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Specific Electromagnetic Approaches Related to the Short-term

Prercursory Parameters Associated to Intermediate Depth Earthquakes (Vrancea Zone, Romania)

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SPECIFIC ELECTROMAGNETIC APROACHES RELATED TO THE SHORT - TERM PRERCURSORY PARAMETERS ASSOCIATED TO INTERMEDIATE DEPTH EARTHQUAKES (VRANCEA ZONE, ROMANIA)

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SUMMARY

The methodology presented in this paper concerning the anomalous behaviour of the electromagnetic parameters was established according to the geotectonic features of the Vrancea zone and its surrounding areas. Subsequently, a specific approach regarding the normalized functions Bzn and ρn, selected complying with temporal invariability criterion for a 2D geoelectric structure in non-seismic condition, taking into consideration just their daily mean distribution versus intermediate depth seismic events recorded simultaneously, was elaborated. The changes of electrical conductivity occurred before and during an earthquake, as a sequence of geophysical processes developed into and in the close vicinity of the Vrancea's seismogenic volume, could be detected by means of the peculiar features of the Bzn and ρn parameters taken throughout the frequency range 10^{-2} - 4.10^{-3} Hz.

Keywords: Electromagnetic parameters, normalized functions Bzn and ρn, electromagnetic pattern, intermediate depth earhquakes

INTRODUCTION

The assessment of natural hazard and risk generally aims at analyzing potential impacts of specific processes to a rather well balanced system, in order to emphasize to what extent it might be affected in the future. As the seismic-active Vrancea zone is one of the "hot" subjects, we focused on a specific approach able to emphasize the short–term precursory parameters associated to intermediate depth earthquakes (EQs), by using electromagnetic (EM) data. It means that a specific EM methodology centered on the pattern recognition and on the anomalous behaviour of the Bzn and ρn parameters (Stanica et al, 2002, 2003) linked to seismic events is to be taken into consideration by respecting some compulsory conditions such as:

- The establishment of the optimum placement of the monitoring site and its EM pattern (a two-dimensional structure, strike orientation and the normal distribution of the Bzn and ρn parameters in non-seismic condition), as well;
- Installation of the specific geophysical system for continuous monitoring of the EM field;
- The accomplishment of the daily mean variations of the Bzn and ρn parameters on certain frequency ranges, in order to highlight, their connection with seismic events.

METHODOLOGY AND RESULTS

Unlike the other type of information (electric or seismic), the electromagnetic data seem to be more acceptable for tackling the short-term precursory parameter, because they are restricted neither to narrow high conducting paths – as the electric data, nor to a short time before the earthquakes – as the seismic ones.

Electromagnetic (EM) phenomena/parameters related to earthquakes:

- Signals possibly emitted from earthquakes sources:
  - geomagnetic/ geoelectric changes in ULF – ELF – VLF – LF – HF bands;

- Anomalous transmission of electro-magnetic waves due possibly to disturbed ionosphere:
  - transmission anomaly of man-made waves (VLF) and scattering of MF radio waves (VHF);

- Anomalous behaviour of the Bzn and ρn parameters:
  - the electric conductivity changes in seismic active zones and their neighborhood.

The last one will be analized in this paper.

It is well known that at the Earth surface the vertical geomagnetic component Bz is entirely secondary field and its existence is an immediate indicator of lateral inhomogeneity. For two-dimensional structure, Bz is produced essentially by $B_\perp$ (horizontal geomagnetic component perpendicular to the geological strike) and consequently a normalized function Bz defined as:

$$Bzn = Bz/B_\perp, \qquad (1)$$

should be time invariant for a given 2D structure in non geodynamic conditions (WORD et al.,1970; Stanica, Stanica, 2003).

Furthermore, in terms of resistivity, we may compute:

$$\rho_z = 0.2\,T\,\left|E_\| / Bz\right|^2 \qquad (2)$$

and

$$\rho_\| = 0.2\,T\,\left|E_\| / B_\perp\right|^2, \qquad (3)$$

where: T is period (sec.), ρ_z is the vertical resistivity, $E_\|$ and $\rho_\|$ are the electric field and the resistivity parallel to the strike.

Thus, the normalized function Bzn may be estimated as:

$$\left|Bzn\right| = (\rho_\| / \rho_z)^{1/2}, \qquad (4)$$

Relation (4) demonstrates that Bzn could be linked to variation of the electric conductivity into the Earth and, its right part lead to the normalized resistivity (Stanica, Stanica, 2003) defined as:

$$\rho n = \rho_\| / \rho_z \qquad (5)$$

Approximate field solution were computed for two simple 2D geometries to illustrate the phenomena discussed above and the results are presented in Fig. 1. Solution for the sloping interface and vertical contact models were obtained by using finite element code. Both models represent two extremes in the dipping angle of interface and similarity in the properties of Bzn is of interes in our approach.

