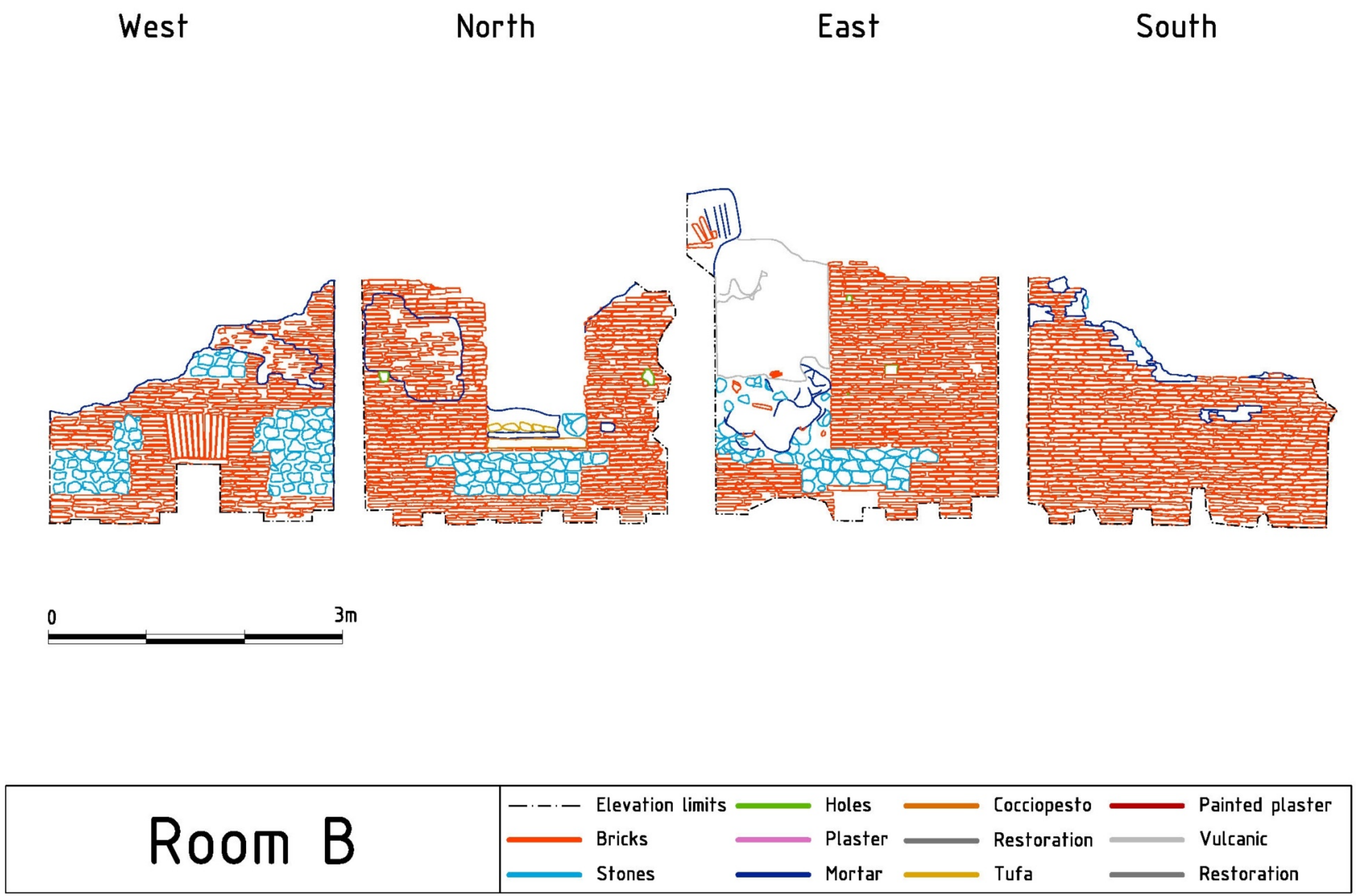
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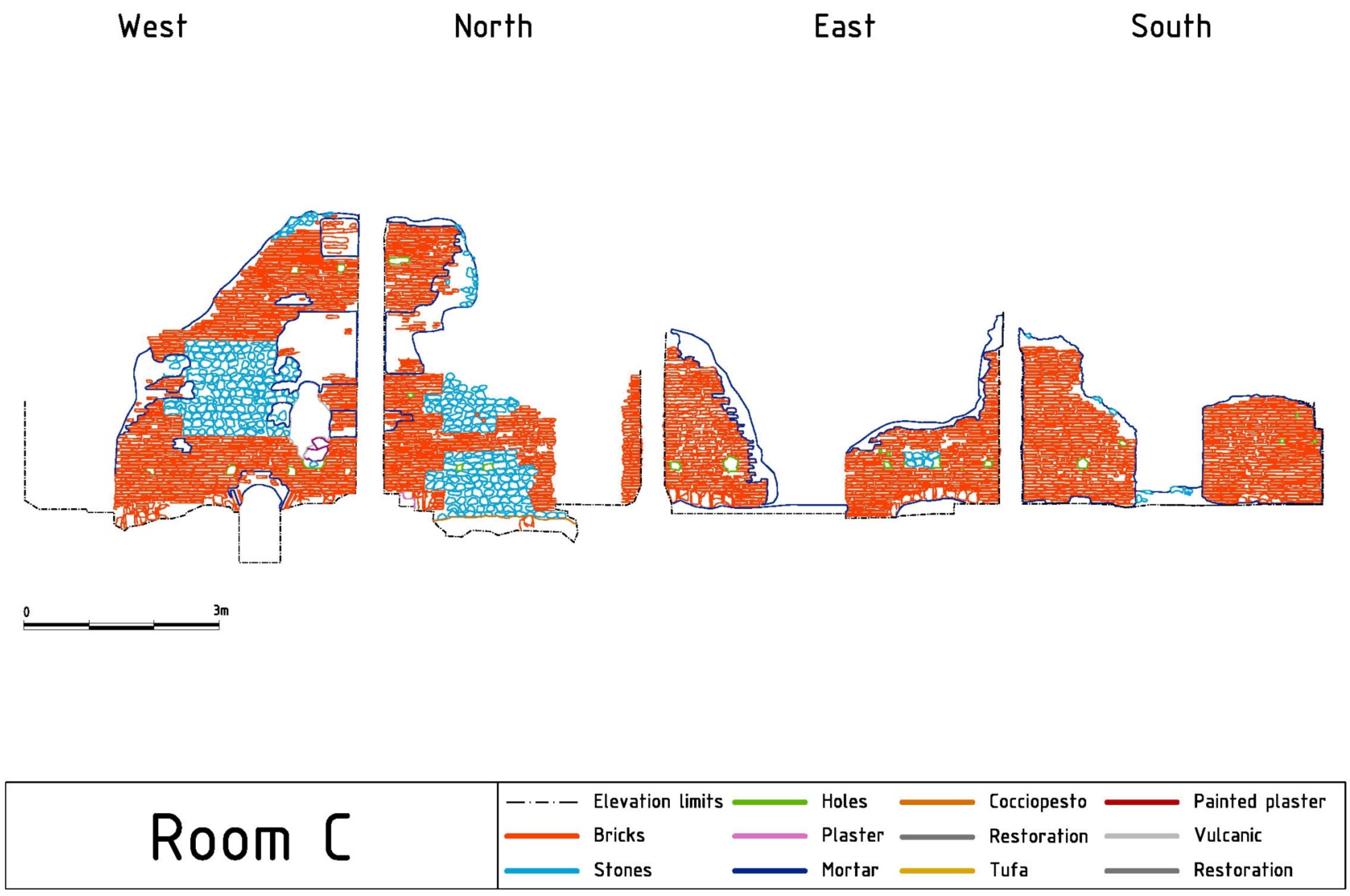
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