GEOPHYSICAL IMAGING SURVEY IN THE SOUTH NECROPOLIS AT THE ANCIENT CITY OF PARION (KEMER - BIGA), NORTHWESTERN ANATOLIA, TURKEY: PRELIMINARY RESULTS

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ABSTRACT

Parion is one of the most important settlements located in the ancient Troas region, in which the city of Troy was the center. Many remarkable and precious archaeological remains have been unearthed so far which point out the city's importance during the Hellenistic and Roman Age. In this study, a first attempt to obtain high resolution images of the subsurface of Parion to guide the archaeological trenches was made by an initial geophysical survey applying Electrical Resistivity Tomography (ERT) technique. The apparent resistivity data, collected using pole-dipole electrode configuration along 11 transects, were inverted by two- and three-dimensional smoothness-constrained least squares algorithms. Relatively compatible results were obtained from two inversion processes. Parallel transects showed the resistivity distribution in three-dimensional images and thus both the horizontal and vertical extents of the anomalous zones were displayed. Additionally, some high anomaly zones located at the end of the first six transects were backed up by archaeological trenches. Thus, taking into account these findings, the other resistivity anomalies located at the different parts of the surveyed area are thought to be the most promising locations for archaeological excavations.

INTRODUCTION

Archaeological studies involve excavations which are time consuming and these excavations also require a huge expenditure of physical effort. Unfortunately, this effort may not be very cost-effective due to the risks of damaging or missing the burial archaeological remains in some cases. On the other hand, archaeological features have some certain physical properties (i.e. magnetic suscep- tibility, electrical resistivity and conductivity, dielectric constant) which can be measured from the earth surface. Thus useful information about some physical parameters of the buried archaeological structures such as location, depth, size, thickness, position and extent can be obtained prior to excavations by using non- invasive and non-destructive geophysical imaging techniques.

The first geophysical survey in an archae- ological site was carried out as early as the late 1940s (Atkinson, 1952). However only since the 1980s the geophysical methods have been widely performed on many archaeological sites. It is known the successful use of geophysical prospection in archaeological sites to unearth buried antiquities (e.g. Hesse et al., 1986; Scollar et al., 1986; Griffiths and Barker, 1994; Tsokas et al., 1994; Neubauer, 1997; Gaffney et al., 2000; De Domenico et al., 2006; Leucci et al., 2007; Drahor et al., 2008). The most commonly applied geophysical methods used for archaeological explorations are electrical resistivity, magnetic, ground penetrating radar and electromagnetic conductivity. These subsurface imaging techniques are carried out easily and quickly on the ground surface without disturbing or damaging the buried archae- ological features. Additionally, the advantages mentioned above increase the popularity of non-destructive geophysical surveys at archaeological sites day by day (e.g. Savvaidis et al., 1999; Diamanti et al.,

2005; Papadopoulos et al., 2006; Ekinci and Kaya, 2007; Büyüksaraç et al., 2008). Direct current resistivity method is one of the most commonly applied geophysical imaging techniques for shallow investigations. Electrical Resistivity Tomography (ERT), the modified version of conventional vertical electrical sounding, is based on reconstruction modeling techniques and is used to obtain high resolution resistivity images of the subsurface. The aim of the technique is to collect apparent resistivity data from the subsurface along a transect using a predefined electrode array in order to generate a model section images. ERT has become an increasingly efficient tool to investigate buried archaeological features due to the ability of detecting walls, voids, graves and some other man-made structures. The low cost of the investigation and the possible resistivity contrast between the archaeological structures and the surrounding soil are also the main advantages of the method (Ekinci and Kaya, 2007). Additionally, ERT has gained more acceptances in recent years due to the technological advances in resistivity-meter systems and the two- and three- dimensional forward and inversion modeling algorithms. Apparent resistivity data are measured along a predetermined line by sequence of a selected electrode configuration for building up a two- dimensional pseudo-section or obtained from a selected area by different arrangements of electrode configurations for three-dimensional surveys (Loke, 2001; Papadopoulos et al., 2006; Drahor et al., 2008). After the data acquisition process, apparent resistivity data are inverted by two- or three-dimensional optimization algorithms in order to obtain true resistivity distribution of the subsurface. At the last stage, volumetric representations, orthogonal and depth slices are generated to display the anomalous zones in the geoelectrical model sections.

