

REVISING GENERAL MAPS IN THE LIGHT OF EVIDENCE BASED ON NEW SURVEYS IN POMPEII AND OSTIA USING A LONG-RANGE LASER SCANNER

Y. Hori^{a,*}, A. Hangai^a, O. Ajioka^b

^a Dep. of Architecture and Urban Design, Faculty of Human-Environment Studies, Kyushu University,
6-10-1, Hakozaki, Higashi-ku, Fukuoka-shi, Fukuoka, Japan- hori@arch.kyushu-u.ac.jp, asa123501@yahoo.co.jp

^b Keisoku research consultant CO., 1-665-1, Fukuda, Higashi-ku, Hiroshima-shi, Hiroshima, Japan -
ajioka@krcnet.co.jp

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ABSTRACT:

New archaeological survey and re-examination of older data in light of modern remote-sensing technology for precise and detailed measurements afford not only fresh insights into ancient building practice, but also new information that may lead to revising general maps retained in popular usage without any consideration of a degree of accuracy. In order to cover the whole area of the cities, we introduced long-range scanning machine, laser ray from which can reach as far as 700 m. The clouds merged into one complete model from more than 300 stations have appeared as a new general map in a three dimensional picture. Since there is no adequate evidence for a reliable degree of accuracy in previous general maps in 1940s and 50s, the laser scanning covering long distances makes a number of salutary points: there is some evidence to corroborate the contribution to the revision of the general maps where the plans of all the buildings were assembled by a single archaeologist; where slight and unavoidable errors may have been also assembled over long distances in the lay-out of the whole city, which may thus have been different with the result coming from aerial photos and laser scanning. These works with the laser scanner, although very different in nature and content, make very valuable contributions to the overall study of the structure and planning of city fabrics in the ancient world.

1. INVESTIGATIONS IN POMPEII AND OSTIA

1.1 Measuring Method

The investigations of ancient cities have been carried out from 2005 to 2007 at Pompeii in the part of research at Japan Institute of Paleological Studies in Kyoto (Hori 2007) and from 2009 and now in progress at Ostia in the part of research directed by Prof. A. Sakaguchi at Nihon University (Sakaguchi 2009). In those investigations we introduced long-range scanning machine, laser ray from which can reach as far as 700 m and more than 10,000 scanning laser beams can be emitted in one second and the object can be described as the cloud of dots having three dimensional coordinates. The measuring of whole city wall and streets in Pompeii has been completed within two seasons and while in Ostia, where the eastern half of the city has been measured, the further field survey will be carried out in 2009 in order to complete the measuring (see Figures 1 and 2).



Figure 1. Measured area in Pompeii

* Corresponding author. This is useful to know for communication with the appropriate person in cases with more than one author.



Figure 2. Measured area in Ostia

In order to cover the whole area of those ancient cities within range of the laser scanner, the framework of main streets of the both cities in a straight line provides us the long street view, which make it possible to create the street plan. And then we fixed the scanner on the crossroads of streets and on several places commanding a wide and overlook view on the cities; such as on the top of the Tower XI and on the hill outside the Vesuvio Gate in Pompeii at a higher level (over 6 m above the ground level, see Figure 3) and on the top floor of a House of Jupiter and Ganymede and the observation floor in the south wing of the Forum Bath in Ostia at a higher level (over 4.5 m above the ground level, see Figure 4). Consequently the whole structures in the visible area were separately measured into 5 or 6 clouds of more than million dots, and thus it have been relatively easy to composed into a three-dimensional model. The pictures drawn in clouds of dots can be uses as plans, elevations and sections directly without any tracing those pictures. In this paper we introduce the plan drawn by the clouds of dots having 3 dimensional coordinates (see Figures 1 and 2), which can revise general maps providing the basic information about the fabrics of the whole city. To illustrate the remains of the wall structure in ancient cities and to see them in their proper perspective and their development, it could be helpful to pass the detailed structural techniques employed in a few of best-preserved of the limited buildings but provided by modern restorers.

