Tu PA2 01

Application of Geoelectrical Techniques in the Investigation of a Coastal Sand Dune Field

J.D. Alexopoulos* (National & Kapodistrian University of Athens), S. Dilalos (National & Kapodistrian University of Athens), S.E. Poulos (National & Kapodistrian University of Athens), G. Ghionis (National & Kapodistrian University of Athens) & S. Mavroulis (National & Kapodistrian University of Athens)

SUMMARY

A geophysical research was carried out to investigate the lithostarigraphic substratum characteristics of the dune field of the central Kyparissiakos Gulf (W. Peloponnese, Greece), which is characterised by the presence of four dune lines. For this purpose, the geophysical techniques of Electrical Resistivity Tomography (ERT) and Vertical Electrical Soundings (VES) were applied, along with detailed morphological mapping and the collection of geological and geomorphological information. The processing of the geophysical data that were collected from two ERT soundings, perpendicular to the general direction of the dune lines, and seven geoelectrical soundings revealed four geoelectrical layers with the two surficial resistive layers adumbrating the extent and thickness of the four sand dune ridges and the associated slags. The third layer, corresponding to the underlying geoelectrical formation of 50-75 Ohm.m, is interpreted as a layer of transgressive Holocene deposits saturated with fresh water, while the deepest geoelectrically identified layer seems to correspond to the “Neda” formation, which consists of marls, sandy marls and conglomerates. It is concluded that the combined application of the aforementioned techniques has the potential to provide valuable data for the investigation of complex coastal depositional environments.

Introduction

Dune fields are not only one of the most dynamic ecosystems closely related to the evolution of the beach zone but also highly sensitive to any change either natural and/or human-induced. The scope of the present geophysical research is to investigate the natural processes that control the formation and evolution of the dune field of the Kyparissiakos Gulf (NE Ionian Sea). The study is focused on the lithostarigraphic substratum characteristics, on top of which the Holocene dune field has developed during the last slow (~1 mm/year) phase of sea level rise (Lambeck 1996). To this end, geophysical techniques (ERT, VES) were applied along with detailed morphological mapping and the collection of all the available geological and geomorphological information.

Geological and Coastal Setting

The study area at Kakovatos is located in the central part of the Kyparissiakos Gulf and is characterised by the presence of a wide (>1000 m) dune field, consisting of four shore-parallel dune lines. From the neotectonic point of view, the Kakovatos area is located in the western part of the E-W trending Minthi Mt. horst (1344 m) consisting mainly of alpine formations of the Pindos unit, which consists of a Mesozoic pelagic sequence and a Paleogene flysch (Fountoulis 1994, Mariolakos et al. 1998). Post-Alpine sedimentary sequences lie unconformably on the alpine formations and comprise continental and marine Pliocene and Quaternary deposits (Fountoulis 1994, Fountoulis and Moraiti 1994 and 1998).