The presented work was carried out to

explore and locate the buried man-made archaeological structures at the south necropolis area of Parion ancient city (Biga-Turkey). It was thought that the results of the geoelectrical imaging survey would guide to the excavations and give insight into the patterning of unexcavated parts of the necropolis. Measured apparent resistivity data gathered along each transect were inverted by two-dimensional inversion algorithm and the results were illustrated jointly (quasi-three-dimensional approach). Additionally, by combining parallel two-dimensional apparent resistivity data sets we used a three-dimensional inversion algorithm (semi-fully three-dimensional approach). More accurate interpretation was aimed by using the results of both two algorithms (Papadopoulos et al., 2006; Berge and Drahor, 2011). In order to carry out a more detailed analysis and improve the interpretation, three-dimensional

volumetric images were produced by using two-dimensional orthogonal and depth slices. These images were generated based on multi-dimensional gridding processes for volumetric data. The technique allows displaying of orthogonal planes in the direction at predetermined positions. Finally, resistivity tomograms displayed many high anomaly zones and the anomalies located at the end of the six lines were backed up by archaeological trenches. Due to this evidence, the other resistivity anomalies in the tomograms are thought to be the most promising locations for the subsequent seasons' excavations.

SITE DESCRIPTION AND HISTORICAL BACKGROUND

Parion is located about 90 km to the city of Çanakkale, NW Turkey (Fig. 1a). The village of Kemer (Fig. 1b) which belongs to the administrative district of Biga, partially
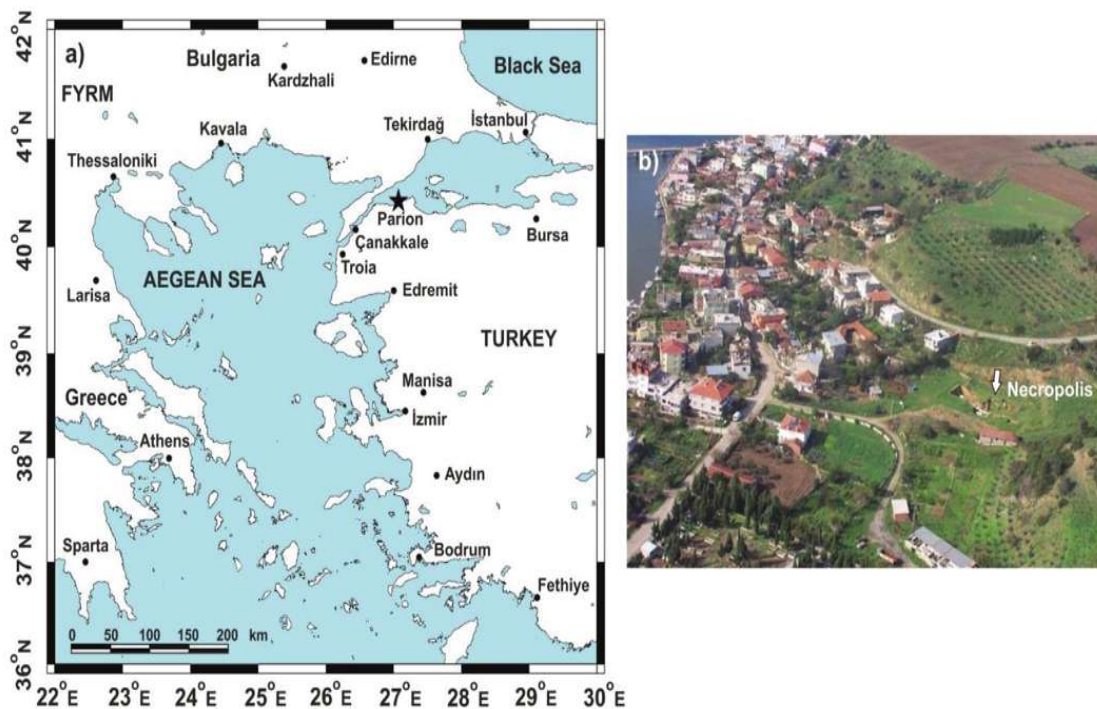

