

REVEALING THE ANCIENT CITY OF LEFKADA THROUGH THE USE OF SHALLOW-DEPTH GEOPHYSICAL PROSPECTION AND GIS TECHNIQUES

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ABSTRACT

The ancient city of Lefkas, opposite the Acarnanian coast, was inhabited from the early times and constituted one of the basic colonies of the Corinthians. The ancient city, following a Hippodamian system, expanded between the borders of the modern settlements Kalligoni and Karyotes, from the slopes of Koulmos, where some (possibly) ritual buildings and the remains of the theatre have been found, towards the coast. Parts of the city were revealed through excavations of the German Archaeological Institute at the beginning of the century and more recently by the Greek Archaeological Service.

Geophysical investigations employed vertical magnetic gradient and soil resistance mapping techniques. Processing of the geophysical data identified a number of characteristics of the ancient city plan: parallel and vertical streets, forming large building blocks, drainage pipes running to the sides of the roads, architectural remains, kilns and wall relics within the building blocks, etc. Further to the south, the density of architectural remnants is decreasing, suggesting a potential location for the southern wall of the city. Aerial and satellite images of the area were also registered to the topographic map and enhanced using image processing techniques.

INTRODUCTION

The Corinthian colony of Lefkas, founded in the end of the 7th century B.C., is located on the north-eastern coast of the Lefkada island, about 2.5 kilometres south of its modern capital city. The location of the ancient city is associated with the control of the channel, which was created between Lefkada and the Akarnanian coast by the Corinthians in the late 7th or early 6th century B.C. This passage was crucial for the navigation towards the Ionian and the Adriatic Sea (Murray 1982).

The city extends between the modern settlements of Kalligoni to the North and Karyotes to the South. The western part of the city follows the natural relief of the gentle slopes of hill Koulmos, while the eastern part extends to the offshore plain. The east and west sections of the city are divided by the modern provincial road leading from Lefkada to Nydri.

The area was not re-occupied after the depopulation of the city in the early 1st century A.D. During the Venetian period land use was limited to olive groves. The development of the area, which began in the 1960s, was rather intensive during the last few years, due to the rapid touristic development of the island. The city walls are preserved today at the north and southwest parts of the city at a height of 2-2.5 m. Their esti-

mated perimeter is 4.5 km. Although architectural remnants (from buildings and terraces) of the ancient city are visible at the slopes of Koulmos, those situated at the plain have been covered by shallow deposits. Thus, shallow-depth geophysical prospection survey was necessary for mapping the layout of the ancient city, in relation to the new design of the urban planning of the area.

PREVIOUS ARCHAEOLOGICAL INVESTIGATIONS

The first information for the remnants of Ancient Lefkas comes from the foreign travelers (Leake, Holland, Pouqueville, Goodisson, Dodwell), who visited the island during the 19th century. Systematic excavations started in 1901 by the German Archaeological Institute. Under the direction of W. Dörpfeld, excavation trenches were opened and remnants of the walls and the ancient theatre were revealed (Dörpfeld 1927). The research discontinued, since Dörpfeld's interests were focused in locating the Mycenaean Ithaka.

In the 1960s' archaeological research was re-activated in the form of rescue excavations conducted by the local Archaeological Service. The rescue excavations, which have been intensified during the last 10 years, uncovered parts of the city's cemeteries, roads and private buildings, contribu-

ting to the reconstruction of the urban planning of ancient Lefkas (Fiedler 1999, Douzougli 2001, Pliakou 2001).

According to the updated results of the archaeological excavations, the city seems to be divided in two parts: one on the hills of Koulmos to the west and one in the plain towards the coast to the east. The part that extends on the hills, where (possibly) ritual buildings and the remains of the ancient theatre have been found (Pliakou 1997, Pliakou 2001), has no specific urban planning, while the part at the plain was built according to an orthogonal system, very similar to the Hippodamian one. According to the information retrieved by different excavation trenches, the parallel streets, with average width 4.5 m (Agallopoulou 1971, Kalligas 1972, Andreou 1979), run across the city every 30 m in an E-W direction, that is from the hills to the sea. These streets intersect vertically with others of about 5.5-6 m in width (Andreou 1977, 1984), creating building plots with their long direction along the E-W axis. The study of the excavation results showed that two private houses, divided by a draining pipe, exist in every building plot (Douzougli 1993, Pliakou 1999). Other draining pipes run along the ancient streets (Agallopoulou 1971, Kalligas 1972, Andreou 1979). These pipes, being on the road surface just outside the houses, functioned as pavements.



