Session VIII-1 of UISPP 2018 in Paris 'Mapping the Past' brought together several contributions reflecting on the need to develop sustainable and reliable approaches to mapping our landscape heritage. The session was guided by the crucial concept termed the 'archaeological continuum'. This concept can be defined as a proactive approach to landscape survey based on the summative evidence detected (or detectable) within the area under examination, reducing spatial and chronological gaps as far as possible through the intensive and extensive application of a wide variety of exploratory methods and analytical techniques. Research work across Europe as well as contributions presented in this session have demonstrated that it is now possible to explore the whole landscape of carefully chosen areas and study them as an archaeological continuum. Archaeological interpretations derived from this kind of approach can be expected to reveal different layers of information belonging to a variety of chronological horizons, each displaying mutual physical (stratigraphic) and conceptual relationships within that horizon. The raising of new archaeological questions and also the development of alternative conservation strategies directly stimulated by the radical ideas inherent in the concept of the 'archaeological continuum' are among the major outcomes of the session.

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Mapping the Past
From sampling sites and landscapes to exploring the ‘archaeological continuum’

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Geophysical explorations of the classical coastal settlement of Lechaion, Peloponnese (Greece)

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Abstract

The geophysical survey at Lechaion was carried out under the framework of the Lechaion Harbor and Settlement Project (LHSP) that aims to study the settlement and its harbor during its habitation. Lechaion was the western and most important seaport of Corinth due to its proximity to the city.

The geophysical results were mainly correlated to a system of parallel N-S roads crossing the site, verifying a number of features that were originally suggested from various historical, aerial and satellite images. Around the lagoon, features follow the direction of the modern shoreline, suggesting that its shape has not changed significantly since the ancient times. To the north of the central lagoon, an area of more than 100 x 100 m has been clearly differentiated from its surroundings suggesting a region of high deposition. The joint employment and interpretation from diverse satellite and ground based techniques proved their efficiency in reconstructing the cultural dynamics of coastal archaeological sites in Eastern Mediterranean.

Keywords: geophysical prospection, coastal settlement, classical period, Lechaion, Greece

Résumé

Une prospection géophysique a été menée à Lechaion dans le cadre du Lechaion Harbor and Settlement Project (LHSP), lequel vise l’étude du site et de son port. Lechaion était le port maritime principal de la ville de Corinthe, située à moins de 3 km à l’est.

Les données géophysiques démontrent l’existence d’un système de rues parallèles orientées nord-sud et confirment les résultats obtenus précédemment à partir de l’étude de photographies aériennes historiques et d’images satellites. Autour du lagon, les anomalies géophysiques suivent l’orientation de la ligne côtière moderne, ce qui suggère que celle-ci n’a pas évolué de manière significative depuis l’Antiquité. Au nord du lagon central, une zone de plus d’un hectare se distingue clairement des environs et semble couvertes par d’importants dépôts. L’étude du site de Lechaion démontre l’efficacité de l’analyse combinée de techniques terrestres, aériennes et satellites pour reconstituer les dynamiques culturelles des sites archéologiques côtiers en Méditerranée orientale.

Mots-clés : prospection géophysique, site côtier, période classique, Lechaion, Grèce
1. Introduction

The first two phases of the geophysical prospection survey at the archaeological site of Lechaion (Figure 1) were carried out in 2016 and 2017 under the framework of the Lechaion Harbor and Settlement Project (LHSP) that aims to the study of the settlement and its harbor from its earliest use during the Mycenaean period and perhaps earlier until its abandonment in the second half of the 6th century CE.

Lechaion was the western and most important seaport of Corinth due to its proximity to the city. Long fortification walls connected the city with the port and the naval dockyard that the Corinthians had formed in the wider area. The foundations of these long walls and especially the western wall have already been revealed in 1892 as part of an excavation campaign. The Corinthians increased the security and port capacity through technical projects on the port. The first infrastructures would seem to have been built during the late Geometric period, to serve first trade with and then colonial expansion into the West. The basilica of Saint Leonidi is hosted in the ancient harbor, which is considered the largest paleochristian church in Greece with dimensions 220 m long and 50 m wide and one of the landmarks in the architecture of churches. Both ports of Lechaion (access to the Corinthian Gulf) and Kenchrai (access to the Saronic Gulf) provided the foundation for the dominance of Corinth during the Classical and Roman periods.

