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New Approaches to the Electro-magnetic Precursors

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LECTURE NOTE (In brief)

A SPECIFIC APPROACH OF THE SHORT-TERM ELECTROMAGNETIC PRECURSORY PARAMETERS ASSOCIATED TO SEISMIC EVENTS

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1. INTRODUCTION

Short-term electromagnetic prediction has not been achieved, yet, despite its importance and many years of research. Recognizing the importance of the recent research works, carried out in countries like China, Italy, Japan, Greece, Russia and USA, published and presented at international symposia, where two kinds of pre-seismic electromagnetic phenomena were reported as: (1) signals possibly emitted from earthquake sources (geomagnetic/geoelectric changes in wide frequency bands); (2) anomalous transmission of electromagnetic waves due possibly to disturbed ionosphere (transmission anomaly of man-made VLF waves and scattering of radio waves VHF), this paper will discuss specifically about a new methodology able to carried out the electromagnetic precursory parameters, time invariant for a given geological structure under non-seismic conditions and which becomes unstable within interval of some days before occurring an seismic event (Stanica, 2001, Stanica et al 2001, 2002, 2003, 2004, 2005). In this respect, in the paper the following topics will be analyzed: geotectonic overview of the Vrancea zone; theoretical base of the normalized functions Bzn and ρn; the establishment of the optimum placement for observation point and evaluation of its geoelectric pattern; monitoring electromagnetic (EM) field in order to accomplish the daily variation of the normalized functions Bzn and ρn, simultaneously with seismic events, with the aim to establish possible interrelation between them.

2. THE GEOTECTONIC OVERVIEW OF THE VRANCEA ZONE

The seismically active Vrancea zone is located within the arcuate portion of Eastern Carpathians (Săndulescu, Visarion, 2000; Fig. 1); it is bounded to the north and northeast by the Scythian and East European platforms, to the south by the Moesian Platform, and westwards by the Transylvanian Basin.

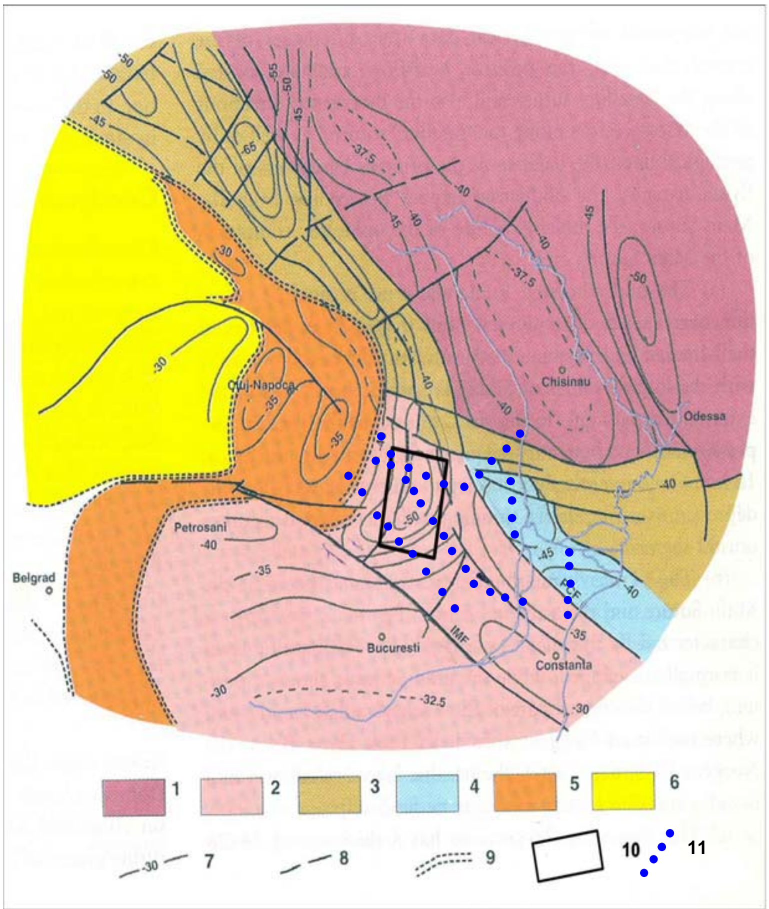

Fig.1. Seismic active Vrancea zone and magnetotelluric profiles on the crustal map (after Săndulescu and Visarion, 2000). (1) Precambrian East European Platform crust; (2) Precambrian Moesian crust; (3) Paleozoic Scythian crust; (4) Cimmerian North Dobrogea crust; (5) Transylvanian type crust; (6) Pannonian type crust; (7) depth to Moho; (8) main deep faults; (9) position of the suture zones at the Moho level; (10) the intermediate-depth seismic active Vrancea zone; (11) magnetotelluric profiles.

