

# LASER SCANNING IN POMPEIAN CITY WALL A COMPARATIVE STUDY OF ACCURACY OF THE DRAWINGS FROM 1930S TO 40S

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## ABSTRACT:

This paper aims to compare between the drawings in 1930s and 40s and the result of our laser scanning from 2005 to 2007 and analyze the causes of their failures. In the 19th century, Mazois makes no difference between drawings of measurement, reconstructions, and his image of the ancient Roman city. Maiuri, who employ professional surveyors, begun to measure the ruins using scientific methodologies in 1930s. The mistakes of Maiuri's surveyor have been made from the beginning and surveyor's interpretation of the result from contradictory measurements was based on a certain prejudice in a wrong way. Eschebach, who applied the aerial survey in 1940s to create the first general map of Pompeii, may draw the map by the simple way in which the street line may perhaps be traced from an aerial photograph. Consequentially his map includes considerable divergence and rotation. However the city wall in Eschebach's revised map was almost exact to the distance along two main streets with a possible error 1-2 m either way. In our own time, archaeological inquiry has profited from using recently developed scientific methodologies including laser scanning and satellite measuring techniques, GPS as well as computer measuring to determine global position. Despite the thoroughness of these procedures and the obvious care in mensuration with which many of drawings were produced, it would have been difficult, if not impossible, to maintain a high degree of accuracy over long distances, because the prejudice or the careless mistakes would exist in the mind of surveyors.

## 1. INSTRUCTION

In Pompeii many researchers share the sense of disorientation, which was aggravated by the general lack of plans and maps in the text. Extracts from Eschebach's maps in 1942 and revised 1969 (1:1000 in scale) are available at the back of his book published in 1995 (Figure 1) (Eschebach 1995), but they are hardly referred to in the text and they are not made easily accessible. And sadly detailed elevations are largely absent. Meanwhile in these 70 years, we find a famous and detailed research on Pompeian city wall of Maiuri (Maiuri 1930 and 1943) giving place to a more sporadic and limited style of investigation and excavation. But no project involving the whole city wall was undertaken. It is clear that one of the chief reasons for this style was below. The city wall is so long and tall that researchers could not measure the whole city wall using traditional and old-fashioned equipments. All of the hitherto unpublished investigations are so fragmentary as to be impossible to grasp the measure of difference between the Roman and pre-Roman architectural details. Based on the research of Maiuri in 1930, the investigation consists of a piece by piece analysis which is intended to facilitate the discussion of whole city wall and urbanization sequences of Pompeii. Our investigation has been carried out from 2005 to 2007 by using methods of measuring developed in these 20 years; laser scanning technology (Figure 2). We introduce an advanced measuring method: 3D scanning system, in which the object can be described as the aggregation of dots having three dimensional coordinates. The measuring of whole city wall has

been completed within two seasons, and of all of the streets in order to be accurate in such long-range measuring of the whole city wall. And the surface of the northern city walls between the Herculaneum and Vesuvio Gates has also been measured in order to create their elevations including towers on an existing map.

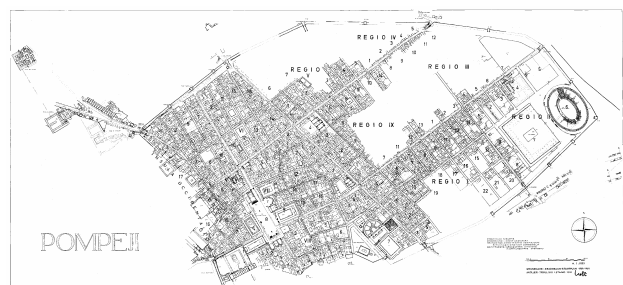


Figure 1. Map published in 1995 (Eschebach 1995)

And some markers of which the longitude and latitude measured by Arch. Rispoli in 2006 were included into our scanning data in order to locate our data on the GPS (GLOBAL POSITIONING SYSTEM) (Sampaolo 2006).

With the general map drawn by Eschebach and elevations by Maiuri, this article offers interim but useful comparisons across the Pompeian city wall in the first half of the last century: in the features of errors in measurement.