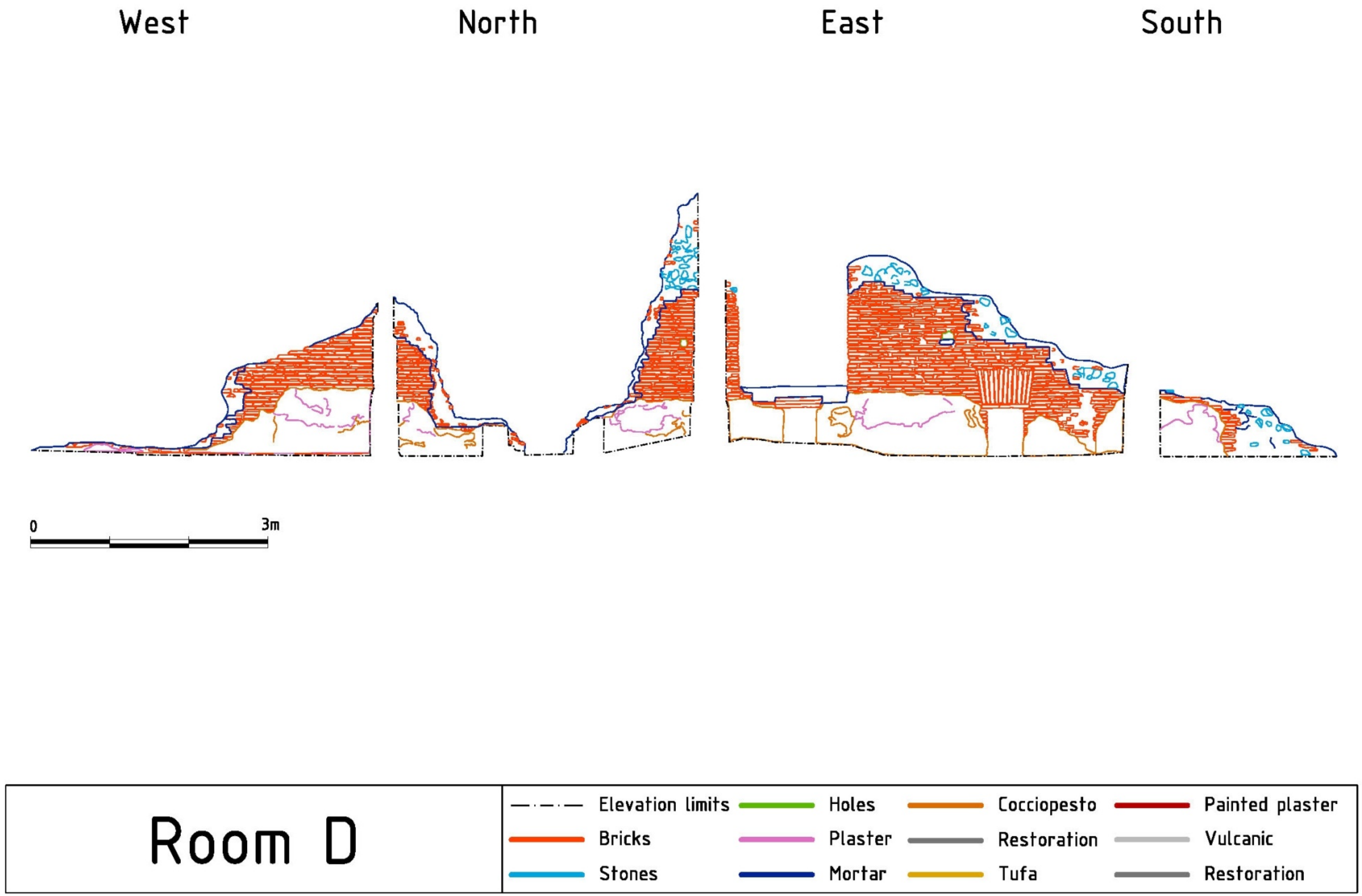
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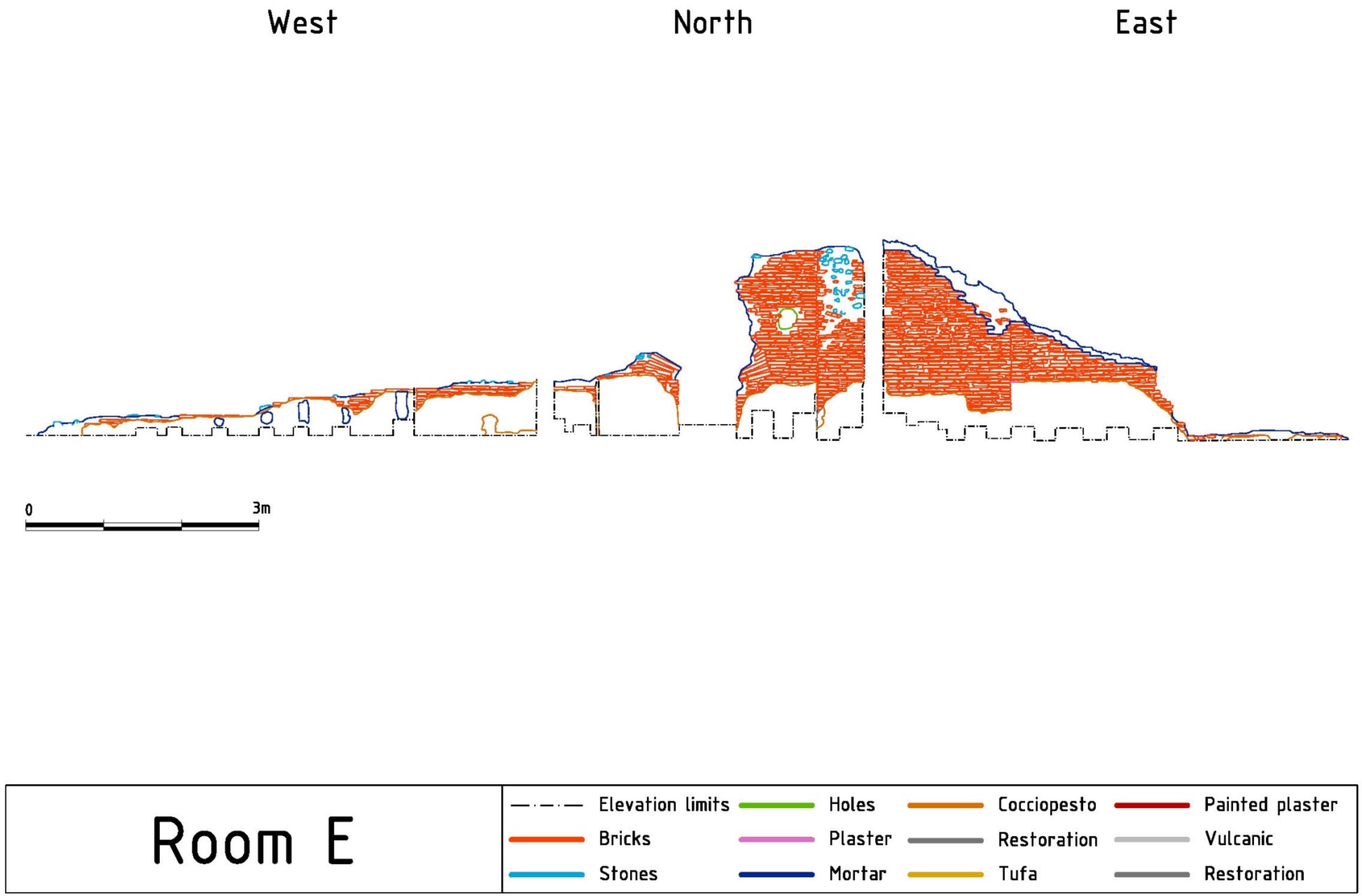
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