Figure 1. Location map of the ancient city of Parion (a) and the view of the village Kemer (b).
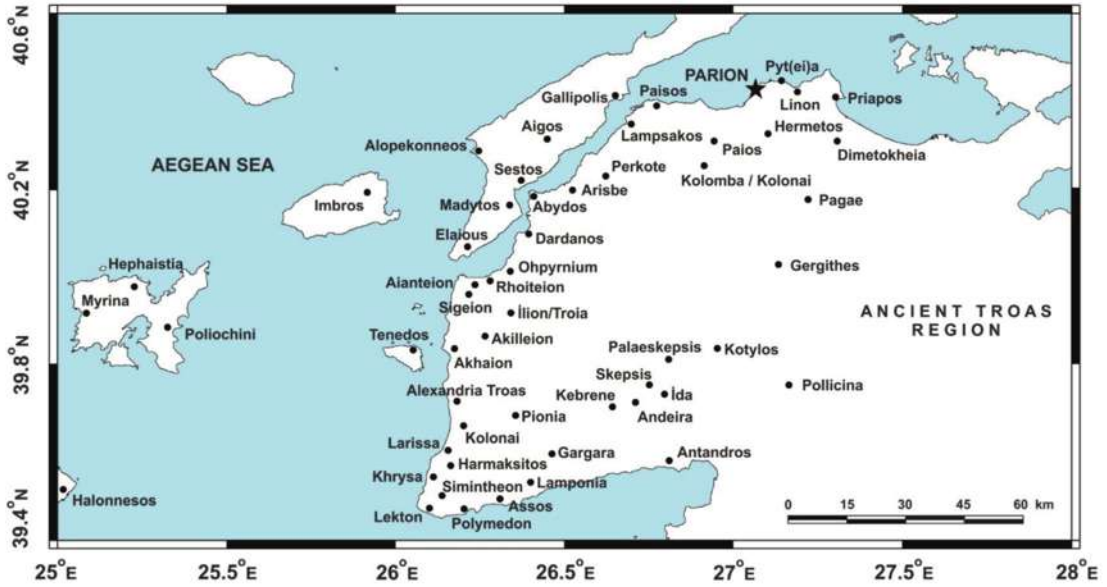
Figure 2. Map of the Ancient Troas Region.

covers the city. Parion is surrounded by about 8 km city walls. According to Başaran (2008) the city is considered as a city of Ancient Troas Region (Fig. 2). Theatre, Roman Bath, Slope House, Stone Tower and Necropolis are the focused localities in Parion (Fig. 3). The city was first investigated during rescue excavations, completed by the archaeology museum of Çanakkale in 2004, and has been under systematic excavation since 2005. Many graves and remains of structures, which are thought to belong to the era from 6th century BC to the end of the Roman period, have been brought to light by archaeological excavations in south necropolis so far (Fig. 4).
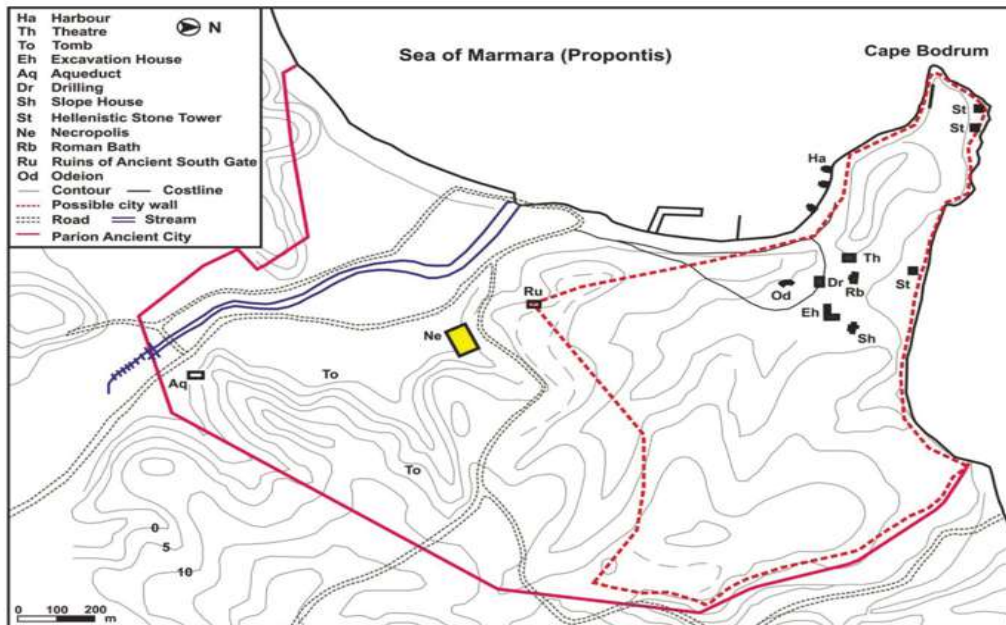