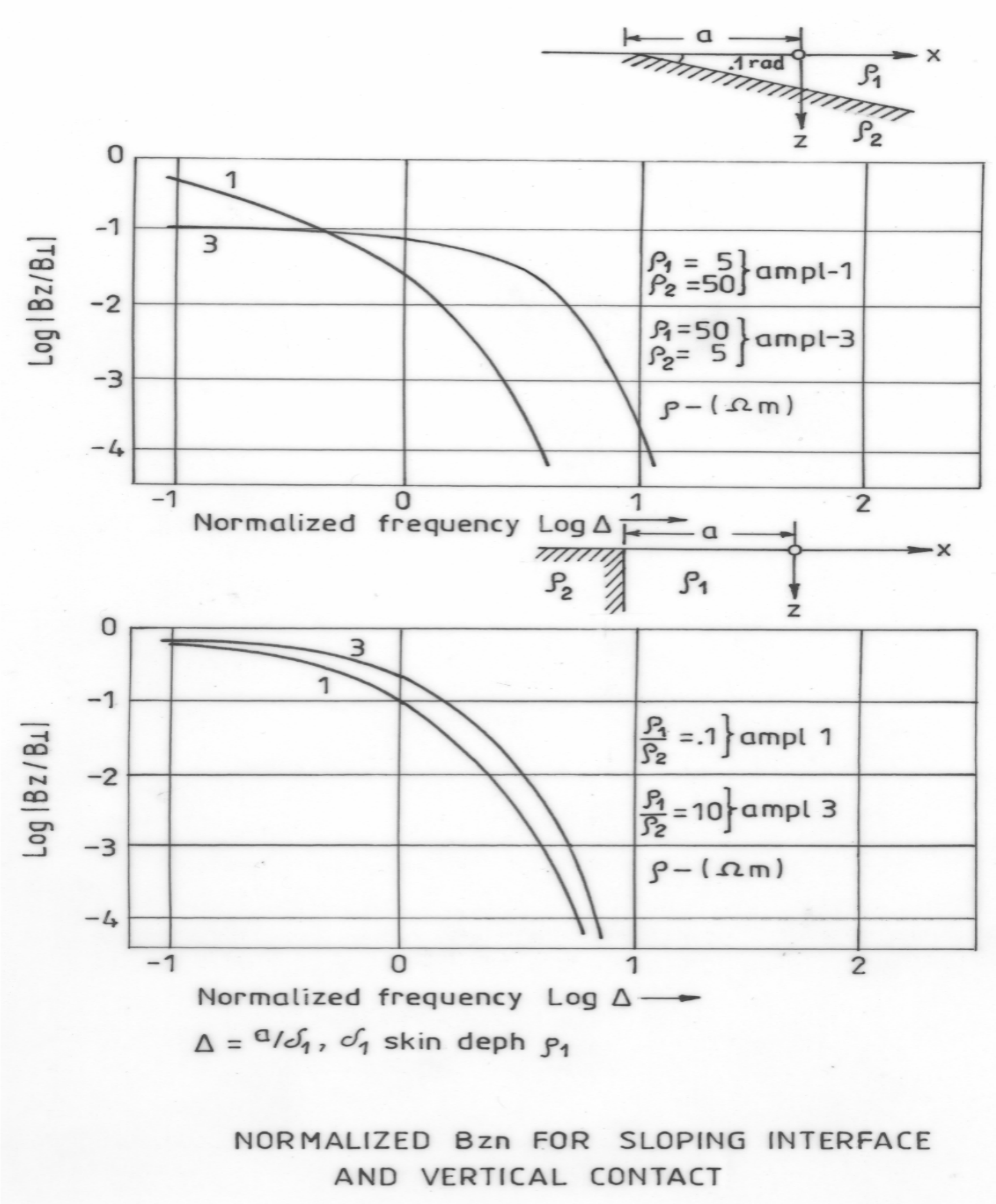

Fig. 1. The normalized function Bz for sloping interface and vertical contact

As a first step, it is important to point out the EM pattern (skewness, strike and specific distribution of the Bzn and ρn parameters in non-seismic condition) for the monitoring site, selected to be National Geophysical Observatory Surlari (OS-Fig. 2) and to extract the anomalous behaviour of the Bzn and ρn parameters, the most probably due to the resistivity changes appeared at the intermediate depth level.

