ACTIVE FAULT DETECTED IN URBAN AREAS USING VES AND ERT GEOPHYSICAL TECHNIQUES STUDY CASE: BUCHAREST, ROMANIA

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Introduction

The seismicity in the Bucharest city area is usually analyzed when assessing the seismic hazard, the recorded events of low to moderate magnitude being difficult to be included in lineaments of active tectonics significance.

The use of geophysical methods in large urban areas is considered to be prohibited due to high intensity of anthropogenic noise (aerial or underground power lines, water sewage or gas pipelines), restricted access in most areas due to buildings, private properties and roads. More of that, the geophysical data acquisition and interpretation is negatively affected by landfills with great variability in thickness and content, and large areas covered with concrete and asphalt.

Previous near surface geophysical works in Bucharest area, mostly as VES resistivity measurements, provided information for geotechnical and hydrogeological studies and remained usually unpublished.

The study dedicated to the detection of active fault systems in the Bucharest city area recently published (Ioane et al., 2014) represented the first stage of a project previously started (Ioane et al., 2010), having as main target a better understanding of local tectonics and its associated seismic risk. After evaluating the regional, local tectonics and neotectonics, as well as the seismicity in Bucharest city area, the next stage of the project, presenting first results in this paper, is dedicated to the geophysical detection of active faults aiming to bring detailed information for the city urban planning.

Methods and results

Considering the physical properties variability and contrasts in the near surface geological structures and the needed resolution for faults and fractures interpretation, the resistivity Electric Resistivity Tomography (ERT) and Vertical Electric Sounding (VES) have been selected to be employed in detecting active faults in Bucharest city area.

ERT measurements were carried out using a SuperSting (AGI) resistivity meter connected to 28 electrodes, the electric cables admitting a 10m maximum distance between electrodes. Wenner, Schlumberger or hybrid arrays using 3, 5 or 10m intervals between electrodes were utilized when investigating the near surface geological structure. The depth of investigation increased when enlarging the electrodes interval, reaching a maximum of 50m for 10m interval, but having as consequence the loss of details in illustrating the surveyed resistivity anomalies. The main results obtained on the ERT survey lines were sections with apparent resistivity and evaluated depths, and inverted sections with calculated resistivities and depths.

VES measurements were carried out in stations situated at 5 or 10m interval, using an IntV3 resistivity meter connected to four electrodes. The injection line length (AB) ranged between 50m and 140m, with increments in successive lateral displacements of 2, 5 and 10m. The main results obtained on the VES survey lines are sections with apparent resistivity for evaluated depths of AB/2 and AB/3.

ERT data interpretation

The ERT method usually provides a higher density of in-depth resistivity values along the survey line, but the projected and obtained resolution depends on the target dimensions and depth, meaning, the choice of the array and electrode interval.

Aiming to illustrate by means of resistivity variability the structure of shallow geological formations up to 50m depth a 270m long ERT survey line with 10m interval between electrodes (Figure 1) was measured north of Bucharest (Baneasa area).