Figure 3. The locations of the focused archaeological studies in the city of Parion.
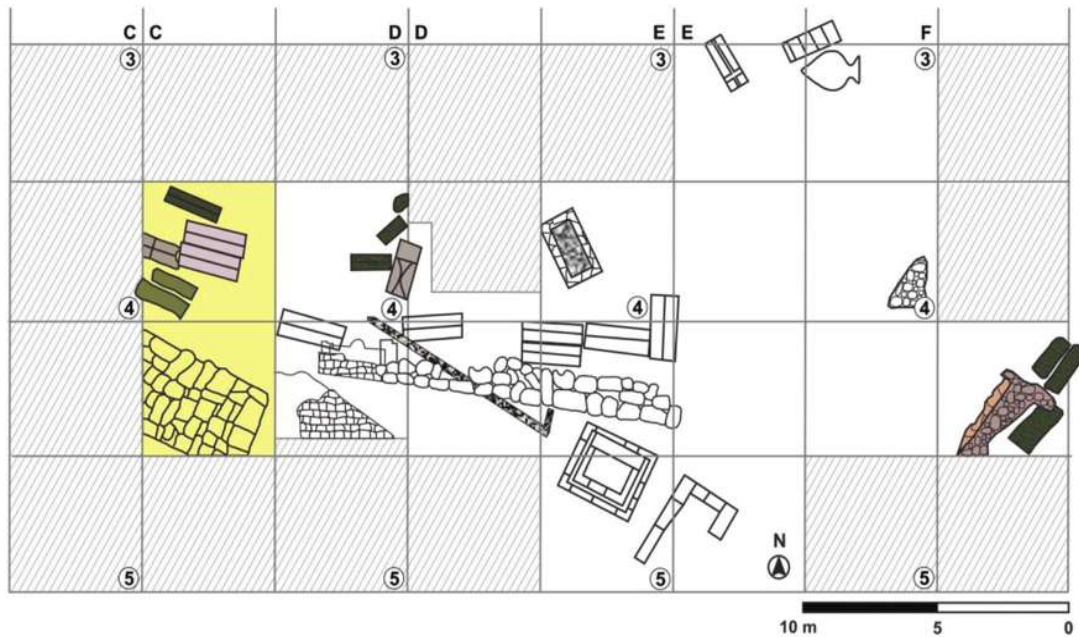
Figure 4. Sketch plan of the necropolis showing some archaeological remains brought to light by the excavations since 2005. Yellow grids (two middle squares at C) show the trenches coinciding with the six geoelectrical resistivity transects.

There are several opinions about the name of Parion. One idea suggests that the city was named after Parion, son of Iason and Demetria, emigrants from Erythraili, who established the city (Leaf, 1923; Bonacasa, 1976; Frish, 1983; Başaran, 1998). Another view holds that the name was originated from the people emigrated from Paros in Colonization Era (Başaran, 2001; Avram, 2004). The third view claims that the city was named after Paris, the youngest son of the King Priam, and therefore it is thought that Parion means "the city of Paris" (Başaran, 1998 and 2005). Although the information about the early period of the city is limited, the historical data of Parion belong to the 6th century BC. It is known that the city came under the rule of Persian domination after the end of the Lydian Kingdom in 546 BC (Mansel, 1988; Başaran, 2002). Later on, Parion became a member of Atika-Delos Sea Union which was founded in 479 - 478 BC to emancipate the cities under Persian rule (Mansel, 1998; Başaran,

2002). During the Peloponnesus Wars (431 - 404 BC) the people of Parion and Athens fought against the Spartans. Following the invasion of Galatians between 278 - 277 BC, the city was captured by Pergamon Kingdom in 271 BC (Mansel, 1988; Başaran, 2002). After Pergamon had come under the rule of Roman in 133 BC, Parion joined to Roman Empire as a political authority and during the first Mithridates wars the city gained a half-independent political status (Başaran, 2002). Additionally, Parion was highly valued in Roman Era and declared as "the favored city" with the title of "Colonia Pariana Iulia Augusta" by Augustus (27 BC - 14 AD) (Magie, 1950; Başaran, 2001 and 2006).

