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Earthquake forecast in Vrancea zone, Romania

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The paper refers to a method and system for determining the seismic precursors, which occur at very low frequencies of infrasound (2 mHz – 200 mHz) and electric currents at ground level, produced by vibrations of the crust as a result of tectonic stress that appears before a seism and the induction effect caused by the movement of the Earth in gravitational field. The result is a forecast of the place, time and magnitude of an earthquake in a range between 1 hour and 2 days before it occurs. The system and method for determining the seismic precursors based on infrasound is composed of sensors of infrasound, a piezoelectric membrane type (tectonic „eardrum") and two pairs of electrodes with the purpose of measuring the electric field of the soil in a square corners. The two systems of measurement are complementary: mechanical vibrations of very low frequency are taken from earthly eardrum and associated electric field through the piezoelectric effect electrodes stuck in the ground. The method correlates filtered low-pass and band-pass electrical signals from two complementary systems of measuring thru a processing module. The data is transmitted via Internet to a computer analysis in order to determine the deformation, the vibrations of the Earth's crust, preceding an earthquake and locating it according to the directions of propagation and frequency spectrum of waves at very low frequencies (2 mHz – 200 mHz).

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1. Methods

Seismic prediction needs a multidisciplinary activity and it is difficult to obtain. There is no general method to be applied in all the seismic zones. This paper refers to a forecasting because the earthquake location will be in the monitored area, its magnitude will be determined thru the approximation of the energetic trends and the momentum of earthquake will be known based on the electromagnetic field and infrasound signals. All of those determinations have some errors that do not fit in the prediction defined by seismologists.

Currently there are specialized departments within the institutions of Geophysics which deals with the measuring of the geomagnetic field, of the radiation level in tectonic fault zone, of the electric field induced in the lithosphere, of the penetration of Solar radiation in the Earth field on the poles, to correlate the position of the clouds with air ionization in the production zone of an earthquake etc.

Seismic prediction is made by processing some measured data or statistic by events analysis (magnitude, location, depth) for a long period of time [1-2].

Electric field measurement is made in Greece, in many locations (Athens University or independent researchers like John Tsatsarogos and C. Thanassoulas) [3-5], in USA, California (Oregon University) for tectonic faults, in Australia (Research School of Earth Science)[6].

The measuring of waves in infrasound domain is made in institutions in Nordic Countries like: USA (Alaska – University of geophysics), Canada (Narod Ring Core), Norway, Finland, Sweden, Russia, Japan. In this research there are also used geostationary satellites GOES 10, 11, 12 endowed with equipment for measuring the flow of electrons, geomagnetic field, the flow of protons and X radiation[7].

The system and method of determination of seismic precursors based on infrasound resolves the technical problem of early determination (between one hour and two days) of the place, moment and magnitude of an earthquake [8]. This is important for the prevention of the responsible authorities and the population in areas of urban agglomeration. This sort of system resolves even the technical problems concerning the protection of large investments (tall buildings or dams) and reduces the panic by information. A seismically forecast may be obtained, such as a weather forecast.

The system and method for determining the seismic precursors based on infrasound is easily achieved, does not require large investments and can contribute to monitoring the environmental and climatic factors in the area where it is installed [9].

Earthquakes are now explained by the elastic rebound theory (Reid, 1911) [10]. Stress is applied to rock or to an existing fault over a period of time. This usually happens at a plate boundary where two plates are moving in different directions, or in the same direction with different speeds. As the stress builds, rock or a locked fault (a fault where the two sides are held together by friction) deform elastically. Eventually, the stress overcomes the rocks strength or the faults friction, and either the rock fractures or the fault slips causing an earthquake. The rock or fault rebounds and the process may begin again. The key point of this theory is that the stress is continually building up and the earthquake act to relieve that stress. For a constant rate of stress increase due to plate motion, the greater the time between earthquakes, the greater the stress release when the earthquake occurs (larger magnitude).

