# SEISMO-ELECTROMAGNETIC PHENOMENA IN TECTONICALLY ACTIVE REGIONS

**H. G. SILVA**
Investigador
Centro de Geofísica de Évora, Departamento de Física da Universidade de Évora – Portugal

**M. BEZZEGHOUD**
Professor
Centro de Geofísica de Évora, Departamento de Física da Universidade de Évora – Portugal

**P.F. BIAGI**
Professor
Universidade de Bari – Itália

**M. TLEMÇANI**
Professor
Centro de Geofísica de Évora, Departamento de Física da Universidade de Évora – Portugal

**R.N. ROSA**
Professor
Centro de Geofísica de Évora, Departamento de Física da Universidade de Évora – Portugal

**A.H. REIS**
Professor
Centro de Geofísica de Évora, Departamento de Física da Universidade de Évora – Portugal

**M.A. SALGUEIRO DA SILVA**
Professor
Departamento de Física da Universidade do Porto – Portugal

**B. CALDEIRA**
Professor
Centro de Geofísica de Évora, Departamento de Física da Universidade de Évora – Portugal

**J.F. BORGES**
Professor
Centro de Geofísica de Évora, Departamento de Física da Universidade de Évora – Portugal

**M. MANSO**
EDISOFT, Lazarim – Portugal

## ABSTRACT

This work presents a research plan that aims to monitor seismo-electromagnetic signals in seismic active regions. Two effects will be considered: electromagnetic field emissions and radio broadcastings. Our study will be focused in the analysis of low magnitude earthquakes almost completely disregarded in literature. We aim to collect novel seismo-electromagnetic emission data emerging from seismic activity. We expect to address the time variation of electromagnetic properties of the crust in relation with the strain field and complement it with the development of proper models. Experimental studies based on the electrical properties of rocks will also be done aiming the understanding of pressure stimulated currents and voltages that produce detectable electromagnetic radiation and can be a cause for seismo-electromagnetic signals.

## 1. INTRODUCTION

The study of electromagnetic phenomena associated with earthquakes (SEM) is a relatively new field of research [1]. These phenomena include recording unusual electrical signals (SES) [2, 3], abnormal ultra-low-frequency electromagnetic emissions (ULF) [4, 5], anomalies in the radio transmissions of very-low (VLF) and low-frequencies (LF) associated with disturbances of the ionosphere [6,7], the variation of total electron content (TEC) [8] and atypical emission in the infrared (IR) [9], all these correlated with the preparatory phase of earthquakes. In fact, after reports of abnormal magnetic signals in the ULF near the epicenter of the imminent Loma Prieta earthquake done by Fraser-Smith et al. [10], SEM has become a very active field of research that is gaining importance among the international scientific community.

Even though, SEM observations were also responsible for intensive discussions on their applicability to the prediction of earthquakes in the short to medium term [1]. However, the development of a system of earthquake prediction is still uncertain and it should not be considered as an immediate objective. Mainly because most of the physical processes involved in the emissions are still not well understood [4] and require more research. Currently, the entire effort in this area is concentrated on the systematic observation of the SEM effects before earthquakes occur and on the understanding of the physics involved in these emissions by developing models [11] and conducting laboratory experiments [12].

In this article we describe our project that plans to monitor seismo-electromagnetic signals in seismic active areas, initially we will focus in the western part of the Eurasia-Nubia plate boundary (WENP). This region has a significant tectonic activity [13] combined with low electromagnetic noise levels and for that reason presents the possibility to perform high quality measurements. Two SEM effects will be considered: ULF electromagnetic field emissions and VLF/LF radio broadcastings. Our study will be focused in the analysis of low magnitude earthquakes, $M \leq 4$, frequent in the WENP region, but almost completely disregarded in literature.

Experimental studies based on the electrical properties of rocks [14] will also be done aiming the understanding of pressure stimulated currents and voltages that produce detectable electromagnetic radiation. Some possible consequences of such analysis are further drawn.

## 2. IMPLEMENTATION OF SEM MONITORING

The main objective of this project is to start monitoring SEM emissions in WENP, this is innovative since SEM did not received until now any attention by the geophysical community in the Iberian Peninsula. Moreover, it is known that electromagnetic waves of low frequency (ULF, VLF and LF) originate the more convincing precursor phenomena to earthquakes when compared to higher frequency waves. This is primarily due to low levels of contamination, great penetration depths and the low attenuation that they suffer [8]. In this sense, two principal SEM effects will be considered: emissions of ULF electromagnetic fields [5, 8] and VLF / LF radio broadcasts [6, 7].