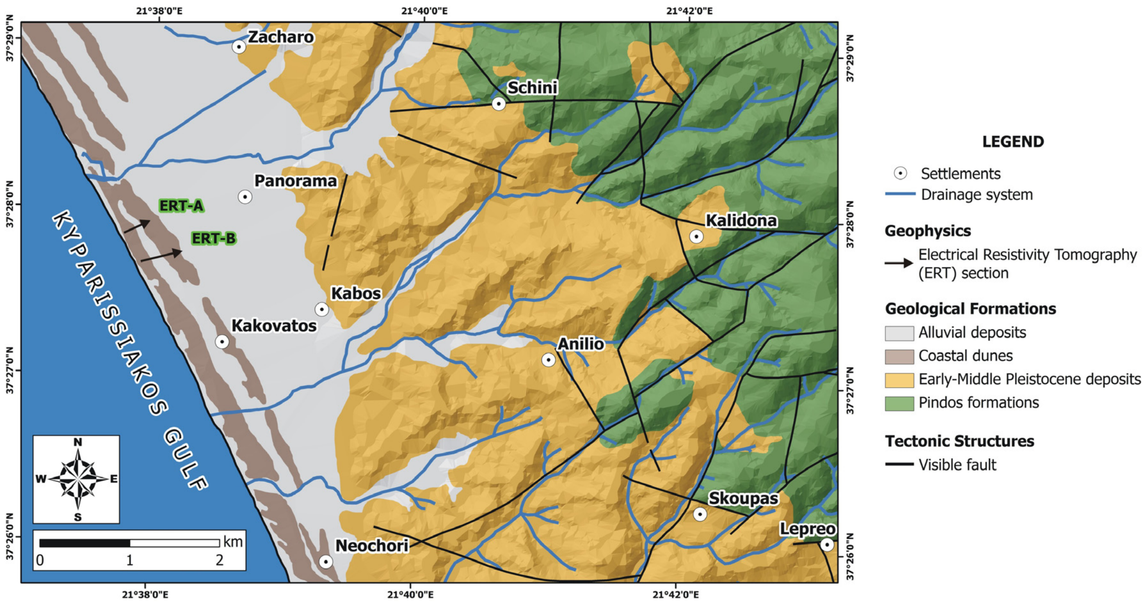

Figure 1 *Simplified geological map of the study area along with the location of the geophysical measurements (ERT-A and ERT-B).*

The Early-Middle Pleistocene and Holocene deposits in the central part of Kyparissiakos Gulf (Fig. 1) consist of marls, sandy marls and polymictic conglomerates with thickness greater than 350 m, with the cobbles originating from limestones (either from the Pindos and/or Gavrovo units), cherts and flysch of the Pindos unit, as well as from metamorphic rocks (Fountoulis 1994, Mariolakos et al. 1998). The Early-Middle Pleistocene deposits are found at altitudes up to 400 m in the Lepreon area (south of Kakovatos) and up to 200 m in the Anilion area (east of Kakovatos), gently dipping (15-20^{o}) to the North (Fountoulis 1994, Mariolakos et al. 1998). Alluvial deposits consist of loose sand, gravel, cobbles and clays while dunes include medium to fine sand and other material of aeolian origin (Karamousalis et al. 2007).

Figure 2 *Coastal sand dune ridges.*

The four dune lines, comprising the central Kyparissiakos Gulf dune field (Ghionis and Ferentinos, 1992, Karamousalis et al. 2007, Poulos et al. 2012), lie at distances from the coastline of 20-40 m (1st), 140-180 m (2nd), 450-470 (3rd) and up to 650 m (4th). Elevations in the dune field vary between 2 and 13 m, with the highest corresponding to the 3rd dune line.

Applied Methodology and Results

In the context of the present investigation, a geophysical survey was carried out with the application of geoelectrical methods commonly used in coastal environments (Balia *et al.* 2003, Khalil 2012, Poulos *et al.* 2009). Thus, two Electrical Resistivity Topography (ERT) sections were carried out (Fig 1), perpendicular to the general direction of the dune lines and across the first three dunes, in order to provide detailed adumbration of the subsurface resistivity distribution up to 40-50 m depth. In addition, seven Vertical Electrical Soundings with the Schlumberger array were carried out, lined in two sections located almost along the aforementioned ERT lines, for deeper investigation of the subsurface litho-startigraphic structure and the identification of the subsurface bedrock. The measurements were carried out during the early spring, after the rainy period, in order to reduce the high resistivity contrast.

A detailed topographical-morphological map of the dune field was produced and the positions of all the geophysical applications were determined, using the high-accuracy real-time kinematic technique of differential GPS.

The ERT measurements were processed with the Res2DInv software, while the Vertical Electrical Soundings with the Ix1D software and their 1-D geoelectrical models have been generated. For a combined interpretation, these models have been embedded in the final inversion model of the ERT (Fig. 3). In addition, the core log of G1 borehole located on the landward side of the 1st dune line (Fig 3) has been utilised for the interpretation of the geoelectrical measurements, along with the Y1 hydro-borehole, which is providing fresh water throughout the year.

