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ABOUT THE PREDICTION OF VRANCEA EARTHQUAKES (ROMANIA)

CONTENTS

ABSTRACT

This paper makes an attempt to show the stage of earthquakes prediction researches in Romania. At the same time, the authors wished to drew attention of everyone working in earthquake forecasting (i.e. seismologists, physicists, mathematicians etc.) - on the serious limitations of the standard earthquake prediction methods. This because seismology by itself, without geophysics (solid earth physics), geology and geodesy, cannot fully, comprehensively, validate earthquake prediction.

KEY WORDS: Earthquakes, seismotectonics, earthquake prediction

1. INTRODUCTION

Earthquake prediction is a complex undertaking, for it draws on a vast amount of knowledge in numerous sectors of geosciences, particularly solid earth physics as a branch of geophysics that also includes seismology, tectonic physics, gravimetry, geomagnetism etc.

The territory of Romania is characterised by a high seismicity, comparable to that of Greece, Turkey and Italy.

Taking into account the complexity and variety of the tectonics of the Romanian territory, this has been divided into nine seismic provinces, subdivided into smaller parts termed as zones (CONSTANTINESCU & MARZA, 1980). The criteria for this division were based on the seismicity level, the spatial distribution of earthquakes epicenters, the seismotectonic structure and maximum magnitude observed. The most active of them is the region of Vrancea, denominated *Vrancea Seismogenic Zone (VSZ)*.

2. CHARACTERISTICS OF THE VRANCEA SEISMOGENIC ZONE (VSZ).

The Vrancea Seismogenic Zone is situated at the Carpathian Arc Bend (CAB), more precisely in the region of the bow of Oriental Carpathians, roughly constrained by the N45°-N46° parallels and the E26°-E27° meridians. The VSZ is centered upon the triple junction of three tectonic units: the East–European plate, the Inter-Alpine subplate and the Moesian subplate. This situation leads to the generation of crustal and subcrustal earthquakes in a well confined focal volume at intermediate depths (60 to 200 km).

The Vrancea Seismogenic Zone is one of the most peculiar seismic source worldwide, which is interesting as a particular seismotectonic process in itself and consequently focused the attention of numerous seismologists. For convenience, the earthquake population is divided into two groups: the sub-crustal (or intermediate depth) earthquakes, with depths more or equal to 60 km, and crustal (or shallow) earthquakes, with lesser depths.

The subcrustal earthquakes occurring at CAB are usually called "Romanian earthquakes" and they are responsible for overwhelming high seismic energy budget in the area as compared with crustal earthquakes, hence when referring to VSZ it implies mainly subcrustal activity.

The most salient features of VSZ (e.g., PURCARU, 1979; CONSTANTINESCU & MARZA, 1989 and references therein) are:

(a) outstanding persistent, isolated and highly recurrent strong seismicity, with maximum observed magnitude M_w=7.9 and maximum expected magnitude M_w=8.0-8.2, displaying a remarkable regularity (periodicity) in the occurrence of large events (cut-off magnitude $M_w \simeq$ 6.9-7.0);

(b) extraordinary seismotectonic characteristics: extremely compact nest of sub-crustal foci (a volume of 70x40x125 km^3); consistent and stable (thrust type) - pattern radiation; impressive seismic moment release rate (MRR) of $\approx 10^{21}$ N-m/(100km-100yr), comparable with MRR for active subduction boundaries; a rare 'event' in terms of the hypothesis of a terminal phase of detachment of a subducting slab;

(c) severe socio-economic adverse impact (4-5 destructive events/century with surprisingly great mesoseismal distances, up to 400 km, and felt areas, at distances in excess of 2000 km, resulting in catastrophic losses and casualties) on a wide and densely populated area of Romania (especially the town of Bucharest), Rep. of Moldova, Ukraine, Bulgaria, Serbia etc.

The last two major VSZ events, i.e., the 1977 (M_w=7.4) and 1986 (M_w=7.3) were successfully forecasted and respectively anticipated. The forecasting (long term earthquake prediction) of the 1977 event was based on salient regularity patterns in long-term strong SE (cyclicity and paired occurrences) displayed by all large events ($M_w \geq 7$) during a time span more than a millennium.

The 1977 March 04, VSZ large earthquake (M_{GR}=7.2, M_w=7.4) depth = 109 km, was correctly foreca-

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sted by PURCARU (1979), MARZA (1979) and ENESCU *et alii* (2001 and references therein) based on the regularities pattern inferred by the above authors.

A posteriori, MARZA (1979) has reported a precursory seismicity pattern in the depth range 85 to 130 km composed by following stages:

(i) background seismicity (prior to 1963);

(ii) first stage of abnormal quiescence (period 1993-1967);

(iii) a burst of activity, "precursory swarm" (in 1998);

(iv) second (main) stage of abnormal quiescence, seismic gap, starting late 1968 and lasting 3400 days;

(v) the mainshock, which ruptured the quiescent volume.

It is to be noted that the quiescence period compare very well with RIKITAKE (1975) relationship between precursor time and forthcoming shock's magnitude.

Perhaps, it is worth mentioning the abundant narrative tales about unusual earthquake lights over the epicentral area and abnormal bio-systems behavior a few hours before both mainshocks in 1977 and in 1986.