For the ULF measurements, LEMI-30 induction high-resolution magnetometers (Fig.1a) built by the Lviv Centre of Space Research, Ukraine which measure the three components of the magnetic field (X, Y, Z) will integrate the existing networks of seismic stations in the Iberian Peninsula and the Western Mediterranean Broad Band Network [15]. Initially, two magnetometers will be installed in the south of Portugal, two candidate areas, among others, are Vila do Bispo and Tavira (these areas have a frequent seismic activity and low electromagnetic noise levels). A third sensor, LEMI-18 flux magnetometer also fabricated by the Lviv Centre of Space Research, Ukraine, will constitute a mobile station for temporary measurements like calibrations, noise level measurements etc. All these devices will integrate in the future a network of ULF magnetic sensors, South European Geomagnetic Array (SEGMA), and form a European network for the observation of ULF radiation related earthquakes.

In what regards the VLF/LF broadcasting, it will be install a radio receiver from Eletronika, Italy capable of monitoring up to 10 frequencies distributed in these bands, see Fig.2a. It will be located in a field facility of the University of Évora at Mitra, near the seismic station EVO [15] and will be integrated into the International Network for Research on Earthquake Precursors (INFREP). The most important of such measurements is that the path of the radio waves from the transmitter to the receiver crosses the area from the epicenter of the future earthquake. Therefore, transmitters installed in Monaco (France) and Sicily (Italy) will be used, these are being already monitored by other INFREP receivers. In a second phase, the signals from three other transmitters (if possible) will be examined: Azores, Madeira, Ceuta (Fig. 2b). Possibly one new receiver will be installed in North Africa in a third stage of project.

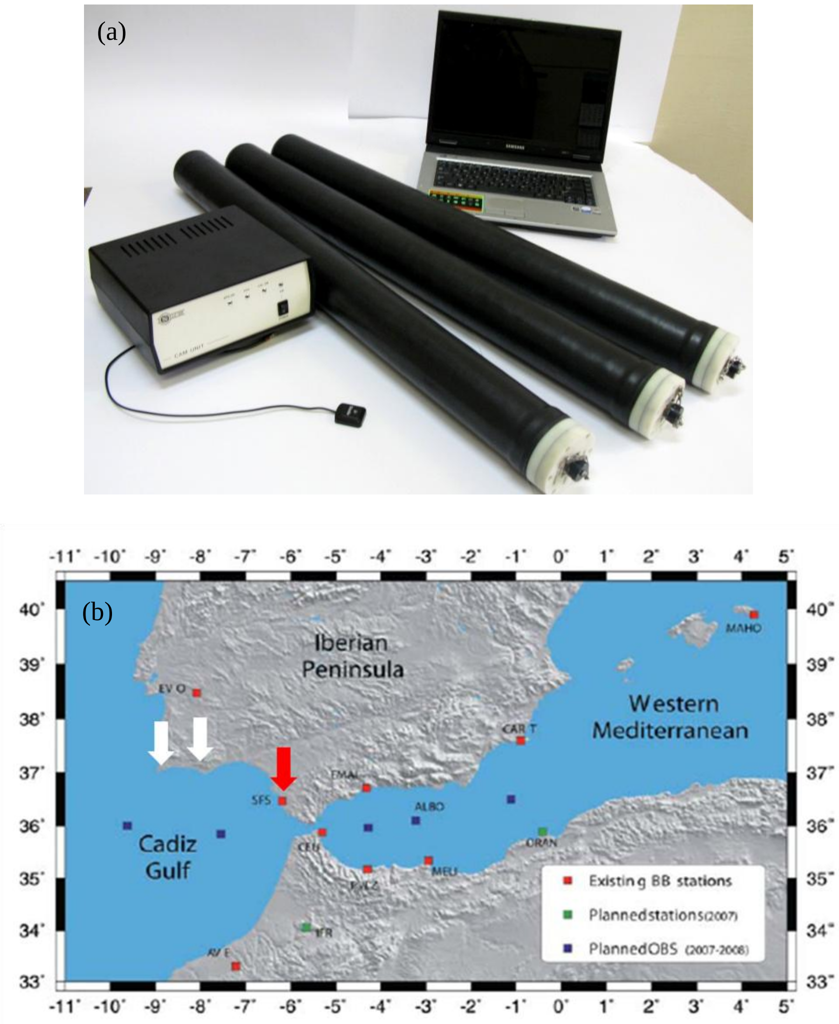


Fig.1 – a) High-resolution magnetometers (LEMI-30) which measure the three components of the magnetic field (selected from Lviv Centre of Space Research brochure). b) Map of Western Mediterranean Broad Band Network (Adapted from [15]). White arrows indicate the ULF sensors fixed to mobile and red.

