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The use of "space syntax" for the study of city planning and household from geophysical maps: the case of Dura-Europos (Syria)

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INTRODUCTION

The site of Dura-Europos in Syria is one of the most significant examples of city planning in the Greco-Roman Near East. After the excavations carried out by F. Cumont (1921/1922) and those of the Franco-American mission directed by M. Rostovtzeff (Yale University mission, 1928–1937), research was resumed in 1987 by the Franco-Syrian mission directed by P. Leriche (CNRS) and Y. Shohan (DGAMS). Today we have abundant archaeological information on the domestic buildings and on the main lines of the city plan, enhanced by the good preservation of the remains (fig. 1a. b).

As about a quarter of the site has been excavated so far, the importance of additional information obtained through geophysical prospecting is of great interest. The objective is to understand the particularities of the urban plan as a whole and to study the internal organization of the different blocks. Between 2001 and 2003, a magnetic survey campaign was carried out between the main road and the southern gate in the southern part of the city, which provided a much more nuanced and thorough image of the urban characteristics of Dura-Europos. We can now study how the Hellenistic type of urban planning functioned in the Roman period.

Dura-Europos was founded at the end of the 4th c. BC. The excavators proposed two hypotheses regarding the date of the development of the city and the establishment of the urban plan and its ramparts, though. Rostovtzeff believed that the establishment of the urban plan followed shortly after the foundation of the city[1]. The most recent hypothesis, put forth by Leriche, proposes a later date, in the second half of the 2nd c. BC. Up to that point, Dura-Europos was a military base with the citadel and a group of houses surrounding it[2]. At the time when the city was taken by the Parthians (113 BC), only the agora, the fortifications and some monuments had been erected. Whatever was the case, this problem does not affect the present study, which is based on the interpretation of the results of geophysical surveys and thus on the last state of occupation of the site. After ruled by the Parthians, the city was taken by the Romans (165 AD), who occupied it until 256, the date of the fall of the city to the Sassanians. At that time, the city was definitively abandoned.

[1] M. Rostovtzeff, Dura-Europos and its Art (Oxford 1938).

[2] P. Leriche, Pourquoi et comment Europos a été fondé à Doura?, in: P. Brulé – J. Oulhen Rennes (eds.), Esclavage, guerre,économie en Grèce ancienne. Hommages à Yvon Garlan (Rennes 1997) 191 – 210.

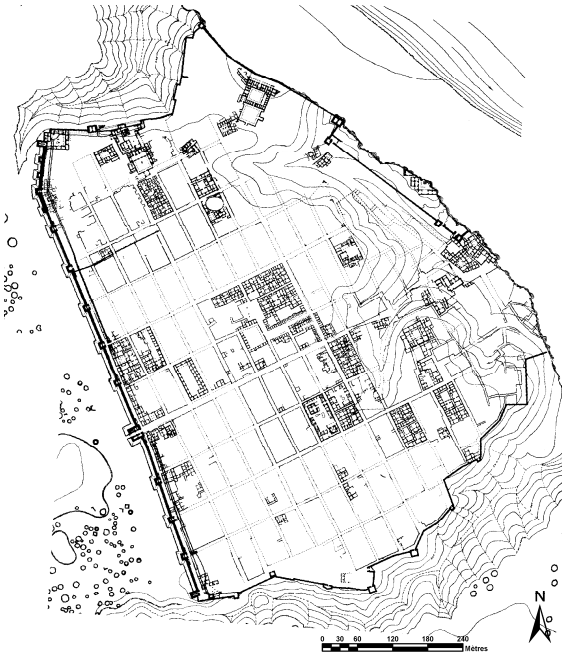

Figure 1a. Dura Europos. General plan established by the Yale University mission.

PRESENTATION AND IMPORTANCE OF THE MAGNETIC SURVEY

The geophysical survey was carried out between 2001 and 2003 (fig. 2) by means of the magnetic method, with a Caesium gradiometer[3]. This method enabled recognition, both rapid and detailed, of the southern part of the site and provided excellent results for Dura-Europos in regard to the stone structures as well as those of mud-bricks (fig. 3). The magnetic image offers us a complete and detailed vision of this sector. The quality of the geophysical image provided the possibility to study the urban plan based on geophysical data, complementary to the usual approach based on the data from the excavations. Studies of urban plans are usually based on excavation data that is intermittent but comprehensive information on the structures and their chronology, from which we may attempt to infer the general characteristics of the spatial organisation of the site. Although the information contained in the magnetic image is not that precise, it nevertheless permits the studies, over an extended surface, of the realization of a theoretical concept of urbanism, as well as an understanding of the modifications after several centuries of occupation[4].

Figure 1b. Aerial view of the site of Dura-Europos from the south-west.