DATA ACQUISITION AND PROCESSING

Geoelectrical imaging survey at south necropolis was carried out using the pole–dipole electrode array configuration. As is

known, the pole-dipole array geometry has relatively good horizontal coverage, but it is considered to be more effective than the dipole-dipole array because the movement of one transmitter electrode is sufficient and the array produces considerably higher receiver voltage (White et al., 2003). The most obvious advantages of pole-dipole array over the dipole-dipole and wenner-schlumberger arrays are the speed of data acquisition, superior depth of investigation and the volume of the data (White et al., 2003). Additionally, it is not as sensitive to telluric noise as the pole-pole array (Loke, 2001). Therefore pole-dipole array was considered to be the most suitable electrode array for this survey. The apparent resistivity data were collected in an area of 23 m by 20 m, over 11 parallel transects, each 23 m long, with line spacing 2 m. There were no significant topographical changes in this part of the necropolis. Taking into consideration the archaeological information obtained from the trenches next to the geophysical survey area at the necropolis such as depth and dimension, the penetration depth of the survey was set to about 4.5 m with electrode spacing of 1 m. The remote current electrode was placed sufficiently far from the survey lines i.e more than 66 m (more than 6 times the largest C1-P1 distance used (n factor) on the survey line). A total of 2057 apparent resistivity values were collected for 11 data levels (n=1 to n=11) using the IRIS-Syscal R1 Plus resistivity-meter. In order to enhance the quality of the measured apparent resistivity data, we set the number of stacks (repeat measurements) to 4 and it was increased to 8 when the relative standard deviation of the stacked data was greater than 2 %. The procedure was applied to only a small number of datum points since the relative standard deviation values were less than 0.5 % for a clear majority due to the low noise level of the surveyed site. Even though the pseudosection representation produced from apparent resistivity distribution may

give some information about the location of the causative sources, the parameters such as size, depth, thickness and extent cannot be estimated correctly. Thus we applied two- and three-dimensional inversion methods in order to obtain true resistivity images of the subsurface using Res2Dinv and Res3Dinv software products (Loke and Barker, 1996), respectively. The aim was to interpret more accurately by taking advantages of the results of both two algorithms. These inversion algorithms, based on smoothness-constrained least-squares (deGroot-Hedlin and Constable, 1990; Sasaki, 1992) implemented by a quasi-Newton optimization technique (Loke and Barker, 1996), iteratively calculate a resistivity model, trying to minimize the difference between the observed apparent resistivity values and those calculated from the model (Loke and Barker, 1996). The calculated apparent resistivity values were obtained by finite element method using 4 nodes per unit electrode spacing during the inversion process. The inverse model resistivity sections were selected at the iteration after which the root mean square (RMS) error did not change significantly. Satisfactory results were obtained after 5 iterations for all lines and the RMS errors were between 0.8 - 4.3 %. The three-dimensional inversion of collated resistivity data obtained from 11 transects produced an inverse model resistivity at the end of 5 iterations with a RMS error of 4.1 %. Due to low RMS errors, the obtained results can be considered as a reliable representation of the true resistivity distribution of subsurface. Finally, a MATLAB-based code including visualization functions was used to display the resistivity distribution of each profile jointly in three-dimensional volumetric slices and depth sections. These visualization techniques allowed displaying the three-dimensional volume in a range of user-selected orthogonal slices of bounding surfaces. Therefore the extents of the anomalous zones were easily displayed.

RESULTS AND DISCUSSION

The nearly WSW-ENE trending tomograms displayed a resistivity distribution of a depth range of about 4.5 m and showed many remarkable high resistivity anomalies. The resistivity tomograms obtained from two- and three-dimensional inversion processes are illustrated in Fig. 5a and b, respectively. The jointly represented tomograms indicated that the overall resistivity range in the surveyed area varies between about 20 and 200 ohm-m except a negligible amount of datum points. Test measurement carried out on an area on the outer part of the site where the existence of archaeological remains is not expected showed that the covering material has a moderate resistivity values ranging between 25 and 84 ohm-m. In the light of this information, high resistivity zones, i.e. more than 110 ohm-m, were considered to be the possible traces of the man-made archaeological burial structures.