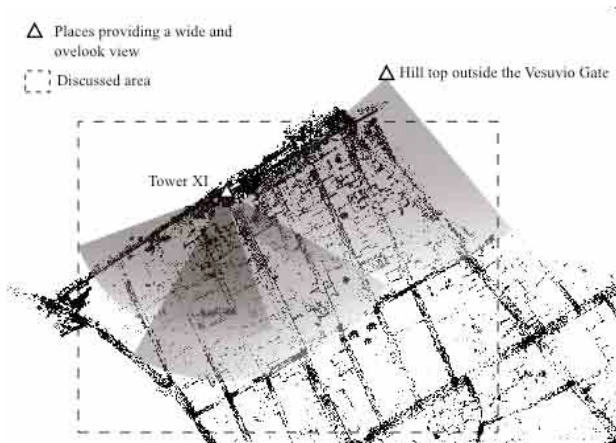


Figure 3. Long Range Scanning from the places at a higher level in Pompeii

1.2 Discussed areas in Pompeii and Ostia

In the clouds that have been created in scanning the street view from the places on the crossroads, do not include the information about the inside structure of the buildings consisting of the interior walls. And thus the clouds measured by the scanner fixed on the places commanding wide and

overlook views have been composed into the clouds of street views. Firstly, in Pompeii, those places, which can provide wide and overlook views, are located to the area of the northern defence line of the city between the Vesuvio and Ercolano Gates, which will be discussed below (Figure 3).

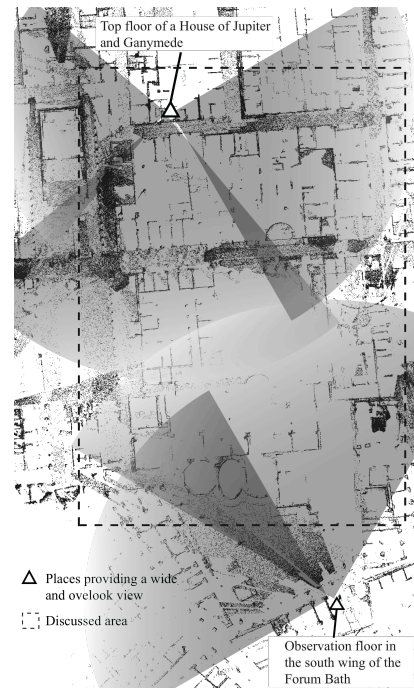


Figure 4. Long Range Scanning from the places at a higher level in Ostia

Secondary, the Pompeian city wall including towers, which will be also discussed below, is the longest, tallest and also oldest construction in the city. One of the characteristics of the Pompeian city wall is that they appear to have been constructed along straight lines drawn between gates. With the exception of the east outer perimeter of the amphitheater, which will be also described below, it consists a single curtain wall of massive squared blocks, laid without an inner wall and settled on a south-east corner of the city wall. Compared with city walls briefly drawn to a scale 1:1000 on the latest general map (the Rica Map of Pompeii, 1984), the result of laser scanning can remarkably illustrate the detailed figures of city walls (Figure 5).

Thirdly, in Ostia, those places can be found in the eastern area of Forum, which will be comparative with a general map (Figure 4).

2. GENERAL MAPS PUBLISHED BEFORE 1990S

2.1 Maps of Pompeii and Ostia published in 1940s and 50s

In Pompeii, the latest general map published in 1984 by the Soprintendenza Archeologica di Pompei (SAP), which can be referred on digital files in the CD-ROM attached at the end of the book "*The World of Pompeii*" in 2007 (Dobbins, J.J. and Foss, P. W. 2007), has been revised by the result of the aerial survey (Van der Poel 1984). However the previous and first general map published by Eschebach in 1941 and revised in 1969 is still widely referred. What makes that recent work by SAP especially important for a scholarly audience is that it includes many of the recent corrections of errors in the previous

general map and the latest view on the city fabrics, an area of Roman urbanization that has seen an enormous increase in archaeological work in the thirty years after 1940s.