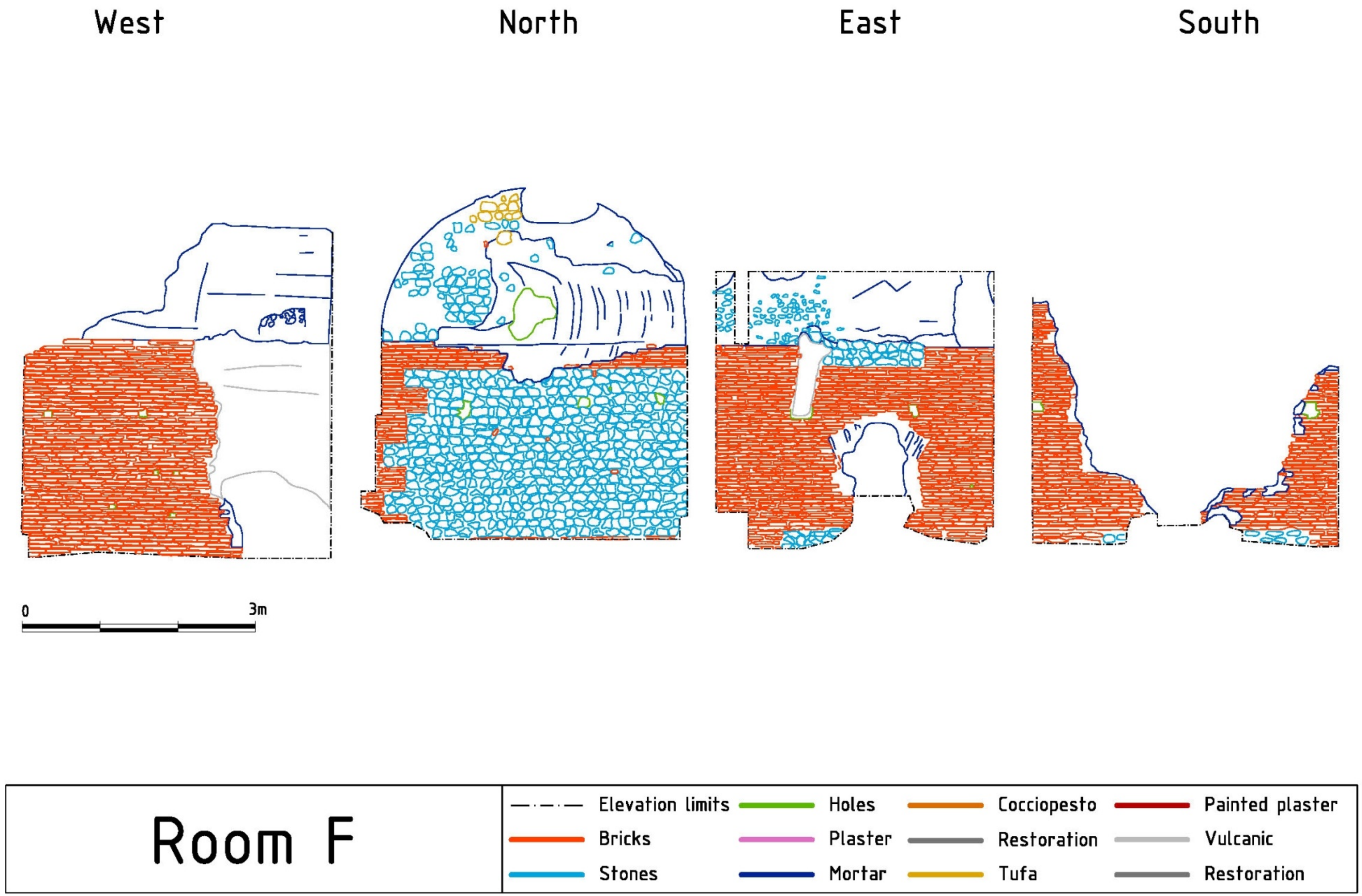
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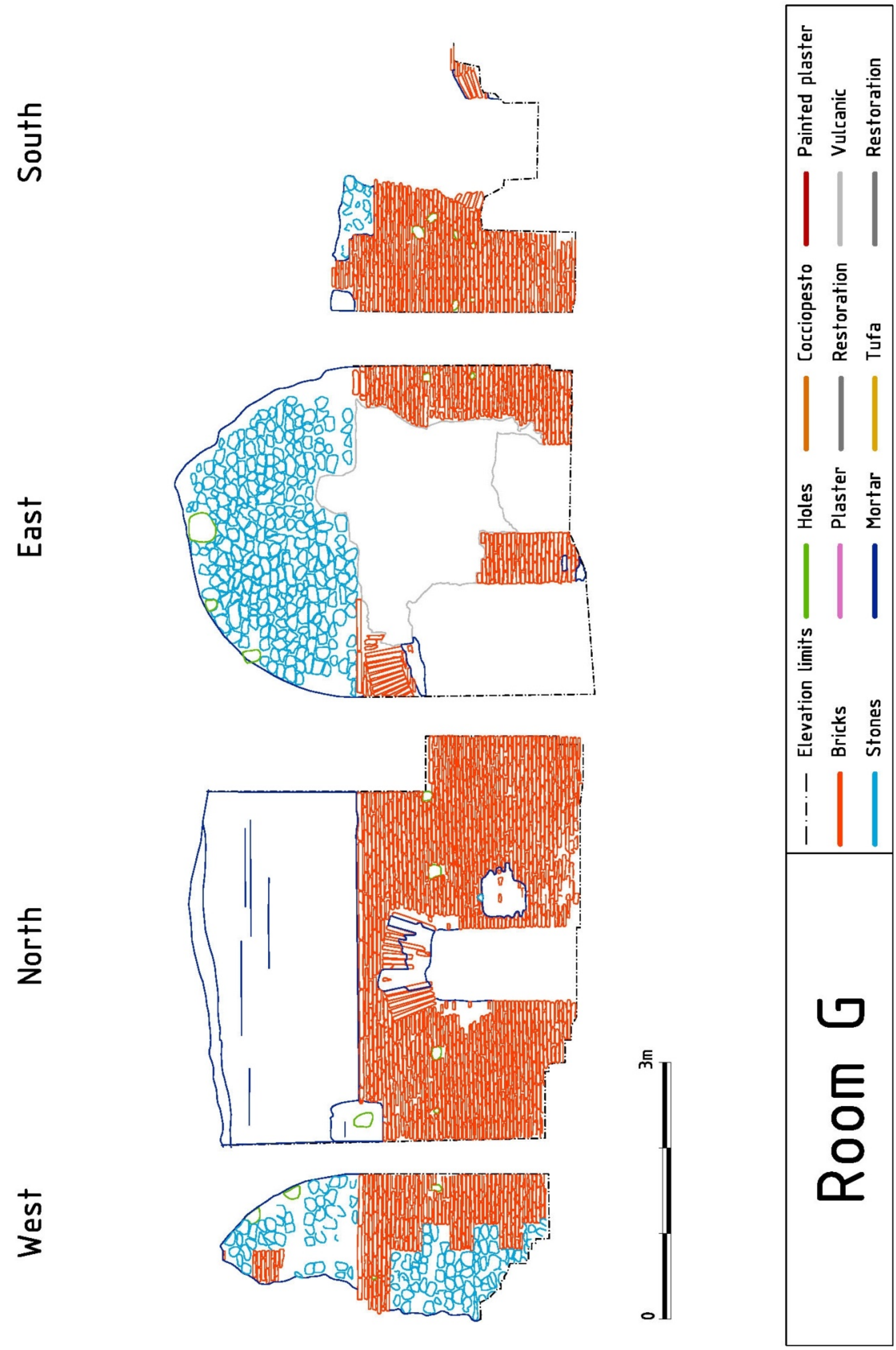
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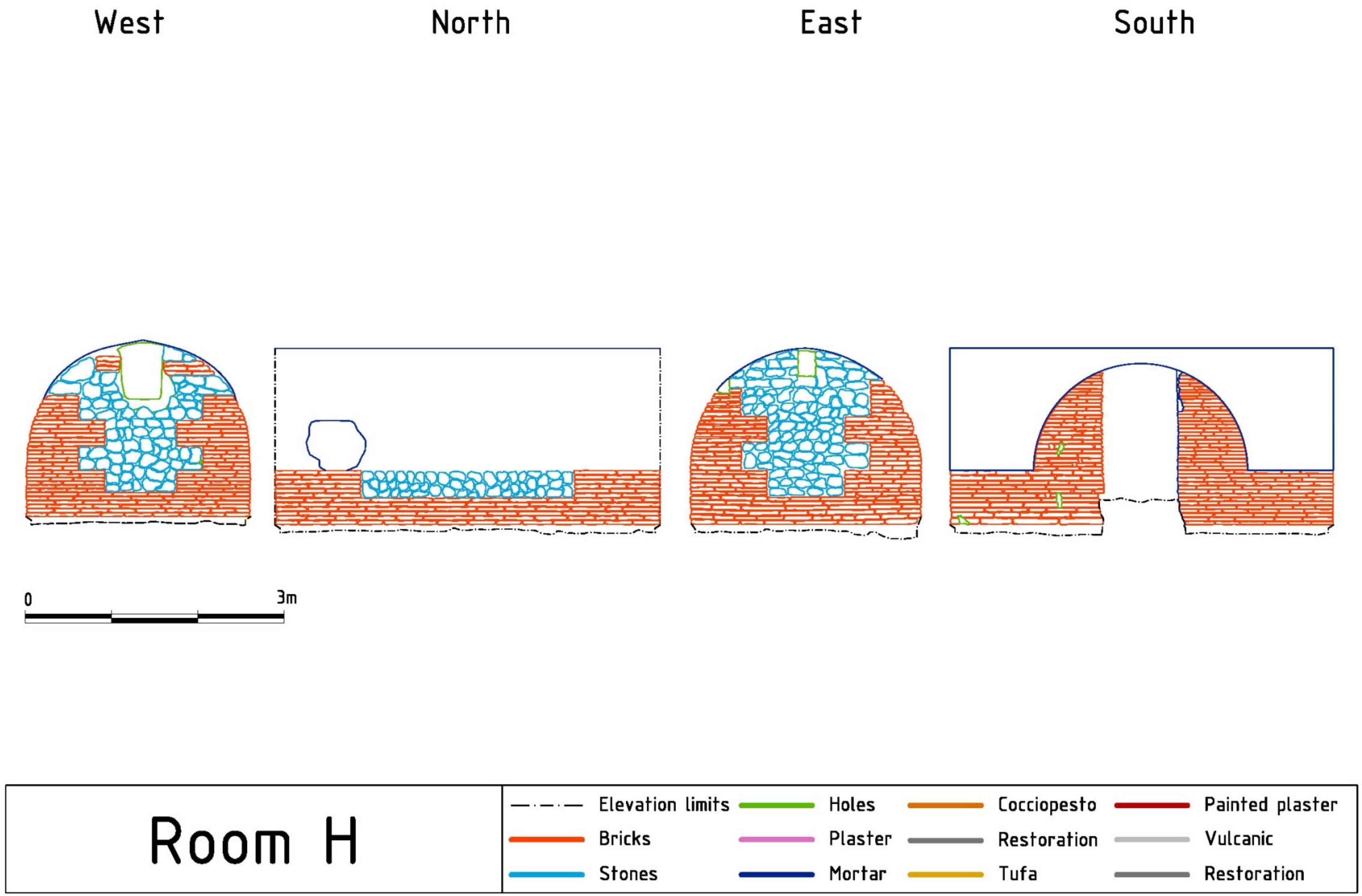
