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Measuring the Roman building sites. The case of the *opus reticulatum* in the Necropolis of the Porta mediana in Cumae

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Abstract - **The study of a peculiar Roman constructive technique, such as the *opus reticulatum*, and the identification of an evolutionary line provide new data about the buildings where such technique was applied. Metric and dimensional studies, connected to dated contexts, increase chronological data and that can be set out with other chronological clues provided by the archaeological study of the site. The implementation of this method, based on the direct and dimensional analysis of the stone's elements used in the walls and the processing of the metrical data, show the trend of the *opus reticulatum* not only for some monumental tombs but also for other buildings of the city of Cuma. Here, with the study of a small part of the necropolis, it is possible to outline the setting of a complex building site that interested three different sectors.**

I. ARCHAEOLOGICAL CONTEXT

We analyze a specific area of the necropolis of Porta mediana at Cumae: a building complex situated along the Eastern boundary of a square outside the city gate (Fig. 1 e 2). It's a compound that has many different construction phases, starting from the end of the 2nd century B.C. and ending with the late Medieval age. During this long period the functions of the edifices in this area changed several times: funeral spaces at the beginning, then commercial buildings, later artisanal area and finally, in the Northen part, farmstead. The first funeral monument is attested in the Eastern part of this area: the mausoleum MSL46070 dated at the end of the 2nd century B.C. After that, during the late Republic period/beginning of Augustan age, other funeral buildings occupied this area: 5 mausoleums were identified and dated stratigraphically to this period. The tombs MSL46175 and MSL46144 situated inside the sector D46b; the structure MSL46346 found inside D46d; the edifice MSL60111 identified in D60a and the last, dated in the first years of Augustus' reign, the mausoleum MSL60137, found in D60c sector. It is believed that during this period a road existed crossing this area and leading to the Monte Grillo.

During the Tiberian period the mausoleum MSL43001 was built, right in front of the Porta mediana. No other transformation seems to have occurred in this area till the construction of the monumental mausoleum MSL58057, in the last quarter of the 1st century A.D. In the Flavian age there is also the beginning of the construction of a big terrace, starting from the Eastern part of the sectors analyzed and continuing eastward. At the beginning of the 2nd century the *columbarium* MSL59001 was probably built, in the Southern part of the area, next to the city walls and the Porta mediana.

In the same period, but before the mausoleum MSL59001's construction, the Northen part of the area changed function, from funerary to commercial, with the construction of a large building including one shop (BTQ60066), a space with an uncertain purpose (EFN46104) and a vaulted undefined hall (ENS46313). Not all the funeral edifices were destroyed: the mausoleum MSL60137, the tomb MSL58057 were preserved.

From the mid-3rd century A.D. the whole area was abandoned and the structures began to decay. In particular from the 5th century the implantation of some tombs around the ruined structures started. Some tile graves were installed in the Eastern part of the D60a sector and some other sepultures inside the space EFN46310. After this, starting from second half of the 6th century, the area became a sort of quarry in order to recover building materials, in particular marble's rests of the siding to produce lime.

In this period, these sectors became an artisanal area, with the construction of two kilns for the production of tiles inside the mausoleum MSL59001 and an other smaller ones inside the space D60a.

After a long period of abandonment which produced numerous colluvial levels, between the 8th century and the Late Medieval age, the Northen part of the area was reoccupied. In the D60 sector a tower house was built over the level of destruction of the Roman structures. The farmstead was occupied roughtly a century and it is possible that its end was due to a catastrophic event that destroyed the building.

This study evaluates the phases of funerary and commercial buildings using the reticulate work in its