AREA OF STUDY

The area of our studies is the entire part of the city which extends to the south of the main road from the Palmyra gate. This sector is defined to the west and south by the fortifications, with the Palmyra gate and the south gate for access, and to the east by the edge of the plateau. The access to the lower town palace and the Euphrates bank was possible by a ravine passing under the Strategeion Palace. We should also mention the existence of a so-called secondary gate south of the Palmyra gate and to the north of tower 17. This gate was briefly used during the construction of the Palmyra gate and was then walled up[5].

[3] For a general presentation of geophysical survey methods see C. Gaffney – J. Gater, Revealing the Buried Past. Geophysics for Archaeologists (Strout 2003). – For a more detailed presentation of magnetic prospecting and remote sensing cf. I. Scollar – A. Tabbagh – A. Hesse – I. Herzog, Archaeological Prospecting and Remote Sensing (Cambridge 1990) 422 – 519.

[4] For a general presentation of the study of urban plans based on geophysical images cf. C. Benech, Etude des plans d'urbanisme, Dossiers de l'archéologie 308, 2005, 12 – 19.

[5] J. Abdul Massih, The Secondary Gate at Doura-Europos, in: Leriche – Gelin 1997, 47 – 54.

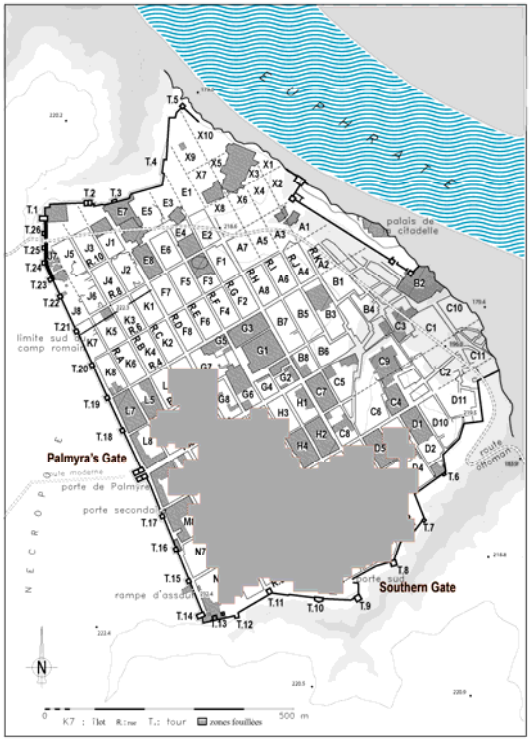

Figure 2. Location of the magnetic surveys carried out between 2001 and 2003 and identification of the blocks.

The research area ends at the northern edge of the main street, whose role could be underestimated and will demand caution in the interpretation of the results obtained; the main street certainly played an important role in the distribution of circulation between the northern and the southern part of the city. The southern quarters of the city are the sectors where the original urban plan was the best preserved and did not undergo the extensive modifications observed farther north in the sector of the agora and especially in the northern quarter of the city where a Roman camp was established. In the south, we have a sector where little excavation work has been done and for which it was possible to obtain a consistent and continuous map, linking the different already known monuments and integrating them into the spatial logic of an urban plan.

FUNCTIONING OF AN ORTHOGONAL PLAN

Our interpretation of the street network is based on the use of Space Syntax tools. Space Syntax was developed in 1984 by B. Hillier and J. Hanson from the Bartlett School of London[6]. It provides useful tools to objectively describe the spatial configuration of buildings and settlements and has been widely used in the study of urban morphology. Particularly in regard to the study of the street network, two appliances are usually used to describe it, namely the axial map and the visibility graph. With Space Syntax, streets are not considered independently but as a whole open space; this space is divided into the least possible number of convex spaces. A convex space is defined as a polygon, where no line between any two of its points crosses the perimeter. The axial map of the open space structure of a settlement will be the least set of axial lines which pass through each convex space and make all axial links.

The axial map is therefore a set of axial lines which are the longest lines that can be drawn through an arbitrary point in the spatial configuration. It provides a representation of the street network which emphasizes the "skeleton" of the street network in terms of axiality and connections.

There are many parameters used in Space Syntax to describe the characteristics of the axial map more precisely. Here, I will present the most common ones:

. Length: length of the axial lines

. Connectivity: number of intersections with other axial lines

. Relative asymmetry (relative depth): indicates how ›deep‹ the system is at a given point following its asymmetry. Relative asymmetry can also be thought of as the measure of integration which is mathematically the inverse value which can be understood as the level of accessibility of the system at a given point.

The plan of Dura-Europos, inspired by the Hippodamian model, is composed of a wider main street and secondary streets, which are

[6] B. Hillier – J. Hanson The Social Logic of Space (Cambridge 1984).