Most of the region was covered by magnetic and GPR techniques, which proved to be the most efficient for the particular geomorphogical settings of the coastal settlement. A number of sections of the site were scanned by various methods in order to address specific questions that arose from the geophysical data. This manifold approach has proven to be most effective when question
driven geophysical prospection is undertaken during the investigation of an archaeological area (Sarris 2013).

2. Methodology

Magnetic, ERT, EMI, soil resistance and GPR were employed in a complementary manner to record the subsurface information at specific areas of the archaeological site of Lechaion. These geophysical techniques were chosen as the most appropriate for meeting the goals of the project, according to the needs of the research, the geomorphological characteristics of the site, and the expected subsurface archaeological targets – with respect to the detection and mapping of them.

Magnetic survey was carried out using a Sensorik and System technologie (SENSYS) MX Compact Survey System. SENSYS MX is a multi-channel measurement system, equipped with 8 FGM600 gradiometers, navigated via a DGPS using the NMEA 0183 standard. In areas which were difficult to navigate with the extension of the multisensory system, two handheld Bartington vertical magnetic gradient magnetometers (fluxgate gradiometers) were employed. The electromagnetic induction data were collected with a CMD Mini Explorer unit by GF Instruments designed for multi-depth measurements. CMD Mini Explorer is used for the assessment of ground conductivity and of in-phase (susceptibility) using three dipoles centered at distances (0.2 m, 1.71 m, 1.18 m) and a frequency of 30 KHz, thus having a variable effective high/low depth range (0.5/0.25 m, 1.0/1.5 m, 1.8/0.9 m). For GPR data collection, the Noggin Plus-Smart Cart system by Sensors and Software was used with a 250 MHz antenna. For prospecting with GPR, grids were designated to delimit the areas of interest and data were collected in parallel transects along the Y direction. The Syscal Pro resistivity meter connected to the Syscal Switch Pro 96 (Iris Instruments) was used to capture and store the ERT field data. The instrument has the capability to simultaneously drive up to 96 electrodes which are laid out along a transect and which are connected to the resistivity unit through a multicline cable. Resistance mapping was completed with the Geoscan Research RM85 instrument configured in a Twin probe electrode array.

All the geophysical techniques emphasized the detailed mapping of the investigated areas (0.5 m by 0.1 m sampling for magnetic measurements, 0.025 m along the GPR transects separated at 0.5 m parallel profiles, 1 m inter-electrode spacing for the ERT, 1 m by 1 m for electrical resistance etc.). Magnetic techniques covered the largest section of the site (57,700 sq. meters), followed by the GPR survey (23,500 sq. meters) and the soil resistance mapping (8,000 sq. meters). EMI methods scanned about 6,100 sq. meters and the ERT lines targeted specific sections covering 4,100 sq. meters (Figure 1).

3. Processing of geophysical measurements

Despiking, Grid matching, Line equalization techniques were applied to magnetic, soil resistance and EMI data before using a Kriging algorithm for interpolation. Compression of the original dynamic range of values and the application of derivative filters enhanced the subtle anomalies. Colour and grey scale geophysical maps were produced: Hot colours (reddish colours) in colour maps and light (white) colours in grey scale maps represent high intensity values. Cold colours (bluish colours) in colour maps and dark (black) colours in grey scale maps represent low intensity anomalies. GIS software (ArcGIS v.10.3) was used to rectify the geophysical maps and overlay them on the topographic plan of the site and other satellite or aerial images.

