Mo PA2 05

ERT and VLF Measurements Contributing to the Extended Revelation of the Ancient Town of Trapezous (Peloponnesus, Greece)

J.D. Alexopoulos* (National & Kapodistrian University of Athens), S. Dilalos (National & Kapodistrian University of Athens), A. Tsatsaris (Technological Educational Institute of Athens) & S. Mavroulis (National & Kapodistrian University of Athens)

SUMMARY

A geophysical survey was carried out in the archaeological site of Kyparissia (Megalopolis, Greece) applying the Very Low Frequency technique, as preliminary combined with highly detailed Electrical Resistivity Tomography. Settlements of the ancient city of Trapezous (limestone slabs 0.5m height x 0.5m width) have already been uncovered from the local Ephorate of Prehistorical and Classical Antiquities, revealing a regularly planned town of the classical period. The geophysical research was performed at the non-excavated area of the plain, vicinal to the already exposed remaining, where, according to the expected geometry, the buried walls and drainage channel should be continued to. Fifteen parallel sections with distance 5m and spacing interval 1m were carried out. The processing with the application of Fraser and Karous-Hjelt filters led to the construction of respective maps, indicating some resistive lineation which could be a result of the buried settlements. Moreover, two detailed ERT sections were carried out with spacing 0.20 and 0.25m and total length 200m. The processing using the robust inversion, which is indicated for such environments, adumbrates quite clearly a sharp resistive target that could be the limestone slabs of the ancient walls or drainage channels, confirming the expected lineated geometry of the town.

Introduction

The archaeological site of Kyparissia, where the ruins of the ancient city of Trapezous are found (Karapanagiotou, 2005), is located in the northwestern part of the Megalopolis basin (Arcadia, Central Peloponnese), within 8 km northwest of the Megalopolis town and 0.5 km northeast of the Kyparissia village (Fig. 1). The local archaeological 39th Ephorate of Prehistorical and Classical Antiquities has already conducted preliminary rescue excavations as the mining activity of Greek Electrical Company is extended.

The excavations revealed a part from a rare regularly planned town from the classical period. The general picture so far reveals six (6) parallel streets 4.6 m wide. With a direction W/SW to E/NE, traversing the central and southern zone of the area and creating six building blocks (Karapanagiotou, 2005). Each block has 54 m width constructed by two (2) rows of houses separated by a drainage channel 1.5 m wide. The pre-mentioned streets were made from packed earth while at the sides there were another drainage channel and a pavement made of limestone slabs. The excavations revealed the houses' stone walls until a height of 0.4-0.6 m. made from limestone slabs and packed earth, while their width was up to 0.4-0.5 m (Karapanagiotou, 2005). Both internal and external walls had almost the same characteristics. Based on the above archaeological data, a geophysical survey has been conducted in order to contribute to the adumbration of more ancient settlements extending to the vicinal unexplored area (west) of the already uncovered town.

Geological Setting

The area of the ancient Trapezous comprises post-alpine formations of Pleistocene age and alpine formations of the Pindos geotectonic unit (Athanassiou et al., 1972; Marinos et al., 1959, Lüttig and Marinos 1962, Gold, 1962, Vinken, 1965, Papadopoulos et al., 1997) (Fig. 1). In particular, the eastern part of the ancient city is founded on a Pleistocene fluvial terrace of Thoknia-Potamia formation consisting of silt, clays, sands and loose conglomerates (Fig. 1). In the western and northern part of the ancient city, Horemi formations including alternations of marls, clays and lignite beds with intercalations of sands and layers of loose conglomerates overlie the Pleistocene terrace of Thoknia-Potamia formation (Fig. 1).