Figure 3. Magnetic map of the southern part of the city (scale -5/+5 nT/m).

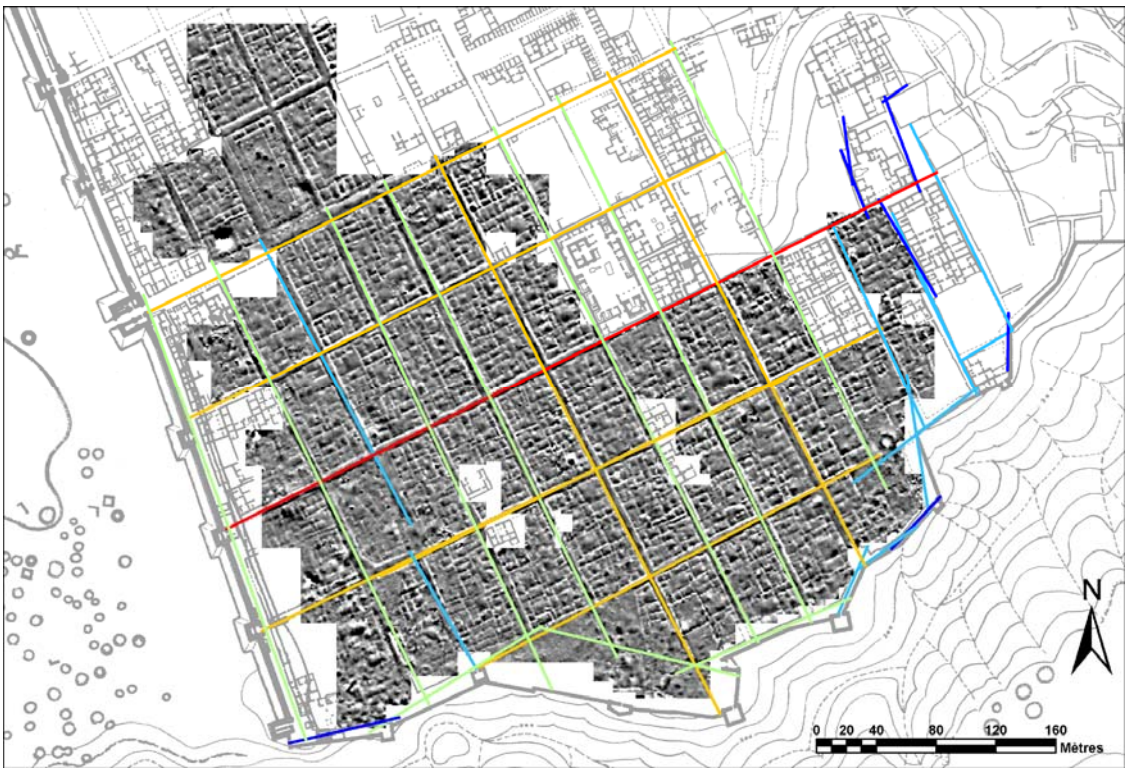

Figure 4. Axial map calculated from the magnetic image and the excavation data (minimum blue / maximum red).

