



USING VERTICAL ELECTRICAL SOUNDINGS TO CHARACTERIZE SEAWATER INTRUSIONS IN THE SOUTHERN AREA OF ROMANIAN BLACK SEA COASTLINE

Bogdan Mihai NICULESCU¹ and Gina ANDREI¹

¹ *University of Bucharest, Faculty of Geology and Geophysics, Department of Geophysics, 6 Traian Vuia Street, 020956 Bucharest, Romania; bogdan.niculescu@gg.unibuc.ro*

Introduction

Seawater intrusions are represented by the movement of saline water of marine origin into freshwater aquifers, due to natural processes or human activities (e.g. sea level rises or decreases of groundwater levels). They are one of the main causes of contamination for coastal freshwater aquifers and are frequently generated by the uncontrolled exploitation of potable water in pumping stations from coastal areas.

Seawater intrusions are most accurately delineated and monitored by using surface and airborne electromagnetic induction methods in frequency or time domains or surface DC geoelectrical investigations, such as the Vertical Electrical Sounding (VES) or the Electrical Resistivity Tomography (ERT) imaging techniques (e.g. Binley & Kemna, 2005; Paine & Minty, 2005; Goldman & Kafri, 2006; Werner et al., 2013). In Romania, such intrusions have been identified in the southern coastal area of the Black Sea, in Vama Veche and Costinești resorts at distances reaching 500 to over 2000 m from the coastline, contaminating the main aquifers hosted within Sarmatian (late Middle Miocene) limestones.

Methods

The Costinești seawater intrusion has been investigated and monitored over a long time interval (since 1991) by means of repeated VES surveys carried out with ABEM Terrameter resistivity meters, using Schlumberger electrode arrays with maximum emission line spacings (AB) of 200 m. The repeated surveys were performed on a reference profile of about 900 m in length and WNW – ESE orientation, on the lineament of several water exploitation wells and pumping stations. The midpoint of the surveys profile was located at about 2100 m distance from the coastline.

In Vama Veche area, a total of 23 Schlumberger VES surveys with maximum AB of 200 m were conducted at about 2.5 km north of the Romanian-Bulgarian border. The surveys were performed with an ABEM Terrameter resistivity meter on two parallel profiles oriented approximately WSW – ENE and reaching the coastline. The length of each survey profile was approximately 800 m and the north-south distance between the profiles was 100 m. The apparent resistivity data were interpreted using a set of novel software applications elaborated in MATLAB programming environment. Digital linear filtering was used for the forward modeling of VES curves and the 1D interpretation was carried out by using a pseudo-inversion algorithm (randomly generating sets of true resistivities and layer thicknesses, within predetermined limits, and selecting the optimal geoelectrical model via a maximum fitting error criterion).

Results

Figure 1 shows an example of the VES surveys results in Vama Veche area, in terms of apparent resistivity (ρ_A) cross sections. The low values ($\rho_A < 20 \Omega\text{m}$, marked "Intrusion") recorded on the coastline side of the southern profile, at large emission line spacings ($AB/2 > 60 \text{ m}$), reflect the presence of a seawater intrusion. This deep ρ_A anomaly is not recorded on the northern profile, possibly due to an escarpment effect for the VES stations located nearby a steep coastal cliff. Figure 2 illustrates an example of 1D interpretation carried out by using the elaborated MATLAB codes, assuming a 5 layers geoelectrical model (left: optimal true resistivity model; right: measured VES data - red markers and theoretical VES response of the optimal model - blue markers and curve). The presence of the intrusion is suggested by the true resistivity decrease at 52 m depth, in good agreement with the results of water testing in a well drilled 500 m away from the coastline.

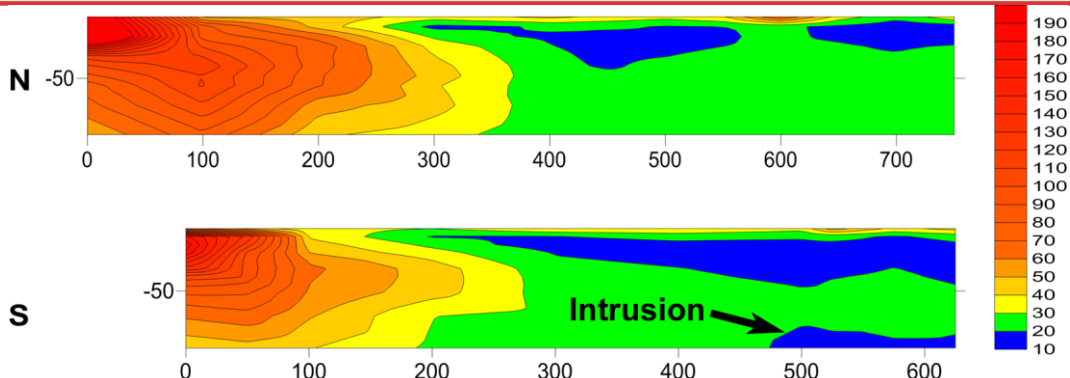


Figure 1. Apparent resistivity cross sections in Vama Veche area corresponding to the VES survey profiles (two VES stations on the southern profile were excluded). Horizontal axis: distance along profiles [m]; vertical axis: depth [m].

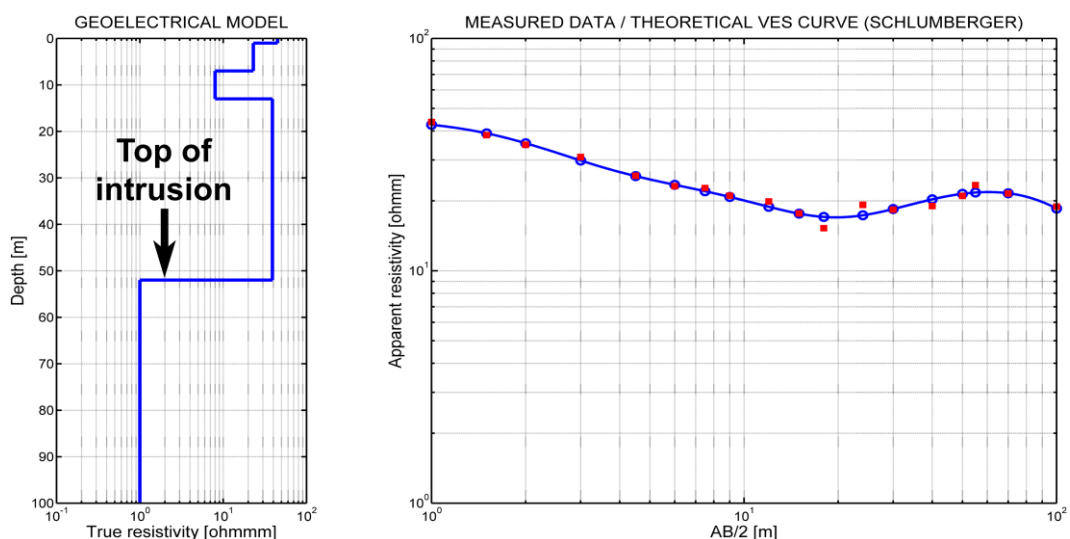


Figure 2. Quantitative interpretation of a VES recorded in Vama Veche area, by using the elaborated MATLAB codes.

Conclusions

The Vertical Electrical Sounding (VES) method has been proven effective in the study of freshwater contamination with seawater on the Romanian Black Sea southern coastline. VES data interpretation carried out with newly elaborated MATLAB codes was validated by direct observations in a well drilled in Vama Veche resort, 500 m away from the coastline, which produced saltwater at depths in excess of 40 m.

References

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