The hypocenters of the intermediate-depth seismic events recorded in the area are concentrated within a seismogenic body having approximately a parallelepiped form, which is about 80 km long and 40 km wide, extending to a depth of about 180km. According to the seismic historical catalog (Table 1), 18 earthquakes with magnitude higher than 6.5, occurred in the area with a periodicity of three to seven times per century.

Table 1

Strong intermediate-depth earthquakes in the Vrancea zone, since 1600

No	Date: m/d/y	Magnitude
1	9/01/1637	6.6
2	9/09/1679	6.8
3	8/18/1681	6.7
4	6/12/1701	6.9
5	10/11/1711	6.7
6	6/11/1738	7.0
7	4/06/1790	6.9
8	10/26/1802	7.4
9	11/17/1821	6.7
10	11/26/1829	6.9
11	1/23/1838	6.9
12	10/06/1908	6.8
13	11/01/1929	6.6
14	3/29/1934	6.9
15	11/10/1940	7.4
16	3/04/1977	7.2
17	8/30/1986	6.9
18	5/31/1990	6.7

Several models have already been proposed for the Vrancea zone (Fuchs et al., 1979; Constantinescu and Enescu, 1984; Oncescu, 1984; Oncescu et al., 1984; Trifu and Radulian, 1989; Khain and Lobkosky, 1994; Linzer, 1996; CRC 461, 1999; Stănică et al.; 1999; etc.). In particular, Fuchs et al.(1979) considered the Vrancea zone as a place where an oceanic slab, detached from continental crust, is sinking gravitationally. Oncescu (1984) and Oncescu at al. (1984) proposed a double subduction model on the basis of 3-D seismic tomographic images: in their interpretation, the intermediate-depth earthquakes are generated within a vertical surface separating the sinking slab from stable lithosphere. Constantinescu and Enescu (1984) emphasize that the breaking off of the oceanic lithosphere took place after the beginning of the collision, and that the resulting slab is almost sub-vertical. Trifu and Radulian (1989), analyzing the seismic behaviour of the Vrancea zone, proposed a model based on the existence of two active zones located at depths of 80-110 km and 120-170 km. Both zones are characterized by local stress inhomogeneities capable of generating large earthquakes. Khain and Lobkosky (1994) suggest that the Vrancea zone results from delamination processes occurred during continental collision and lithosphere sinking into the mantle. Linzer (1996) shows that the vertical position of the Vrancea slab may be due to the final rollback stage of a small fragment of oceanic lithosphere; the authors also reconstruct a migration path of the retreating slab between the Moesian and East European platforms. The CRC Group 461 (1999), taking into consideration that the geometry of the subduction zone was not unequivocally defined, proposed four possible configurations for the Vrancea zone. The subduction process was modeled as: a subduction beneath the suture zone; a subduction beneath the foredeep area; two interacting subduction zones, and a subduction beneath the suture, followed by delamination. In two papers, Stănică et al. (1999) and Stănică, and Stănică (2002) show the results of magnetotelluric tomographies and propose: (i) a continental origin for the seismogenic body, and (ii) that the changing orientation of the slab strike with depth is the result of a geodynamic torsion. In Fig. 2 (Stănică et al. 2004) is presented a possible model for the deformation processes acting in the Vrancea zone, in order to relate the observed main features characterizing its deep structure and the seismicity of the area. Based on these data, the authors conclude that the directional change of collision in the Eastern Carpathians is preserved in the EM tomographic image, as the N-S oriented high-velocity body might represent older westward subducted material detached from the foreland lithosphere, but still attached to the upper NE-SW trending portion of the Vrancea slab. This kind of information are integrated with available geological and geophysical data such as: the induction arrows map (Pinna et al., 1992) showing the Carpathian electrical conductivity anomaly (CECA), and the map of the brittle-ductile transition zone within the lower crust, where the Trans-European Suture Zone (TESZ), with a width of about 40 km, is also clearly delineated (Stănică et al., 1999).