As shown in Figure 3, after the combination of the ERT model with the 1-D VES models, high resistivity surficial formations (>1.000 Ohm.m) were identified, with a maximum thickness of 5 m. Relatively more conductive zones (100-150 Ohm.m) exist between these highly resistive surficial areas. An underlying, geoelectrically rather homogenous, formation of 50-75 Ohm.m extends to depths of 15-55 m (shallower in the area close to the coastline up to the start of the 2nd dune). The deepest geoelectrical formation investigated (11-32 Ohm.m) is mainly defined by the VES processing models (greater depths of investigation), while at the tomogram it is illustrated only at the left bottom edge.

As shown in Figure 3, the results of the soundings models correlate very well with the high accuracy resistivity tomograms and are quite informative about the distribution of the resistivity in depths greater than the limits of the ERT investigations.

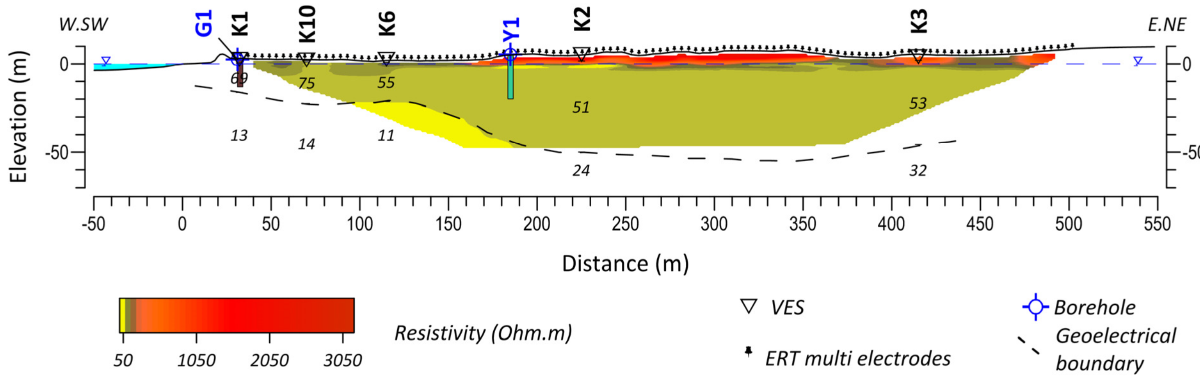

Figure 3 *ERT-B (inversion model) with VES 1-D interpretation models embedded (ERT RMS 11%, 6th iteration).*

Interpretation and Discussion

The combined geophysical results illustrated in Figure 3 contribute to the identification of the lithological-geological structure of the study area.

The surficial highly resistive zones (>1.000 Ohm.m) seem to correspond to the dry sand dune sediments. The 4 different ridges are readily identifiable in the geoelectrical section (figure 3), with the first ridge located at a distance of 20 m from the coastline, the second lying at 165-370 m with thickness up to 5m, the third at 400-430 m and the fourth appearing at 460 m. The surficial lower resistivity zones (100-150 Ohm.m) between the ridges correspond to slags, marine-lagoonal deposits usually located between sand dune ridges, rich in fine material.

The underlying geoelectrical formation of 50-75 Ohm.m is interpreted as a layer of transgressive Holocene deposits, originated from the sea transgression. The thickness varies from 15 m near the coastline to almost 55 m under the 2nd and 3rd sand dune. Taking into account the relatively low resistivity of this formation and the fact that the hydro-borehole Y1 provides fresh water (5 m^3/h), the formation seems to be saturated with fresh water, indicating a lateral feed of the aquifer. Moreover, based on the description of the borehole core G1, interleaved sandy and muddy layers are expected in this formation.