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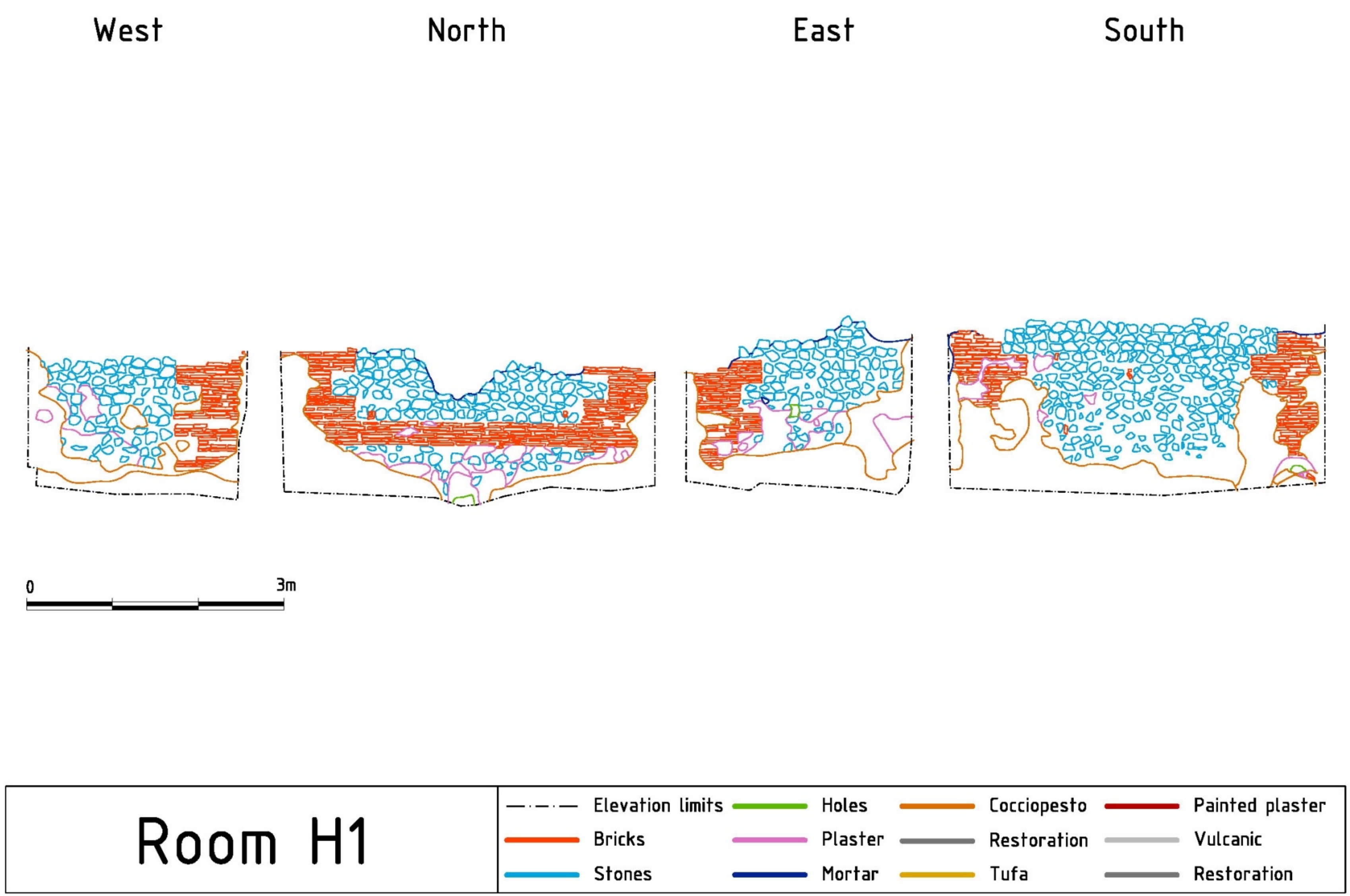
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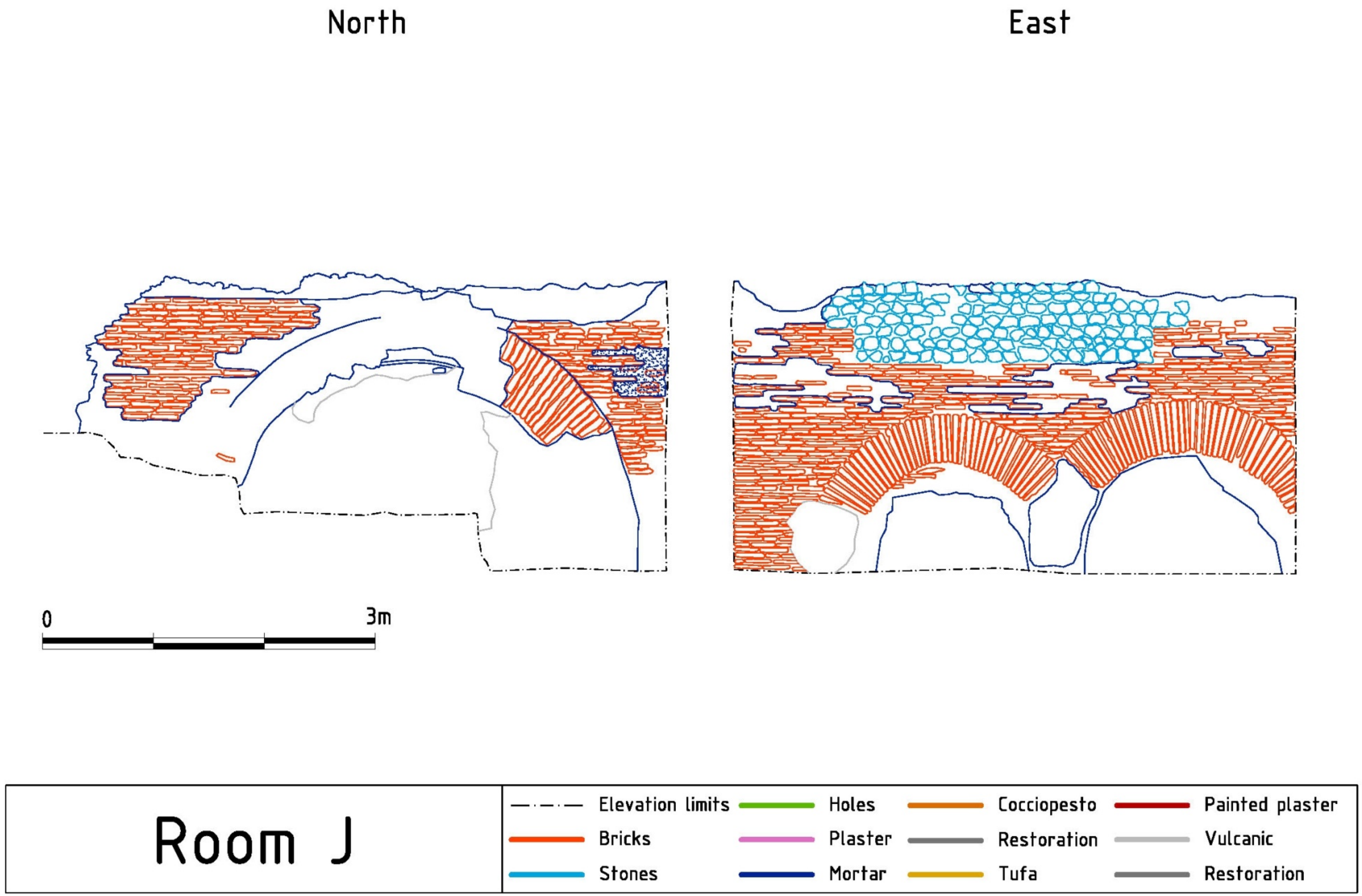
