THE 20TH INTERNATIONAL GEOPHYSICAL CONGRESS & EXHIBITION OF TURKEY
25-27 November 2013 ▪ Rixos Lares Hotel, Antalya

Tectonic regime of the southern, central part of the Mygdonia basin by applying 3D TEM modeling

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Abstract: *The transient electromagnetic method (TEM) has gained increasing popularity over the last years especially in hydrogeophysical and geotectonic applications. Many portable systems for TEM measurements are commercially available. The TEM-Fast 48HPC was used for collecting the soundings. The main purpose of this work was the definition of the geotectonic characteristics of the study area. Detailed geological survey was applied prior the geophysical measurements and all the available borehole logs were collected. All the data integrated to produce a secure and reliable geotectonic model of the area under investigation. Joint systems of faults was detected which are in aggreement with the recent geophysical and tectonic studies in the area. This work shows clearly the applicability and efficiency of the TEM in studying complex geotectonic environment.*

Keywords: *Volvi Lake, TEM, Tectonic, 3D TEM modeling*

INTRODUCTION

The geophysical techniques offer a suitable method for depicting the tectonic and other subsurface characteristics of an area under investigation. Among all geophysical techniques (Gravity, GPR, Magnetics, Resistivity, Seismic refraction, etc.) electromagnetic methods are undoubtedly one of the leading ones in the exploration and management of sedimentary environment (Barsukov et al. 2007). TEM method has been used worldwide for many environmental surveys (including geotectonic studies) since several theoretical studies on the applicability of the method for environmental investigation was undertaken. The transient electromagnetic (TEM) method is a fast and cost-effective method for exploring the subsurface and is of interest in this work.

This paper describes a recent evaluation study of the applicability of a simple-fast-robust-portable TEM system, the TEM-Fast 48HPC developed by AEMR Ltd, using single loop 50x50m (coincident loop) for shallow-depth geological mapping for depicting the tectonic regime of the southern part of the central part of the Mygdonia basin in northern Greece, close to Thessaloniki city.

GEOLOGICAL and TECTONIC SETTINGS of THE STUDY AREA

The Mygdonian basin, situated between the two lakes Volvi and Lagada ca. 45 km northeast of Thessaloniki, is a Neogene graben structure with significant seismic activity along distinct normal fault patterns (Karagianni et al. 1999). Fluvioterrestrial and lacustrin sediments (approximately 200-500 m thick) overlie the basement composed of gneiss schist. The faults in the broader area have E-W, NW-SE, and NE-SW directions. The fault of Gerakarou-Nikomidino-Stivos-Peristerona is at the area of study and in particular we are interested on revealing any of the shallow normal faults close to the surface using geophysical data. Those faults are supposed to follow the general strike direction of the fault that is almost E-W, however strike directions of WNW-ESE to ENE-WSW are also found in the area.

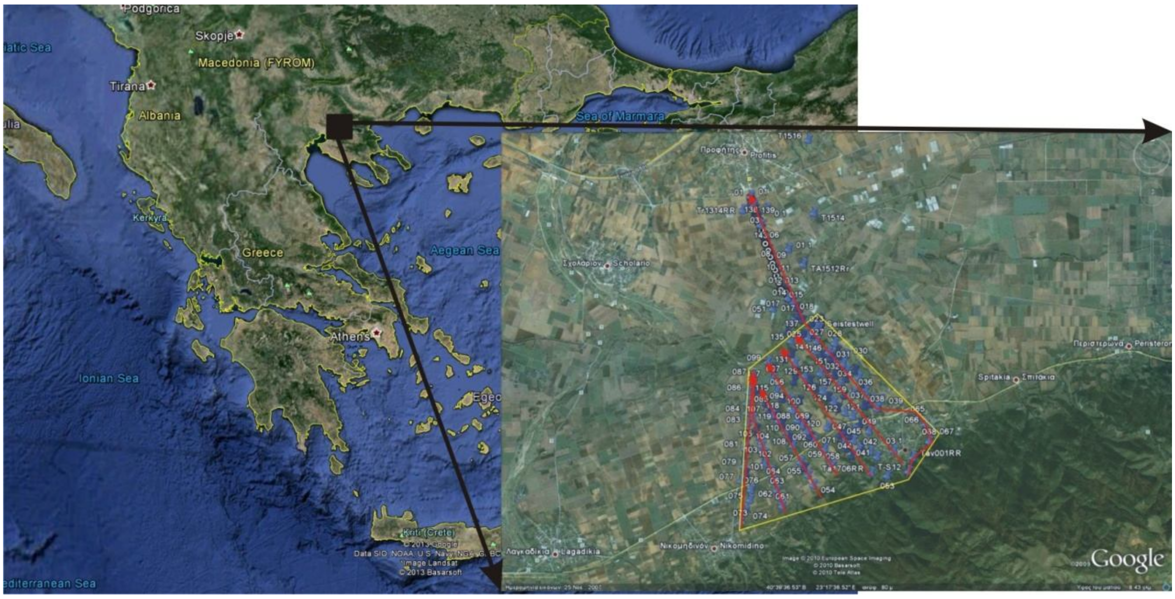

Figure 1 The study area (black filled rectangle) and the locations where the TEM soundings were collected are presented (GoogleEarth screen shot). Yellow polygon defines the area used for 3D TEM modeling.