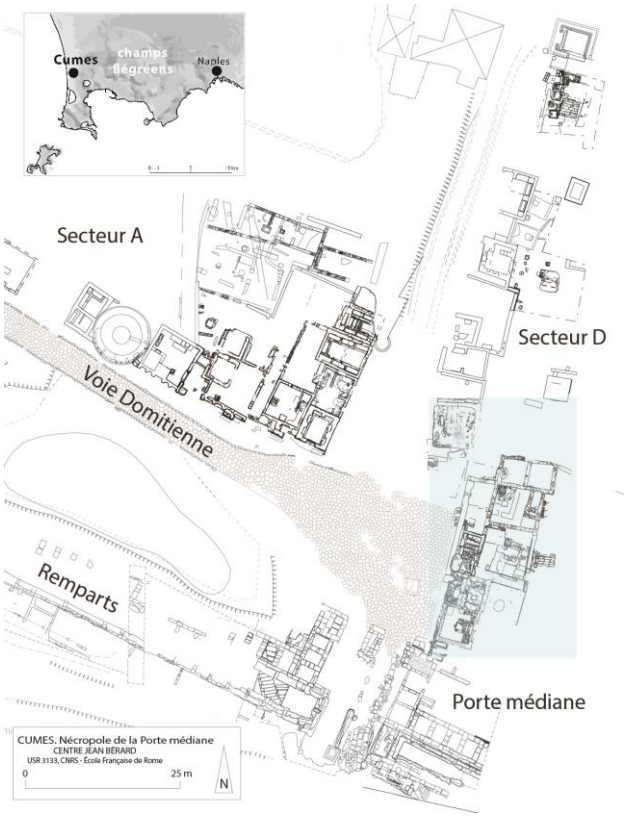

Fig. 1 - Plan of the Eastern part of the Necropolis of Porta mediana at Cumae.

well-defined form and not in its first appearance of the *opus quasi reticulatum*.

A. The mausoleum MSL58057 [1]
It is a funeral building composed of a big quadrangular podium and a hypogeum chamber. In its first phase (last quarter of the 1st century A.D.) the mausoleum hosted inhumations and in the second phase, at the beginning of the 2nd century A.D., some niches were carved in the walls and cinerary urns where built in. The first entrance door was closed and a new one was opened in the Northern side of the building.

B. The columbarium *MSL59001* [2]
The funeral building, built up at the beginning of the 2nd century A.D., has a hypogeum chamber with a continuous series of niches that probably helded cinerary urns, along all the walls. Today only 15 niches are preserved, but no urn was found during the excavation. The second phase (mid-6th century A.D.), with the kilns, is not analyzed here, but shows the destruction of a part of the Western wall in order to open a new entrance to the room.

C. The open space EFN46104 [1; 3]
In the D46 sector the transformation of the beginning of the 2nd century A.D are significant. There were the removal of the upper part of the mausoleums MSL46175

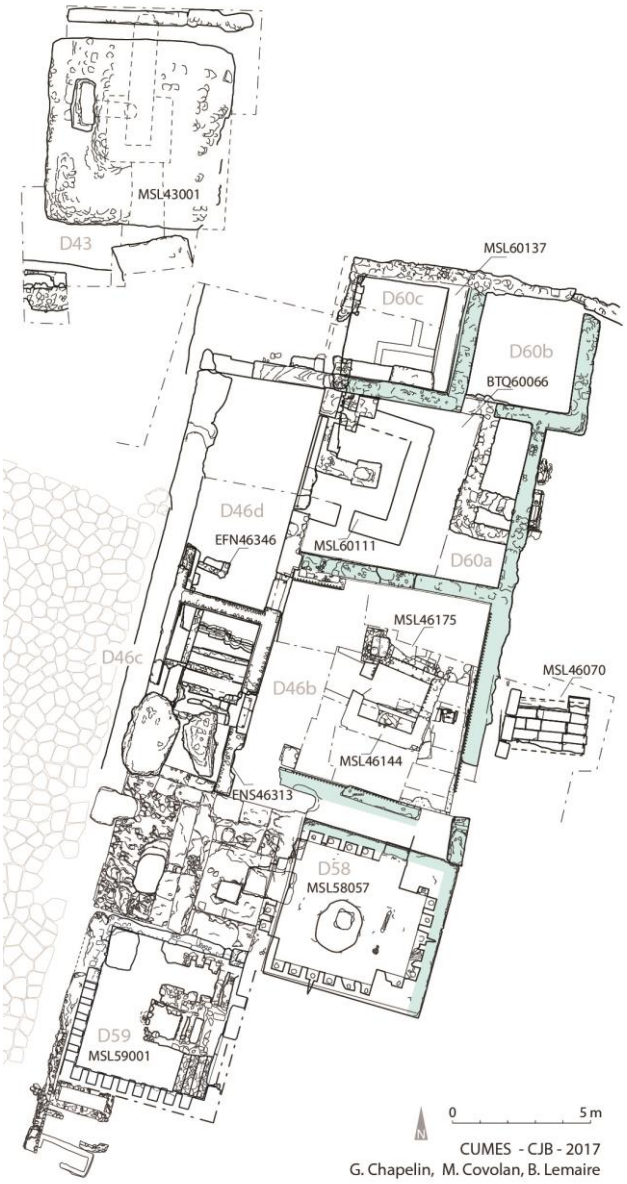

Fig. 2 - Plan of the analyzed sectors and monuments, with the indication of the analyzed walls in light blue.

and MSL46144, in order to create a large open area. This space was partly occupied by the new entrance of the funeral monument MSL58057.