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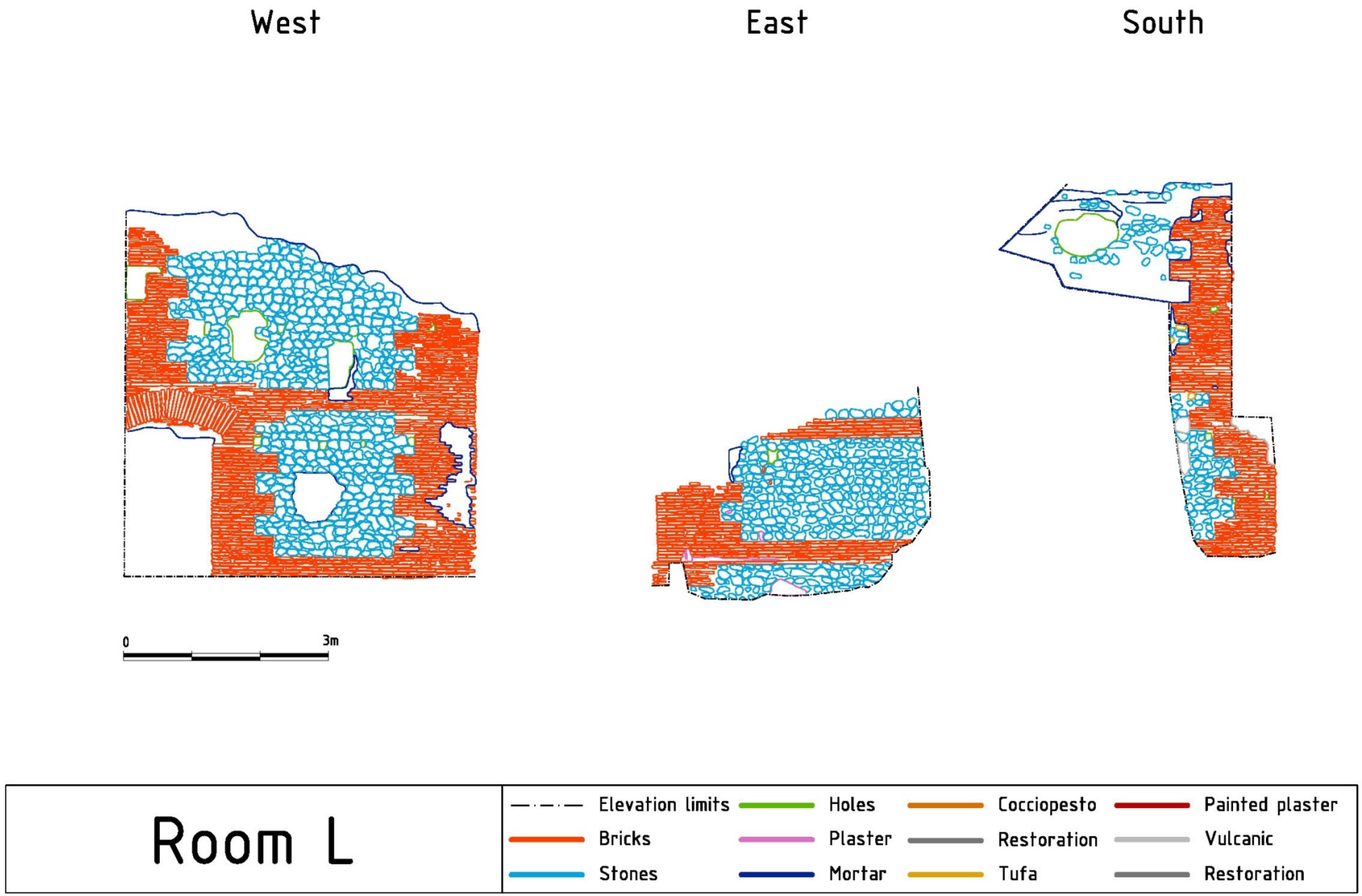
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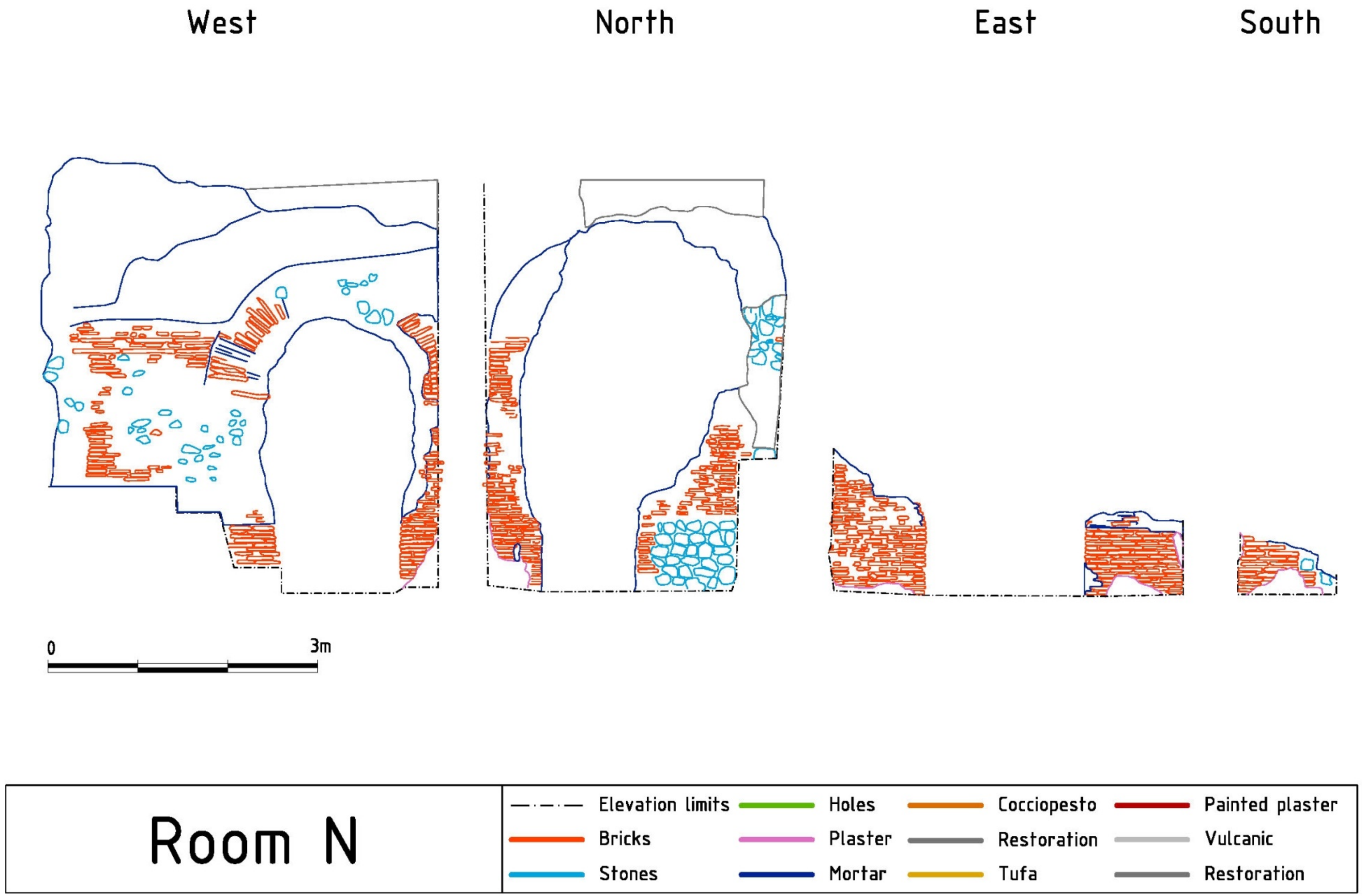
