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EARTH PHYSICS

THE BIO-LOCATION METHOD USED FOR STRESS FORECASTING IN VRANCEA (ROMANIA) SEISMIC ZONE

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Abstract. Large and destructive intermediate-depth earthquakes in Vrancea have been generated about every century during the last millennium. Possible earthquake precursors, such as bio-location data obtained across crustal faults, and three component magnetic continuous recordings, have been used in the last decade in and around the Vrancea region. After-the-fact correlations have been published, but the interpretation was not accepted due to a subjective evaluation. As a result, a real-time methodology was implemented. A successful real-time stress forecasting was possible for a large normal depth regional earthquake at Van, eastern Turkey, and another small-moderate intermediate-depth event in Vrancea. The stress forecasting was able to offer few data for the expected event, so no earthquake prediction was possible for the location and magnitude. Our data suggest the so called earthquake precursors were not related to physical anomalies at an intermediate depth of 70-150 km in Vrancea, but they had been generated by resistivity anisotropy variations and magnetotelluric wave splitting (MWS) around crustal faults. On the other hand, resistivity anisotropy anomalies can be related to principal compressive/extensional stress variations in magnitude and direction observed around tectonic faults before, during and after moderate to large local and/or regional earthquakes. Finally, an earthquake prediction for the next large and destructive intermediate-depth Vrancea earthquake is not possible. Instead, successful stress forecasting in real time can be issued for some local and/or regional moderate-large earthquakes.

Key words: stress forecasting, crustal faults, bio-location.

1. INTRODUCTION

Earthquake prediction research has been conducted for over one hundred years with little practical success. As a result, [1] and [2] proposed that earthquakes of any size are not predictable. There are also views showing hope: [3] among others, developed the concept of seismic gaps before large-great earthquakes. [4] indicated deterministic intermediate, short-range and imminent earthquake precursors.

[5] regarded all time scales, from seconds to a few decades, before a large-great destructive earthquake to be useful for society. [5] did not agree with [1] and [2] that large earthquake have no preparatory stages. [5] proposed that after a large event the stress in the region surrounding the rupture zone is reduced below a self-organizing critical state (SOC) and remained so for a long period of time. When SOC is reached, this can be regarded as a long-term precursor rather than an impediment for earthquake prediction.

[6] suggested that many large and destructive earthquakes showed an after-the-fact precursory seismic pattern. The problem is such patterns differ from region to region and event to event in the same region. A seismic pattern alone is not a definitive tool for earthquake prediction. Measurements of other physical parameters related to stress, such as our proposed electromagnetic field, or biological parameters obtained across crustal faults, should be made concurrently in order to indicate possible earthquake precursors.

[7] remarked that “there is no doubt in my mind that many moderate-large earthquakes are preceded by real precursors, but their causative process remain murky, mainly because we lack good observations in real-time.” [7] suggested that the crust of the Earth is not an uniform elastic continuum, idealized in theoretical models, but it is broken up into blocks of various sizes. The block boundaries are fractures, which have different constitutive properties from the blocks, and which may produce local amplified strains that are not anticipated by continuum models.

[8], based on an idealized crust, discussed theoretical models of rock mechanics prohibiting a stress propagation at large distance and in a short period of time in the interior of tectonic plates from the active plate boundaries.

[9] showed classical geophysics failed to explain stress variations observed in China at large distance from future large-great earthquakes. Classical geophysics regarded rocks at equilibrium to their geological environment. Anisotropy has been considered imprinted in rocks during past episodes of deformation. The author proposed instead a “new geophysics” able to explain for the first time earthquake precursors based on stress variations in magnitude and direction recorded at large distance from the epicenter of a future large-great earthquake. The author suggested stress can propagate in the tectonic plate interior at a distance 200 times larger than the volume of the hypocenter region. The explanation might be that stress-induced fluid-saturated vertical micro-cracks are so many and so closed spaced that they verge on failure by fracturing and hence are critical systems far-from-equilibrium and self-organizing. When stress is reaching critical level before a large earthquake, micro-cracks start to coalesce in the hypocenter area and the stress decreases at a large distance. The stress decrease can be regarded as a precursor for a main shock.