Between the moment of limit of elasticity overcome and fault rupture there are generated very low frequency waves which can be measured with specialized sensors.

The stresses in the Earths crust, are the result of a very complex system of forces. The main driving force is mantle convection - hot, less dense material rises along mid-ocean ridges, cools, and subsides at subduction zones, and the plates "ride" these convection cells. Though there is little doubt that convection does occur in the mantle, current modeling suggests that it is not so simple. Many geologists argue that the force of convection is not enough to push enormous lithospheric plates like the North American plate. They suggest instead that gravity is the main driving force: cold, dense oceanic crust sinks at subduction zones, pulling the rest of the plate with it. These forces lead to the interaction of tectonic plates in fault zones, dilations and compression of Earths crust.

We "see" the effects at surface in Earths mantle like very slow waves. Our tectonic "eardrum" sensors type can measure these variations of low frequency (pressure variations) while electrodes stuck in the ground are to notify the surface electric field generated by piezoelectric effects which modified the existed field.

Thru the Earths crust, electric currents circulate, produced by the movement of the tectonic plates and the effect of electromagnetic induction caused by the Earth rotation in magnetic field. These currents are combined with the piezoelectric effect caused by the stress that appears in the soil of the fault plane [11-12]. Direction of propagation of waves of very low frequency is determined using electrodes orthogonal mount. Soil resistivity depends on the placement of electrodes and the exterior conditions. This allows measurements to monitor the environment.

For epicenter zone localization, many monitoring stations are required. The intersection of directions is the location of earthquake. The magnitude is determined from wave's amplitude and from the energetic evolution of the area and the time of production from the frequency of the field signals and infrasound. For this reason a method applied in Vrancea is not available in other regions because the structure of the soil is different. The errors that occur are the result of composition of the effects of several adjacent seismic zones. The global estimation of the energy accumulated is made through the conversion of the magnitudes accumulated in energy. In this way is made a graphic of energy on which estimations and simulations can be made. We can know what will be the energy released at some point and, from it, which will be the magnitude of the earthquake through which the release of the tectonic stress will be obtained.

2. Results and discussions

The method and system of prediction were implemented for Vrancea zone. Starting 2004, graphics were made of the energy based on the seismicity measured on this area. There have been mounted: tectonic eardrums, pairs of electrodes and magnetometers in several stations. The measurements indicates the existence of seismically precursors that manifest up to 2-5 days before the production of an earthquake >4 on Richter scale. A local landmark could not be made because after each earthquake, the epicenter zone modifies. All the stations in the territory are connected to a server which gathers data. The processing of the data is made independent thru specialized programs made for this purpose.

First, we transform the earthquake magnitude in energy and will get diagram from figure 1.

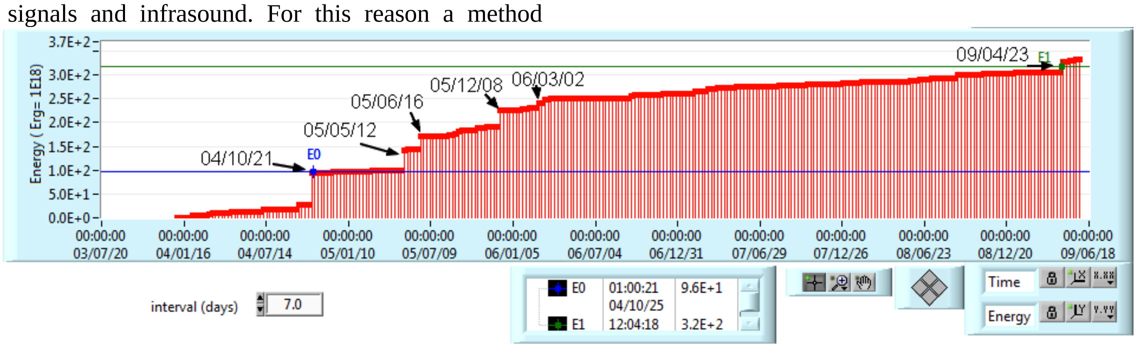

Fig. 1. Vrancea Energy Graph from 2004.

