ANOMALOUS BEHAVIOR OF THE ELECTROMAGNETIC PARAMETERS ASSOCIATED TO INTERMEDIATE DEPTH EARTHQUAKES

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Le comportement anomal des paramètres électromagnétiques associés aux séismes de profondeur moyenne. La méthodologie, en ce qui concerne le comportement anormal des paramètres électromagnétiques, présentée par l'étude, a été établie conformément aux aspects géotectoniques de la zone de Vrancea et des zones environnantes. Ultérieurement, on a mis au point une méthode spécifique pour les fonctions normalisées Bzn et ρn, sélectionnées selon le critère de l'invariabilité temporelle des structures de type 2D dans les conditions de manque de sismicité, en considérant seulement la distribution moyenne qui leur est spécifique, en fonction des événements sismiques de profondeur moyenne. Les changements de conductivité électrique parus avant et pendant un séisme, comme succession des procès géophysiques déployées dans la proximité du volume sismogène de Vrancea, peuvent être détectés à l'aide des caractéristiques de la fonction Bzn et ρn sur l'intervalle de fréquence 10.

Key words: anomalous behaviour of the EM parameters, normalized functions Bzn and ρn, EM pattern, intermediate depth earthquakes.

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 seismic events, by using electromagnetic (EM) data. It means that a specific electromagnetic methodology centered on the pattern recognition and on the anomalous behaviour of the Bzn and ρn parameters associated to intermediate seismic events is to be taken into consideration, certainly 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;

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– 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.

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:

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

should be time invariant for a given 2D structure (Word *et al.*, 1970, Stănică *et al.*, 2002, 2003).

Furthermore, in terms of resistivity, we may compute:

$$\rho_z = 0.2\,T\,|E_\parallel/Bz|^2 \quad (2)$$

and

$$\rho_\parallel = 0.2\,T\,|E_\parallel/B_\perp|^2, \quad (3)$$

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

Thus, the normalized function Bzn may be estimated as:

$$|Bzn| = (\rho_\parallel/\rho_z)^{1/2}, \quad (4)$$

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

$$\rho n = \rho_\parallel/\rho_z. \quad (5)$$

As a first step, it is important to point out the EM pattern (skew, 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 (NGOS-Fig.1) 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. The NGOS is located at about 140 km far away from the epicentral seismic active Vrancea zone and the criteria for this selection are:

– the existence of a logistic base able to supply optimal EM information (specially prepared buildings and operators);

– making evident a two-dimensional geological structure and its strike orientation;

– real time data transfer to the central center (Institute of Geodynamics, Bucharest) by electronic connection.

In order to determine the EM pattern at the NGOS we have used both the magnetotelluric equipment GMS-06 (Metronix, Germany), 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". The "MAPROS" program is able to perform the following basic tasks:

– real time data acquisition and processing;

– robust estimation of transfer functions;

– real time display of time series and all important electromagnetic parameters ($\rho_\perp$, $\rho_\parallel$, skew and strike, etc).

Using magnetotelluric tensor impedance decomposition procedures (Bahr, 1988), it was possible to separate the local effects from the regional ones and to identify the MT parameters: (i) skew (Fig. 2); (ii) strike orientation (Fig. 3); (iii) resistivities perpendicular ($\rho_\perp$) and parallel ($\rho_\parallel$) to the strike (Fig. 4). Having this information, a specific methodology able to use those frequencies corresponding to the 2D structure and intermediate depth interval has been applied. Under these circumstances, for the NGOS the both frequency range of 10^{-2}-4.10^{-3} Hz and strike direction (E10^{o}N) have to be included (see Figs. 2, 3 and 4).

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. One of the horizontal components of the three axis magnetic sensor has been always orientated perpendicular to the geological strike.

Subsequently, the changes of electrical conductivity inside the Vrancea 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.

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. 5, 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 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 Fig. 6 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.

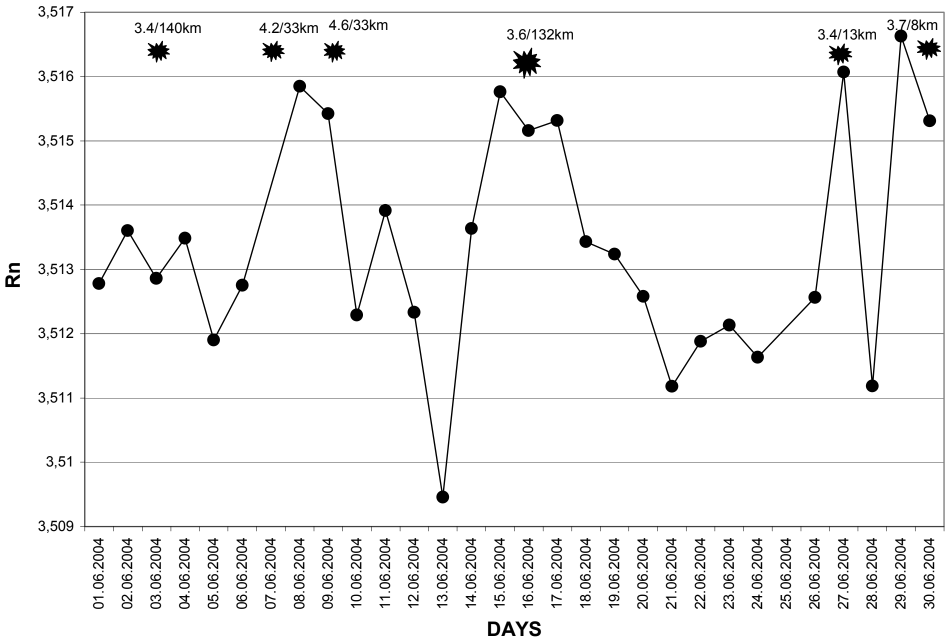

Fig. 6 – Daily mean variation of the ρn (written as Rn) represented simultaneously with seismic events (star) which have mentioned their magnitude/depth; the dashed thicken line of 3.512 (± 0.0002) represents its normal distribution.

CONCLUSIONS

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 close, the corresponding domains are superimposed and maximum amplitude value of the analyzed electromagnetic parameters may correspond or not with the maximum magnitude of the earthquakes**.

Several days before an earthquake occurred, the daily mean variation of the normalized functions Bzn and ρn displayed 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.

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

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

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