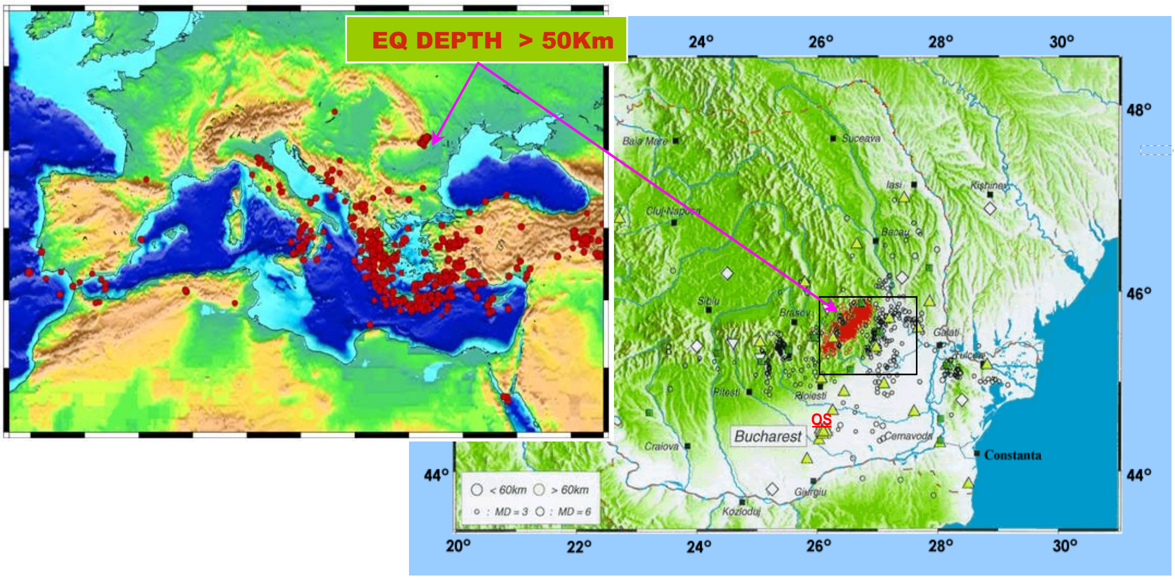

Fig. 2. Map of the eartquakes occurred at the depth > 50km. Seismic-active Vrancea zone (rectangle) and National Geophysical Observatory Surlari (OS).

The National Geophysical Observatory Surlari is located at about 140 km far away from the epicentral seismic active Vrancea zone and the criteria for this selection consist of:

- Logistic base able to supply optimal EM information (specially prepared buildings and operators);
- Two-dimensional geological structure and its strike orientation;
- Real time data transfer to the central office (Institute of Geodynamics, Bucharest) by electronic connection.
- In order to determine the EM pattern at the National Geophysical Observatory Surlari we have used both the magnetotelluric equipment GMS-06 (Fig.3), having 5 channels (two electric-Ex, Ey and three magnetic: Bx, By, Bz), 24 bit resolution, GPS, two frequency ranges (LF: 4096sec.-1kH; HF=0.5kH - 10kH) and adequate software packages "MAPROS".

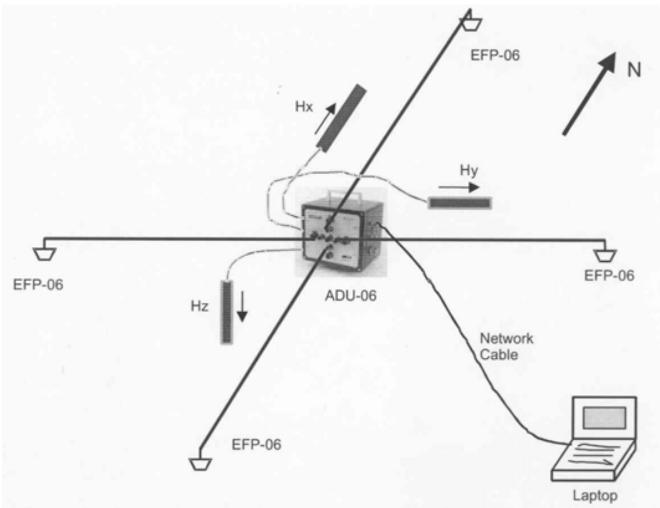

Fig. 3 . Magnetotelluric equipment GMS-06 (Metronix, Germany)

The “MAPROS” program is able to perform the following basic tasks:

- Real time data acquisition and processing (Fig. 4);
- Robust estimation of transfer functions;
- Real time display of time series and all important electromagnetic parameters ($\rho_{\perp}$, $\rho_{\parallel}$, skew and strike, etc).