We observe that we are on a new seismic step in this period. Let's magnifier the last period and we'll get the graphic from Fig. 2.

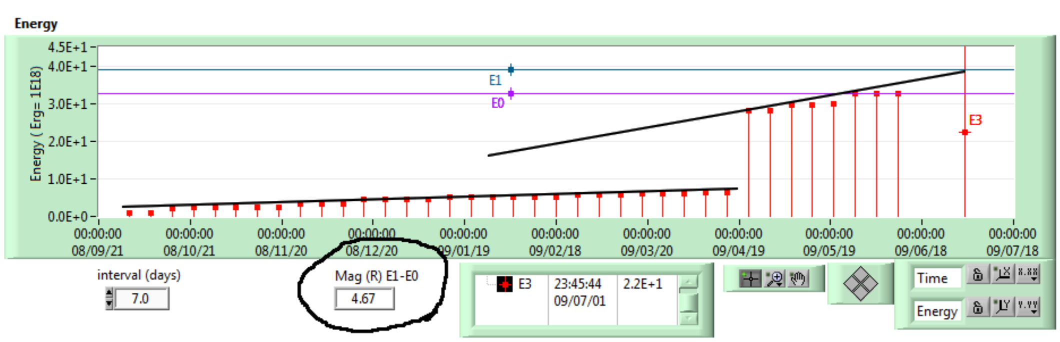

Fig. 2. "step" Vrancea Energy Graph.

We don't have enough data for estimate how long will be this period but is obviously that the short time forecast indicates an increase of magnitude.

The "sticks" from figure 3 indicates the time between two earthquake (Delta a), their magnitude (Mag), the quality of determination (Q), and the depth of earthquake. We observe that long period without earthquakes issucceeded by a seismic intense period.