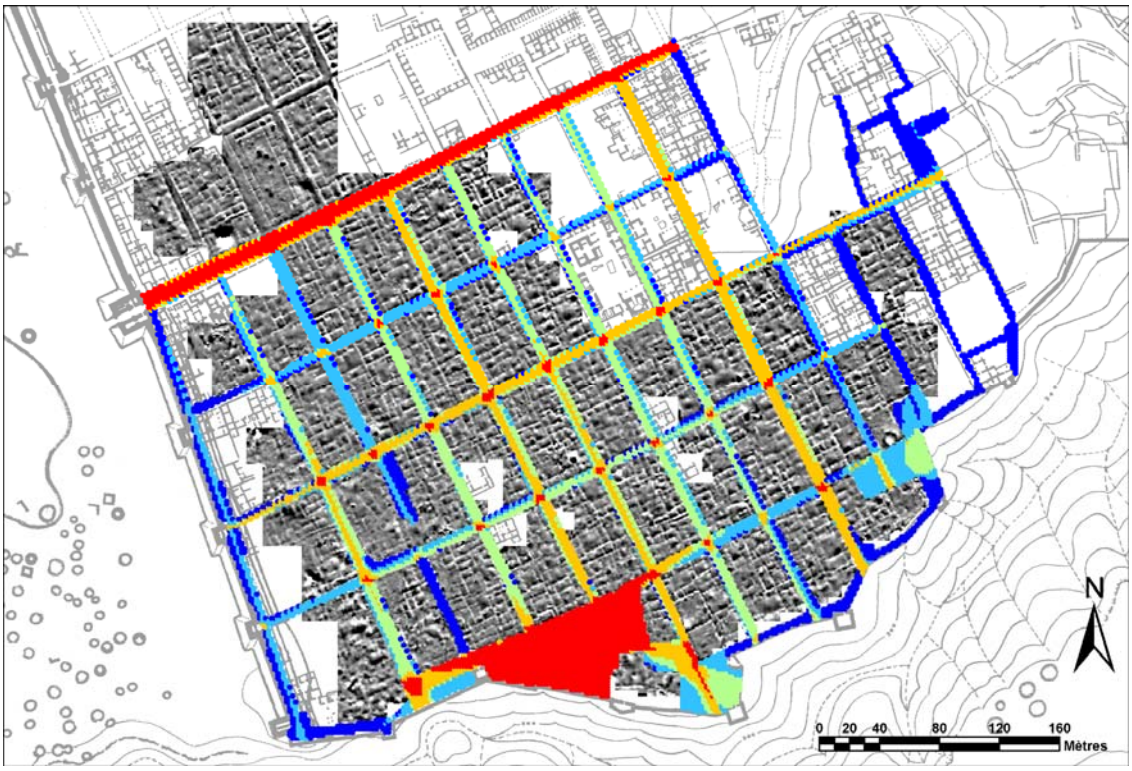

Figure 5. Visibility Graph Analysis of the network of streets. The colour scale expresses the values of visual connectivity (minimum blue / maximum red).

theoretically of the same width, cutting the urban space into regular blocks of about 35 × 70 m. On the magnetic image we can see that the urban plan is relatively well preserved in this sector of the city. Four major "irregularities" should be noted:

1) A single street, street B, ends between blocks N5 and N3.

2) The southwest corner of block N5 is cut off: it is the only block in this sector which does not have a quadrangular form, together with a only partially built-up block to the west of I11;

3) In this sector, near the southern gate, there is a large non-constructed space, which is unique in the configuration of the south of the city.

4) Street 7 ends abruptly on the west side of the blocks D3 and D4, which are side by side. The study of the construction techniques used at Dura-Europos by J. Abdul Massih has shown that the wall which marks the western edge of these two blocks dates to the Hellenistic period, and therefore before the establishment of the orthogonal plan[7]. The axial map of the street network, based on excavation data and the geophysical map (fig. 4), shows that the skeleton of the quadrangular plan is mostly preserved; only streets 7 and 9 should be pictured with several axial lines, because of the deformations on the edges of the blocks.

Of course, the main street plays a major role as it gives access to most of the longitudinal streets. In terms of connectivity, the main street does not register the highest value (in yellow) because of the effect of the edge mentioned above. For the transverse streets (east-west orientation), we observe the strongest connectivity (in red) for street 5, which plays a preponderant role in crossing all of the street network, from the western rampart to the edge of the plateau to the west. It is the only transverse street that has an intersection with all the longitudinal streets (north-south

[7] Cf. J. Abdul Massih, L'architecture en pierre de taille et en blocage de *djousse* à Doura-Europos (Syrie). Histoire et urbanisme, *Thèse 3ème cycle*, Paris, 2000, esp. 227 – 229.

orientation).

All the longitudinal streets may be considered to have the same value of connectivity between the main street and street 5 (i.e. a single axial line for all the longitudinal streets between the main street and street 5). By considering the entire street layout in terms of connectivity, two streets are predominant: street E, which offers direct access to the southern gate by crossing all the transverse streets, and street H, characterised by a higher connectivity as it cuts the two axial lines of street 7 and those of the street which runs along the south rampart. Otherwise its connectivity would be the same as for streets F and G, since these three streets have the same number of intersections. It is in any case more important than street I, which does not give access to the street which runs along the south rampart.

Streets 5 and E are thus the two streets which permit access to the farthest points of the network, as they intersect with all the other streets[8]. Moreover, their central position in the urban plan creates two predominant axes in the circulation in this part of the city. One can easily imagine that this dominant role was devised at the conception of the urban plan, even if there is no hierarchy in the streets in a Hippodamian plan except for the main thoroughfare. They all have the same width and therefore the same facility of circulation. Moreover, in terms of distance, the orthogonality of the plan means that the possibilities of going from one point to another are multiple. However, once the layout of the streets begins to be modified, a hierarchy among the streets appears, which uses and reflects the development of the mode of circulation within the city.