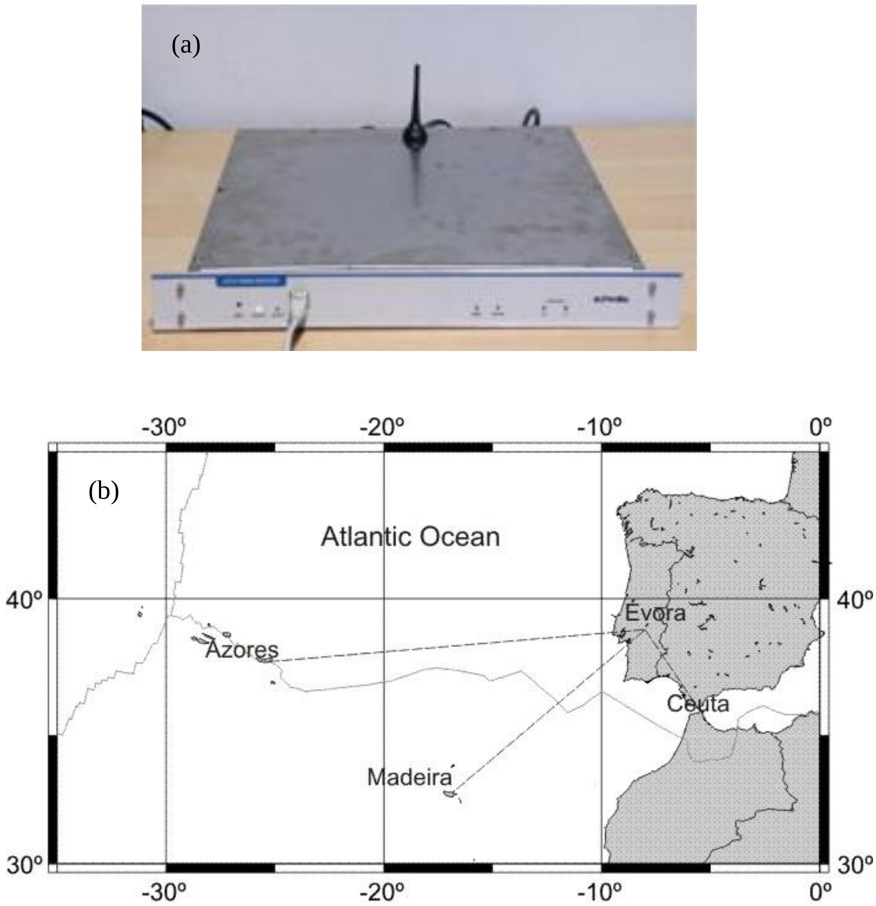


Fig.2 – a) The front panel of the Eletronika receiver (elected from the INFREP site, http://beta.fisica.uniba.it/infrep/). b) Map of the transmitters planned for measures VLF/LF: Azores, Madeira and Ceuta.

## 3. ELECTRICAL PROPERTIES OF ROCKS

The rather interesting electric properties of rocks are a result of their behavior as both conductor and dielectric. Besides, present investigations [12] have shown interesting pressure stimulated currents [16] and voltages [17] that could have some implications in SEM but also in identifying the facture risk of different materials like granite and even cement [18].

In the first stage of this part of the project we will study the electrical properties of different granitic rock types (there types will be studied, presented in Fig. 3). Initially, the dependence of water content and the temperature will be considered in order to properly establish the fundamental mechanism of charge transport in the rocks. This is an important step in order to afterwards understand appropriately the pressure stimulated current and voltage experiments and most authors have disregarded it. The following measurements will be done: impedance spectroscopy, impedance versus voltage, impedance versus temperature, current versus voltage, and current versus temperature. The results will also be interpreted in terms of local porosity [19], and fractal geometry of the fissures network [20]. Once this initial stage is complete new samples will be analyzed and pressure stimulated experiments will be done and discussed.


Fig.3 Picture of the three granitic rock types considered in this work.

## 4. DISCUSSION AND EXPECTED RESULTS

These studies might eventually prove to be of interest in identifying new methods to supervise collapse risk of degraded buildings or endangered cliffs, by monitoring the EM radiation emission due to the abnormal stress field produced by such structures in the shallow crust, complementary to existing acoustic vibrational techniques for monitoring the mechanical stability of building structures.

Further, with this research effort, it is likely that new SEM data linked with seismic activity in the WENP region could emerge and contribute to a better understanding of SEM. In addition, such data could be used in searching for a relation law between the strength of SEM anomalies and the magnitude and/or local (referred to the place where the sensors will be installed) ground motion of the impending low magnitude earthquakes. This objective could give an important insight on the driven mechanisms responsible for these phenomena and present a decisive contribution to the development of this field.