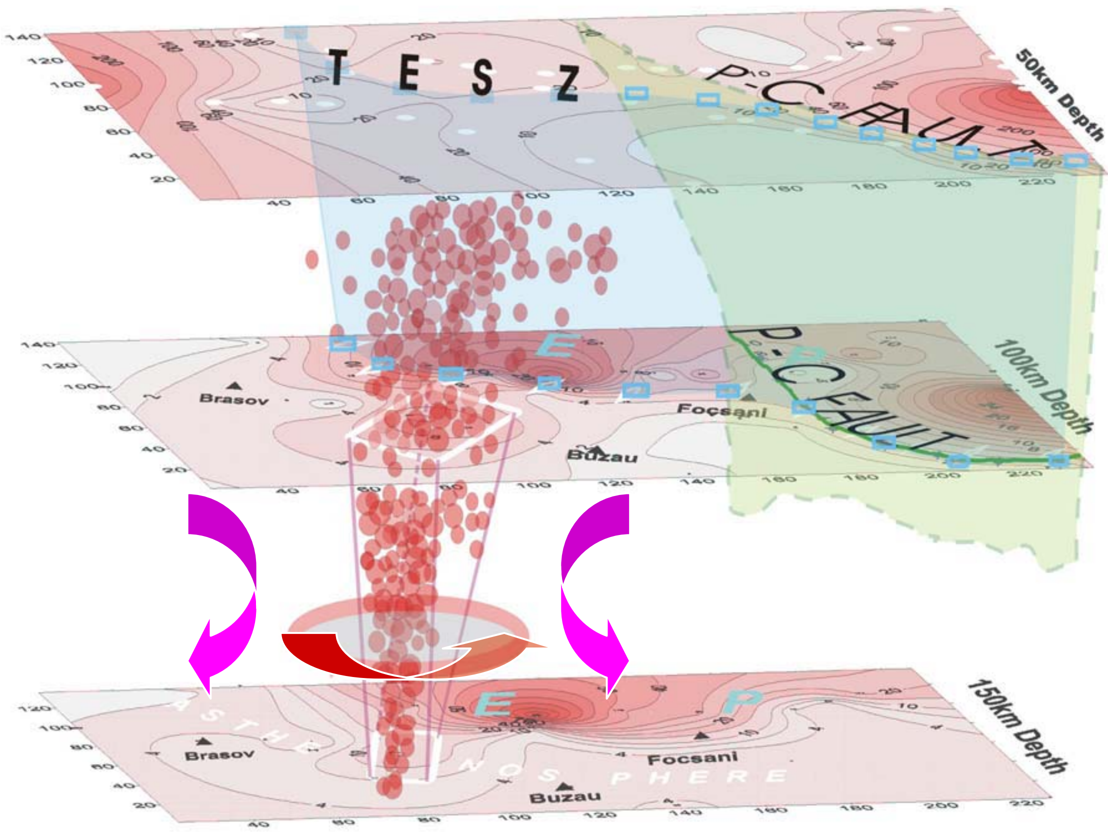

Fig.2. 3-D electromagnetic tomographic image for the Vrancea relic slab. Red circles are intermediate-depth foci; red arrow indicates the torsion direction of the relic slab; pink arrows indicate descending asthenospheric current occurred on the both sides of the relic slab

3. THEORETICAL BASE OF THE NORMALIZED FUNCTIONS Bzn and ρn

Is well known that at the Earth surface the geomagnetic component Bz is entirely secondary field and its existence is an immediate indicator of lateral inhomogeneity (Ward et al., 1970). Bz is produced essentially by B⊥ (precisely for two dimensional cases) and consequently a normalized Bz function defined as:

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

should be time invariant for a given 2D structure (Stanica, 2001, 2002,).

In addition to the magnetotelluric tensor impedance, vertical resistivity ρ_z may be computed:

$$\rho_z = 0.2\ T\ \left| E_{\parallel} / B_z \right|^2, \qquad (2)$$

where: T is the period (in seconds) and $E_{\parallel}$ is electric field parallel to the geological strike direction.

Also, it is possible to write the relation:

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

where: $\rho_{\parallel}$ is resistivity parallel to the strike.

Thus, in terms of resistivity the normalized function Bzn may be estimated as:

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

where : $\rho_{\parallel} / \rho_z$ is "so called" normalized function ρn

$$\rho n = \rho_{\parallel} / \rho_z \qquad (5)$$

In order to verify this hypothesis the approximate field solutions were computed for two simple 2D geometries:

1. Solution for the sloping interface model was obtained by summing all plane waves propagation at real angle, ignoring effects of apex ;
2. The vertical contact solution was computed for two resistivities

The both models represent two extremes in dipping angle of the interface.

As we have seen in relations (1) and (5), the normalized functions Bzn and ρn could be used as precursory parameters of seismic events, measuring the vertical component Bz (obtained directly from continuous monitoring of the geomagnetic field),

$B_\perp$, $\rho_\parallel$, ρ_z (all evaluated by using the magnetotelluric tensor impedance decomposition technique - Bahr,1988, 1990 and MAPROS software packages).