Some resistive zones were determined at the end of the first six ERT slices (RZN 1 through RZN 6) obtained from both two inversion procedures (Fig. 5a and b). This anomaly zones showed that the results of
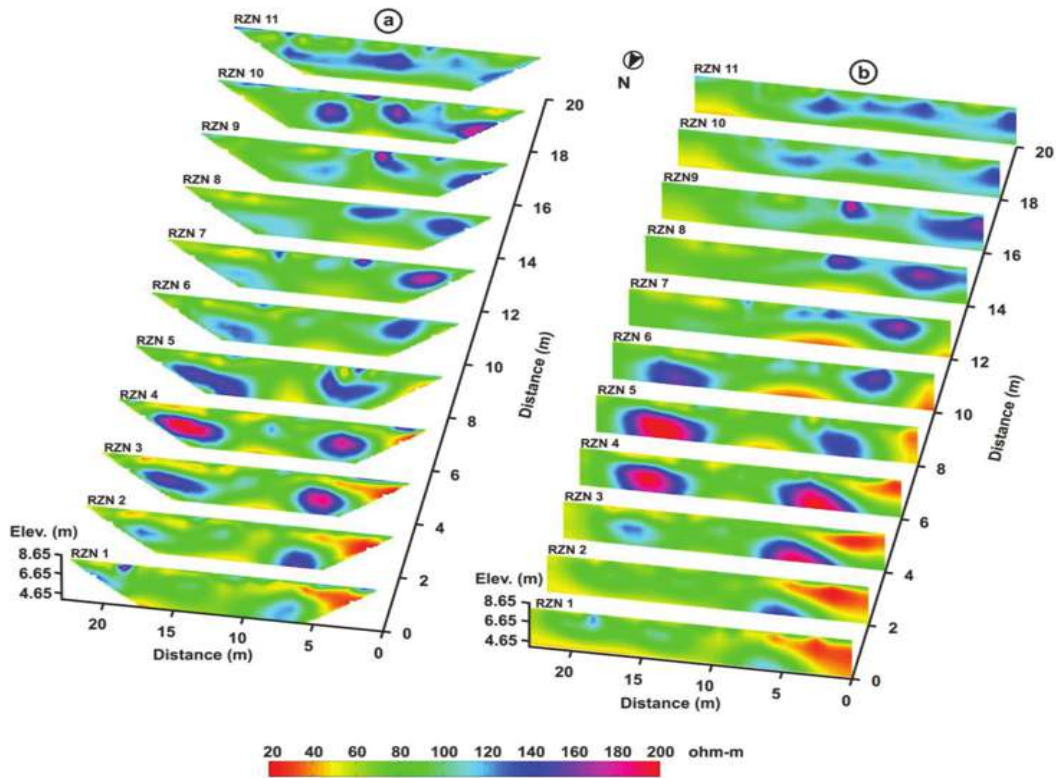

Figure 5. Geoelectrical imaging of the surveyed area with orthogonal slices obtained from two-dimensional inversion (a) and three-dimensional inversion approach (b) (note that the long axes were exaggerated for the illustrations).

two- and three- dimensional inversions are in accordance with each other about the location. However, it was observed that there is no certain agreement between the two inversion procedures about the vertical extent of the anomalous zones. Thus, in order to investigate these zones in a more detailed manner, the inverted resistivity

data were demonstrated as depth slices starting at the elevation of 8.15 m down to 4.15 m with an interval of 0.5 m (Fig. 6a and b). It can be clearly seen from Fig 6a that the high resistivity zone, marked by white arrows, is located between the elevations of about 6.65 and 4.65 m. The decrease in the intensity of the anomaly from mentioned level to downward suggests that the possible man-made archaeological structures do not exist below the elevations of about 5.15 – 4.65 m. On contrast to two-dimensional inversion results, depth slices (Fig. 6b) obtained from three-dimensional inversion procedure showed that the anomalous zone, highlighted by white arrows, continues downward vertically to an unknown depth level without decreasing intensity (maybe more than 5 m below the ground surface). Considering the information obtained from the results of the