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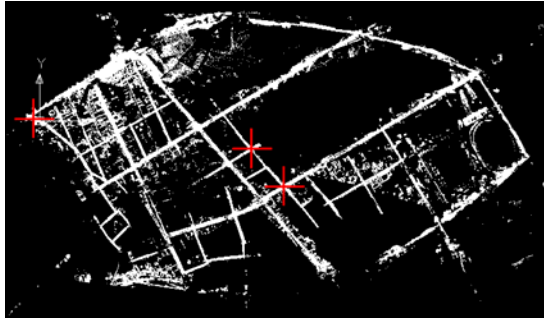


Figure 2. Measured area using laser scanning  
(Crosses are connected GPS points)

## 2. SURVEYORS BEFORE THE 20TH CENTURY

### 2.1. C. F. Mazois

Pompeii has been one of the most famous archaeological sites in Europe in the late 19th century.

A French architect C. F. Mazois who worked in the remains of this Roman city under the Queen Caroline's support was brought into close proximity to a past which has been preserved by the eruption of Vesuvius in AD 79. His four-volume compendium of measured drawings and descriptions of buildings including the city walls and the gates excavated in the early 19th century added another layer to our appreciation of the recording of the ancient city (Masois 1824).

As archaeologists measured the houses, gates and city wall, the scale and nature of the remains make it easy for them to create their own idea of an local ancient Roman city in the first century AD.

This experience of the Roman city draws upon the physical reality of the past as it has been preserved: archaeologists begun to reconstruct their reality of the city. However, these reconstructions are distinctly idealized. From Mazois' drawings and explanatory text, we can discern the two different fabrics of walls (*opus incertum* and *opus quadratum*), but the dimensions of each stone blocks do not be given. Actually the tower, which Mazois has drew, does not exist (see Figures 3 and 4).



Figure 3. Mazois' drawing of the Tower X

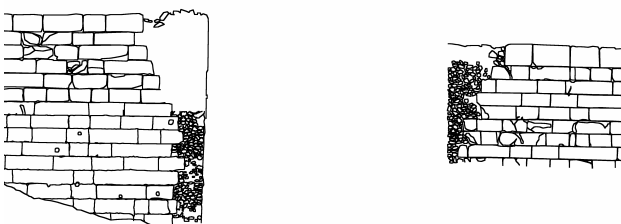


Figure 4. Elevation of the Tower X drawn using laser scanning

## 3. SUVEYORS IN 1930S AND 40S

### 3.1. A. Maiuri

The best work of A. Maiuri who was the longest-serving director of Pompeii belongs to the pre-second world war period. His study of the city wall established a chronological sequence of phases running through from the 6th century to 89 BC (Sulla's siege). The appearance of the city wall shown by his drawings is still made in recent guidebooks (La Rocca, E. and De Vos M. and A 1976).

In the elevations of the Tower X and the curtain walls shown in the report published by Maiuri (Maiuri 1930), who employed his own surveyors, there are cardinal and careless errors (Figure 5). A nail which is still surviving on the surface on the city wall suggests that his surveyor measured the vertical distance between the stone blocks and horizontal tracing tape in order to draw those elevations (see Figure 6).

They drew the stone blocks monolithically same in the height, however the blocks can be gradually shorten in their height from the above to the bottom (see Figure 5).

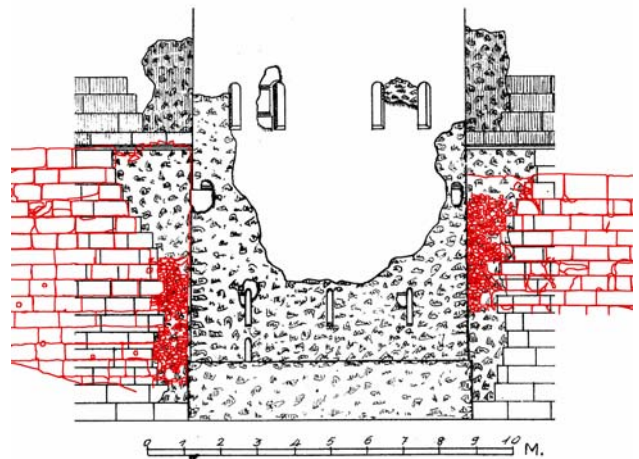


Figure 5. Maiuri's elevation of the Tower X and measured elevations using laser scanning (in red)



Figure 6. A nail surviving on the city wall  
(approximately 20 m west of the Herculaneum gate)

Furthermore, the fact is that the courses of the wall stretching from the east side of the Tower X correspond to the courses across the area of the wall on the west side of that Tower, but such courses was not built at the complete same level (gradually higher in the western part). Such heterogeneous feature was not

identified by Maiuri's surveyors. They might simply elongated those courses on the east side, which could be running at the same level on their eyes, to the west side including the wrong measurement. One of the characteristics of the Pompeian city wall is that every single course between above and below blocks appears to be running almost horizontally and continuously between the towers. In Greek and Egyptian fortification walls, those horizontal courses often running in zig-zag; in this investigation we identified an only example of butt jointed boundary. The surveyors in 1930s brought it in the full but wrong belief that those courses run continuously beyond the towers at the same level. A comparison of the elevations shows that the surveyors in 1930s were following an established pattern with regard to the image and prejudice but still did not have abundant scope to exercise their creative faculties.