Earthquake precursors, such as our proposed electromagnetic and bio-location anomalies around faults, might be related to variations of the magnitude and direction of the principal compressive/extensional stress and as a result are related to anomalies of the resistivity anisotropy. However, earthquake precursors are not sufficient to enable someone to perform a successful earthquake prediction. They are not able to indicate in real-time the location and magnitude for an earthquake. That is why [10] developed the concept of stress forecasting able to offer some but not all indications expected for a successful real-time earthquake prediction. The authors based their stress forecasting on shear-wave splitting (SWS) recorded around crustal faults. We will show magnetotelluric-wave splitting (MWS) around a crustal fault might be able to offer a similar information when compared to SWS.

Theory and observations suggest that MWS, caused by fluid-saturated stress-aligned micro-cracks, directly monitor low-level deformations before fracturing, faulting, land sliding and earthquake occurrence. [11] proved all the above to be true for SWS. The authors showed that the reappraisal of existing data sets suggested the stress begins to relax and cracks close from tens of minutes to months before the earthquake actually occurs, with the logarithm of the duration of the relaxation proportional to the magnitude of the impending earthquake. The duration of relaxation appears to be directly correlated with earthquake magnitude, and may have implications for the earthquake source process and the ability to stress forecast earthquakes. In the past, it had been wrongly assumed that the accumulation of stress before large earthquakes continued until the stress was released by faulting at the very time of the event [11].

2. BIOLOCATION AND GEOMAGNETIC PHENOMENA AROUND FAULTS USED FOR STRESS FORECASTING

The bio-location phenomena observed in consolidated rocks across faults, caves, or salt domes, and in unconsolidated rocks in landslide areas or shallow underground water above the water table filtering towards springs, might be related to MWS. However, we need to prove in a further research how a bio-locator might be sensitive to electromagnetic anomalies related to resistivity anisotropy, created by variation of tectonic stress magnitude and direction. In the last 20 yrs bio-location, known in the former Soviet Union as “biophysical effect” had no clear geophysical explanation [12].

Geomagnetic and/or electric field measurements in the past have documented natural signals attributed to stress changes in magnitude and direction, before, during and after large earthquakes [13 and 14].

The bio-location methodology for stress forecasting is indicated in Fig. 1. The distance BC measured in meters across the Coza-Valea Neagra Fault at Plostina [15] is repeated several times during one day then repeated every next day of the year. The BC data had been transmitted in real-time to the National Institute for Earth Physics (INFP) with a laptop computer carried in the field.

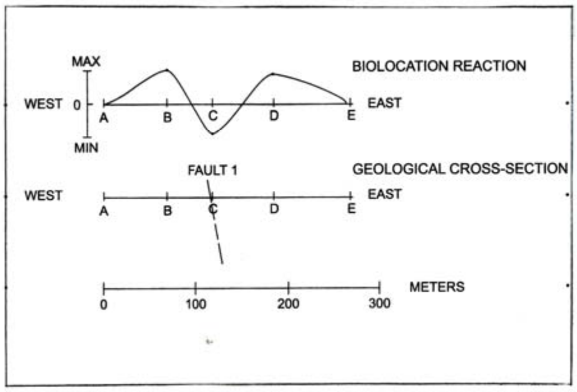

Fig. 1 – A bio-location reaction indicated at an arbitrary scale,
obtained across Coza-Valea Neagra Fault at Plostina, Vrancea, Romania [15].

Fig. 2 indicates BC variations in correlation to seismic activity in Vrancea during May-October 2010. BC data in Fig. 2 are indicated across two perpendicular faults, one the Coza-Valea Neagra Fault and the other one Paraul Adanc Fault at Plostina, Vrancea.