It is interesting to see whether the logic of circulation imagined at the beginning, which is marked by the important roles of streets 5 and E, was preserved, or whether the network evolved in such a way that the circulation habits changed over the centuries. The functioning of this network, especially marked by the diminishing (even interruption) of the streets or the loss of their linearity, was closely related to the places to which they led or which they crossed. Among these places, the different points of access to the network in this part of the city certainly play a major role, namely the Palmyra gate, the south gate and the access to the lower part of the site. However, perhaps other important points in the city deserved easy access as well: religious or administrative centres, public places, open spaces, storage zones etc.

The hierarchy of the streets, as it appears in the excavation results and on the geophysical maps, is therefore closely related to the social, cultural and economic life of the city. We will first attempt to describe the changes in the urban plan in the southern part of the city of Dura in detail and then show the results in terms of circulation.

VISIBILITY GRAPH ANALYSIS

The visibility graph is based on the concept of the isovist that was developed by M. Benedikt in 1979 (independently from Space Syntax)[9]. An isovist is the area in a spatial environment directly visible from a location within the space.

The visibility graph shows the visibility relationships between locations[10]. In fact, we do

[8] We note that circulation within Dura-Europos was forbidden for vehicles. The excavations of the Franco-Syrian mission have shown that access to the Palmyra gate was by stairs. Cf. P. Leriche – J. Abdul Mass ih – M. Gelin, La porte de Palmyre à Doura-Europos, in: Leriche – Gelin 1997, 21 – 46.

[9] M. Benedikt, To Take Hold of Space: Isovists and Isovist Fields, Environment and Planning B 6, 1979, 47 – 65.

[10] For a first approach of using Visibility Graph Analysis in Space Syntax, cf. A. Turner – A. Penn, Making Isovists Syntactic: Isovist Integration Analysis, in: Proceedings of the 2nd International Symposium on Space Syntax, Brasilia 1999 http://www.vr.ac.uk/publications/turner 1999-000.htm (25. 10. 2008), and A. M. Turner – O. S. Doxa – A. Penn, From Isovists to Visibility Graphs: A Methodology for the Analysis of Architectural Space, Environment and Planning B 28, 2001, 103 – 121.

not visualize the isovists themselves but the result of their intervisibility. The visual connectivity is the number of locations visible from a given point; it is a local measure, because it does not depend on the whole structure of the city plan. In the case of an orthogonal plan, the visualization is very interesting because the connectivity emphasizes small variations in the linearity of the streets. Even though the urban plan maintained a certain regularity, the visibility graph analysis enables the observation of variations, which are not inconsiderable in terms of width and linearity in the street network.

Such an approach is particularly interesting for the study of geophysical images. It is in fact difficult to precisely work out the geometry of the urban plan from these images because we must accept approximations[11] . The use of the visibility graph analysis is based on the visual perception of the space whose slight deformations (or in our case approximations intrinsic to the nature of geophysical images) have no influence on the obtained results (fig. 5).

Of course, the main street possesses the strongest visual connectivity (in red) as it is much wider than the other streets. We also have a strong connectivity for the non-constructed space near the southern gate. Strong connectivities also appear at the intersections of streets (mostly also red), a logical observation, as the crossroads benefit from relations of intervisibility on two axes. This information is all the more interesting as it enables an estimation of the orthogonality of the crossroads. We see that most of the intersections with street 5 have a strong connectivity, except for the street at the ramparts and street I. Next are the crossroads of street D with streets 3 and 7, then street H with streets 7 and 9. These crossroads therefore constitute important points for access to the different sectors of the southern part of the city.

In regard to the transverse streets, street 5 possesses the strongest visual connectivity; this connectivity is weaker in its east and west extremities, though, beyond the crossroads with street I. These results nevertheless confirm its dominant role in the circulation in this part of the city. The linearity and the width of the road were preserved for the largest part of its outline in order to ensure a good circulation of people and goods.

As for the longitudinal streets – streets D and H – have the strongest connectivity. Here, the visibility graph analysis reveals a hierarchy which is not easily perceptible through a classic observation of the plan. The street favoured for access to the southern gate appears to have been street D, which leads to the non constructed space near the gate and not street E, which has a weaker connectivity. For the eastern part, one can clearly see that street H (in yellow) dominates street I (in blue) and that circulation towards the lower part of the site should follow the first. Street H then continues in a very linear manner up to the southern rampart, ensuring easy access to the entire south-east quarter of the plateau.

Thus we see that after four centuries of occupation, the essential elements for a good circulation within the city have been preserved. The dominant role of street E competes with street D, which opens onto the non-constructed space near the southern gate; this change can be explained by the fact that transit through this non-constructed space avoids congestion in the circulation around the gate and provides room for holding goods and animals which enter and leave the city. To the east, street H is without doubt the easiest way of access to street 5 and from there to the lower part of the site, even though this access is located near street I, which is, however, less passable.