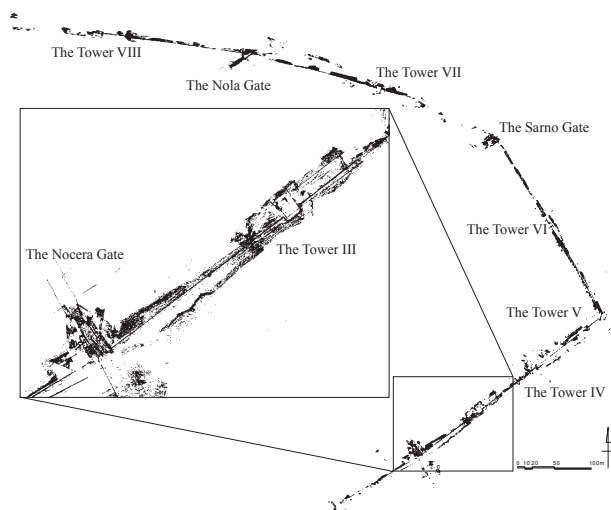


Figure 5. Clouds of Eastern Half of the Pompeian City Wall (The Tower III and The Sarno Gate are magnified.)

In Ostia, “*Atlante di Ostia antica*” published by V. Manucci provides the latest general map (Manucci 1995), which is traced from an aerial photograph, achieved the same result as that coming from the laser scanning, however the buildings in the area covered by trees, which did not come out in the photos, can not be measured in aerial survey. And thus a general map in the monumental works by G. Calza in 1940s and 50s (Calza 1953) and by R. Meiggs in 1960s (Meiggs 1973), in which plans of building measured one by one on the ground were probably inserted in the map coming from the aerial survey carried out in 1940s as discussed below, gives a useful account of those covered area (Hori and Hangai 2009).

In the central area of Ostia including the Capitolium in the Forum and the high-rising buildings such as the buildings facing Via di Diana and Via dei Balconi and the Forum Bath, although data from laser scanning coincides very closely with an aerial photograph by Manucci, between the general map in 1953 and the results from scanning data and aerial photograph. However, when we set the clouds forming the street view of Via dei Balconi right above the Calza’s map, those clouds closely overlapped on the *Capitolium* and the façades of the buildings along Via dei Balconi. And then considerable divergence appears in the south and east façades of the Insula. The length of the diagonal of that city block measured by Calza falls short of the figure coming from the clouds by approx. 30 cm. And the high walls surviving in the Forum Bath has been moved about 20cm to the north-west against the true location, on the other hand clouds forming the walls of the south-west wing of that building complex closely overlaps the figure drawn by Calza (Figure 6).

Despite the obvious care in mensuration with which many of them were produced, it would have been difficult to maintain a high degree of accuracy over long distance or high elevations, because cordage would have been used for such measurements. Since there is no adequate evidence for a reliable degree of accuracy in previous general maps created in 1940s and 50s, the laser scanning covering long distances makes a number of salutary points: there is some evidence to corroborate the contribution to the revision of the general maps where the plans of all the buildings were assembled by a single archaeologist;

where slight and unavoidable errors may have been also assembled over long distances in the lay-out of the whole city, which may thus have been different with the result coming from aerial photos and laser scanning.

The result of laser scanning in two previously published articles indicated that, despite the thoroughness of the scientific procedure and the obvious care in mensuration with many of drawings produced by surveyors in 1940s and 50s at each ancient city, it would have been difficult to maintain a high degree of accuracy over long distance and on high-raised buildings, because of the prejudice or the careless mistakes, which would exist in the mind of the surveyors (Hori, Ajioka and Hanghai 2007 and Sakaguchi 2009).

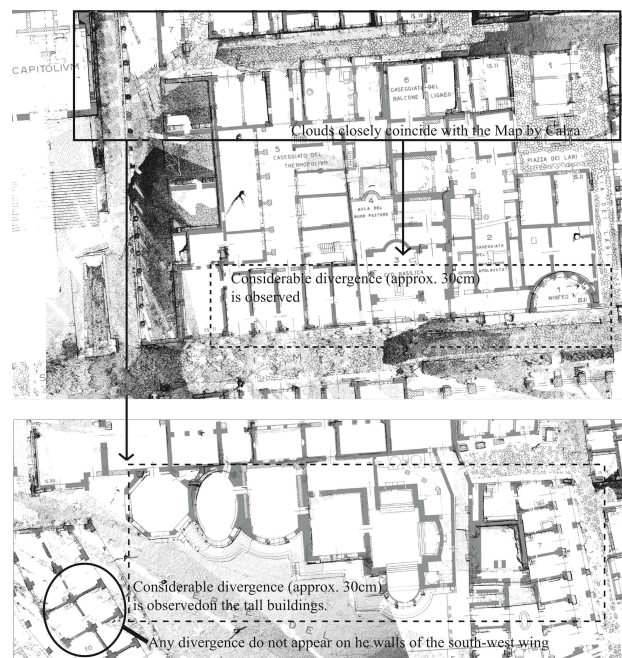


Figure 6. Clouds overlapped (black dots) on the General Map by Calza (grey in colour)