D. The shop BTQ60066 [3; 4]
The commercial activity was built over the destroyed mausoleum MSL60111. The new building, dated from the beginning of the 2nd century A.D., is developed in two different rooms: the main one opens directly to the Porta mediana' square (D60a), the second is linked to the North-Eastern part of the first space (D60b). The presence of a counter with places for food and beverage preparation and storage, and a little oven are clues for

interpreting this room as a *caupona*.

II. METHODOLOGY

The work begins with the editing of a form in order to facilitate the constructive technique analysis. This form relies on already published studies concerning on *opus reticulatum*, such as Lugli's [5], Coarelli's [6], Torelli's [7], Adam's [8], Medri's [9], Giuliani's [10] e Dessales' [11; 12].

The walls are checked from the foundations to the elevation. It continues with the characterization of the walls facings, taking into consideration the materials, their manufacturing, and the measurements of stones and joints. For the ashlars' metrical analysis it has been decided to sample 50 ashlars, following the statistical and dimensional method of survey presented by H. Dessales [11]. For each ashlar the left (L1) and the right (L2) sides are measured, together with the diagonal between the vertexes of the two sides. Than we calculate how many elements are present inside one square meter surface and the dimensions of the modules of 5x5 ashlars or the length of 5 courses and of 5 joints. The least and maximum thickness of the joints are also measured.

After the measurements, the collected data are processed in spreadsheets in order to compare the different masonry information. The metrical analysis, based on the Medri's method, is resumed in a table including all the metrical values (Table 1). The principals measures evaluated are the number of ashlars in a square meter (NT), the percentage of the ashlars (CT) and mortar's (CM) coverage surface, the minor (L1min, L2 min) and superior (L1 max, L2max) length of the two different measured sides and their mode (L1mod, L2mod), the standard deviation calculated in relation to the mode of the sides (Illm) and the other in connection to all the sides' measures (Ill).

The percentage of the ashlars' coverage surface is calculated

$$CT = Average\ area\ x\ NT \tag{1}$$

taking the obtained value and converting it into percentage. The measurement of mortar's coverage surface equals to

$$CM = 100 - CT \tag{2}$$

The average area, used in (1) is the mean of the 50 ashlars' areas; these are calculated using the Erone's formula, thanks to the two sides' measurements and the diagonal length.

The standard deviation Illm is evaluated with the Excel function DEV.ST, considering the L1 and L2 distinct values.

$$Illm = DEV.ST\left(\frac{L1\ or\ L2\ lenght - L1\ or\ L2\,\mathrm{mod}}{L1\ or\ L2\,\mathrm{mod}}\right) \tag{3}$$

The Ill values is calculated as follows

$$Ill = DEV.ST(L1\ or\ L2\,\mathrm{max} - L1\ or\ L2\,\mathrm{min}) \tag{4}$$

The standard deviation values are both important. The first (Illm), calculated in connection to the mode's values, allow to understand how much the lengths of the sides deviate from the most frequent side's measurements. The smaller is the Illm's value, the higher is the quantity of ashlars with the sides' length equal to the mode.

The standard deviation computed in relation to all the sides' lengths, allows instead to analyze the wideness of the interval between the smallest and the longest length. This value shows the variety of ashlars' dimension used in a facing. If the measurement is high, it entails a large number of ashlars with various dimensions. This implies that different stone-carvers have worked to produce the ashlars for a single facing or that various stocks of materials were used.

An accurate study of these values and of measurements directly done on the walls does not produce a linear and valid evolution in relation with the chronology. We have tried, with this type of data, to give importance to the trends that can assume a value in relation with the chronology of a site, based on stratigraphic and ceramic dating and on epigraphic sources. This method can be applied for funeral and private buildings, and also for public monuments.

The complete analysis of the *opus reticulatum* concerning 22 building, for a total of 103 facings of 73 walls, is presented in M. Covolan's papers [13; 14].