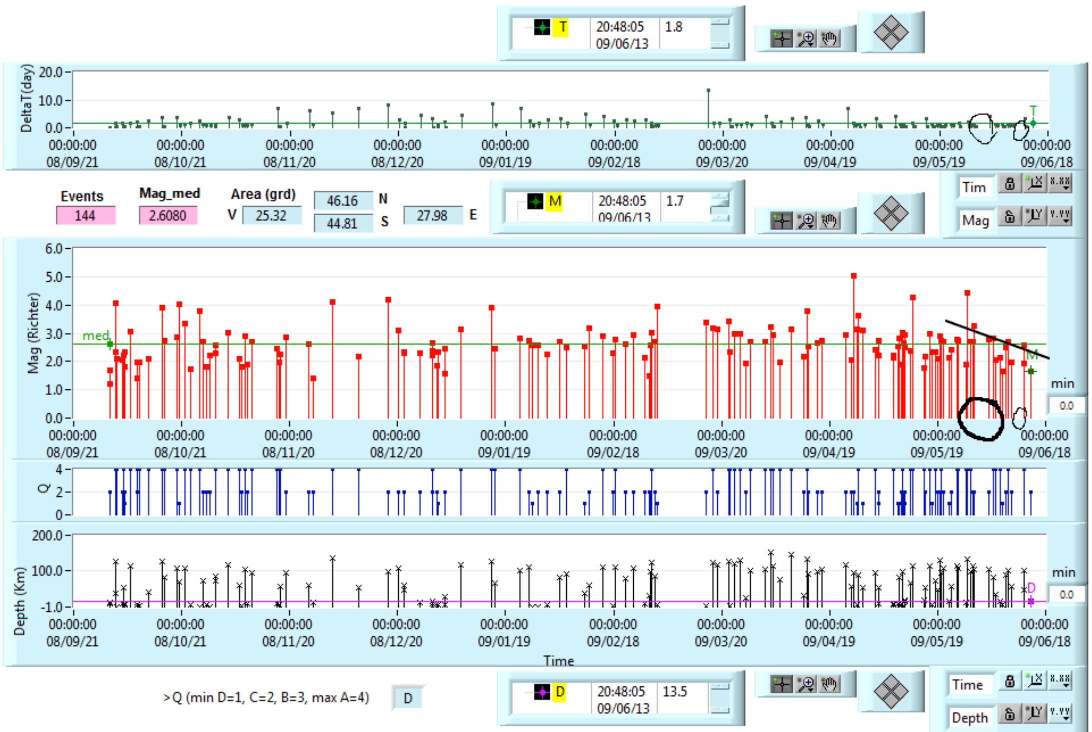

Fig 3. Vrancea seismicity (time between earthquakes, magnitudes, quality of determination, earhquake depth)

The tectonic "eardrums" are piezoelectric sensors that look like a membrane. A precursor vibration ended by a 4, 3 Richter earthquake is presented in figure 4. The waveform indicates the earth break effects.

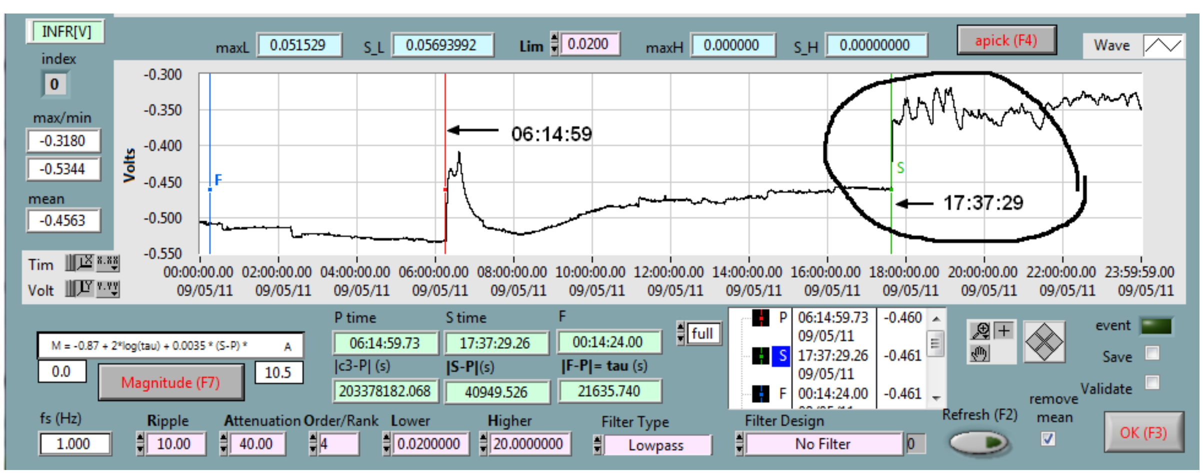

Fig . 4. Infrasound precursor.

The whole signals from the stations located in Vrancea are collected into a computer and displayed like in Fig. 5.