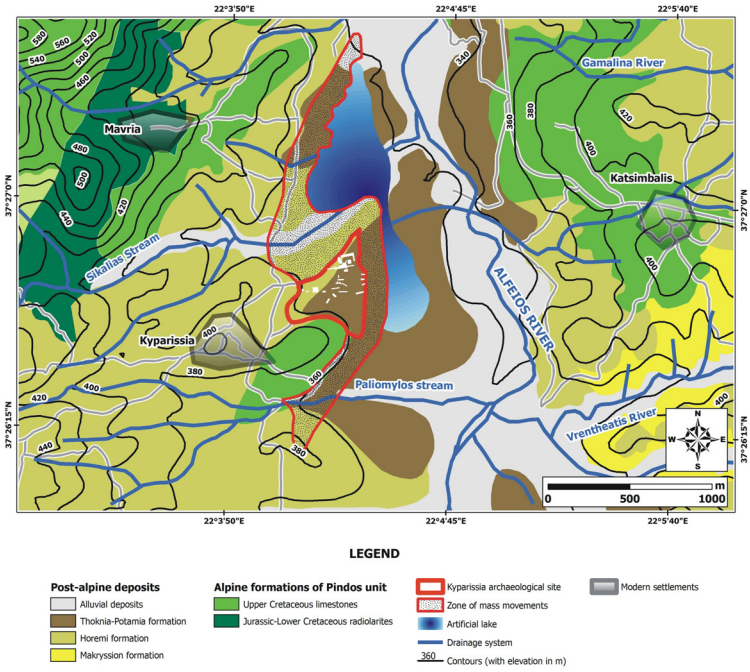

Figure 1a *Geological map of Kyparissia archaeological site.*

Figure 1 b,c *Limestone slabs of moderate size (0.5mx0.5m) have been used the ancient buildings.*

Methodology

Having in mind all the uncovered archaeological settlements, their regular geometry (parallel roads and rows of houses) and the contrast of the surrounding geological environment (post-alpine formations) with the structural material of the town's walls (limestone slabs 0.5x0.5m average). The ERT and VLF geophysical methodologies were carried out, applied successfully in the past at similar research sites (Abbas M.A. 2012, Khalil M.A. 2010).

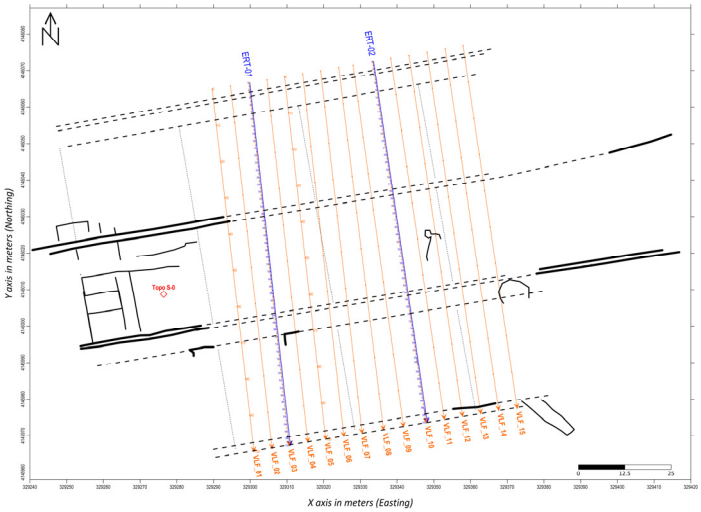

Figure 2 *Map of already uncovered ancient settlemets (black lines) and expected extensions based on the geometry (black dashed lines). The geophysical survey is also illustrated. The blue lines stand for the ERT sections (2) and the orange lines for the VLF sections (15).*

First, we applied the Very Low Frequency (VLF) method consisted of 15 parallel sections with interval 5m and data spacing 1m. The total length of each section was 100m (Figure 2). Moreover for highest accuracy the Electrical Resistivity Tomography (ERT) was carried out and more specifically two sections of total length 200m with electrode spacing 0.20m and 0.25m. The spacing was decided based on the dimensions of the already uncovered wall settlements (0.5x0.5m). From these two ERT sections we gathered 5.833 data points.