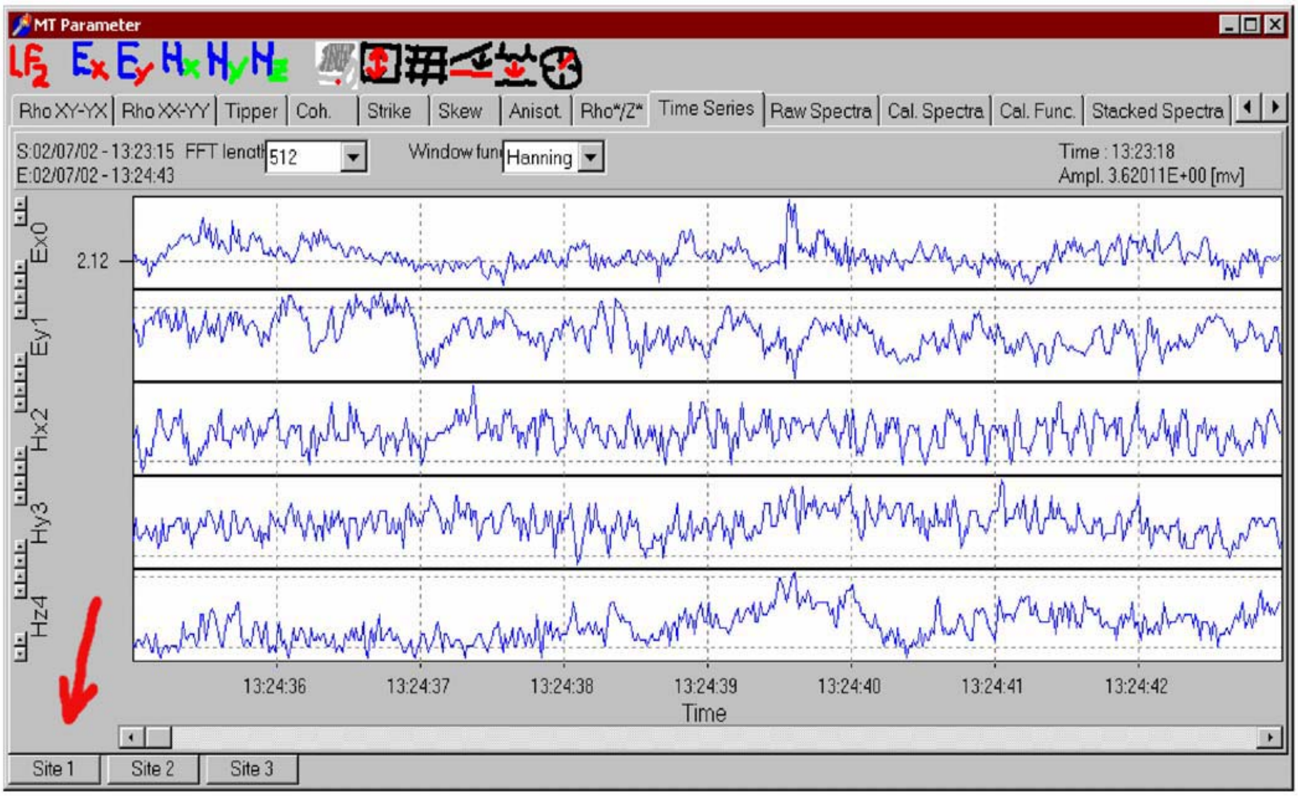

Fig 4. The MAPROS software packages (real time EM time series).

Using magnetotelluric tensor impedance decomposition technique (Bahr, 1998) and the MAPROS software packages, it was possible to separate the local effects from the regional ones and to identify the MT parameters: (i) skewness; (ii) strike orientation; (iii) resistivities perpendicular ($\rho_{\perp}$) and parallel ($\rho_{\parallel}$) to the strike. Having this information, a specific methodology able to use those frequencies corresponding to the 2D structure and intermediate depth interval has been applied. Thus, at the National Geophysical Observatory Surlari, we used the frequency range of 10^{-1}-4.10^{-3} Hz (Fig. 5), skewness < 0.3 (Fig.6) and the geological strike oriented N100^{0}E (Fig. 7).