Finally, the deepest geoelectrically identified layer of the section has even lower resistivity values (10-30 Ohm.m) and is interpreted to be the "*Neda*" formation, consisting of marls, sandy marls and conglomerates. The marls, as a non-permeable formation, not only block the sea water intrusion, but also contribute to the saturation of their overlying transgressive formation with fresh water from the hinterland.

Conclusions

The application of both the Electrical Resistivity Tomography (ERT) and the Vertical Electrical Soundings (VES) techniques, combined with in situ geo-hydrological data, provide an efficient tool for the investigation of coastal complex depositional environments (e.g. dune fields), including their aquifers.

Acknowledgements

The authors would like to thank Mr. Michelioudakis D., Mr. Ntavarinos G., Ms Kaplanidi H. and Ms. Giannouli D. for their contribution at the field measurements. The research was funded by the UoA Special Account for Research Grants (contract 70/3/11078).

References

Balia, R., Gavaudo, E., Ardau, F. and Ghiglieri, G. [2003] Geophysical approach to the environment study of a coastal plain. *Geophysics*, **68**(5), 1446-1459.

Fountoulis, I. [1994] Neotectonic evolution of the Central-Western Peloponnese. *PhD thesis, Faculty of Geology and Geoenvironment, GAIA, 7, National and Kapodistrian University of Athens*, 386. (*in Greek*)

Fountoulis, I. and Moraiti, E. [1994] Sedimentation, paleogeography and neotectonic interpretation of the post-alpine deposits of the Kyparissia–Kalo Nero basin (W. Peloponnese, Greece). Proceedings of the 7th Congress of Geological Society of Greece, *Bulletin of the Geological Society of Greece*, **XXX**(2), 323-336 (*in Greek*).

Fountoulis, I. and Moraiti, E. [1998] Sedimentation paleogeography and neotectonic interpretation of the post-alpine deposits of the Neda basin Central-Western Peloponnese, Greece. Proceedings of the 8th Congress of Geological Society of Greece, *Bulletin of the Geological Society of Greece*, **XXXII**(1), 251-262 (*in Greek*).

Ghionis, G. and Ferentinos, G. [1992] The morpho- and hydrodynamics of the coastal zone of the gulf of Kyparissia. *33rd Congress-Plenary Assembly of CIESM*, Trieste, Italy, Rapp. Com. Int. Mer Médit., **33**, 134.

Karamousalis, T., Poulos, S., Maroukian, H. and Ghionis, G. [2007] Geomorphological characteristics of the sand dune field of the central Kyparissiakos gulf. *Proceedings of the 11th International Congress of the Geological Society of Greece*, **XXXX**(4), 1530-1537, Athens.

Khalil, M.H. [2012] Reconnaissance of fresh water conditions in a coastal aquifer_synthesis of 1D geoelectric resistivity inversion & geohydrological analysis. *Near Surface Geophysics*, **10**, 427-441.

Mariolakos, I., Sabot, V., Fountoulis, I., Marcopoulou-Diacantoni, A. and Mirkou, R. [1998] Neotectonic map of Greece at scale 1:100000, Filiatra sheet. *Earthquake Planning & Protection Organization*, Athens.

Lambeck, K. [1996] Sea-level change andshoreline evolution in Aegean Greece since Upper Palaeolithic time. *Antiquity*, **70**, 588-611.

Poulos, S.E., Alexopoulos, J.D., Karditsa, A., Giannia, P., Gournelos, T. and Livaditis, G. [2009] Formation & evolution of the Ververonda Lagoon (Porto-Heli Region, SE Argolic Gulf) during historical times, on the basis of geophysical data and archaeological information. *Zeitschrift für Geomorphologie*, Supplementary Issues, **53**(1), 151-168.

Poulos, S., Gaki-Papanastasiou, K., Gialouris, P., Ghionis, G. and Maroukian, H. [2012] A geomorphological investigation of the formation and evolution of the Kaiafas sand-dune field (Kyparissiakos Gulf, Ionian Sea, eastern Mediterranean) in the Late Holocene. *Enviromental Earth Sciences*, **66**(3), 955-966.