3. THE GEOELECTRIC PATTERN OF THE MONITORING SITE NATIONAL GEOPHYSICAL OBSERVATORY SURLARI (NGOS)

With the aim of identifying the best placement for continuous monitoring of the EM field and to reveal the short-term precursory parameters of the seismic events, we made magnetotelluric (MT) measurements at NGOS (Fig.3) by using the GMS 06 system installed on mobile laboratory of geodynamic (Stanica, Zugravescu, 2002).

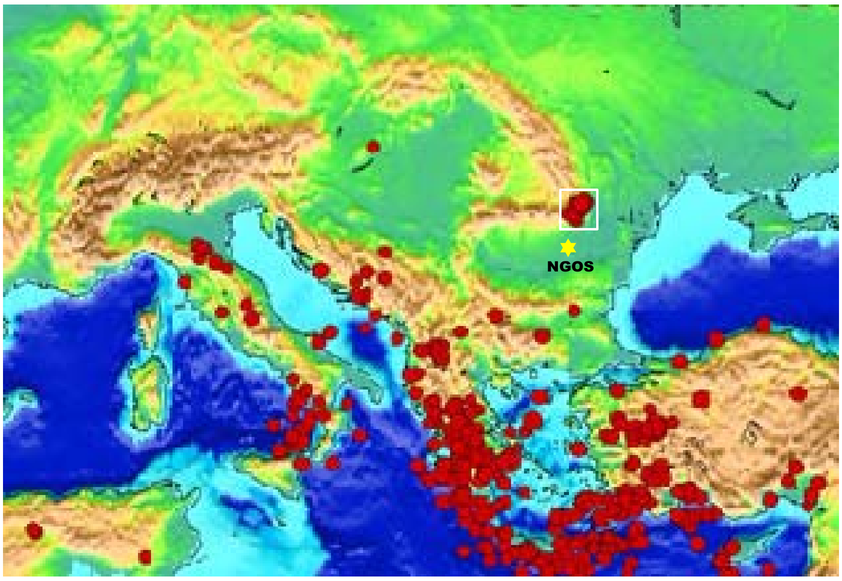

Fig. 3. Map with the monitoring site (NGOS)

In order to evaluate the geoelectric pattern below the measuring point, the MT data processing have been made with the help of MAPROS software packages (Metronix, Germany) and, consequently, the following basic tasks have been performed:

- Real time-display of the electromagnetic data and all important parameters ;
- Evaluation of skew coefficients (here being less then 0.2 what means that the geological structure is of 2D type – Fig.4) and strike direction (which for subcrustal levels is about east-west, thus correct values of $B_\perp$ are given by the horizontal geomagnetic component orientated towards north);

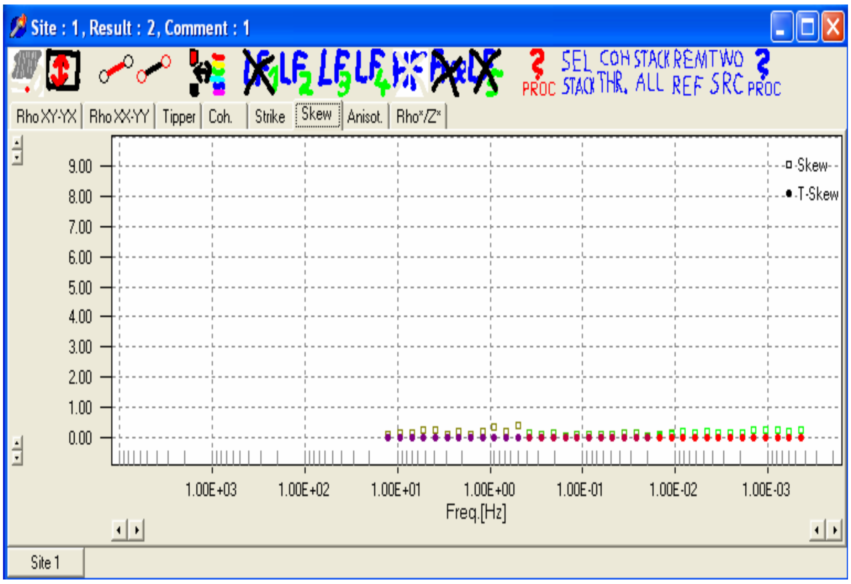

Fig.4. Real time-display of the electromagnetic parameters (skew)