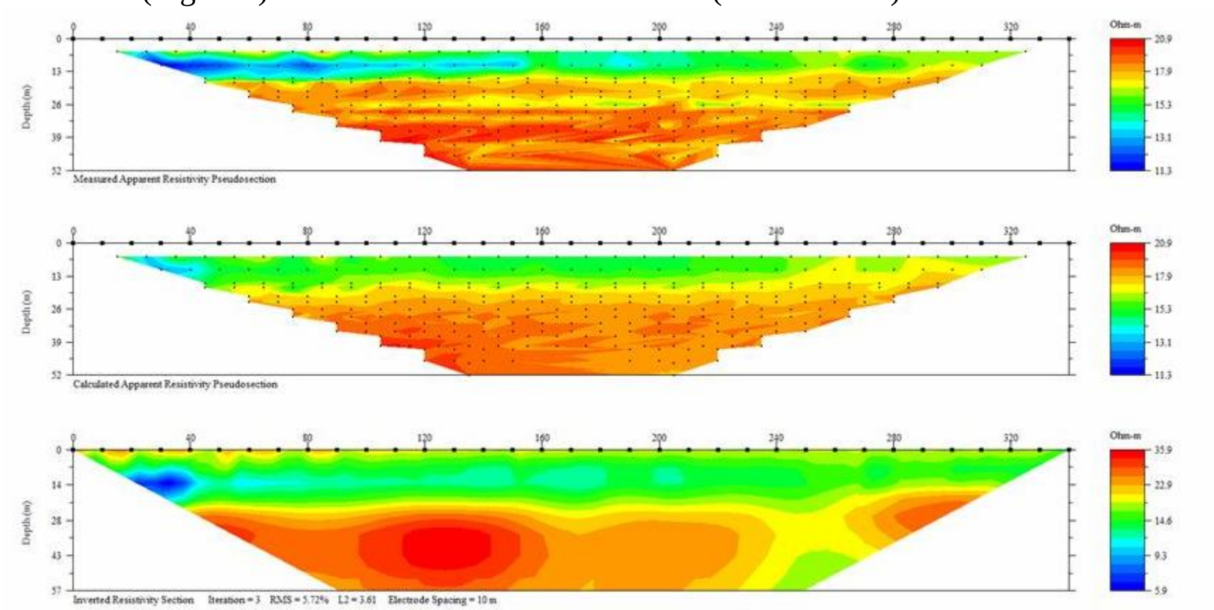

Figure 1 – ERT apparent resistivity section and inverted resistivity section in the Baneasa area

The ERT data presented in Figure 1 illustrate a thick mixed sequences of low resistivity rocks (clay) with higher resistivity ones (sands) for the first 25 m, covering a thick high resistivity formation (gravel) which deepens at more than 50m. This high resistivity layer, better observed in the inverted section, may be used as a reference level when looking for faults. Between 240 and 280m the inverted section reveals a break in the high resistivity layer (red) and a vertical displacement, here interpreted as a fault. The vertical displacement had as consequence the lower resistivity (green) layer thinning. Due to the low resolution of ERT data there is no possibility in this case to evaluate the fault inclination.

The ERT data presented in Figure 2, recorded in the northern part of Bucharest with 3m interval between electrodes, have a good resolution and are able to illustrate by means of resistivity anomalies the near surface geological structure up to 20m.

