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SEISMO-ELECTROMAGNETIC PHENOMENA IN TECTONICALLY ACTIVE REGIONS

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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.

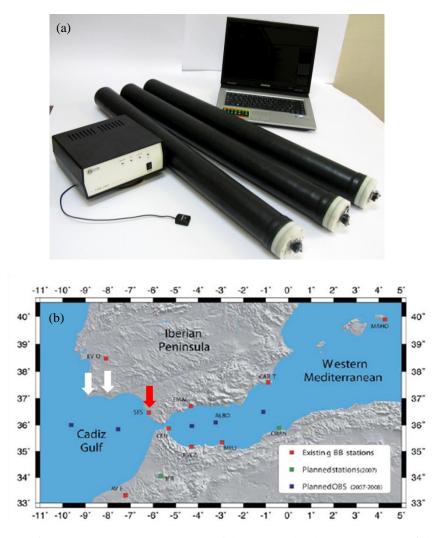


Fig.1 – a) High-resolution magnetometers (LEMI-30) which measure the three components of the magnetic field (selected from Lviv Centre of Space Research brochure). b) Map of Western Mediterranean Broad Band Network (Adapted from [15]). White arrows indicate the ULF sensors fixed to mobile and red.

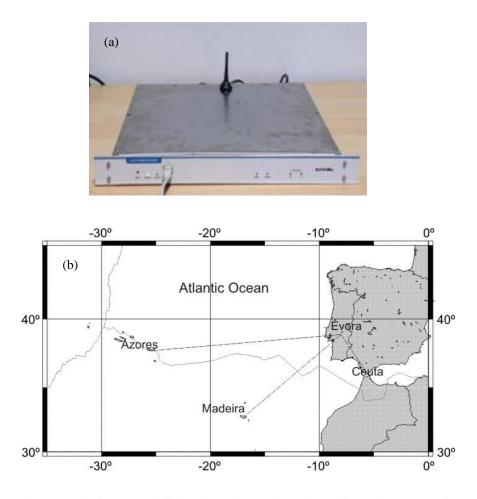


Fig.2 – a) The front panel of the Eletronika receiver (elected from the INFREP site, http://beta.fisica.uniba.it/infrep/). b) Map of the transmitters planned for measures VLF/LF: Azores, Madeira and Ceuta.

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.

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