Figure 1 Layout and codification of the geophysical grids, as seen through their overlay on the aerial image of the site

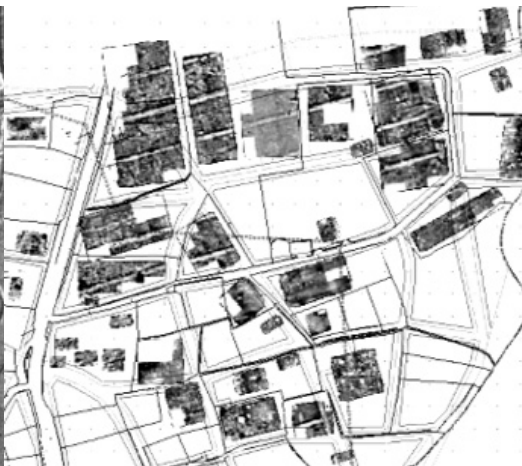


Figure 2 Results of the vertical magnetic gradient survey. The road network, structural relics, drainage pipes, kilns, and wall remains are obvious in the mosaic of the magnetic grids

The aforementioned conclusions have been compared with other known examples in the wider area, like the city of Amvrakia (also a Corinthian colony), which is in the area of modern Arta (Andreou 1993). It is worth mentioning that the orthogonal city plan system in ancient Lefkada was formed almost two centuries before the creation of the Hippodamian system.

GEOPHYSICAL PROSPECTION

The geophysical survey of the archaeological site was carried out in two phases (April 13-23 and June 16-27, 2002). In the first phase of the campaign, both magnetic and soil resistance techniques were employed in selected grids in order to test the registered signals originating by the subsurface targets. The second phase of the fieldwork activities was devoted to

the extended coverage of the site through the use of magnetic techniques.

A Geoscan fluxgate gradiometer (FM36) was employed for the measurements of the vertical magnetic gradient. The gradiometer readings were able to smooth away the geological trends and diminish the external noise. Measurements had an accuracy of 0.1 nT/m. In the measurements of the soil resistance, a Geoscan resistivity meter RM15 with a Twin Probe electrode configuration was used with a spacing of 0.5 m between the mobile electrodes (Clark 1990). Emphasis was given to the wide coverage of the site with a sampling interval of 1m, while high-resolution measurements were carried out in a limited number of grids of specific importance.

The magnetic measurements in grids C, B, A and U (Fig.1), east of the provincial road from Lefkada to Nydri, indicated the existence of a network of parallel streets, at a SW-NE direction, lying at a distance of 35 m apart (Fig.2). They have a width of about 3.75-4.5 m and appear as high anomalies lying within the range of 5-15 nT/m above the background magnetic level. The dipole character of the anomalies suggests the existence of a drainage pipe running at the northern part of the roads. A road, perpendicular to the rest, appears at the northern part of grid B. Similar evidence comes from

grids X and Z, suggesting that the town plan was consisting of a dense network of parallel and perpendicular roads, which divided the ancient city in building blocks.

Grids X and Z are of particular interest, since there are clear indications of architectural relics within the building blocks in both vertical magnetic gradient and soil resistance data (Fig.3). The outline of the magnetic anomalies suggests the

good preservation condition of the particular structural remains. The roads appear as high magnetic anomalies within the ~3-15 nT/m range and as high resistance anomalies within the ~8-15 Ohms range. The parallel road system seems to fade out towards the east. A vertical linear anomaly, which appears at the eastern side of the particular grids, seems to be of a different nature, probably consisting of two sections, and can be considered as a candidate target for the location of the wall surrounding the town. The rest of the grids (VOR1, VOR2, TH1, TH2, TH3) towards the north-east indicate a loosen clustering of architectural remnants, which extent to the coast-line.

Streets and architectural relics are also present in grids D, E and F. In contrast, areas investigated west of the provincial

road from Lefkada to Nydri (grids Q, S and T), did not reveal any significant anomalies, although it has to be mentioned that none of the above grids was laid at the projection of roads, which were identified east of the provincial road. On the other hand, north of grid T there are surface indications of a wide path leading at the top of hill to the west.

The area to the south of the SW-NE dirt-road, which divides the area of interest in north and south sections, exhibits a lower interest, as it is indicated by the decreasing density of geophysical features. The area of grids R1-R5 exhibits an elevation difference of about 3-4 m with respect to the dirt road and the north section of the surveyed region. In the projection of the dirt road to the west, large stone blocks may be correlated to the ancient city wall. Similar evidence exists along the dirt road reinforcing the hypothesis that at least a large section of the city wall is located along its length.



Figure 3 Details of the geophysical survey in ancient Lefkada. Comparison between soil resistivity (upper right) and vertical magnetic gradient (lower right) maps in grids X and Z

Another road is present at the northern section of grid I, although its continuation fades away towards the east in grid Z4. A structure consisting of a number of compartments extends south of the road. The strong magnetic signature of the central anomaly in grid I suggests the existence of a kiln structure. Similarly, the strong negative vertical magnetic gradient anomaly to the south is probably caused by an ancient well. Other candidate kiln structures are indicated in grids P and V.