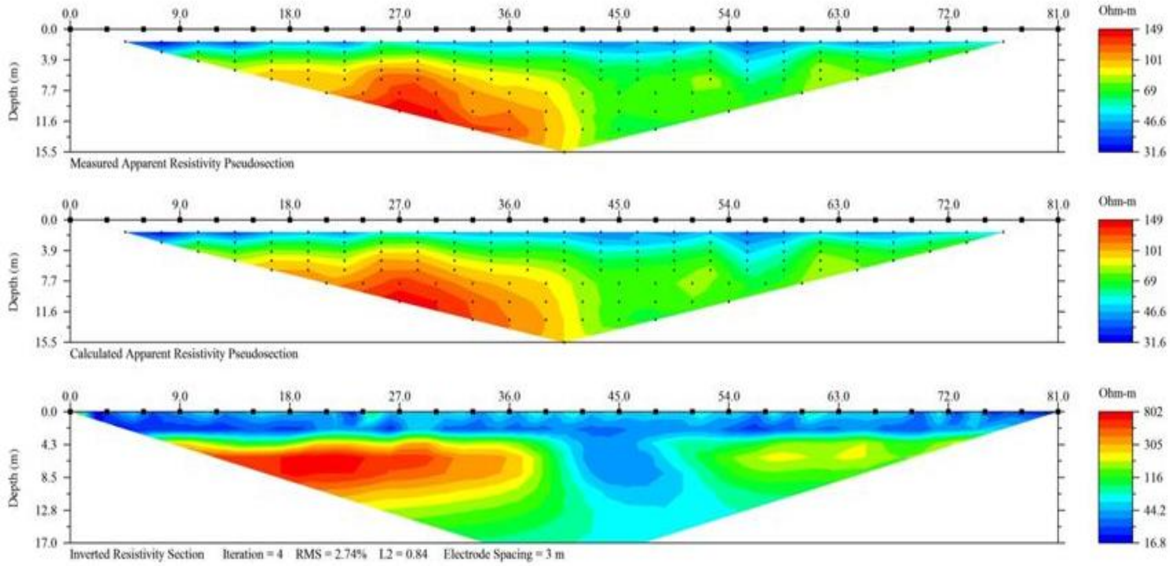

Figure 2 – ERT apparent resistivity section and inverted resistivity section in the northern part of Bucharest

Beneath the soil cover, the apparent resistivity section reveals a contact between high resistivity sediments compartment (gravel and sands) and a lower resistivity one (sands and clays), suggesting the presence of a fault with significant vertical displacement. The inverted resistivity section better depictes the interruption of high resistivity anomalies and illustrate, by a low resistivity quasi-vertical anomaly, the fault zone and its probable in-depth inclination.

The vertical low resistivity anomaly situated between the upper low resistivity anomaly (soil and phreatic aquifer) shown until 5m depth and the lower low resistivity one, shown at depths below 15m, suggests a connection between aquifers here created by the fault zone.

VES data interpretation

The VES surveys provide apparent resistivity values at different depths beneath the VES station, depths closely related to the distance between injection electrodes.

The detailed VES measurements carried out in a densely built zone situated in the western part of Bucharest (Militari district area) succeeded to illustrate for the first 50m depth (Figure 3) numerous vertical contacts between high resistivity and low resistivity sectors, here interpreted as faults and fractures. The vertical low resistivity anomalies, interpreted as having various widths, are associated with high permeability tectonized zones filled with groundwater and highly conductive water, leaked form the sewage network or provided by past industrial activities.

Besides the vertical local tectonic features shown on the apparent resistivity section, of high significance are considered to be the “diagonal” low resistivity anomaly detected in the western half of the survey line, crossing the vertical fractures and interrupting high resistivity “pillars” of less tectonized rocks.