INTERNAL DIVISION OF THE BLOCKS

The internal division of the blocks at Dura-Europos recognized so far was a division into

[11] C. Benech – A. Hesse, Some Considerations on the Integration of Geophysical Data into Archaeological Research, in: M. Posselt – B Zickgraf – C. Dobiat (eds.), Geophysik und Ausgrabung. Einsatz und Auswertung zerstörungsfreier Prospektion in der Archäologie, Internationale Archäologie. Naturwissenschaften und Technologie 6 (Rahden 2007) 175 – 186.

eight equal plots. In a block of 35 × 70 m each plot measured 17.5 × 17.5 m; that is a surface area of 306.25 sq. m. This division into eight plots is not preserved in any known block of Dura-Europos, neither through the excavations nor on the geophysical maps. Many clues exist, though; in certain cases, dwelling units exist which occupy exactly 1/8 of the total surface of the block (fig. 6a. b).

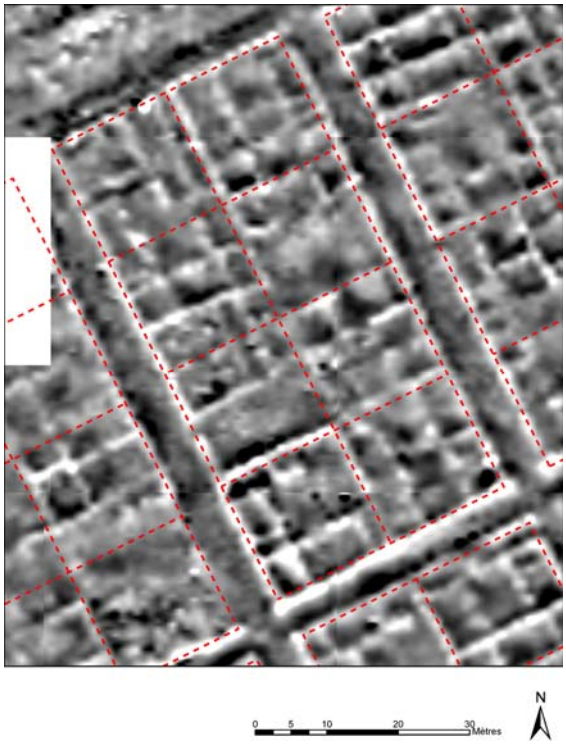

Figure 6a. Block M3.

The geophysical maps have shown that another type of internal division of the blocks existed; this is a division into six equal units, which appear very clearly on blocks I10 and I11 (fig. 7).

However, these two blocks have particular dimensions, i.e. 37.2 × 65.7 m, probably due to the southern fortification lines, which did not permit a block of normal dimensions: maybe this loss of surface was compensated by enlarging the block (37.2 m instead of 35 m), so that its surface was just about equivalent to the other ones (2444.04 sq. m for I10 and I11 rather than 2450 sq. m for the other blocks). Because of the division into six units, the plots are larger with a surface area of 408.34 sq. m rather than 306.25 sq. m for the division into eight, though.

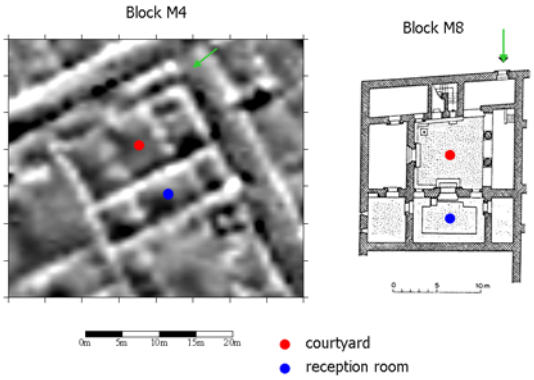

Figure 6b. Detail of the dwelling unit situated at the north-east angle of block M3 (cf. fig. 6a) and plan of the dwelling unit situated at the north-west angle of block M8.

Two of the plots of block I10 have not been built up and for the moment their function remains unclear; their position near the southern gate suggests zones for storage or the holding of animals (a single other example is known near the Christian house[12]).

Apart from these two particular cases, the other units of blocks I10 and I11 are occupied by dwellings and thus have the same function as the blocks divided into eight units, with of course larger dwelling units.

Figure 7. Blocks I10 (on the right) and I11 (on the left).

We also find this division into six plots in the blocks of normal size, but not as often as the

[12] This non-built up area is mentioned without more detail in C. Kraeling, The Christian Building, Dura-Europos: Final Report 8, 2 (New Haven 1967).

division into eight, which appears to have been predominant. There are however a few very clear examples where the dwelling units occupy exactly 1/6 of the total surface area of a block, i.e. 408.33 sq. m (and thus slightly larger than the dwelling units of blocks I10 and I11) (fig. 8). There is also the case of block D5, where the two types of division coexist (fig. 9a. b), although it is not known whether they were at use at the same time.