excavations next to the investigation area, the results of the two-dimensional inversion seemed to be more logical. These anomaly zones coincide with two grids of the archaeological trenches conducted by excavation (highlighted by yellow grids in Fig. 4). Some graves and archaeological remains were unearthed in these grids since 2009. The view of the surveyed area before and after the excavations, trenches, and close-up views of the some unearthed material in these grids are shown in Fig. 7a, b, c, d and e, respectively. These grids have a surface elevation of 8.65 m and 7 tile graves, dated as 1-2th centuries AD, made of flat or trapezoidal (convex) tiles were found between the elevations of 8.65 - 7.85 m (Kasapoğlu, 2007) (Fig.8a). The anomaly of these thin remains can be clearly seen from Fig. 9 highlighted with thick white arrow in the resistivity tomogram of RZN 1.
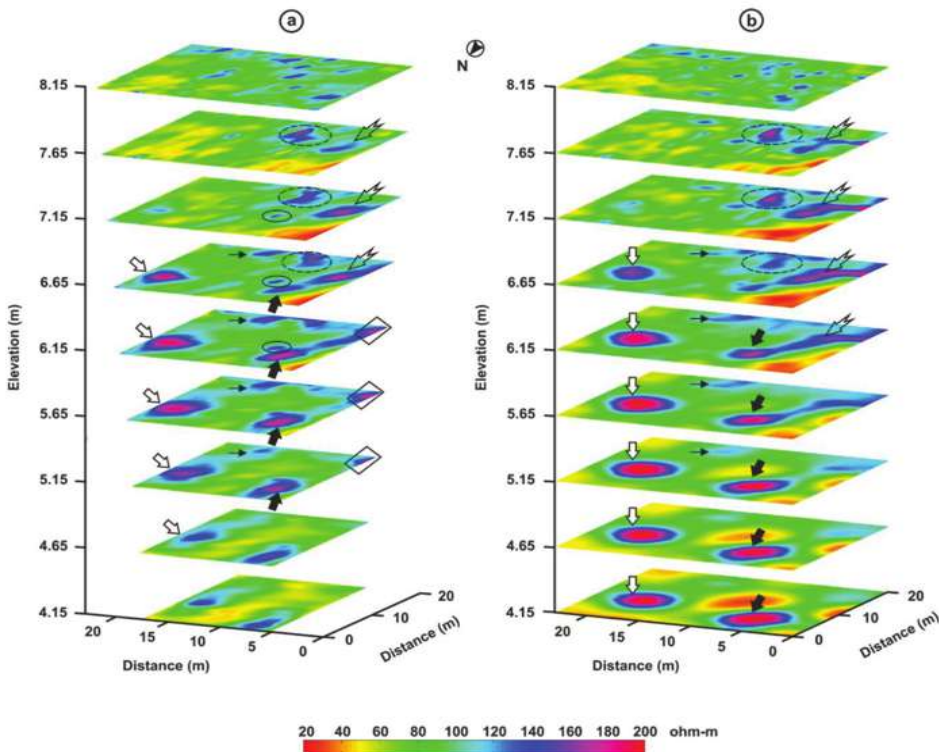

Figure 6. Geoelectrical imaging of the surveyed area with depth slices obtained from two-dimensional inversion (a) and three-dimensional inversion approach (b) (note that the vertical axes were exaggerated for the illustrations).

Figure 7. The views of the surveyed area before and after the excavations (a, b), archaeological trenches (c), and the close-up views of the some unearthed materials coinciding with high resistivity zones (d, e).
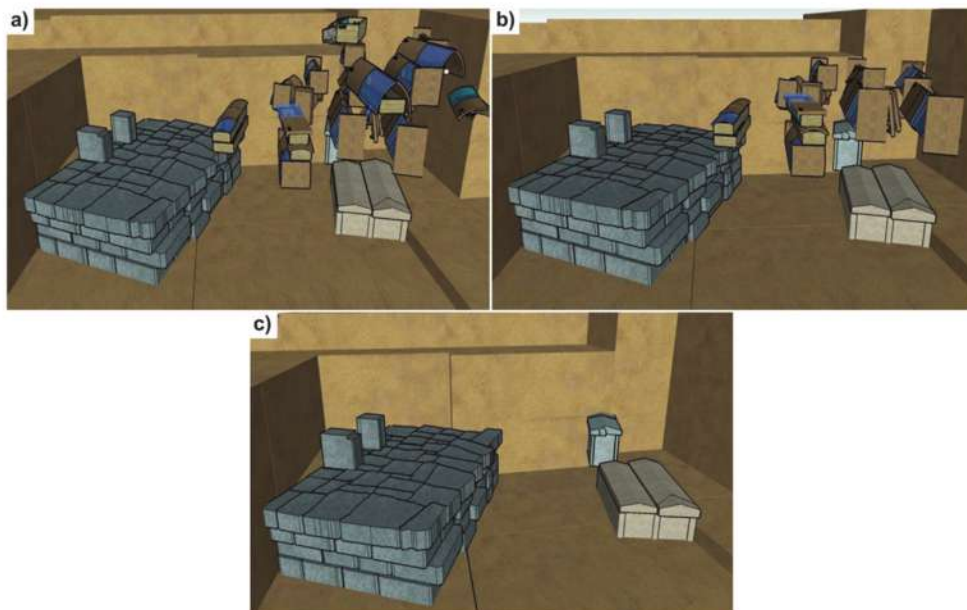