In reference of the VLF measurements, we applied the Fraser (Fraser 1969) and the Karous-Hjelt filters (Karous, M. and Hjelt, S.E., 1983) with KHFFILT (Pirttijarvi, M., 2004), in order to enhance the anomalies caused by possible subsurface ancient settlements. Topographical corrections were not applied since the study area was relatively flat. The Fraser filter transforms the zero-crossing into peaks, indicating the centre of the conductive structures under positive peaks and the centre of the resistive ones above negative peaks. From the application of the Karous-Hjelt filter we obtain relative current density pseudo-sections. Theoretically, the ancient walls made of limestones (resistive material) are expected to be indicated as negative peaks with Fraser filter and with lower values of relative current density (low resistivity). For better illustration of possible indications of ancient remainings and their direction, we created horizontal maps/slices (Fraser 1969) after the application of Fraser (Figure 3a) and Karous-Hjelt filters for the depths of 1 and 2m. (Figure 3b). Some resistive zones with basic parallelism have been delineated.

The processing of the data from the two ERT sections was performed with Res2DInv software. For these sections we measured with Differential GPS (DGPS) the coordinates and elevation of each electrode for higher accuracy of the inversion and illustration of the subsurface micro-structure. The most indicative inversion method used for archaeological environments (sharp and shallow targets) is robust (Drahor, M.H., 2011), which gives realistic images of possible ancient settlements. Indeed, after the inversion lots of well-discernible resistive targets (>120 Ohm.m) seem to appear that could be interpreted as limestone slabs from the covered settlements.