In elevation of the inside walls flanking the Tower XI on either side that was drawn by his surveyor (Figure 7), the serious mistakes appears to have made in the setting out of the horizontal lines of the courses of blocks on the right-hand inside wall, only major elements of the city walls that were defined in the foundations. His surveyor skipped the seventh course from the top and then the bottom line of the inside wall was drawn at approximately 30 cm higher level than the real one. He was thus the ideal person to cover up the mistake; not only could he be expected to carry out the measurement, he was also well qualified to interpret the result in a wrong way: erasing the top course of the left-hand inside wall (Figure 8). Why he did made such decision?

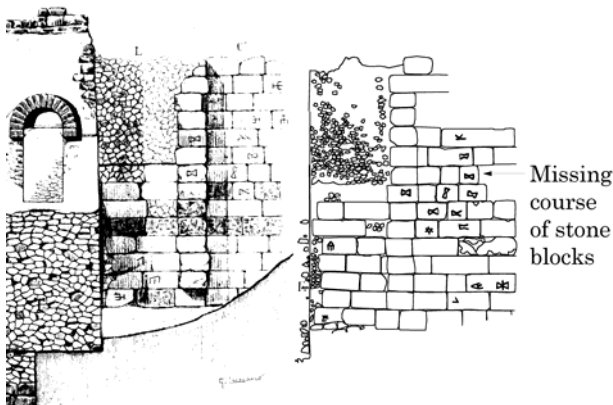


Figure 7. The right-hand side of the Tower XI (left: elevation in Maiuri 1930, right: scanning data)

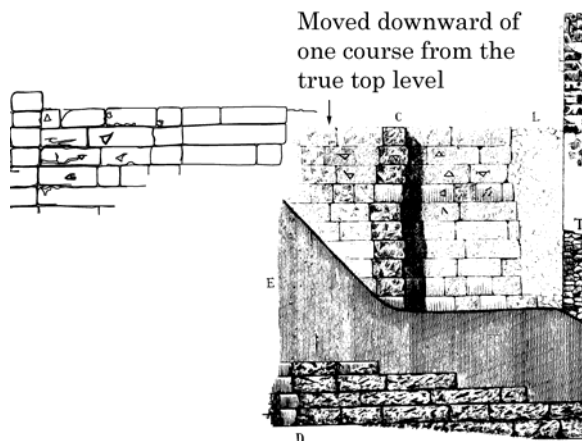


Figure 8. The left-hand side of the Tower XI (left: scanning data, right: elevation in Maiuri 1930)

A typical example of the prejudice can be seen in the treatment of the mistake on elevation of the inside walls. In fact, we must admit that his reaction was skeptical, a skepticism which was perhaps due to a certain prejudice of which he was victim, whereby the bottom line of the third course of blocks in the right-hand wall must correspond to the top line of the left-hand wall.

This treatment reflected a conviction given by Maiuri that the towers belong to the later-phase of the fortification of Pompeii (Maiuri 1930), and that therefore the courses of the inside-walls flanking the Tower XI on either side must not be only continuous and also all of the courses of the wall must be continuous beyond the towers. However the latter conviction, which did not be shared by Maiuri, was no more prejudice on the inside walls flanking the Tower XI, because Maiuri identified the remains of the pre-existed gate below the Tower XI despite of previous continuous city wall.

The two causes of these errors on the elevation are as follows; the mistakes of Maiuri's surveyor which have been made from the beginning of measuring and surveyor's interpretation of the result from contradictory measurements which was based on a certain prejudice in a wrong way.

### 3.2. H. Eschebach

Eschebach published the first general map of Pompeii in 1941 and the revised version in 1969 including new excavated insulae in south-eastern area (Figure 1). In the revised version, the distance between the east and west ends of Via di Nola and between the cross-roads (Via dell'Abbondanza and Via Stabianathe) and the Sarno Gate were increased accurately in comparison with the scanning data, however some errors are still observed as below.