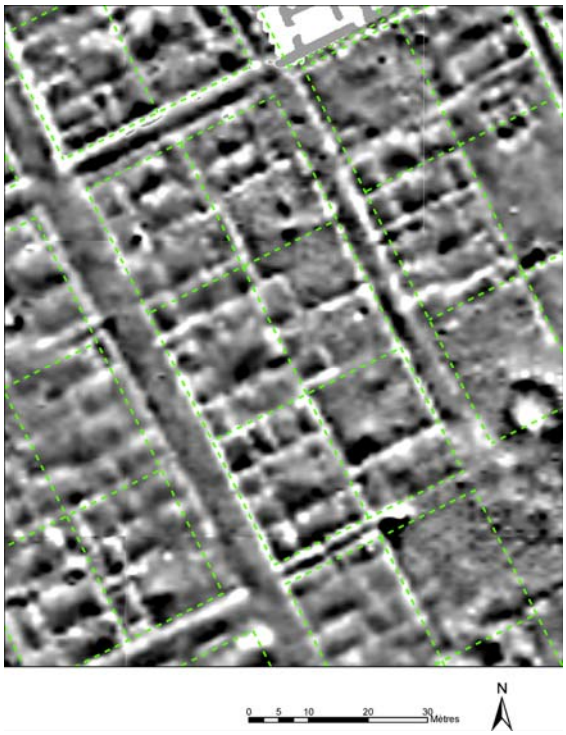

Figure 8. Block D8.

M. Pilet, who conducted the excavation of this block, was not able to establish a reliable chronology and to determine how the different rooms and houses functioned[13]. Moreover, this question remains unanswered for the entire plan. The cases that are the clearest and the most characteristic of this division into six units seem to be concentrated in the south-eastern section of the city, though.

DISCUSSION AND CONCLUSION

For a complete and thorough study of the

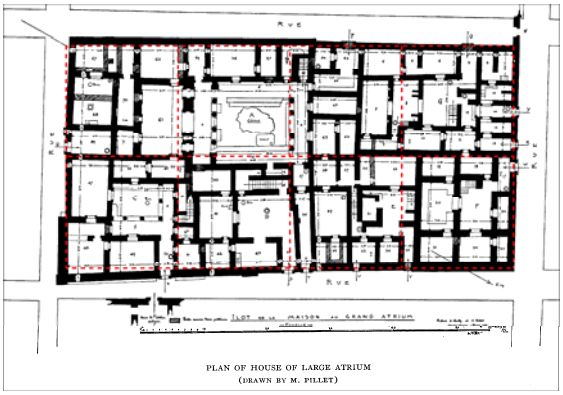

Figure 9a. Block D5 with a theoretical division into eight parcels

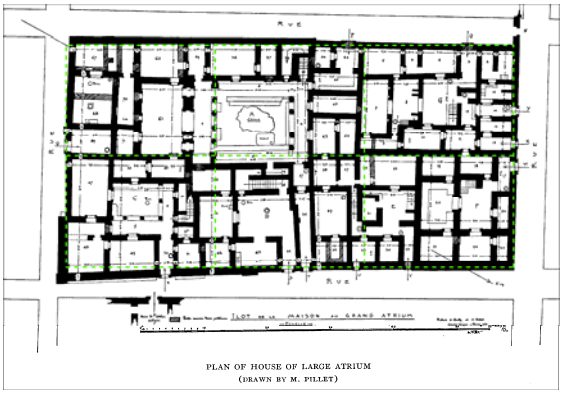

Figure 9b. Block D5 with a theoretical division into six parcels

spatial organization of this sector of the city and the relationship between the different elements of the city, the interpretation of the geophysical maps, which is in progress, must be completed. The synthesising document is only a stage in the original analysis (fig. 10). It juxtaposes the excavation data (function of the excavated buildings), the results of the Visibility Graph Analysis and the results of an earlier work on the interpretation of geophysical maps, which has so far dealt with the identification of the dwelling units[14]. This previous study has shown that the courtyards, central elements in the organization of the houses of Dura-Europos, had surface areas which were well correlated to the size of the houses. The identification of the courtyards on the geophysical image therefore enables us to count the dwelling units as well as to gain an idea of the size of these units based on

[13] M. Pillet, La maison au grand atrium, in: Rostovtzeff 1933, 27 – 32.

[14] C. Benech, New Approach to the Study of City Planning and Domestic Dwellings in the Ancient Near East, Archaeological Prospection 14, 2007, 87 – 103.