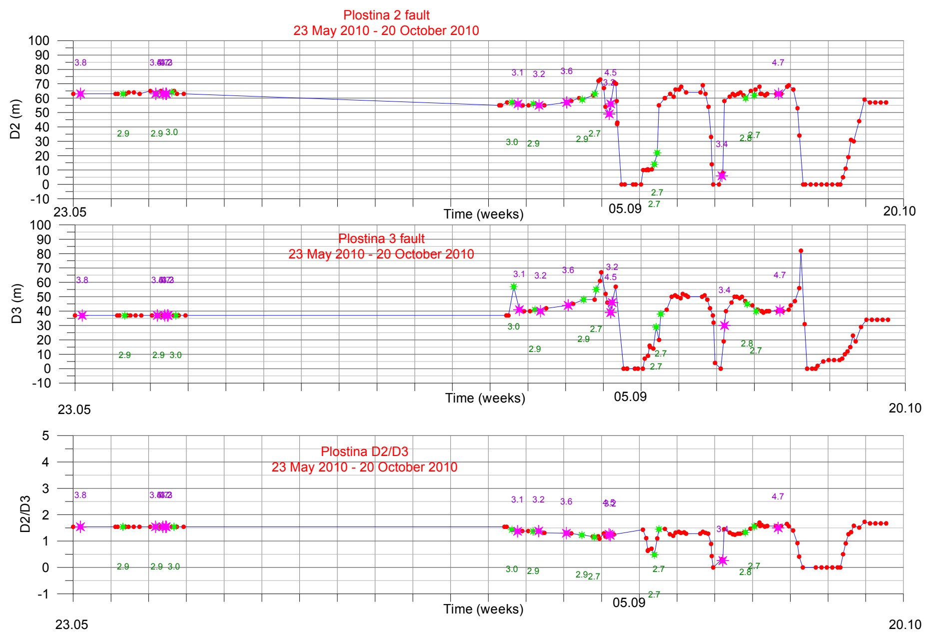

Fig. 2 – BC variations during May–October 2010, measured across Fault 1, the Paraul Adanc Fault, and the ratio BC Fault 1/BC Paraul Adanc Fault. Stars indicate intermediate-depth earthquakes in Vrancea.

Fig. 2 suggested the distance BC was about 60 m for days and weeks, then it decreased sharply before and after certain small intermediate-depth earthquakes in Vrancea. The ratio BC Coza-Valea Neagra Fault/BC Paraul Adanc Fault, showed drops, suggesting stress variations in magnitude and direction before, during and after small earthquakes.

Fig. 3 indicates BC variations measured across the Coza-Valea Neagra Fault at Plostina during October 2011. The distance BC during October 15-October 20 increased sharply from about 60 m to 400 m, then dropped to zero on October 21. Such a bio-location anomaly was never observed at Plostina, Vrancea. On October 21 at 11:00 AM a stress forecasting was issued to INFP: “A seismic warning is indicated for a large seismic event during a window of time October 22-October 26, 2011.” The stress forecasting was not able to indicate the location for such a large earthquake and the exact magnitude. As a result an earthquake prediction was not possible. However, in the short window of time predicted, a large earthquake Mw 7.2 has been recorded in Van, eastern Turkey.

[10] suggested the window of time for a large earthquake Mw 7.2 can be as long as a few months after a stress relaxation had been observed at a large distance from the rupture-zone area. However, there is no way to know when an earthquake might be recorded. It is true a large earthquake might be recorded at a few months after the stress drop. But the same magnitude earthquake can be recorded a few days or weeks after the stress drop. The window of time of 4 days predicted for the Van, Turkey, magnitude Mw 7.2 earthquake was just a wild guess.