- 1) The map must rotate in approximately 7 degrees in counter-clockwise direction to provide true geographical orientation.
- 2) In the north and south part of the map; Via Consorale and Via delle Terme in the north-western area and the southern part of Via Stabiana, there is considerable divergence between his map and scanning data (Figures 9 and 10).
- 3) In detailed comparison with the scanning data, Vico di Mercurio in his map deviates increasingly northwards in the west end and the eastern part of Via dell'Abbondanza also deviates northwards further and closer to the Sarno Gate (Figures 11 and 12).



Figure 9. Divergence between Eschebach's map and scanning data in the northern area

The map in 1969 by Eschenbach suggested a slight deviation in location of streets around the perimeter of the city, a tendency observable on the map in 1941, but the result of an aerial survey by the only way in which the whole city could be measured in the pre-war period, coupled with that deviation increasing outer and further, is warning that this is evidence to be used with great caution.

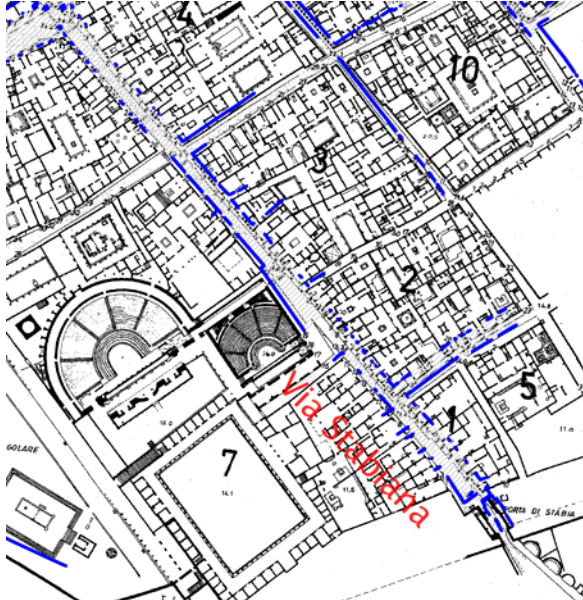


Figure 10. Divergence between Eschebach's map and scanning data on Via Stabiana (that reflects on the eastern area)



Figure 11. Divergence between Eschebach's map and scanning data on Vico di Mercurio (that reflects on the northern area)



Figure 12. Divergence between Eschebach's map and scanning data on Via dell'Abbondanza

The rotation as mentioned above can be identified using technique of GPS. However, when we superpose his map on the aerial photograph, the considerable divergence in 2) does not seem to be only caused by the slope of the hill in the north and valley in the south (Figure 13), but also by the simple way in which the street line may perhaps be traced from an aerial photograph, which is shown in his book. He may follow the shadows of the high remained walls from the south side on the streets, which lengthened on Vico di Mercurio and Via dell'Abondanza, because his wrong lines completely coincide with the configuration of the shadows of the aerial photograph and scanning data, on the other hand, accurately follow the wall on that photograph (Figures 14 and 15).

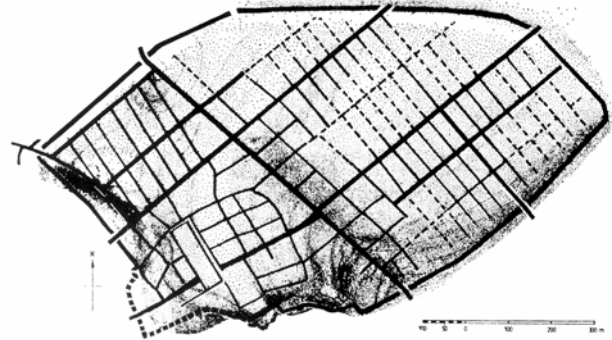


Figure 13. The contours on Eschebach's map (from Echebach 1995)

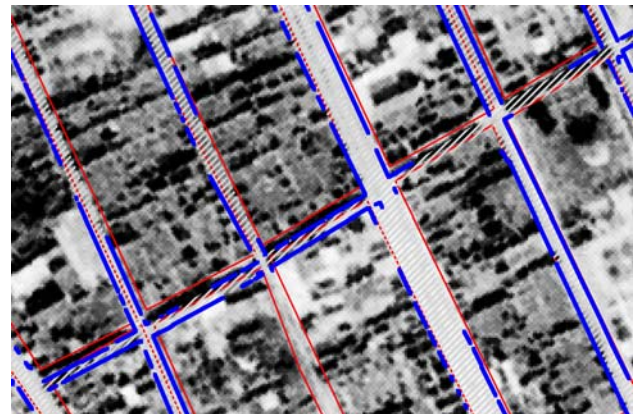


Figure 14. Superinposed scanned data (in blue) and Eschebach's plan of blocks (in red) on an aerial photograph of Vico di Mercurio