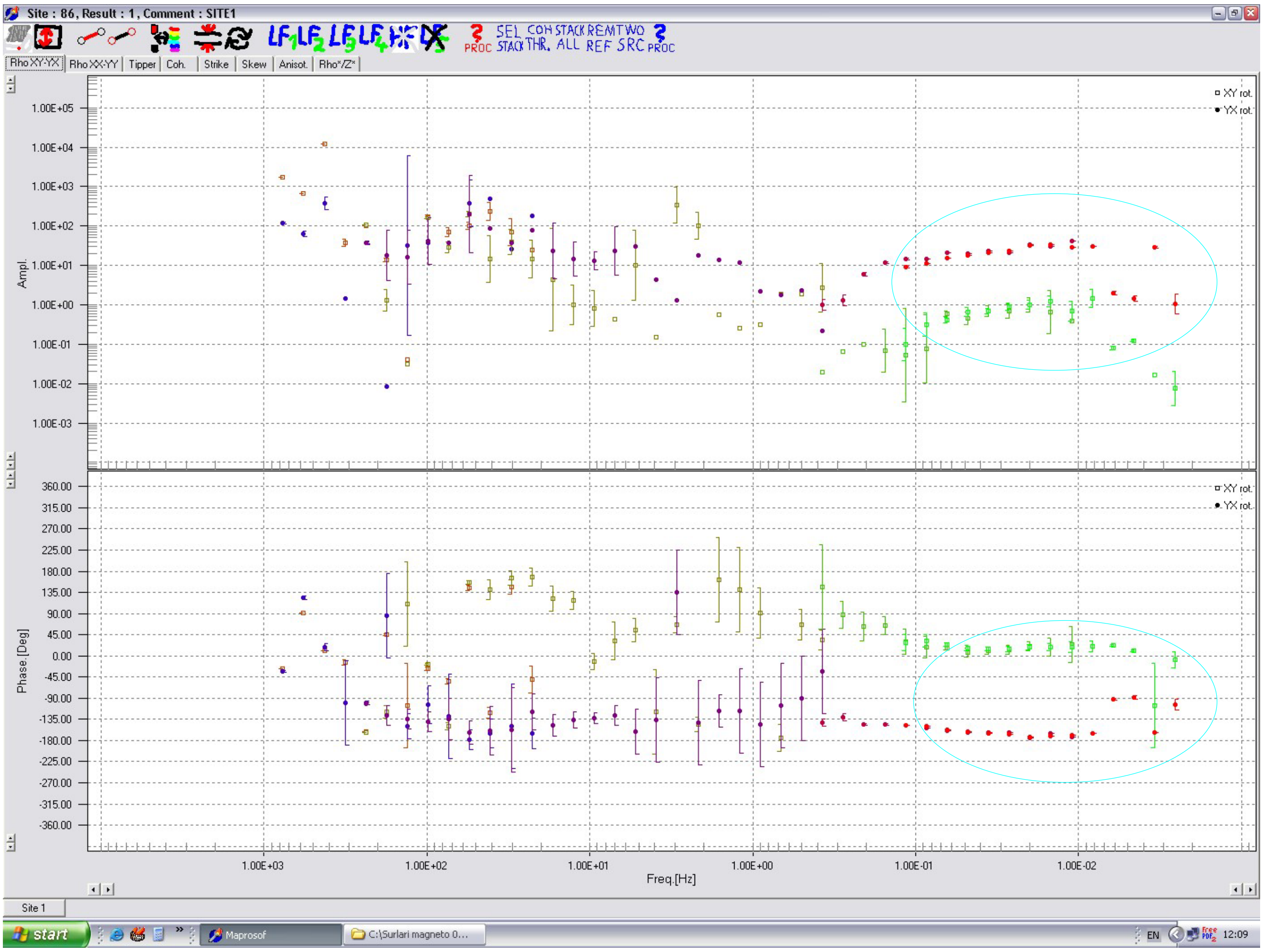

Fig. 5. Real time display of the resistivity (ρ‖, ρ⊥) and phase (φ‖, φ⊥)