GEOPHYSICAL METHOD USED

The TEM method has been used in environmental studies over the last decade. A detailed description of the method is given by Danielsen et al. (2003) and it belongs to the category of controlled source EM methods. The TEM method makes use of a direct current transmitted into the transmitter (Tx) loop lying on the ground creating a primary, stationary magnetic field. The direct current is switched off which induces an eddy current system in the ground. The current system will decay and further induce a secondary magnetic field that is measured in the receiver (Rx) coil. Since the secondary response is measured in the absence of primary field, the sensitivity to errors of Tx/Rx geometry is dimishing. The TEM method has excellent resolution of conductive layers at depth, whereas the resolution of resistive layers is limited (Christensen and Sørensen, 1998).

Data Acquisition

The TEM surveys were carried out by using a single square loop (used as transmitter and receiver) configuration of dimensions 50x50m, allowing an interpretation of the data in terms of the subsurface resistivity structure down to a depth of a maximum of 100-120m. The system was set to transmit current up to 4 Amp with 32 active time gates from 4 μs to 1024 μs and the stacking time about 3 minutes. In total, 485 soundings (Figure 1) were collected in 159 locations, over a period of two weeks (August 2010). Several soundings were taken at each location in order to minimize the noise and get the most information from site. The root mean square (rms) error of the final data set was less than 4%.

TEM MODELING

The TEM-RES processing commercial software was used for processing the raw data. The raw data were tested for their quality (noisy data or “contaminated” data from superparamagnetic effect) and poor quality data (soundings or points onto the TEM curve) were edited or removed depending on their significance.

Initially, for each sounding, the best apparent resistivity versus (vs) time curve is selected in order to produce a 1D horizontal layered model. Processing of the raw TEM data yields a vertical profile of apparent formation's apparent resistivity versus depth.
Two ways were followed for 1D modeling of the TEM data. The data were transformed from apparent resistivity with time ($\rho_\alpha(t)$) to resistivity change with depth ($\rho(h)$) or the data were inverted using an initial model and defining the appropriate inversion parameters into the inversion algorithm (Barsukov et al. 2007).

3D modeling of TEM data - Model construction - Processing steps

The method used for calculating the electromagnetic field in the time domain for a 3D inhomogeneous subsurface was based on the theory and algorithm originally presented by Druskin and Knizhnerman (1988). The grid can be irregular and each grid node get the value of the field' derivative at specific location ($E_{i,j,k}$).