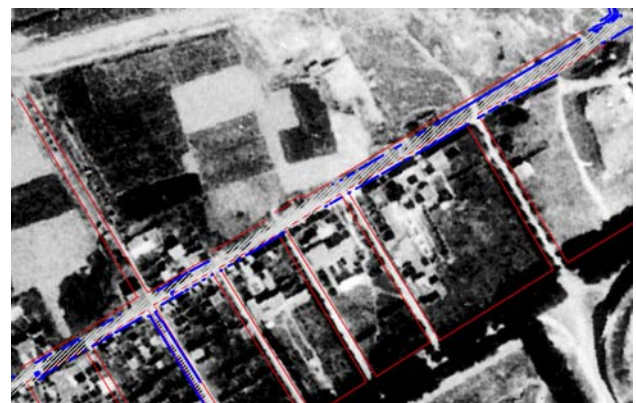


Figure 15. Superinposed scanned data (in blue) and Eschebach's plan of blocks (in red) on an aerial photograph of Via dell'Abbondanza

A further feature visible on his map is makeshift displacement (approximately 2m east and 3.5m north) and rotation (approximately 6 degrees anti-clockwise) of the area consisting of the northern city wall and insulae 1, 2, 5, and 7 of Regio VI at either end of the city wall between the gates Herculaneum and Vesuvio, probably because of the misplacement of Vico di Mercurio (Figutr 16). It is reasonably simple for Eschebach to lay out the each city block, which may measured one by one, on the ground when compared with a design given entirely by aerial measurement, especially where the dimensions are large and the layout complex. The deviation, therefore, on Vico di Mercurio was absorbed into shortened insulae on the south and displaced insulae to the north.



Figure 16. Insulae and city wall pushed into the north by the divergence of Vico di Mercurio

However in general comparison with the result of our laser scanning, the city wall in Eschebach's revised map (see figure 1), which was almost exact to the distance along two main streets; Stabiana and Abbondanza streets, measured in laser scanning externally with a possible error 1-2 m either way (less than 0.1%). Although in two isolated areas, such as city wall between the Tower IX and the Nola Gate in the north-eastern area and the south-eastern area from the Sarno to Nocera Gates, small deviations in the shape, caused by errors in resulting from long-distance measuring, have much less effect on the reliability of his map than do deviations of similar scale in modern maps incorporating far larger and more objects.

#### 4. CONCLUSION

Finally achieving accuracy was difficult, if we consider that each blocks nearly 60m in long had to be measured with an error of only 6cm (0.1%). It is suggest that Eschebach designed the layout on every block, which had been measured independently block by block, on the basic line accurately measured between the gates located on both ends of main streets. When we extract from his map, great care have to be devoted to ensure that some deviations are considered, because plans extracted from his map of 1:1000 in scale, ordinary are

magnified to those of 1:100 and any error will be increased 10 times. And those plans are also copied and used in other publication, this adds an extra source of error.

Conclusively obstructions of measuring, such as uncovered area and screens of towers hiding the surface of city walls, made same errors in measuring as those occurred in the our works, but wrong conviction of surveyors still existed in 1930s. However the work of Eschebach is note worthy for its accuracy. Despite the thoroughness of these procedures and the obvious care in mensuration with which many of them were produced, it would have been difficult, if not impossible, to maintain a high degree of accuracy over long distances, because the prejudice or the careless mistakes would exist in the mind of surveyors.

#### References

Hschebach, H. and Eschebach, L., *Pompeji vom 7. Jahrhundert v. Chr. Bis 79 n. Chr.*, Köln, 1995

La Rocca, E. and De Vos M. and A., *Guida archaeologia di Pompei*, Milan, pp. 86-90, 1976

Maiuri, A., *Studi e Ricerche sulle fortificazioni pompeiane*, Momumenti antichi pubblicati a cura di accademia nazionale dei Lincei, vol. 32, Rome, pp.113-290, 1930.

Maiuri, A., *Pompei. Isolamento della cinta murale fra Porta Vesuvio e Porta Ercolano*, *Notizie degli Scavi*, pp.275-94, 1943

Masois, F., *Les Ruins de Pompéi*, Paris, 1824

Sampaolo, F., *Pompei: Area archeologica Nuova cartografia georeferenziata*, Pompei, 2006

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