Meanwhile, for there to a perfect fit between the surviving structures and the survey plan used as the basis of analysis, the general map that have more than a basic plan must have correspond exactly with original structure. A good example is a plan of northern defence line at Pompeii by Maiuri in 1930s (Maiuri 1930), known from the general map revised by Eschebach in 1960s (Eschebach 1970), which showed a perfect correspondence between his map and clouds coming from laser scanning (Figure 7), although the whole map must rotate in approximately 7 degrees in counter-clockwise direction to provide true geographical orientation and avoidable mistakes of Maiuri’s surveyor have been made on the elevation of the city walls (Hori, Ajioka and Hanghai 2007). Furthermore, the city blocks of VI, 9 and 11 of his map, on which we have based our clouds including the city blocks, must rotate in approximately more 0.3 degrees in clockwise direction by a negligible fraction (45cm divergence at the south-west corner of VI, 9) in order to provide true geographical orientation (see Figure 7 below). However in general comparison with the result of our laser scanning, the north-west Pompeian city blocks drawn by Eschebach in 1950s was almost exact to the distance between tower XI and Vicolo di Mercurio.



Figure 7. Clouds overlapped (black dots) on the General Map by Eschebach (grey in colour)



Figure 8. Clouds overlapped (black dots) on the Rica Map (grey in colour)

2.2 Revising the Map of Pompeii by Arial Survey in 1980s

The correspondence in the north-east city blocks between the clouds by laser scanning and the Rica Map, which is the latest general map of Pompeii, results in the confirming the substantial accuracy of the laser scanning made in our survey, however in the unsatisfying the positional relationship between those city blocks and the city wall (Figure 8).

The clouds forming the west façades of the buildings in the VI, 9 facing the Via del Mercurio is closely running along the plan of the front walls of those buildings in Rica Map, on the other hand, the city wall in the same map must move 80cm to the north in order to correspond them to the clouds in laser scanning. Since the clouds forming the innermost part of Via Mercurio, which have been captured in one station within long range of laser scanning, merged to this three dimensional model, it is difficult to commit an error in the merging or take wrong measurement. The positional relationship between the city walls and city blocks must be revised.

3. CONTRIBUTION OF LASER SCANNING TO ARCHAEOLOGICAL STUDIES

3.1 Revising the topographical maps in Pompeii

Ancient cities, such as Pompeii and Ostia, remind us of the reality of urban development in Roman times, and the urban development, in many respects, could be deeply influenced by their topographical feature. The precise relationship between those feature and urban planning is tantalizing, in view of what we know about dealing between land surveyors and architects at the city administration, while the topography of Pompeii and its surroundings come into play an important role for determining the conditions of urban planning. Eschebach provided the basic data concerning the ground level of the main streets (Figure 9).

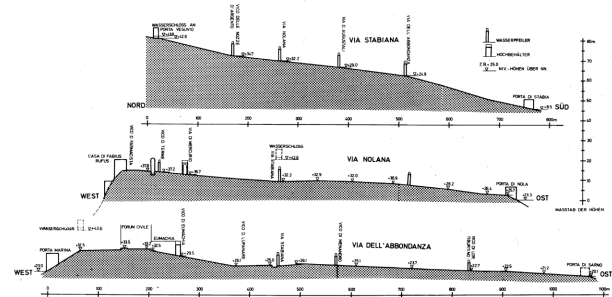


Figure 9. Sections of the grounds of the main streets by Eschebach

His purpose is to examine the system of water supply through the water towers, rather than simply the work of drawing the topographical feature of Pompeii. The degree of his hypothesis based on those figures has been going to be high, but, when the effects of adding much more parameters coming from the clouds by laser scanning are easily calculated; such as contour lines of the ground level, and they do not alter Eschebach's basic data (Figures 10 and 11).

Admittedly, a number of assumptions can be made in order to move from the water supply system to the city planning as a whole, but the resultant figures coming from laser scanning are far more detailed than any figures handed down in the old-fashioned mesuration.