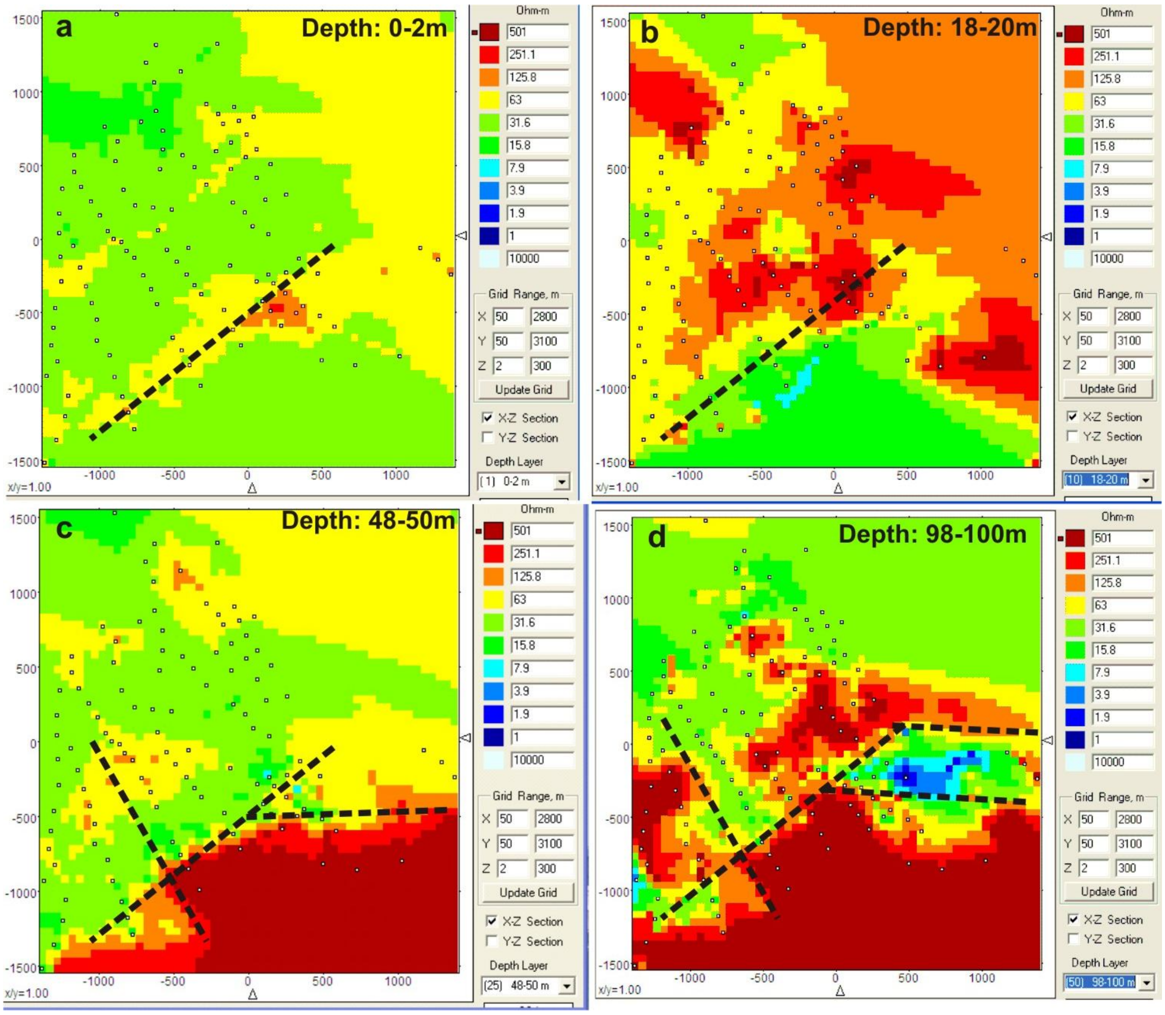

Figure 2 3D model of the the south part of the study area. Depth slices at 0-2m **a** 18-20m **b** 48-50m **c** and 98-100m **d** are presented. Red and blue colors represent the resistive and conductive layers, respectively.

The study area was discretized in 208320 voxels (57, 63 and 61 nodes in X,Y and Z direction, respectively) by using a constant grid size of about X:50m, Y:50m and Z:5m. Dense gridding along all axes was used in order to elaborate the topography of the study area into the final 3D modeling. High resistive air with conductivity $\sigma \approx 10^{-4}$ Ohm.m^{-1} was used for nodes shallower the "real" earth surface. Prior 3D modeling, all soundings were processed by applying 1D inversion, assuming 5-6 layers based on a prior knowledge of stratigraphy and geology from boreholes' logs into the study area. For 3D modeling, the early times, t=8-250 microsecond from the TEM responses (curves) and with error of measurements less then 10% were used to increase the accuracy of the final resulted 3D model. Moreover, late times (t>250us) were noisy due to high IP effect (negative signals). Based on the time gates (from the TEM response curves, t<200-300 us) used, the investigation depth is about 100-120 meters.

At the next step, the 3D model was constructed for calculating the TEM response. At this stage, since the software is still under development, the trial and error method was used for modeling, comparing at each time the observed with the calculated response. In areas where the signal present high gradient (about 10-15% of the whole study area), the 3D model is edited in order to reduce the rms error (fitting between observed and calculated data) by recalculating the TEM response. The iterative procedure is repeated till the RMS error is decreased below 8% (a predefined threshold).

The depth slices presented in figure 2 show faults striking at E-W, NW-SE, and NE-SW directions as expected. The results are further compared with borehole logs found in the area and other geophysical models for the same area (Manakou, et al. 2010; Bastani, et al. 2011)

CONCLUSIONS

A geoelectromagnetic survey which was carried in a grid, acquiring enough soundings to reconstruct the 3D subsurface resistivity distribution by applying 3D modeling of collected TEM data. The resistivity models are also compared with the existing borehole information in the study area and show a very good correlation. The resulted geomodels depict that probably normal faults with azimuth directions of NE–SW, NW-SE to E–W cross the bedrock. The detailed geo-electromagnetic survey in combination with the geological, tectonic and other available data proved as a useful tool for investigation of the tectonic regime of an area under investigation.

ACKNOWLEDGEMENTS

This project is implemented through the Operational Program "Education and Lifelong Learning", Action Archimedes III and is co-financed by the European Union (European Social Fund) and Greek national funds (National Strategic Reference Framework 2007 - 2013), Project Title: Interdisciplinary study for exploring, understanding and management of groundwater resources. Pilot field investigation North-Western and Central Crete (AQUADAM).

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