Figure 8. Three-dimensional illustrations of unearthed archaeological structures coinciding with high resistivity zones (a, b and c).
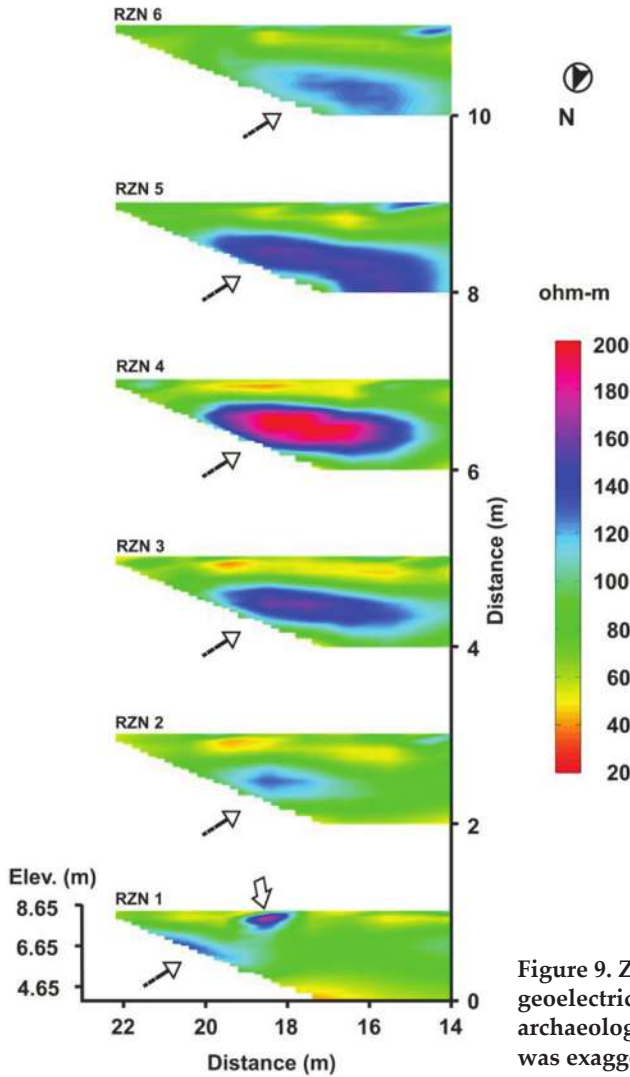
Figure 9. Zoomed views of the first six geoelectrical resistivity slices coinciding with archaeological trenches (Note that the long axis was exaggerated for the illustration).

Additionally, 11 tile graves, mostly dated as the 1st century AD, that had been formed by flat and trapezoidal (convex) tiles like the graves nearly above them were found at the elevations of 7.85 – 6.65 m (Fig. 8b), and these parts of the trenches represent slightly high resistivity values in the tomogram of RZN 1, marked with thin arrow (Fig. 9). Therewithal, at the elevations of 6.45 – 4.95 m one stone-chest tomb (Kasapoğlu, 2007) and two marble-chest tombs, which are thought to belong to the Hellenistic Period, were uncovered. Some golden jewelry were also found in these tombs. High resistivity

zones in RZN 2 and 3 highlighted with arrows point out these remains (Fig. 9). At the elevations of 5.95 – 4.95 m just in the south of those graves, an architectural remain formed by sandstone plates was unearthed. The traces of this platform marked by arrows in Fig. 9 can be clearly seen from the tomograms of RZN 3 through RZN 6. The dimension of the structure is about 5.50 x 3.30 x 1.00 m and was made of four rows of sandstone plates, each having about 0.25 m thickness, placed successively (Fig. 8c). Due to the knowledge obtained from the graves unearthed around this

platform, it is believed that this remain belongs to the 6 – 5th century BC. Although the meaning of this platform is yet not certain, the information that will be obtained from the next seasons' excavations will help us to understand the usage purpose of this architectural structure.

CONCLUSIONS

This paper presents the preliminary results of the first archaeogeophysical survey performed in the south necropolis at the ancient city of Parion. The geophysical study focused on quasi and semi-fully three-dimensional evaluation of geoelectrical imaging data, composed of relatively dense parallel two-dimensional transects in reconstructing the subsurface electrical resistivity properties of the necropolis area, by ERT technique. By taking the advantages of two- and three-dimensional inversion approaches and also the multi-dimensional volumetric visualization techniques, the produced electrical resistivity tomograms were interpreted in a more accurate manner. Additionally, excavated archaeological trenches in two neighboring grids coinciding with the geophysical survey area revealed the high degree of accordance between the man-made archaeological structures and the geoelectrical anomaly zones having high resistivity values. In the light of the obtained results, the other high resistivity anomaly zones observed in resistivity tomograms marked by symbols are thought to be the buried archaeological remains with a high degree of probability. Thus, these zones are the most promising locations for the following archaeological excavations. Summarizing, it can be concluded that the non-destructive and non-intrusive ERT technique and the use of multi-dimensional volumetric visualization methods are very suitable and effective strategy for the exploration of buried archaeological remains.

ACKNOWLEDGEMENTS

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