As a final remark it is important to mention that laboratorial experiments concerning the electrical properties of rocks could also contribute for a better understanding of the physics of the SEM phenomena.

## 5. ACKNOWLEDGMENTS

This work has been partially developed through the project SIRAS with the support of the Agência de Inovação (ADI) and the programs: Quadro de Referência Estratégica Nacional (QREN), COMPETE – Programa Operacional Factores de Competitividade and FEDER - Fundo Europeu de Desenvolvimento Regional. One of the authors (HGS) gratefully acknowledges support from FCT through the grant SFRH/BPD/63880/2009.

## 6. REFERENCES


[1] Uyeda, S. et al. (2009) Short-term earthquake prediction: Current status of seismo-electromagnetics, Tectonophysics 470, 205.

[2] P. A. Varotsos, P.A. et al. (2006) – On the recent advances in the study of seismic electric signals (VAN method), Phys. Chem. Earth 31, 189.

[3] Konstantaras, A. et al. (2007) – On the electric field transient anomaly observed at the time of the Kythira M=6.9 earthquake on January 2006, Nat. Hazards Earth Syst. Sci. 7, 677.

[4] Bleier, T. et al. (2009) – Investigation of ULF magnetic pulsations, air conductivity changes, and infra red signatures associated with the 30 October Alum Rock M5.4 earthquake, Nat. Hazards Earth Syst. Sci. 9, 585.

[5] Telesca, L. et al. (2009) – Investigating non-uniform scaling behavior in Ultra Low Frequency (ULF) earthquake-related geomagnetic signals, Earth and Planet. Science Lett. 268, 219.

[6] P. Biagi, P. et al. (2008) – An overview on preseismic anomalies in LF radio signals revealed in Italy by wavelet analysis, Annals of Geophysics 51, 237.

[7] P. Biagi, P. et al. (2009) – A pre seismic radio anomaly revealed in the area where the Abruzzo earthquake (M=6.3) occurred on 6 April 2009, Nat. Hazards Earth Syst. Sci. 9, 1551.

[8] Chauhan, V. et al. (2009) – Ultra-low-frequency (ULF) and total electron content (TEC) anomalies observed at Agra and their association with regional earthquakes, Journal of Geodynamics 48, 68.

[9] Ouzounov, D. et al. (2007) – Outgoing long wave radiation variability from IR satellite data prior to major earthquakes, Tectonophysics 431, 211.

[10] Fraser-Smith, A. C. et al. (1990) – Low-frequency magnetic field measurements near the epicenter of the Ms 7.1 Loma Prieta earthquake, Geophys. Res. Lett. 17, 1465.

[11] O.A. Molchanov and M. Hayakawa (1995) – Generation of ULF electromagnetic emissions by microfaturing, Geophys. Res. Lett. 22, 3091.

[12] Freund, F.T. et al. (2006) – Electric currents streaming out of stressed igneous rocks - A step towards understanding pre-earthquake low frequency EM emissions, Phys. Chem. Earth 31, 389.

[13] Bezzeghoud, M. et al. (2008) – Seismic activity in the Azores Region in the context of the western part of the Eurasia-Nubia plate boundary, International Seminar on Seismic risk and rehabilitation on the 10th Anniversary of the July 9 1998 Azores Earthquake, Azores – Portugal.

[14] Silva, H.G. et al. (2010) – Electric properties of granitic rocks, Jornadas de Física por ocasião da Jubilação do Professor Rui Namorado Rosa, Évora – Portugal.

[15] Davila, J.M. et al. (2007) – Broad band "western mediterranean" an ocean botton "fomar" seismological networks", CSEM / EMSC Newsletter, May 2007 pp. 16-17.

[16] Vallianatos, F. et al. (2004) – Electric earthquake precursors: from laboratory results to field observations, Phys. Chem. Earth, Vol. 29, 339.

[17] Aydin et al. (2009) – Observation of pressure stimulated voltages in rocks using an electric potential sensor, Appl. Phys. Lett., Vol. 95, 124102.

[18] Vallianatos, F., and Triantis, D. (2008) – Scaling in Pressure Stimulated Currents related with rock fracture, Physica A, Vol. 387, 4940.Kenyon, W.E. (1994) – Texture effects on megahertz dielectric properties of calcite rock samples, J. Appl. Phys., Vol. 55, 3153.

[19] Haslund, E. (1994) – Measurement of local porosities and dielectric dispersion for a water saturated porous medium, J. Appl. Phys., Vol. 76, 5473.

[20] Miguel, A.F. et al. (2000) – Fractal geometry description of the permeability of a natural fissured rock, 9th International Congress on Deterioration and Conservation of Stone.