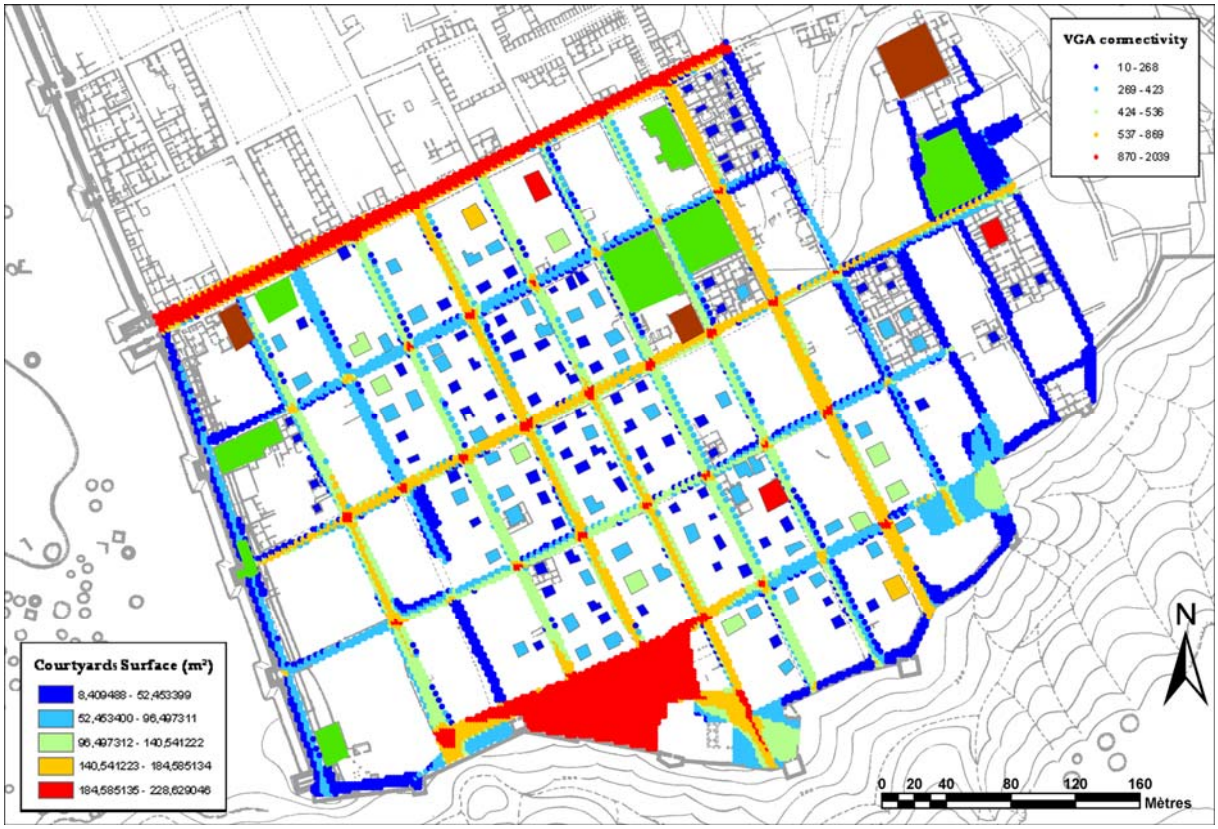

Figure 10. Synthesizing document.

the surface area of the courtyard. Except for a few complex cases, most of the dwelling units have been identified.

Through this synthesizing document interesting relationships arise. One important sector, in which the temples of Gaddes, Artemis and Atargatis as well as the Odeon are located, is extremely accessible by the main street, as well as by the streets H and 5. The temple of Zeus Kyrios and the temple of Aphlad are located in more out-of-the-way sectors (essentially along the line of the fortification), though. The temple of Zeus Megistos, the oldest in Dura-Europos, lies in a particular spot at the end of street 5 and adjoins the Strategeion Palace, a place of power in the city. The intersection of streets D and 5 is marked by a strong concentration of relatively small dwelling units (courtyard <100 sq. m) and confirms the importance of these two thoroughfares for circulation in the southern part. As for street H, it continues through the blocks on the south-east of the plateau, which is characterised by a lesser density of dwellings, relatively larger courtyards, a few non-built up spaces and very certainly public or religious buildings, whose plan and function remain to be determined.

A thorough study of the urbanism requires an extensive knowledge of the urban plan, and not only the theoretical plans inferred from the excavation of ›type-blocks‹ or the occasional finding of streets. The use of a geophysical survey is increasing on ancient urban sites, which is why it is important to work on the thorough interpretation of these images. They considerably enhance the archaeological information and open new perspectives on the urban morphology in antiquity.

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