Finally, additional evidence of the extension of the city plan was provided by grids N1 and N2 to the SE. In grid N1, a cross-section is aligned in agreement to the street orientation at the north section of the surveyed region. The NW-SE road seems to be at the projection of the road registered at the NE edge of grid B, while there are also indications from grid N2 that the road continues further to the south. Due to its proximity to the coast, it is very probable that the road may lead to Lygia, where the ancient port facilities of the city were located. More specifically, in Lygia there is a mole used to connect the Eastern coast of Lefkada with the Akarnanian coast,

where the fortress of Agios Georgios-Plagia is located (Murray 1982). The mole was constructed to protect the southern entrance of the canal, cut by the Corinthians and it is probably dated to the same period, namely about 600 B.C. Similarly, the SW-NE road seems to lead to the ancient cemetery, which has been located to the west of the provincial road.

A series of diagrammatic maps representing the geophysical anomalies has been overlaid on the different cartographic layers of the site (Fig.4).

CREATION OF A GEOGRAPHICAL INFORMATION SYSTEM

The development of a Geographical Information System was considered essential for the better representation of the results of the geophysical prospection survey in accordance with the new urban planning design. The specific Geographical Information System contains data in both vector and raster format, transformed in the same geodetic reference system, namely the Hellenic Geodetic Reference System 1987 (EGSA '87), which is used by the National Cadastre of Greece. ESRI ArcView GIS 3.2 and ERDAS Imagine 8.5 were used for the realization of the GIS.

3D topographic data in ASCII format were converted to database

files in order to create a digital elevation model in a TIN surface format, covering the area from the modern city of Lefkada to the modern settlement of Lygia. These files were imported in ArcView and converted to shapefiles. The urban planning vector files were also used in order to determine how the results of the geophysical prospection are going to affect the proposed design plan. A number of different shapefiles was created including the road network, building plots, existing buildings, boundaries of the research area, protection zones, a.o. The outline of the boundaries of every geophysical grid was also added as a polygon. Finally, the interpretation of the geophysical maps in the form of a diagrammatic drawing (line- and polygon-shapefiles) was included and was compared to the corresponding drawings of the known archaeological remnants.

Three geographically registered orthophoto maps (date: 1998, scale 1:5,000), provided by the Ministry of Agriculture and covering the same area as the TIN model, were joined creating a photo-mosaic. This mosaic was used to georeference the rest aerial photos, provided by the Hellenic

Ministry for the Environment, Physical Planning and Public Works (Hellenic Mapping and Cadastral Organization). These 1:6,000 scale photos, which were obtained at different dates (16/05/1985 and 12/10/1994), were scanned in high resolution, so as to achieve the optimum result in the quality of every image. These photos were also processed through histogram equalization and geometric registration in order to form a time sequence of aerial mosaics.



Figure 4 Diagrammatic representation of the magnetic and soil resistance anomalies

Geophysical prospection survey grids were exported in jpeg format, both as B/W and colour images, and they were geometrically corrected, using their aforementioned vector borders. Finally, scanned photos and designs of the excavations were added as hotlinks.

The available vector and raster format layers were combined in the creation of the Geographical Information System and they were superimposed on the TIN of the area. In this way, the user can choose between one of the different period's aerial photo mosaics as background information or between colour and B/W images of the geophysical grids, while at the same time he can have a direct access to the designs and pictures associated with the excavations. Most important, the user can explore which of the geophysical anomalies fall into

the extents of the new urban planning design and can do the appropriate modifications. Finally, several queries related to the topographical and archaeological data can be performed.

RESULTS - CONCLUSIONS

The geophysical prospection survey at the archaeological site of ancient Lefkas resulted in a wealth of information, providing an accurate image of the city plan and indicating the limits of the ancient city. A road network, structural relics, drainage pipes, kilns, and wall remains are included among the candidate targets that were registered by the soil resistance and magnetic techniques. The results of the geophysical survey are in perfect agreement to the surface monuments and the excavation results, completing in a large degree the fragmentary image of the ancient city.

More specifically, the city plan seems to extend to the north of the area of interest (namely, north of the SW-NE dirt-road and east of the provincial road). In contrast, the south section of the area exhibits a lower density of architectural remains and an increasing number of candidate kiln structures, suggesting workshop activities. The above observations, together with the surface monuments along the dirt-road and the elevation difference between the north and south sections in the other sides of the dirt road, suggest that part of the southern city wall is probably running along the dirt-road.

The importance of the GIS in registering the geophysical maps in a common cartographical context is obvious, due to the different areas that were surveyed. GIS contributed to the overlay of the geophysical images on the topographical layout and the aerial mosaic of the region. In this way, it was possible to have an accurate picture of the distribution of the geophysical anomalies and their correlation with the surface relics. Aerial mosaics contributed to the analysis of the evolution of the landscape. A three-dimensional representation of the research area combining the digital elevation model, draped with an aerial photo mosaic and the architectural remnants, found in the previous excavations and geophysical survey is under construction. The final system will contribute in the management of the archaeological relics of ancient Lefkas.

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