Similar was the processing of the ERT data. Despiking and compression of the dynamic range were applied to each one of the 2D ERT tomographies to remove apparent extremely noisy resistivity measurements. Different 2D resistivity inversion algorithms (Loke and Barker 1996) were used to process the data. The algorithms divide the subsurface in rectangular parameters of constant resistivity that can vary their value independently during the inversion process.
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Processing of the GPR data was carried out using EKKO Project 2 by Sensors and Software. Preprocessing included the trace reposition of the individual GPR transects, time zero correction and the application of a Dewow filer. Following this, GPR signals were enhanced through background removal, application of a SEC gain and band pass filtering in the frequency domain. By the time the processing on the radargrams was complete, Hilbert Transform was applied to calculate the instantaneous amplitude and extract depth slices, namely horizontal slices depicting the registered reflectors with increasing depth. Depth values were estimated based on the hyperbola curve fitting method ($v \approx 0.9-0.95 \text{ m/nsec}$).

4. Discussion of Results

Despite the high noise levels due to the intense historical and modern exploitation of the land, the magnetic survey that was carried out to the south section of the site indicated that the settlement expanded around the lagoon, which seems to have retain its shape from the ancient times (Figure 2). The structural remains follow the same orientation of the shore line of the lagoon. The structures are mainly orthogonal, having internal divisions and some of them are of monumental dimensions. Magnetic values are more pronounced closer to the lagoon, suggesting a denser occupation in this section, probably of more coastal type of activities. Further to the central east region, 4 almost parallel segments, 5, 9 and 5 m apart correspondingly, starting from the northern one, represent the relics of a large compound, which appears with strong signals in the GPR measurements (Figure 3). Indeed, within the first 50-160 cm below the surface, a three aislled basilica appears. It has a length of more than 31 m (35 m including the apse), which means it is about 1/5-1/6 times the size of the large basilica of Leonidi which lies to the NW. Immediately to the south and east of the basilica high reflectance anomalies dominate the region in contrast to the surrounding region. In consideration of their depth (150-160 cm) and amorphous shapes, they can be interpreted as geological formations. In contrast, the area to the NW of the basilica exhibits more homogeneous and quiet magnetic levels, which may be caused due to depositional processes from the narrow channel immediately to the north. This may be indeed the case, as the particular narrow width section of the lagoon could be exposed in frequent high energy water masses entering the channel of the lagoon from the east. Similar signs of siltation and high salt concentration are shown by the high EMI conductivity measurements to the south of the central south section of the lagoon.

Within the lagoon, the magnetic measurements registered very vague anomalies that are hard to identify as residues of sunken ships or any massive architecture. The only strong candidate is an area of $\sim 28 \times 8 \text{ m}$, located at the south end of the lagoon, exhibiting slightly higher values than the rest of the surrounding region. On the other hand, the 7 parallel ERT transects that were executed in the north section of the lagoon produced a 3-layer stratigraphy consisting of: a top 2 m thick conductive layer A ($0.2-0.6 \text{ Ohm.m}$), related to fine clay sediments, saturated with saline water; a middle more resistive silty or/and sandy clay layer B ($1.0-4.0 \text{ Ohm.m}$) of variable thickness (5 m in the interior of the lagoon, 9 m towards the periphery of the lagoon), most probably due to the slight dipping trend of the bottom Layer C towards NE, which is of intermediate resistivity values ($0.6-1.0 \text{ Ohm.m}$) (Figure 4).

To the east of the Leonidi basilica, three long N-S features (A25, A20 and A26) that can be identified with roads are visible in the magnetic data, merging to a common location that can be a crossroad (Figure 5). The largest segment of them (feature A25) extends for about 40 m in a slightly NW-SE direction to turn to the E-W direction (feature A26) at the cross section with the N-S street A20. The signature of the street A21 is clearly defined for about 43 m, before fading away as we move towards the north and at the interface of anomaly A28, which defines the boundary of a region that consists of a very smooth low magnetic background. This region seems to continue further to the east as it registers in a very similar way to the GPR data. Despite the fact that magnetic data cannot directly indicate possible siltation or deposition processes (like EM, GPR or ERT methods), the fact that there is a clearly defined outline of a relatively magnetically ‘quiet’ region indicates...
Figure 2. Top: Results of the magnetic survey at the south and north sections of the ancient settlement of Lechaion. Bottom: Diagrammatic interpretation of the results of the magnetic anomalies.
a differentiation from the rest of the area. This is indeed in perfect agreement with the GPR data, which define the same area of high conductivity (and thus absorption of the GPR electromagnetic waves) (Figure 6). The GPR signal becomes saturated below the 60-100 cm depth.