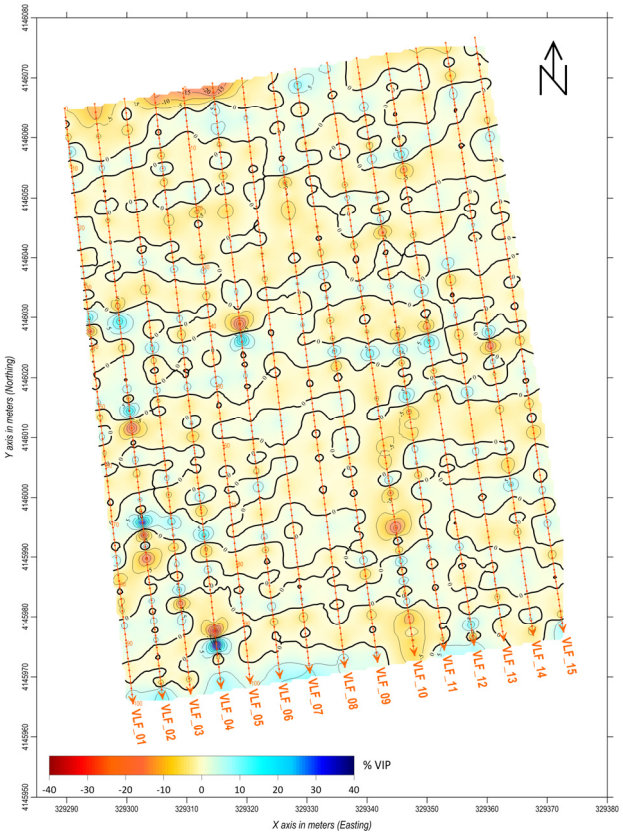

Figure 3a *Fraser filter map .*

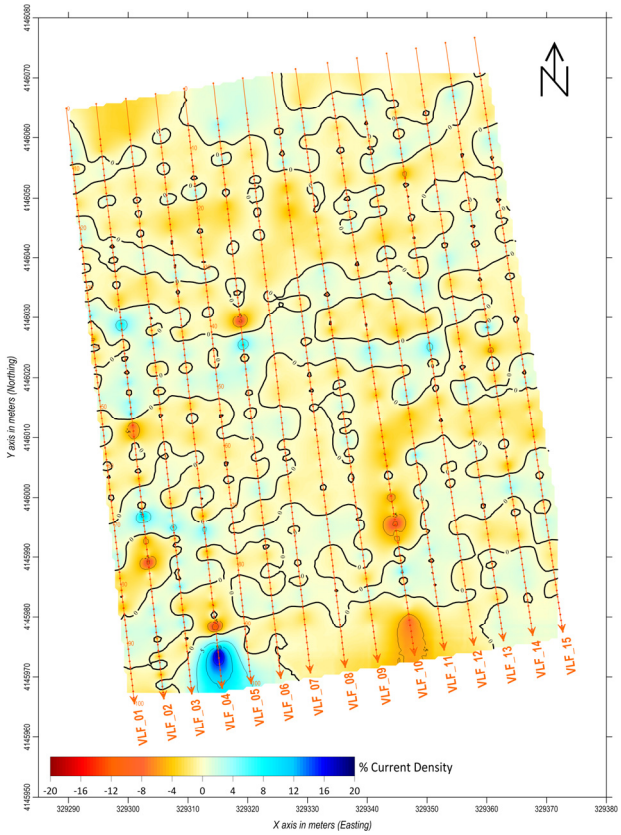

Figure 3b *Karous-Hjelt filter map for 2m depth.*

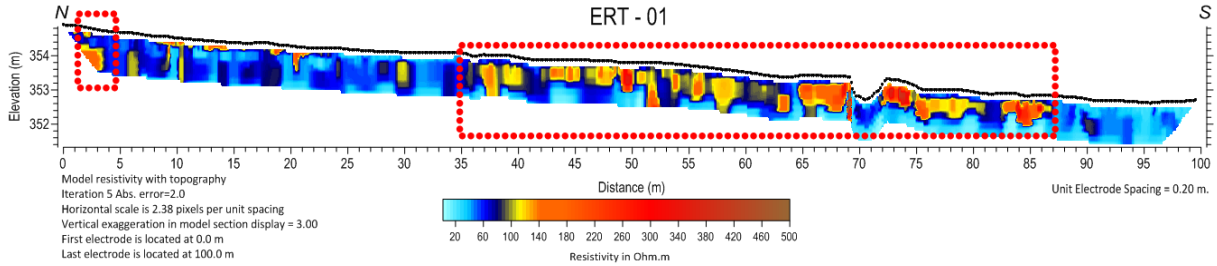

Figure 4 *Inversion model of ERT-01 (Vertical exaggerated 1:3). RMS=2%, 5th iteration, electrode spacing 0.2m.*

Discussion/Conclusions

Taking into consideration all the geophysical data we had gathered and processed using the VLF and ERT methodologies along with the archaeological data from the vicinal revealed part of the town from the classical period and especially its well-formed geometry of structure, we came along with some linear zones which could indicate buried extensions of ancient settlements. These indicated lineations (figure 5) are highly possible to be either remaining walls of the houses either remaining of the drainage channels and pavements of the roads' sides, as all of them were built with well-formed resistive limestone slabs.

Acknowledgements
The authors would like to thank Mr. Michelioudakis Dimitrios for his contribution at the field measurements. Moreover we would like to thank the Director of the 39th Ephorate of Prehistorical and Classical Antiquities Anna-Vasiliki Karapanagiotou for the guidelines and Mr Grigorakaki Grigori and Mr Fritzila Stamati for the useful conversations.