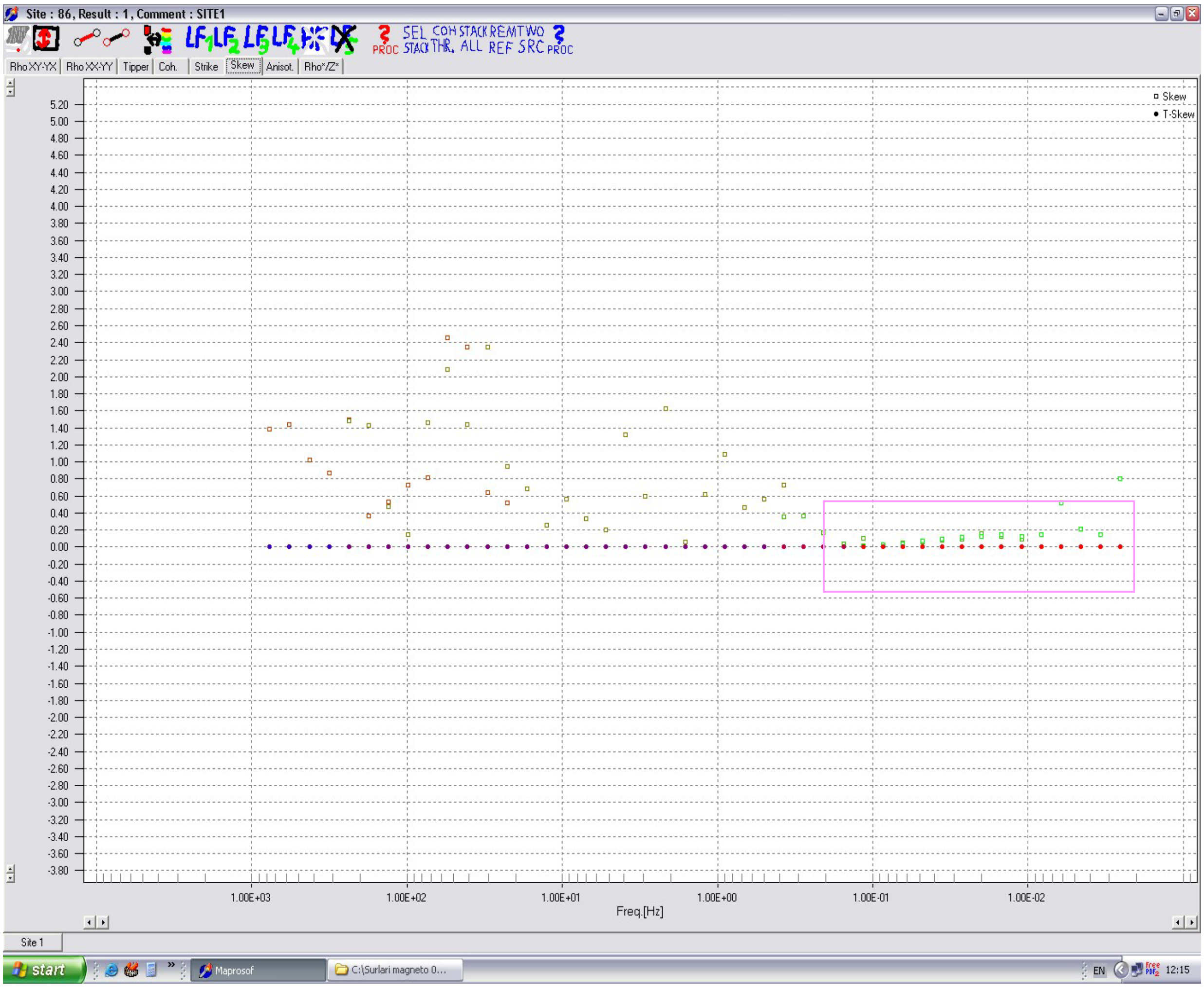

Fig. 6. Skewness parameter having values less then 0.3 (in rectangle)