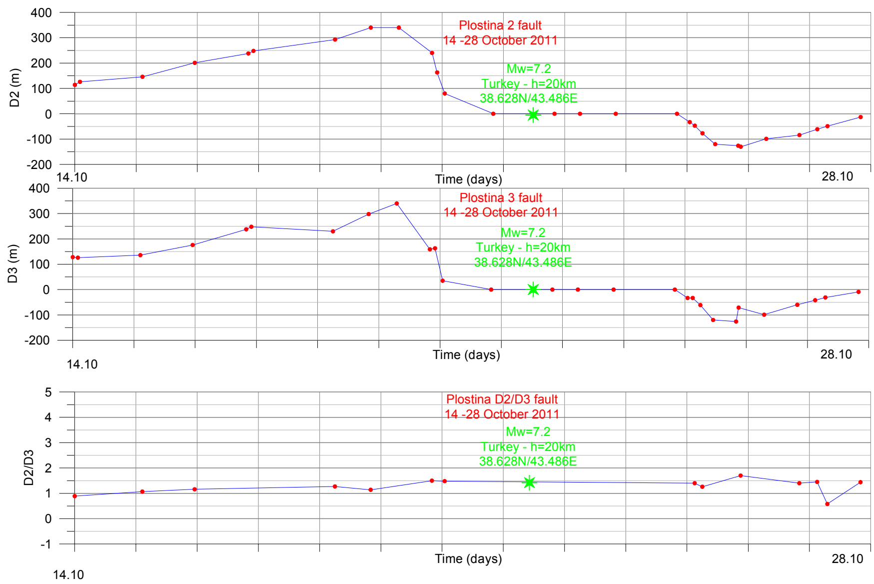

Fig. 3 – Biolocation BC data on Coza-Valea Neagra Fault measured during October 14–October 28, 2011.

After the large earthquake recorded in Van, Turkey, the bio-location reaction recorded across the Coza-Valea Neagra Fault at Plostina reversed from an M shape as indicated in Fig. 1 to a W shape. Bio-location reactions with an M shape can be regarded by convention as "positive" and W shape as "negative." Positive M type of reactions can be associated to a compressive environment and W type of reactions to an extensional one. [16] observed the stress around a fault according to a photoelastic model experiment. The author obtained similar M shapes for the anomaly of far-field compressive stress around the fault and W shapes for the extensional stress anomaly. It is interesting to note W shapes of the biolocation reaction during October 25–28, 2011, have been recorded not only across the Coza-Valea Neagra Fault at Plostina, but across the Horgasz Fault situated 60 km west from Plostina at Covasna. Fig. 4 indicates the Horgasz Fault at Covasna.

Fig. 4 – The Horgasz fault seen on the Google Map, Covasna, Romania.

Similar to Plostina, Vrancea, the bio-location research in Covasna used two perpendicular faults. One was the Horgasz Fault indicated in Fig. 4 along the Horgasz Creek, and the other Covasna Fault. The Covasna Fault cannot be seen on the Google Maps since it is covered by young sediments of clay, sand and gravel. Fig. 5 shows bio-location variations across the Horgas Fault and Covasna Fault, measured during March-April 2010. The correlation to the Vrancea earthquake activity is not clear since the magnitude of the events during the Spring of the year 2010 were small, as large as magnitude 3.0. Such a low magnitude event in Vrancea has a high probability of occurrence, about one every week.