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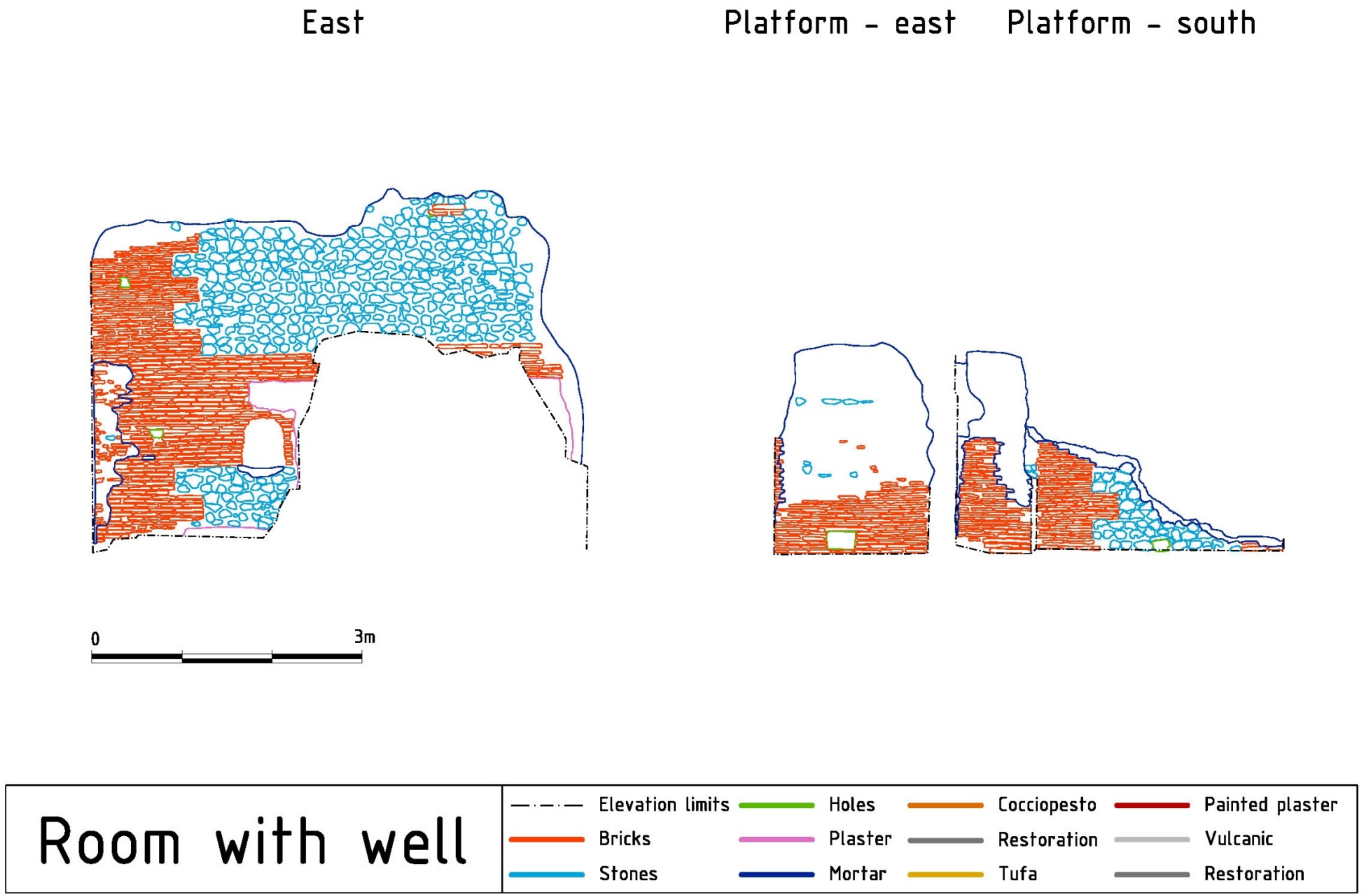
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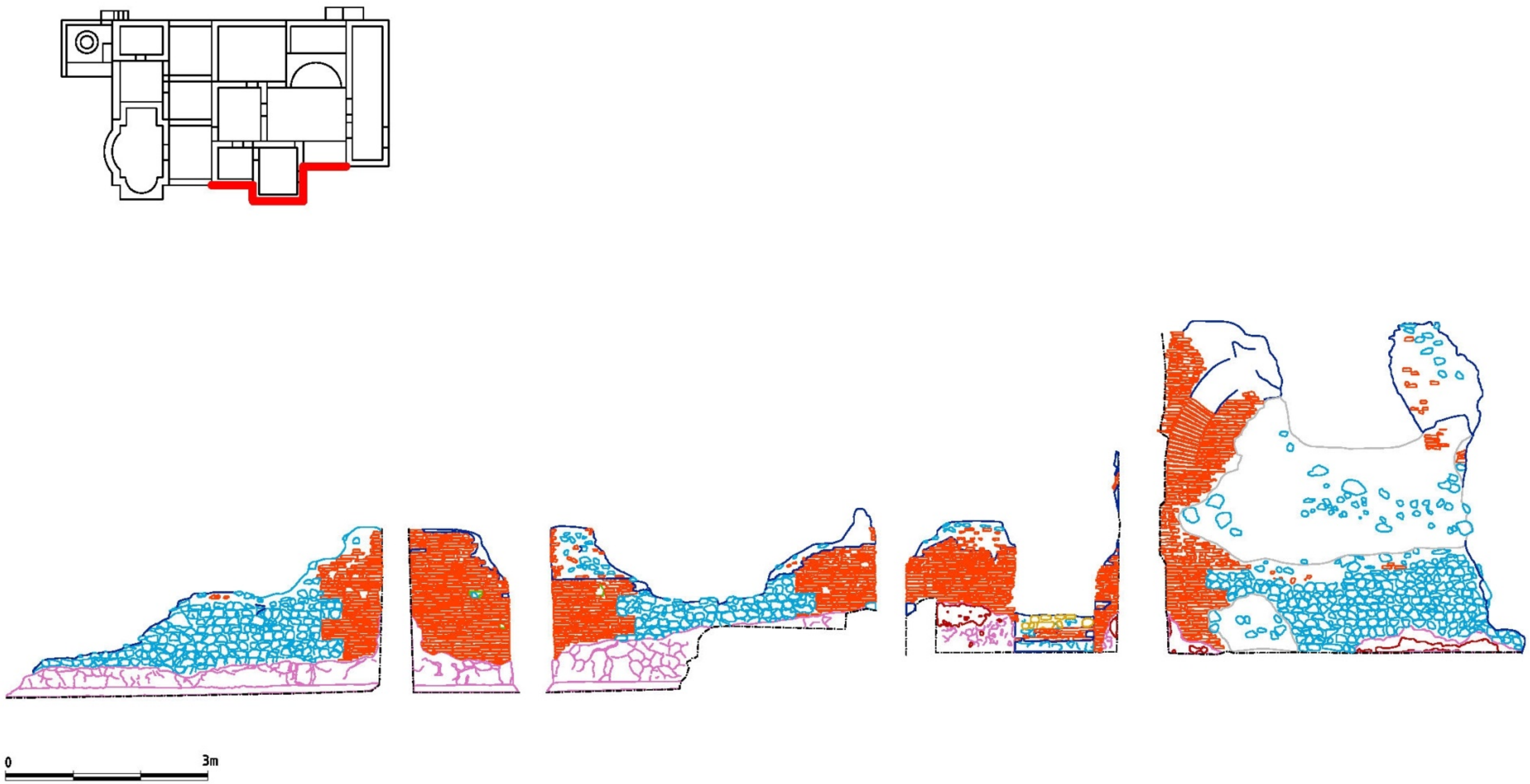