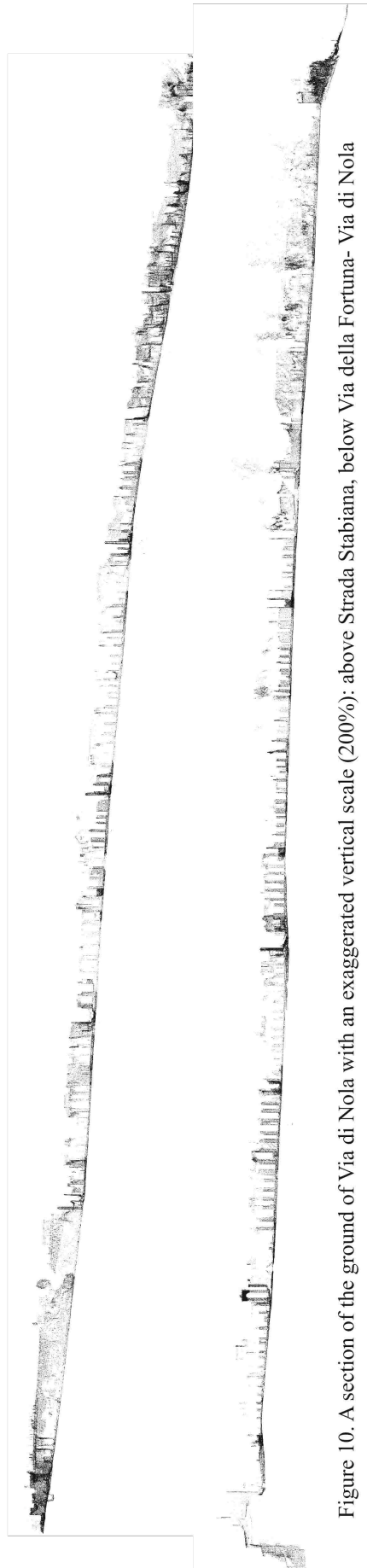


Figure 10. A section of the ground of Via di Nola with an exaggerated vertical scale (200%): above Strada Stabiana, below Via della Fortuna- Via di Nola

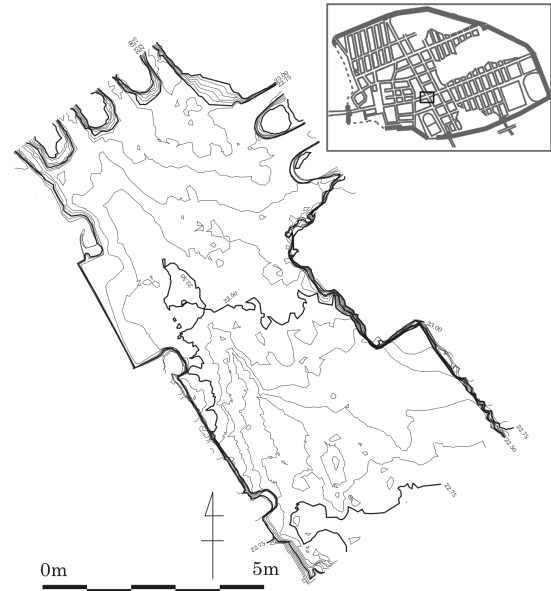


Figure 11. Contour lines of the ground level of Strada Stabiana at the Horconius Cross-roads

Geological cores put down through the precinct outside of the gates have allowed us to reconstruct the nature of the terracing of the natural surface, which was carried out as the first step in preparing the site for construction. The sections with an exaggerated vertical scale show how the ground was cut into a series of steps in the development of the city.

3.2 Detailed analysis of the layout of Pompeian city walls

The main contribution of this laser scanning technology is that it provides very useful and detailed three dimensional data from the whole ancient sites - the relationship between research and measuring technology. In Pompeian city wall, for example, the city walls is not in fact a straight line but are composed of a series of long sections on slightly different alignments in other two places, a pattern fully in accord with the construction process suggested as below in Hori 2007.