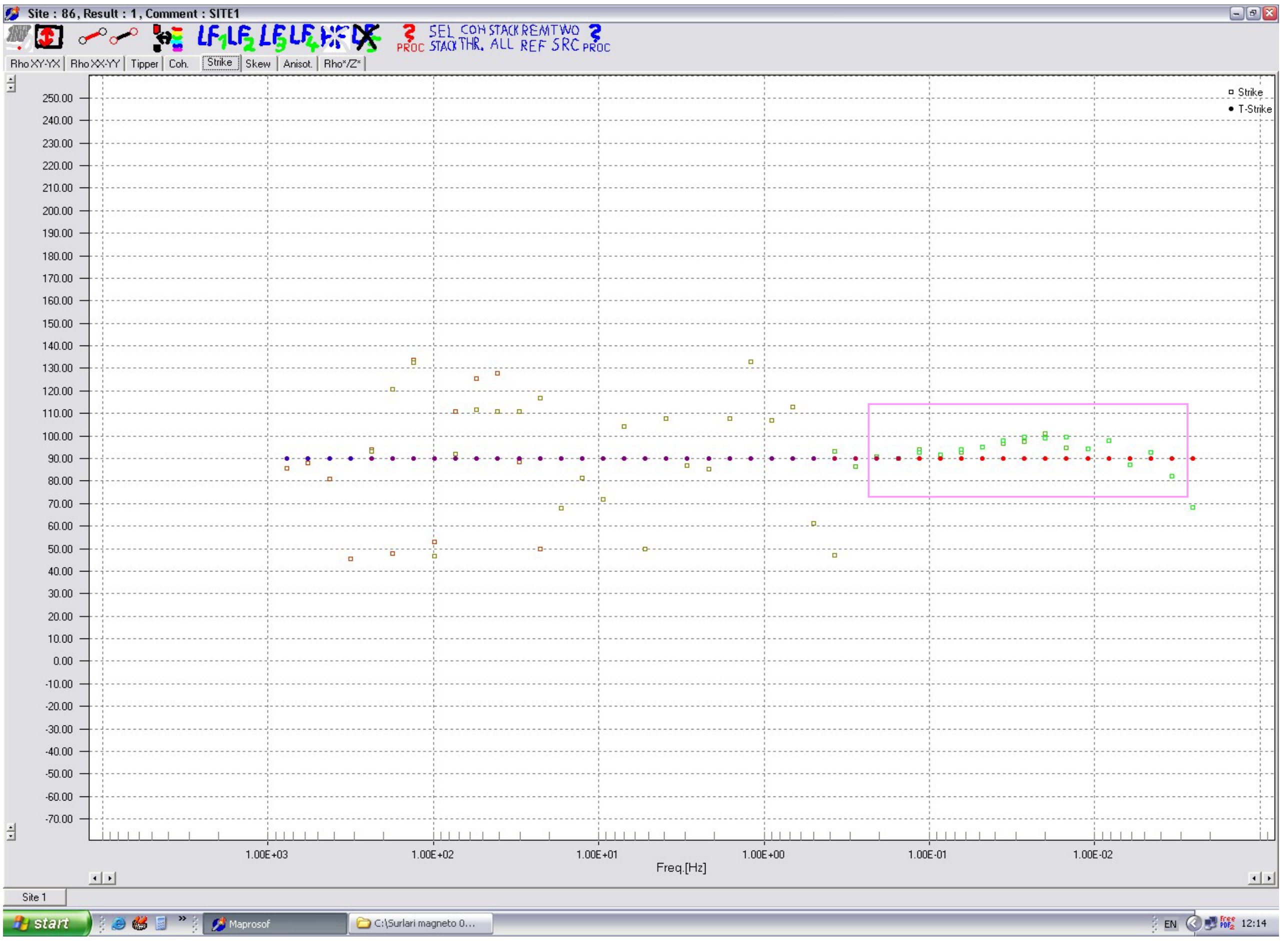

Fig. 7. Strike parameter having the interest orientation in rectangle (about N100^{0}E)

The continuous monitoring of the geomagnetic data was accomplished by using the recording system MAG-03 DAM (Bartington, England), with 6 channels, 24 bit resolution able to collect the data from the three axis magnetic field sensor MAG-03 MSL (frequency range: DC- 1kHz) and a laptop for real time data storage and processing (Fig. 8). One of the horizontal components of the three axis magnetic sensor has always been orientated perpendicular to the geological strike. Subsequently, the changes of electrical conductivity inside of the Vrancea's seismogenic volume and its surroundings, before an earthquake occurred, as a sequence of the lithospheric conductivity changes produced by the dehydration of the rocks associated with rupturing processes and fluid migration through faulting system inside the Vrancea's seismic active volume and its surrounding areas, have to be reflected by the Bzn and ρn parameters.

Fig. 8. Recording system MAG-03 DAM (Bartington, England)

To have a comprehensive view on the applied methodology, the daily mean distribution of the parameters Bzn in correlation with Vrancea's deep seismic events occurred simultaneously is shown in Fig. 9 , within a span of 49 days (27 December. 2005-13 February 2006). It is easily visible that there are some domains characterized by increased values as a direct consequence of the thermo-mechanical processes occurred at subcrustal level before and during of the earthquakes. The earthquakes magnitude is marked by vertical lines, with values oscillating between 2.1 and 4.3. According to this information, it is admitted that major changes of $B_{\perp}$ component at intermediate depth are produced.

For a better understanding of this methodology, it is also presented Figure 3 that contains the daily distribution of the normalized function ρn, correlated with the simultaneous seismic events, for a month interval (01.06-30.06.2004). This figure emphasizes increasing values of the ρn parameter by comparing with its normal distribution (3.512 ± 0.0002) in non seismic conditions, due to the same geodynamic processes and consequences mentioned above.