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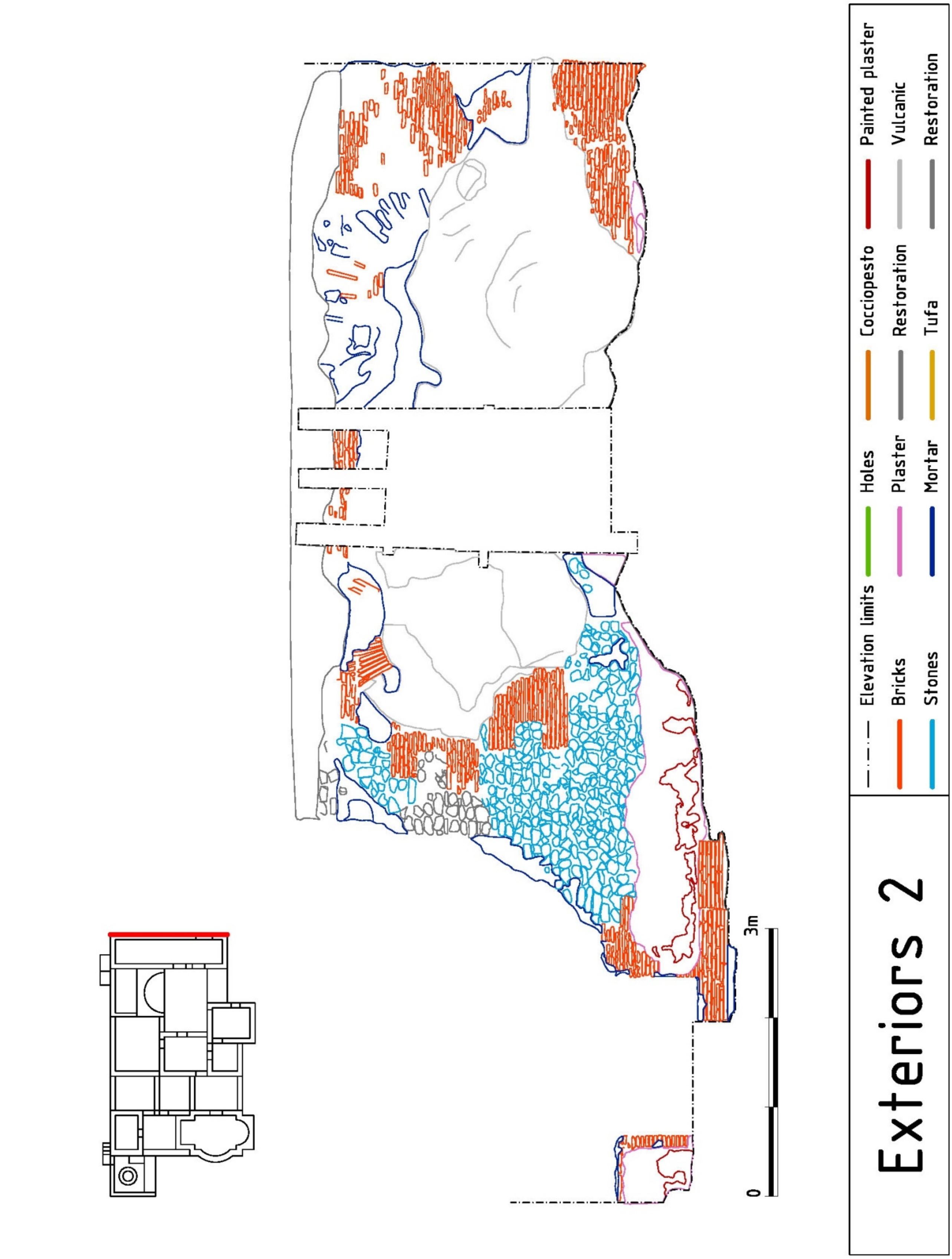
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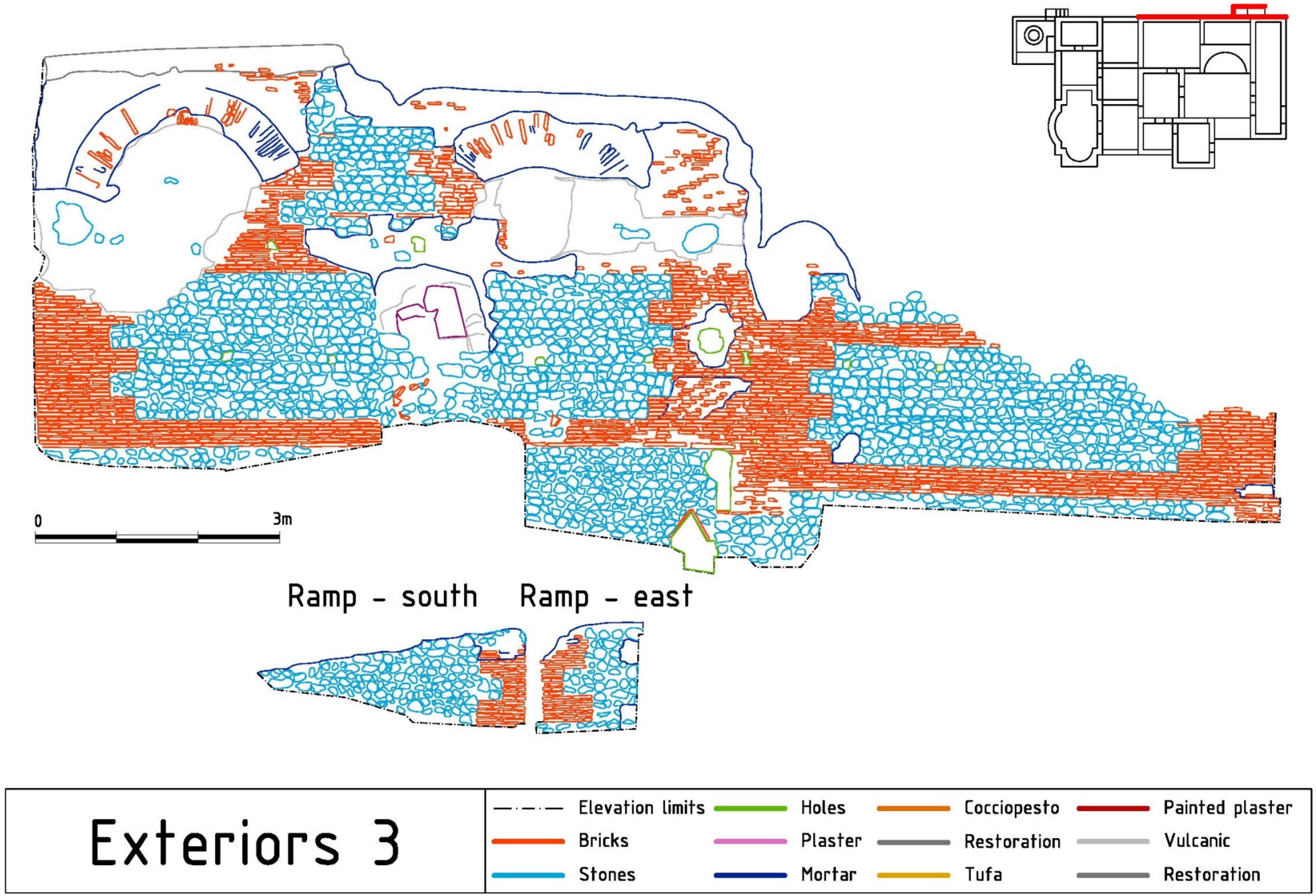