The outer city wall between the Vesuvio and Ercolano Gates is not a straight line (Figure 12), a line along with the wall between the Vesuvio Gate and the Tower X changes direction, slightly 1.2 degree at the Tower X. The three Towers X, XI, and XII are almost identical and placed at regular intervals, the only substantial difference between them being that, where as the change of direction is very slight in the case of the Tower X (less than 2 degrees), at the eastern end of the city wall there is difference of nearly 1m in the depth of two sections of city walls, meanwhile the inner wall is entirely straight beyond the Tower X (Figure 12). This outer wall between the Vesuvio Gate and the Tower X laid on end at right-angle to the axis of the Vesuvio Gate. Since it is the north outer wall that shows the clearest signs of damage inflicted by Roman artillery, while Region VI has yielded examples of stone balls with the city was bombarded, the north outer wall has been existed at the Social War before the attachment of towers and the Vesuvio Gate was constructed (or improved) between the construction of the double curtain, in which cases it may represent a strengthening of the city defence in connection with the wars between the Etruscans and the Greeks at the end of the six or the beginning of the fifth century BC, and the application of a new defence system with a single wall backed by a wide rampart in the early third century. Until the towers had been constructed at that area,

the corner has to have been existed 40 m west from the Vesuvio Gate.

The city wall between the Tower VII and the Nola Gate also changes direction, slightly 1.6 degree at 82 m west from the Nola Gate (Figure 13). Though two or three courses of the stone blocks appear above the modern ground level, those courses probably were covered by new wall in opus incertum at the west end of the city wall. In this area, military designers answered with thickened walls to protect against share failier, which happens often in massive stone block wall and may be caused by earthquake attack, and the round corner at the east side wall of the Nola Gate to prevent the prying out of corner stone, which may be also caused by earthquake. They followed the line, along which the eastern wall flanking the Tower VII meets the western wall on slightly different alignment (1.6 degree). Conclusively, since, excluding the eastern wall, which change directions at the two place, the general shape of the city wall from the line between the gates is entirely straight (at less than 2 degrees), Pompeii did have systematic planning involving the almost wide view of urbanisation.

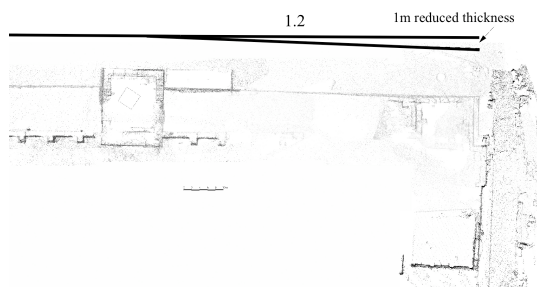


Figure 12. The city wall between the Tower X and the Vesuvio Gate in Pompeii

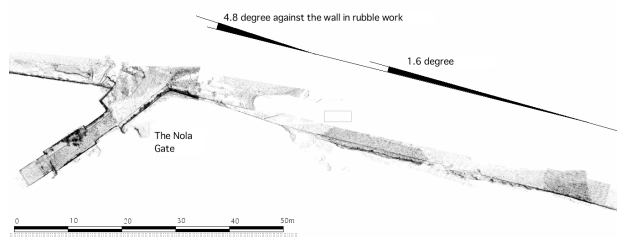


Figure 13. The city wall between the Nola Gate and the Tower VII in Pompeii

CONCLUSION

The Greeks emerge as the pioneers of instrumental surveying and, though their equipment and methods were simple comparing the Renaissance or modern standards, the Greek Roman can be reminded of a level of technical sophistication, which must count as one of the greatest achievements of the ancient world. New instruments with levelling devices appeared in Renaissance, which was partly inspired by the description of Vitruvius, before modern surveying began with the introduction of the spirit level and optics in the mid seventeenth century; it is possible to measure with a considerable accuracy rather than the revolutionary instrument achieved by modern electronic technology.

We must remember that the level of urbanization in those periods; Greek and Roman, Renaissance and modern, was high by comparison with other periods.

In addition to the revision of the general maps, our investigation of the physical fabric of ancient cities has produced new

perspectives on the city's structure, establishing inter alia that the gentle rise and fall of the street surfaces, traditionally regarded as a part of the natural topographical feature, could have been more or less artificial creations founded in particular urban circumstances to meet a specific need. At this point the configuration of the ground in ancient cities, which can be identified by laser scanning technology, has undergone considerable superficial alteration since their establishments.

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