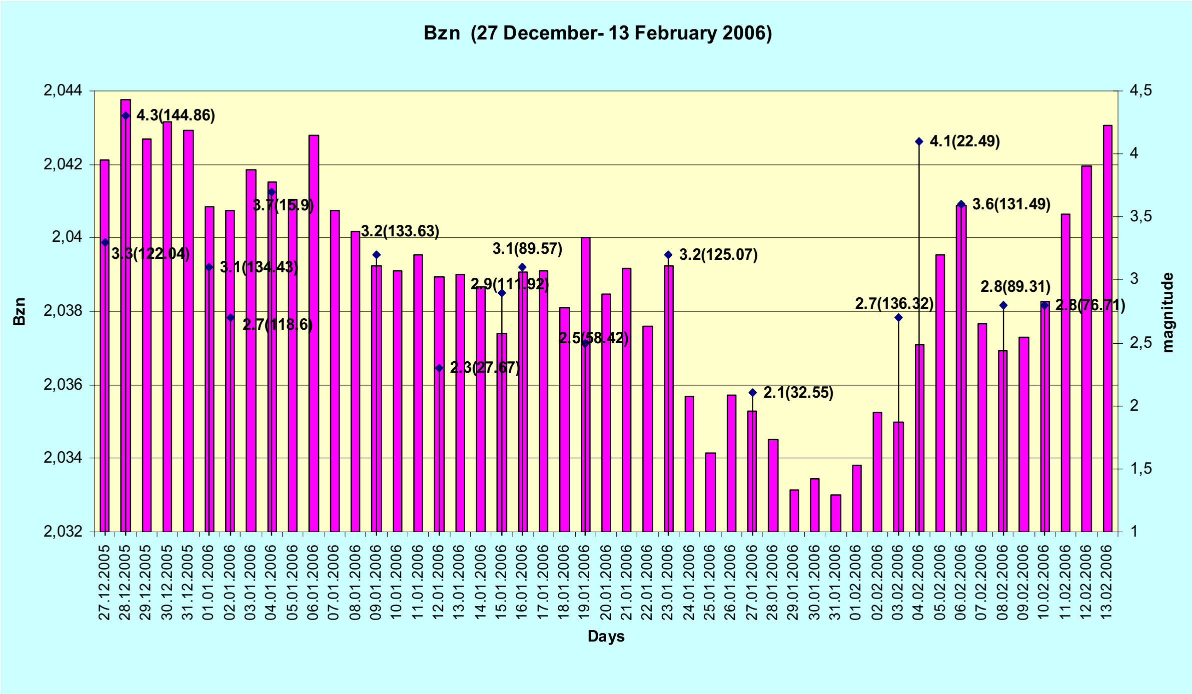

Fig. 9. Daily mean variation of the Bzn represented simultaneously with seismic events (vertical line) having marked their magnitude (depth in km); the line of 2.032 (± 0.0004) represents its normal distribution in non seismic condition.

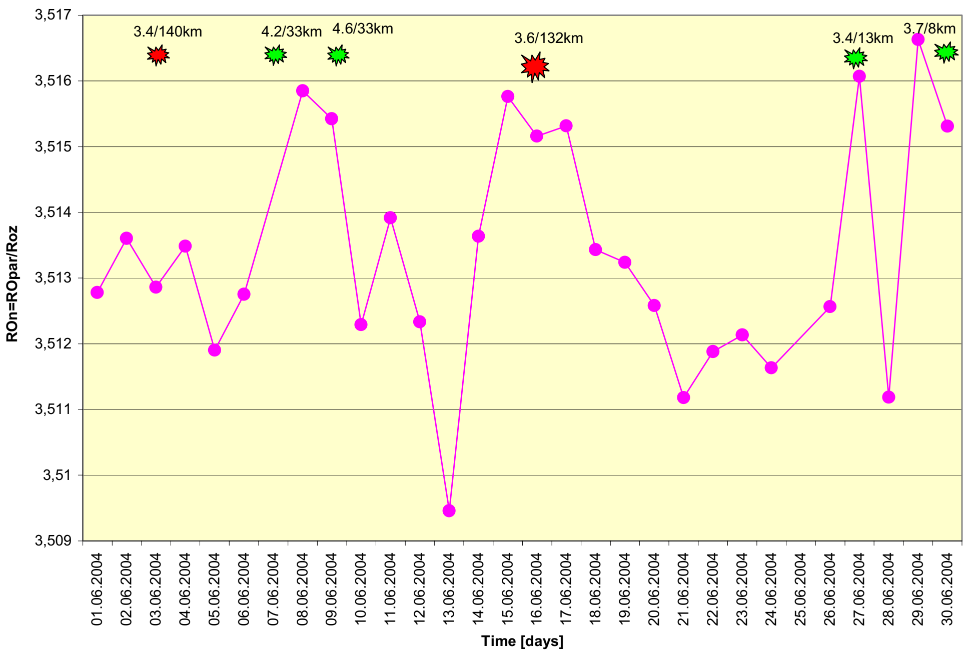

Figure 3. Daily mean variation of the ρn represented simultaneously with seismic events (star) having marked their magnitude/depth; the line of 3.512 (± 0.0002) represents its normal distribution in non seismic condition.

CONCLUSIONS

1. According to all the electromagnetic information correlated with seismic events, it is relieved that the earthquakes are triggered during the instability period of the EM parameters, generated by the resistivity changes occurred at intermediate depth. When the stability and instability periods are very closed, then corresponding domains are superimposed and maximum amplitude value of the analyzed electromagnetic parameters may correspond or not with the maximum magnitude of the earthquakes;

2. Some days before an EQ occurred, the daily mean variation of the normalized functions Bzn and ρn have had an anomalous behaviour marked by a significant increase versus its normal distribution identified in non seismic conditions, as a result of the lithospheric conductivity changes produced by the dehydration of the rocks, associated with rupturing processes and fluid migration through faulting systems developed inside the Vrancea seismogenic volume and its surrounding areas.

3. Even if at present it is not possible yet to make any predictable correlation between the magnitude of seismic event and the amplitude/shape of the Bzn and ρn parameters, for lack of sufficient data concerning extreme events (M>6), there is a chance to make a step forward on this way;

4. As this methodology allows us to know always the structure changes after any seismic event, what permit to use further on the most adequate techniques, it becomes an interesting subject of studying the earthquakes and the associated geodynamic processes.

ACKNOWLEDGEMENTS

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