III. ANALYSIS

The analysis of the *opus reticulatum* pertaining to dated buildings, defines a non-linear trend comparable with the general trend of other edifices of Cumae. The stratigraphic, epigraphic and historic data help to contextualize the mathematic and statistic values.

First are analyzed the two building site that interested only single edifice: the mausoleum MSL58057 (first phase) and the columbarium MSL59001. Later is presented the large building campaign that involve the space BTQ60066, the edifice EFN46104, the modification in the structure MSL58057 and the room ENS46313.

A. The mausoleum MSL58057, first phase

For this phase of the tomb there are only two walls' facing analyzed, the external facings of the Eastern (MR58012) and of the Northen (MR58011 , Fig. 3a) wall.

The structures, as said before, present *opus vittatum* facing inside the burial chamber and *opus reticulatum* facing outside, with quoining with quadrangular ashlars of tuff. The L1 sides' measures ranging between 7,5 and 11 cm, with a mode from 9 to 10 cm; the L2 values are between 4,5 and 12 cm, with a peak of 10 cm. The percentage of the ashlars' coverage surface ranging between 66% and 74%, with 81-84 elements in a square meter (in the Table 1 for the MR58011_sotto there are 72 elements, but they were calculated starting from a half square meter and so less precise compared to the other two values). Looking at the standard deviation values, the Illm is very close for the three facings (0,06 - 0,09) and also the ones calculated in relation to all the measures are situated in a narrow range, from 0,47 to 0,76). The homogeneity of these values is reflected in the lengths of the 5x5 modules, between 52 and 60 cm, in relation also to the thickness of the joints (1 - 4,5 cm) (Table 1).

B. The columbarium MSL59001

The burial chamber is built up with *opus reticulatum*'s facings (MR59002, MR59003, MR59004), with quoining and leveling courses under and above the niches realized with quadrangular ashlars of tuff. The wall MR59001 is different: it has a wider surface in *opus vittatum* and only the upper part is in reticulate work. All the walls are built against earth, so they do not have exterior facings.

The L1 and L2 lengths measure between 6 and 10 cm, with a mode ranging from 7,5 to 9 cm, for the L1 measures and between 8 and 9,5 cm for L2. The standard deviation's values Illm, varying from 0,08 to 0,11, reflected the range not so small of the sides' lengths. Instead, the others deviation's values are between 0,55 and 0,75. The modules 5x5 have small lengths, attested

Fig. 3 - a. The wall MR58011, upper facing. b. The wall MR59001.

Table 1 - Table with the metrical analysis of the buildings' facings here presented.

Edifice	Sample	NT	CT	CM	L1 min	L1 max	L1 mod	L2 min	L2 max	L2 mod	Illm	Ill	Modules	Joints
MSL58057 (1st phase)	MR58012	84	74%	26%	7,5	11	10	7,5	11	10	0,06	0,47	53-59	1,5-3
	MR58011_sopra	81	69%	31%	8	10,5	9	4,5	11	10	0,09	0,76	52-56	1-4,5
	MR58011_sotto	72	66%	33%	8	11	9,5	8	12	10	0,07	0,5	54,5-60	1- 4,5
MSL59001	MR59001	104	67%	33%	7	9,5	7,5	6	10	8	0,09	0,64	49-52	1-3,5
	MR59002_sotto	98	65%	35%	7	10	8,5	6	10	8	0,08	0,62	49-50,5	0,5-3
	MR59002_sopra	112	69%	31%	6	9,5	8	5,5	10	9	0,1	0,75	nr	1-3,5
	MR59003_sotto	104	67%	33%	6,5	10	8	6,5	9,5	9	0,09	0,71	49-50	0,7-3
	MR59003_sopra	96	61%	39%	6	10	9	6	10	8	0,11	0,64	nr	1- 4
	MR59004	91	69%	31%	7	10	8,5	7	11	9,5	0,09	0,55	52-53,5	1,5-3
MSL58057 (2nd phase)	MR58007_B	84	74%	26%	7,5	11	10	7,5	11	10	0,06	0,47	45,5-47	1-2,5
	MR58007_A	81	69%	31%	8	10,5	9	4,5	11	10	0,09	0,76	55-57	1-2,5
	MR58007bis_A	72	66%	33%	8	11	9,5	8	12	10	0,07	0,5	42-42,5	1-2
	MR58007bis_B	126	72%	28%	6,5	8,5	7,5	7	8,5	7,5	0,05	0,26	43- 45	1-2
EFN46104	MR46005_a	120	65%	35%	7	8	7,5	6,5	8	7,5	0,04	0,26	43,5-46	1-2
	MR46005_b	122	70%	30%	6,5	8,5	8	6,5	9	7,5	0,1	0,34	44- 46	1-3,5
	MR60033_B	119	70%	30%	7	8,5	8	7	8,5	8	0,04	0,24	44-46,5	1-2
BTQ60066	MR60033_A	115	69%	31%	6,5	8,5	8	7	9	8	0,05	0,38	46- 47	1-2,5
	MR60082_B	110	69%	41%	6,5	8,5	8	7	9,5	8	0,06	0,42	46- 48	1-2,5
	MR60061_B	126	78%	22%	7,5	8,5	8	7,5	9	8	0,04	0,32	46-46,5	1-2
	MR46005_c	120	72%	28%	7	8,5	7,5	7	9	8	0,05	0,28	46-47,5	1-2
	MR46005_d	116	70%	30%	7	9	8	6,5	9	8	0,06	0,3	47	1-3
	MR60125	126	75%	25%	7	8,5	8	7	8,5	8	0,04	0,3	45,5-47	1-2
	MR60099	111	70%	30%	6,5	10	8	7,5	9	8	0,06	0,43	47-48,5	1-2