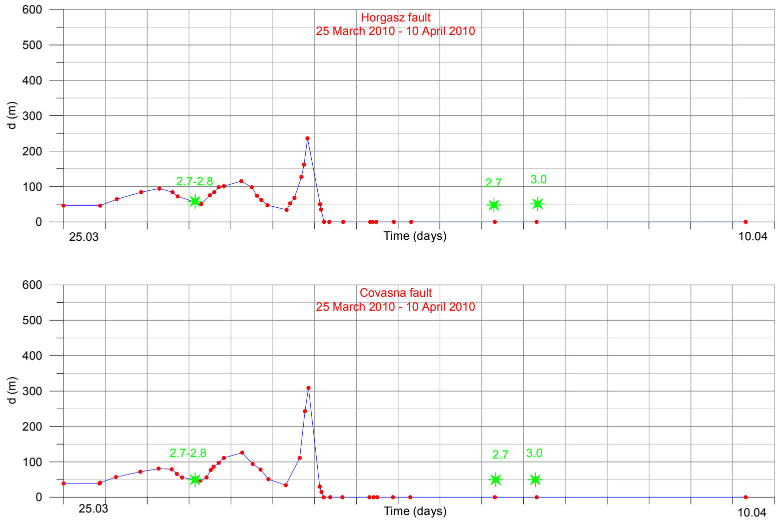

Fig. 5 – Bio-location BC variations at Covasna during March-April 2010.

Starting November 2011 up to March 2012 the bio-location variation measured at Covasna had a different trend (Fig. 6). A sinusoidal variation has been recorded with a period of 21 days. When Figs. 5 and 6 are compared, the period of sinusoidal variation during March–April 2010 was 2–3 days only, and the magnitude of the expected Vrancea earthquake was around 3.0. For a much larger period of 21 days during November 2011–March 2012 a much larger local earthquake was expected.

[17] published in the year 1977 a similar bio-location variation obtained across Covasna Fault during July–November 1976, before the magnitude 7.2 destructive earthquake recorded in Vrancea on March 4, 1977. This time the period of the bio-location sinusoidal variation was 45 days. Based on [10] a relationship can be expected between the magnitude of the event and the logarithm of the period of sinusoidal variations. If a period of 2 days is related to a magnitude 3.0 earthquake and a period of 45 days to a 7.2 magnitude event, for a sinusoidal period of 21 days a magnitude 6.2 intermediate-depth earthquake might be expected. The problem was when such an event might be recorded.

In the morning of January 10, 2012 at 9:00 AM, the rate of bio-location variation increased sharply. The main shock magnitude 6.2 was expected in Vrancea in the next 3-6 days. As a result a stress forecasting was issued in real time to the INFP. About ten hours later, an intermediate-depth earthquake was recorded in Vrancea with magnitude 4.3 and not 6.2 as indicated. However, the Vrancea event of January 10, 2012, was the largest recorded in a few months or so. In the next few days the rate of bio-location variation increased sharply then decreased to zero (Fig. 6). The bio-location sinusoidal variation recovered later during March 2012 after a long interval of zero in February 2012. As a result, the magnitude 6.2 expected intermediate-depth earthquake in Vrancea might be recorded later, probably sometimes in the year 2012.