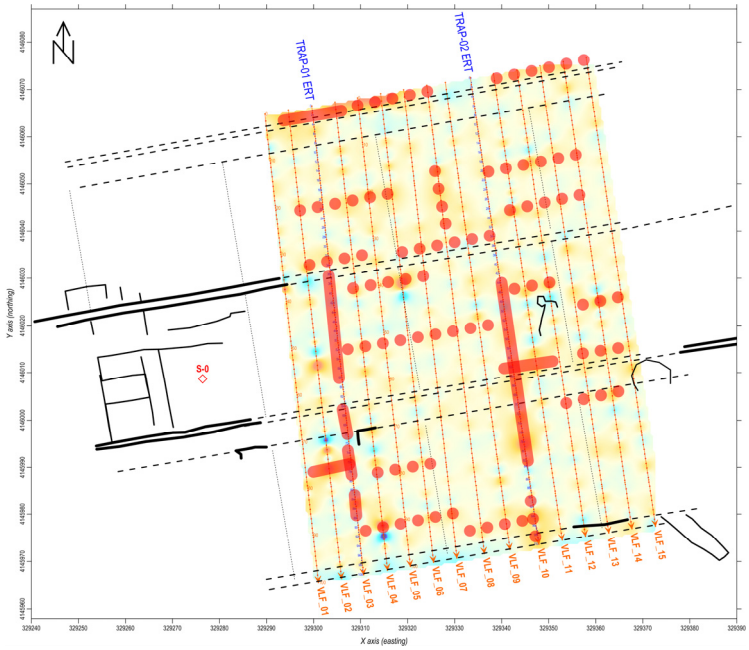

Figure 5
Revealed lineations from the VLF interpretation. Continuous red lines stand for high possibility to indicate ancient settlements while the dashed for lower possibility.

References

Abbas, M.A., Khalil, M.A., Massoud, U., Santos, F.M., Mesbah, H.A., Lethy, A., Soliman, M. and Ragab El Said, A. [2012] The implementation of multi-task geophysical survey to locate Cleopatra Tomb at Tap-Osiris Magna, Borg El-Arab, Alexandria, Egypt "Phase II". *NRIAG Journal of Astronomy and Geophysics*, **1**(1), 1-11.

Athanassiou, A., Kallergis, G. and Kaperonis, N. [1972] Geological and deposit investigation of Marathousa lignite field (Megalopolis). *Bull. Geol. Soc. Greece*, **IX**, 1-36.

Fraser, D.C. [1969] Contouring of VLF-EM data. *Geophysics*, **34**(6), 958-967.

Drahor, M.H. [2011] A review of integrated geophysical investigations from archaeological and cultural sites under encroaching urbanization in Izmir, Turkey. *Physics and Chemistry of the Earth*, **36**, 1294-1309.

Gold, O. [1962] Das neu entdeckte griechische Braunkohlen Vorkomen von Megalopolis. *Braunk. Warm. Energ.*, **14**, 169-180.

Karapanagiotou, A.V. [2005] Preliminary Notices on the Discovery of a Planned, Classical Town near Kyparissia, Gortynia. In: Östby (Eds) Ancient Arcadia. *Papers from the Third International Seminar on Ancient Arcadia, Norwegian Institute at Athens*, 7-10 May 2002.

Karous, M. and Hjelt, S.E. [1983] Linear filtering of VLF dip-angle measurements. *Geophysical Prospecting*, **31**, 782-794.

Khalil, M.A., Abbas, A.M., Monteiro Santos, F., Mesbah, H.S.A. and Massoud, U. [2010] VLF-EM study for archaeological investigation of the labyrinth mortuary temple complex at Hawara area, Egypt. *Near Surface Geophysics*, **8**, 203-212.

Lüttig, G.W. and Marinos, G. [1962] Zur Geologie des neuen Griechischen Braunkohlen-Lagerstaette von Megalopolis. *Braunkohle*, **14**, 222-231.

Marinos, G., Anastopoulos, J. and Papanicolaou, N. [1959] Das Braunkohlebecken von Megalopolis. *Inst. Geol. Subs. Res.*, **3**, 1-51.

Papadopoulos, P., Luettig, G. and Vinken, R. [1997] *Geological Map of Greece, Scale 1:50.000, Megalopolis Sheet*. Institute of Geology and Mineral Exploration, Athens, Greece.

Pirttijarvi, M. [2004] *Manual of the KHFFILT program; Karous-Hjelt and Fraser filtering of VLF measurements, Version 1.1a.* University of Oulu, Finland, 6.

Vinken, R. [1965] Stratigraphie und Tektonik des Beckens von Megalopolis (Peloponnes, Griechenland). *Geologisches Jahrbuch*, **83**, 97-148.