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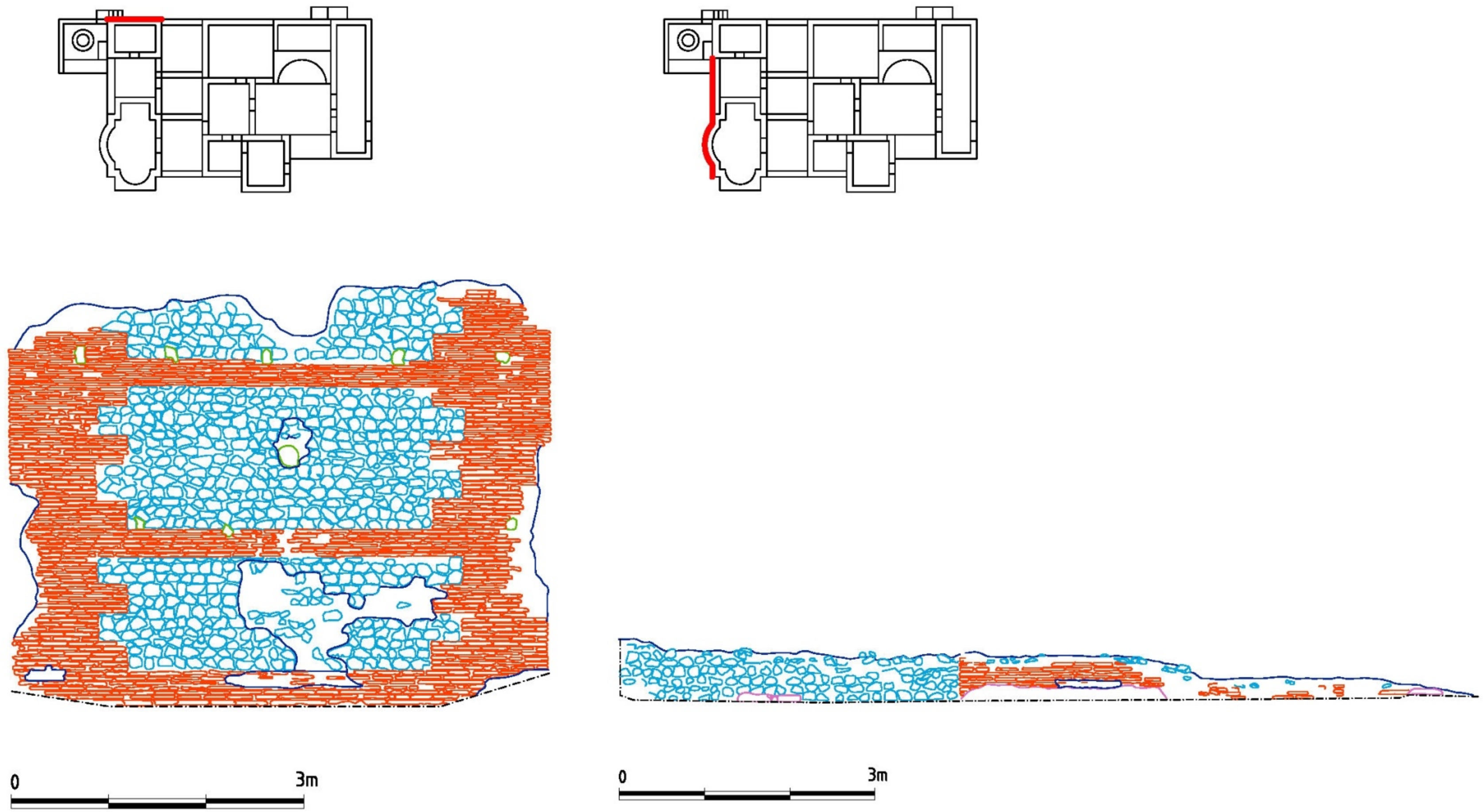


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| Stones | Mortar | Tufa | Restoration |