The NGOS is placed along an alignment delimited towards north-east by the epicentral Vrancea zone (at about 130 km) and to south-west by Bucharest city (at about 40km). The criteria for selection of this point are presented above and the following aspects must be included, too:

- It is far away enough from the epicentral Vrancea zone (about140km), so that the parameter Bzn is not/less affected by the earthquakes of magnitude less than 3.0;
- The existence of logistic base able to supply optimal monitoring of geomagnetic data and electronic connection with Bucharest able to make data transfer in real time;

5. CONTINUOUS MONITORING OF ELECTROMAGNETIC DATA AND RESULTS

The continuous monitoring of geomagnetic data was accomplished using the recording system MAG03 DAM (Bartington – England), with 6channel, 24 bit resolution for the collection of date from three axis magnetic field sensor MAG03 MC/MSL, data transmitted to the laptop via an optically isolated RS232 serial link. The parameters of the data acquisition card are under software control and additional program collects data at each 5seconds and stores one-minute average values to disk (Fig.5).

Fig.5. Geomagnetic system configuration

Daily average distribution of the parameters Bzn and ρn in correlation with Vrancea's deep seismic events occurred simultaneously within the time interval 1-19 March, 2001, and 1-30 June, 2004, are presented in Fig.6 and Fig 7, respectively.

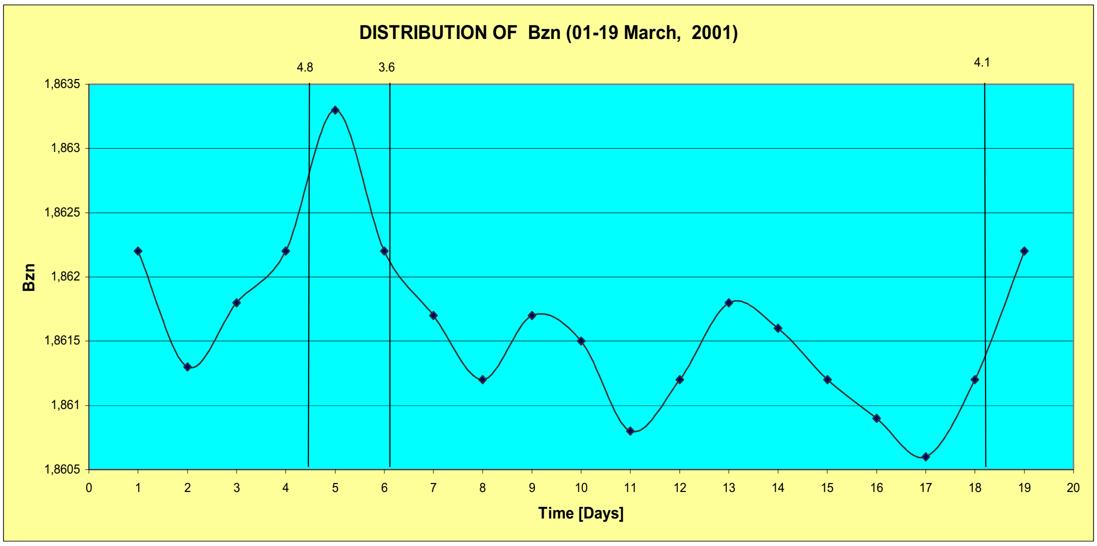

Fig.6. Daily average distribution of the parameter Bzn (vertical line indicates the triggering moment of the earthquake)

Fig.7. Daily average distribution of the parameter ρn (red star is intermediate earthquake; green star is crustal earthquake; 3.4/140km represents the magnitude/depth)

The analysis of the Bzn and ρn parameters distribution permitted us to identify following aspects:

- The normal values of the Bzn and ρn parameters in non seismic conditions are of about 1.8615 (± 0.001) and 3,513 respectively;
- Anomalous behaviour within the range 1.860-1.863 (for Bzn) and 3.513-3.517 (for ρn), respectively, which may be associated with seismic events of magnitude higher than 3.0.

Conclusion

The new methodology regarding short-term precursory parameter applied firstly at the NGOS gives us the possibility to point out the followings:

- With some days before occurring an earthquakes with M>3.0 the normalized function Bzn has a significant increase in respect with its standard deviation, as a result 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 slab and its surrounding areas;

- At this stage of researches, is not possible to make any predictable correlation between the magnitude of seismic event and the magnitude/shape of Bzn function, so that in the near future all the efforts should be done in this direction;
- The study of EM phenomena/parameters associated with EQ is clearly an urgent scientific need in understanding the physics of lithospheric processes and in using all the relevant data in mitigation programs of the natural disasters, such as earthquakes.

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