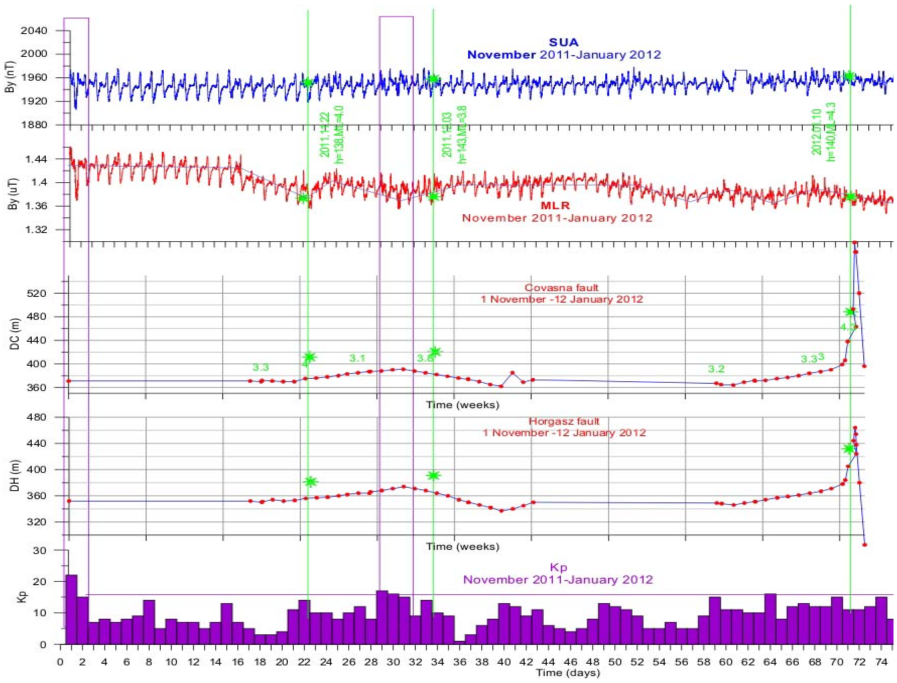

Fig. 6 – Correlation of bio-location measurements with the magnetic field recorded at MLR during November 2011–January 2012.

Fig. 6 shows also a correlation between bio-location variation across Covasna Fault at Covasna and a geomagnetic anomaly recorded at Muntele Rosu (MLR) at Cheia, Prahova. One of the authors of this paper, Iren-Adelina Moldovan, performed a blind experiment. She knew the geomagnetic recording but she did not communicate any data to Andrei Apostol, responsible for the bio-location measurements at Covasna. To our great surprise, the geomagnetic anomaly of the Y horizontal component of the magnetic field recorded at MLR started in the same day when the bio-location sinusoidal variation started. At present time (March 17, 2012) the anomalies are not finished yet.

The geomagnetic station at MLR is situated around the eastern end of a regional fault with an east-west direction. [18] obtained a geomagnetic anomaly of the horizontal Y component of the magnetic field before a 6.4 magnitude intermediate-depth earthquake in Vrancea recorded in the year 2004. It is no surprise the anomaly of the horizontal Y component is parallel to a regional fault and also to the Carpathian Electric Anomaly [19]. As a result, the geomagnetic anomaly obtained before the magnitude 6.4 event [20] might be explained as a result of a resistivity anisotropy variation related to the change in the direction of the principal compressive stress. An anomaly of the MWS might be expected also, related to the regional fault.

The geomagnetic anomaly of the horizontal component Y of the Earth magnetic field at MLR has been compared to geomagnetic data at Surlari-Caldarusani (SUA) in order to reduce possible anomalies related to Solar causes. Surlari geomagnetic station is located 50 km North from Bucharest and 150 km South from Muntele Rosu. From Fig. 6 was clear that no Solar causes are able to explain the geomagnetic anomaly obtained at MLR.

In spite of the fact MLR and Covasna are situated at a distance of tens of km apart, the resistivity anisotropy anomaly and the effect of MWS related to the Horgasz Fault at Covasna and the regional fault at Cheia, Prahova, are similar as suggested by Fig. 6. The reason is the stress anomaly might be similar at Covasna and MLR.

3. CONCLUSIONS

The data offered in Figs. 1-6 suggest bio-location anomalies obtained across faults at Plostina and Covasna and geomagnetic anomalies obtained at Muntele Rosu along a regional fault, in spite of the fact are tens of km apart, are related to a common regional stress anomaly and resistivity anisotropy variation, obtained before, during and after some small-moderate intermediate-depth earthquakes in Vrancea.

The far-field stress related to large regional earthquakes and the near stress related to small-moderate intermediate-depth earthquakes in Vrancea are able to generate similar bio-location anomalies observed across crustal faults at Plostina, Vrancea, and Covasna.

Stress forecasting based on bio-location and geomagnetic data offer certain information before, during and after local and/or regional earthquakes. However, such data are not sufficient to issue a valid earthquake prediction for the location and magnitude of the expected event.

The bio-location phenomena obtained across crustal faults located in and around Vrancea indicate a possible stress transfer from faults situated at an intermediate-depth of 70-150 km to crustal faults situated at a depth of 5-25 km.

Geomagnetic anomalies of the Y horizontal component recorded at MLR cannot be related to physical phenomena existing at an intermediate-depth of 70-150 km. Instead, such anomalies might be related to resistivity anisotropy and MWS anomalies related to a regional crustal fault nearby.

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