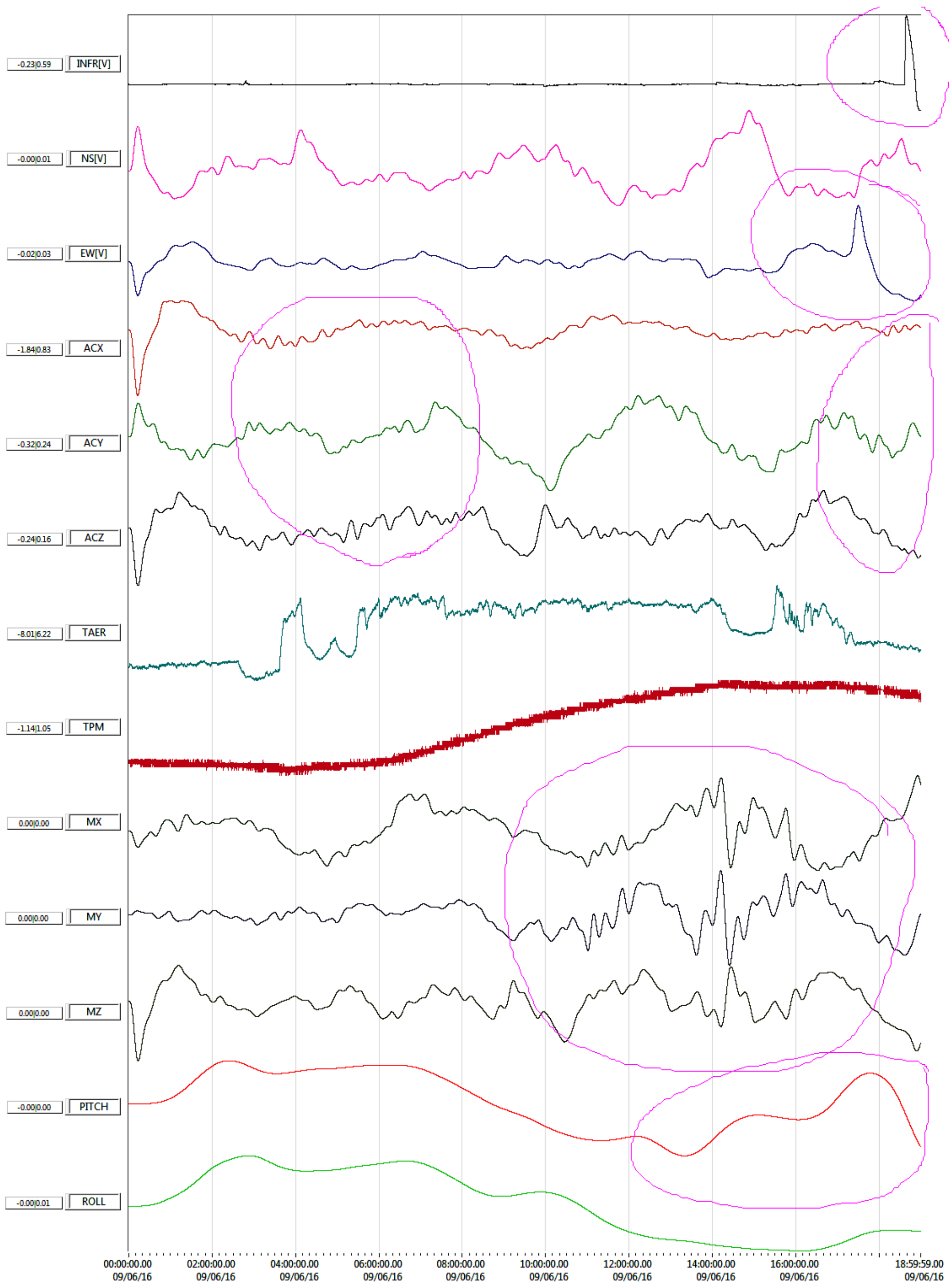

Fig. 5. Bisoca precursor signals.

Analyzing the diagrams we easily observe INFR (infrasound) perturbation, telluric electric currents variations (NS and EW) or magnetometer deviations (MX, MY, MZ).

Supplementary we use an inclinometer (PITCH and ROLL) and temperature sensors (TAER, TPM).

Three servers are waiting the data from the stations which have G3 - GSM modems connected to a local computer.

3. Conclusions

The seismic forecast is possible if we choose carefully the monitoring area. The observation station should be placed in a silent place, far away from town noise, railways, high voltage cable and over an epicentral zone. Our measurements indicate the existence of precursor signals. Minimum one station should be placed outside the epicentral area for telluric currents measurements.

Many stations and more precursors' signals make the determination reliable.

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