between 49 and 53,5 cm; this due also to the restrained thickness of the joints (0,5 - 4). These measures entail a high number of elements in a square meter (91 - 112) and a uniform percentage of the coverage surface. For the ashlars between 61% and 69%, and for the mortar from 31% to 39% (Table 1; Fig. 3b).

The other contexts of this area, the large building dated from the beginning of the 2nd century include three adjacent spaces: the external area (EFN46104) and the two rooms of the shop BTQ60066. These structures were built during a unique campaign, in which are also collocated the transformations in the mausoleum MSL58057.

C. The mausoleum MSL58057, second phase

The new entrance to the mausoleum, on the Northen side of the edifice, is a staircase going down eastward. The new structures are the Northen wall (MR58007) of the stairwell and the barrel vault in *opus caementicium* over the staircase. The wall MR58007, realized in reticulate work and quoining with quadrangular ashlars of tuff, is composed of two different parts: one that is the load-bearing wall, until the beginning of the vault; the other is built above, aligned with the inferior part, in order to define a little space over the barrel vault (Fig. 4a).

The external facing of the lower part (MR58007_A) presents different metrical evidences, with bigger ashlars (Table 1). It is possible to think about a distinct consignment of ashlars and not to a different phase of building.

The L1 lengths ranging between 6 and 8,5 cm, with a peak at 7,5 cm; for the other side (L2) the values are from 6 to 8,5 cm, with the mode between 7,5 and 8 cm. The small dimensions of the ashlars together with the lower thickness of the joints (1 - 2 cm), define a short length of the modules 5x5, between 42 and 47 cm. These aspects stand out also from the number of elements in a square meter (126 - 136) and from the high percentage of the ashlars' coverage surface, between 72% and 77%. Consequently the mortar's coverage percentage is from 23% to 28%. The standard deviation's values are both (Illm and Ill) very close to each other: the first between 0,04 and 0,08 and the second from 0,26 to 0,36 (Table 1).

D. The open space EFN46104

For this area, all the outside walls were built during this phase: the Eastern wall MR46005, which continues also towards North defining the Eastern limit of the shop BTQ60066 and ending up against the Northen wall that divide the two sectors (MR60033). Both present *opus reticulatum*'s facing with quoining with quadrangular ashlars of tuff.

The L1 lengths are between 6,5 and 8,5 cm, the L2 have similar values, from 6,5 to 9 cm. Both the sides' mode ranging between 7,5 and 8 cm. As for the second phase's

Fig. 4- a. The wall MR58007, upper facings. b. The wall MR46005, in the space EFN46104. c. The Southern facing of the wall MR60082. d. The wall MR60125.

walls of the mausoleum MSL58057, also here the small dimension of the ashlars and the lower thickness of the joints (1 - 3,5 cm) entail short lengths of the modules 5x5, attested between 43,5 and 46,5 cm. In these walls the number of elements in a square meter is even higher and tight, from 119 to 122, with a corresponding percentage of ashlars' coverage surface equal to 65-70%

(mortar's coverage surface vary from 30% to 35%. The standard deviation's values for the mode (Illm) are between 0,04 and 0,1, instead the Ill's measures are closer to each other, from 0,24 to 0,34 (Table 1; Fig. 4b).