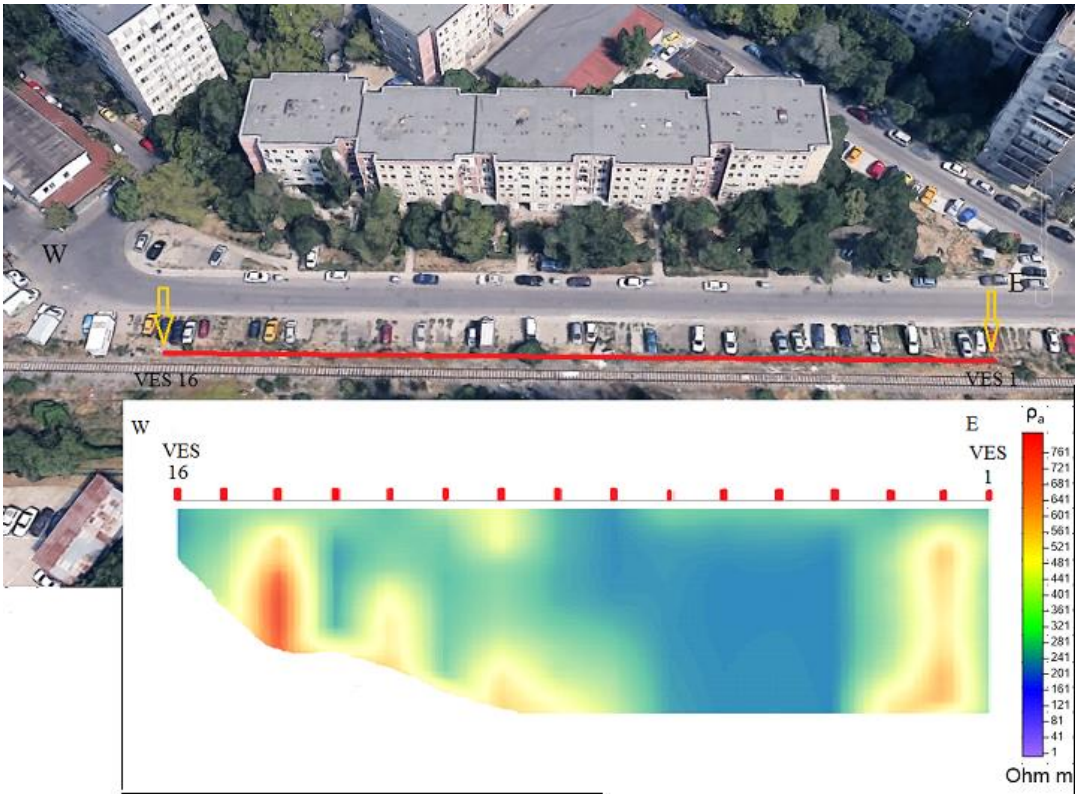

Figure 3 – VES resistivity data (50m depth) in the western part of Bucharest

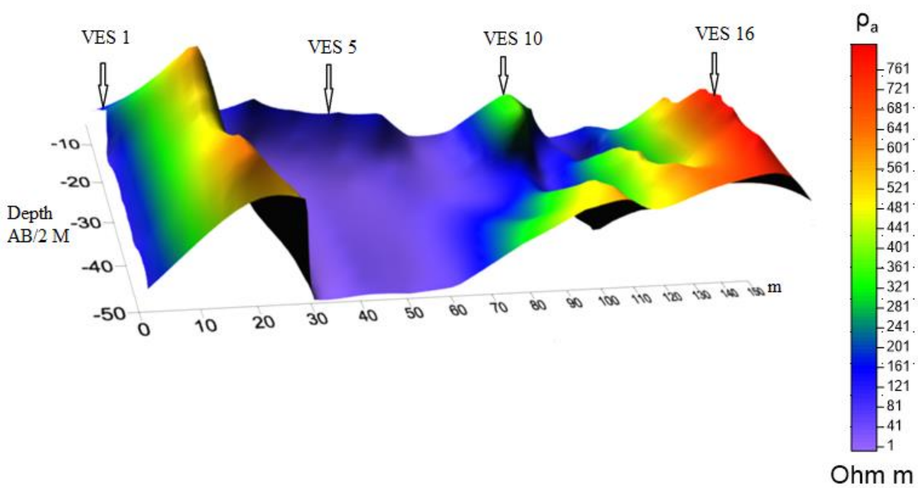

Figure 4 – 3D representation of VES data

Since we consider the relationships between the vertical fault system and the "diagonal" one as extremely important for the high magnitude earthquake effects on buildings in this area, a better graphical representation is given as a 3D apparent resistivity model (Figure 4) of the VES data presented in Figure 3.

Conclusions

Resistivity ERT and VES geophysical techniques have been employed in Bucharest city, Romania, to detect active faults and fractures affecting the geological structure till 50m depth.

The ERT and VES measurement methodologies were adapted to provide high resolution resistivity anomalies in the near surface domain.

ERT data recorded in northern parts of Bucharest revealed the possibility of use a high resistivity layer (gravels) as a marker when looking for vertical displacements.

ERT data showed the possibility to locate faults, to assess their inclination and illustrate vertical connections between aquifers along tectonized zones.

VES data succeeded to detect on the survey line, by means of apparent resistivity contrasts, an important vertical fault system affecting a densely built area, crossed diagonally by an inclined one.

Land sectors located beneath large buildings, situated above junction zones between vertical and inclined faulting / fracturing may offer less stability in case of high magnitude seismic events, as it was the case in Bucharest (Militari district) with the OD 16 nine floors building during the 1977 earthquake.

References

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