Towards the NE, a number of circular high conductive features (A31, A32, A33, A36 and A37) start appearing at the same depth (50-60 cm) and up to a depth of 120-130 cm (Figure 6). Their radii vary from 7 to 11 m. Further to the NE, the soil resistance values reached the highest readings that have been collected in the site, which should be expected due to the sand that covers this particular
Figure 5. Top: Results of the magnetic survey at the north section of the site of Lechaion. Bottom: Diagrammatic interpretation of the magnetic anomalies identified in the north section of the site.
area (indication of sea wave deposition?). This was also confirmed from a couple of ERT lines that were carried out in this particular section and indicated a superficial resistive layer (2 m thick) of more than 60 Ohm.m (sand?). Interesting enough, this high resistive layer was interrupted when crossing the respective round conductive features shown in the GPR slices. The remaining superficial part of the stratigraphy is characterized by patches of a less resistive material (silty sand?) with resistivity 6-60 Ohm.m, below which there is a relatively uniform conductive layer (0.6-6 Ohm.m) that is attributed to a sedimentary formation saturated with salty water.

In the same area towards the NE, a series of extensive linear concave features (with most intense features A38, A39 and A40), extending parallel to the NW coastline, appear in all depth slices below
the 1 m (Figure 6). There is no regularity in the shape or the distance between the particular features and thus it may be possible to constitute traces of depositions from past incoming sea waves that may have modified the coastline in different historical periods.

5. Final remarks

During the two fieldwork campaign seasons, geophysical data started to reveal the formation of the site of Lechaion, both natural and anthropogenic. Having gone through a diachronic habitation, the site exhibits a number of interesting features that can be related to the intense occupation of the site in the ancient times and to the more recent historical activities until the abandonment of the site.

The high density of occupation of the coastal settlement in antiquity has been manifested especially to the south of the lagoon. Fewer structural remains have been located to the north of the lagoon. The geophysical signals (and satellite imagery) support the observations made by Romano (2003, 2006) studying the 1987 balloon imagery taken by Myers (Hemans et al. 1987). At least three – four of the seven N-S 30 feet wide roads that Romano identified in the images of Myers were confirmed through the geophysical techniques. The streets are 37m apart and they fit to the plan suggested by Romano. Similarly, an E-W road was identified to the NW section of the surveyed region. However, the traces of the roads are also visible on the current terrain, extending down to the shallow depth layers (~50-60 cm below the surface) and this may suggest that they may be of a later period.

The above hypothesis can be further supported by the large (~100 x 100 m) low magnetic background and high conductivity central area that was identified to the north of the main lagoon, suggesting a region of high deposition, intact from other geological processes. The ERT measurements confirmed that in this particular region, right below the top sandy layer, there is a highly conductive formation saturated with salty water. If this is the case, then this region could have comprised an outer lagoon connected to the NE (or the northern) coastline but, until further studies are conducted, of an unknown date.

The dynamic interaction between the sea and the coastal region and the intrusion of the sea towards the main lagoons is supported by the geophysical data. This is especially evident by a series of extensive linear concave features extending parallel to the NE coastline, which could be attributed to traces of depositions from past incoming sea waves. This can also support the hypothesis made for the 5 shallow circular conductive features found in the particular region, namely that they are anthropogenic constructions used either as fish tanks or for salt production, similar to the facilities found in other Iron Age and Roman period sites (Wooddwwiss 1992).

References