E. The tavern BTQ60066

The walls of the main room and the ones of the North-Eastern space are all built up in *opus reticulatum* and like the others of the same building phase, with quoining with quadrangular ashlars of tuff.

The L1 lengths ranging between 6,5 and 10 cm, with a majority of mode's values attested at 8 cm. For L2 the measures are similar, form 6,5 to 9 cm of lengths and always 8 cm the mode. Like the walls described in the two precedents sections, there are a lot of elements in a square meter, between 110 and 126 and also a restrained range from 45,5 to 48,5 cm for the modules 5x5 lengths. These lower values are again due to the little dimension of the ashlar and to the thickness of the joints, attested between 1 and 3 cm. The percentages of the ashlars' coverage surface are upper-middle values, from 69% to 78%; consequently the mortar's percentages are between 22% and 31% (Table 1; Fig. 4c-d).

IV. RESULTS

The two buildings, MSL58057 (first phase) and MSL59001, are two different building campaign. The study of the ashlars' dimensions confirmed the stratigraphic dating and the comparison to other buildings in the city confirm the dimensional trend of the ashlars in the respective chronologic periods (Fig. 5). For the last quarter of the 1st century A.D. the ashlars' dimension are bigger than the elements of precedent part of the century [13;14] and also in relation to the period following the construction of the *via Domitiana*. The ashlars are not so precisely carved (general Ill's values between 0,23 and 0,81) and they present big dimensions (from 9 to 11 cm of sides' length) [13; 14].

In the isolated and private building site of the mausoleum MSL59001, the ashlars are still not well carved (Ill's values between 0,55 and 0,75), but the dimensions are a little bit smaller (from 7,5 to 9,5 cm of side's length).

For the three monuments MSL58057 (second phase), EFN46104 and BTQ60066, the metrical data and the stratigraphic connection of the walls entail the contemporaneity of the structures. The identification of only one phase for many buildings is not common and allow to speculate on the organization of the building site. The ashlars at the beginning of the 2nd century A.D. are better carved (general Ill's values between 0,26 and 0,37) and also of smallest dimension (from 7 to 8 cm of sides' length) [13; 14].

The presence in the walls of the big building site of scaffoldings holes of different forms suggest the use of different teams of masons, at least three, one for each single space [15].

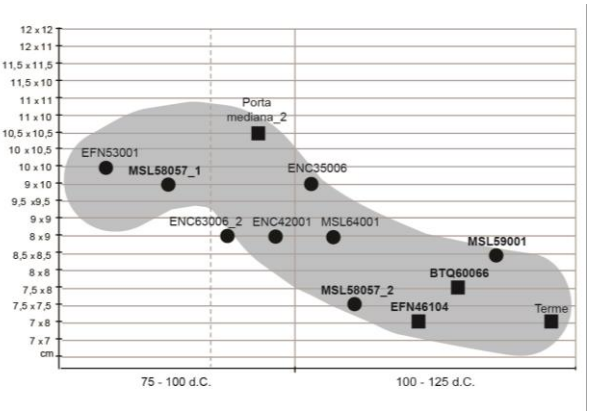

Fig. 5- Diagram of the ashlars' dimensions variation in Cumae at the end of the 1st /beginning of the 2nd century A.D. The circle indicates the funerary buildings, while the square the other type of edifices. The dotted line indicate the via Domitiana*'s construction in 95 A.D.*

There are three different types of putlog holes identified in this building site: rhomboidal, quadrangular and triangular shape. The first type is located inside the staircase of the mausoleum MSL58057. The quadrangular shape is present in the walls' facings within the area EFN46104. They always present a rectangular stone over the holes and two reticulate's ashlars disposed horizontal. Two putlog holes in the North-Eastern corner of the room, have the same shape, but not the same way and precision of construction. They should have been realized by a worker less skilled.

The triangular shape holes are identified on the facings inside the shop BTQ60066. They always have a trapezoidal or rectangular carved stone over the holes.

The first and the last type of scaffolding holes generally require a round section putlog, while the quadrangular ones host without distinction a square or round section putlog.

The *opus reticulatum* of the main building is precisely dated and it can be considered as one of the most important context of Cumae from this point of view. These buildings present ashlars' dimensions that are the reference for the other structures in the Necropolis and in Cumae for the end of the 1st/beginning of the 2nd century A.D.

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