Analysis and discussion of a variety of precursory seismicity patterns (p.s.p.) belonging to all temporal developmental stages of the preparatory geophysical process leading to the destructive major sub-crustal Vrancea earthquake of August 30, 1986 (epicenter = 45.5°N/26.4°E; depth 144 km; magnitude(s) M_W=7.0, M_W=7.3, M_L=7.0; I_o=VIII½ MSK) are performed and documented, clearly proving that the earthquake has not been unexpected. The salient features of the Vrancea Seismogenic Zone and its tectonic setting have been presented elsewhere (*e.g.* PURCARU, 1979; APOSTOL *et alii*, 1985; CONSTANTINESCU & MARZA, 1989 and references therein; WENZEL *et alii*, 1999). The seismological data base used in this study is the earthquake master catalogue of CONSTANTINESCU & MARZA (1989 and references therein), permanently updated and completed on the basis of the data supplied by the real-time telemetered seismographic network of Romania, centered on VSZ.

The anticipation (medium term earthquake prediction) of the 1986 event was based on a variety of precursory seismicity patterns including: pre-seismic quiescence, hypocentral migration, b-slope change etc (*a priori* reported), but also other precursors: seismic (e.g., foreshocks), geophysical (an underground microtemperature anomaly or a telluric current observation) and biological ones, or parameterized earthquake prediction algorithms were observed.

Currently a forecast for the next major ($M_W \geq 7$) VSZ event is attempted with the approximate time window: 2006 ± 7 yr and magnitude range M_W=7.4 ± 0.4; obviously the space interval is not crucial as the spatial extent of the *VSZ* is only 80x40 km^2 (certainly the depth range should be of more interest, but this parameter could be inferred when some physical precursors, e.g., seismic quiescence, would be detected).

The data source used for earthquakes prediction is based on the earthquake catalogue of CONSTANTINESCU & MARZA (1980, continuously updated and refined) hereinafter called C&M. The C&M file covers a period since 984 AD to present (hence covering a time span more then a millennium) and the earthquake size is quantified (in wake of tradition and consistency) in terms of M_{GR} scale, although there are available conversion relationship to other magnitude scale or to seismic moment (see below). The historical events are quantified through the maximum/epicentral macroseismic intensity (MSK-64 scale), using a conversion scheme to M_{GR} described elsewhere (e.g., C&M).

3. MAIN FEATURES OF LONG-TERM STRONG SEISMICITY OF VSZ

Various investigators attempted to infer some chief features of the recurrence regularities of VSZ (first pointed out by the pioneering work of POPESCU, 1958): e.g., PURCARU (1979), ENESCU *et alii* (2001 and references therein), MARZA (1996 and references therein), CONSTANTINESCU & MARZA (1989), SANDI & MARZA (1996).

The inferred recurrence patterns refers to strong seismicity, that is, events with $M_{GR} \geq 6.8$ (or M_W>7.0), which is the threshold above which widespread damage is experienced. We prefer to use, for reasons of consistency of the historical data set, the M_{GR} scale; although the conversion to M_W or m_W is straightforward. With this cut-off magnitude a data set of 38 sub-crustal strong VSZ events are present in the available time span of more than a millennium covered by C&M catalogue. The overall time series of this population looks random, however based on the known finding that the superposition of periodical time series yields randomness to the overall distribution, one may proceed conversely, i.e., to split the overall (apparently random) sequence into highly periodic/cyclic/regular components, as it was discussed by UTSU (1965) in respect to what can be termed "hidden periodicities".

This inference was first done concomitantly and presumably independently by PURCARU (1979) and ENESCU *et alii* (2001 and references therein), later these findings were refined and updated (using more data and further approaches), by PURCARU (1979), MARZA (1996 and references therein), SANDI & MARZA (1996), and others.

Extensive analyses in order to detect premonitory changes in seismicity patterns as possible precursors of the Vrancea strong shocks were performed (POPESCU *et alii*, 2000; ENESCU, 1983) for past and future earthquakes. Analysis and discussions of a variety of precursory seismicity patterns belonging to all temporal developmental stages of the preparatory geophysical process leading to the major Vrancea earthquake of August 30, 1986, were performed and documented, clearly proving that the earthquake has not been unexpected (MARZA, 1979).

Recently, in Romania, a new method, named Geostatistic, was used for earthquake prediction. This method allows the estimation of seismic potential for a given seismic area at every moment of further large earthquake's occurrence, and the magnitude of that earthquake. The method had been checked for a large number of exhausted cycles, for a lot of seismic areas from the world, with good results.

On this moment the method is checked in real time conditions by watching of about 150 seismic areas from the world. On this process, there were predicted, until now, 5

earthquakes (three moderate earthquakes in the frame of EU Project called "Assessment of seismic potential in European large earthquake areas", ASPELEA, managed by NOA-Greece, and 2 large earthquakes) all of them confirmed by the international seismological agencies.

The CN algorithm has been initially created for the retrospective analysis of the seismicity patterns which precedes the strong earthquakes in the California-Nevada regions. The algorithm has been modified so that it can be applied, without any parameters adjustment, for all the seismic regions in the world. The method consists in analysis of a set of precursory phenomena reflected in the temporal evolution of the seismicity recorded in the earthquake catalogue. Although it was firstly conceived for crustal events, the CN algorithm can be also applied for prognosis of intermediate earthquakes. The results are different depending on the seismic region which is under study. Thus, in case of Vrancea and Sicilia regions, where the paleosubduction is one of the possible interpretations, the results are positive (in case of Vrancea the strong earthquakes from 1977, 1986 and 1990 have been predicted), while for intermediate earthquakes within the regions where the subduction is still active, the algorithm can not be applied.

Another method applied in Romania is the Magnetotelluric method (ENESCU *et alii*, 2001 and references therein), one of several geophysical methods that can be used for earthquake prediction, it use a new attempt for detecting electromagnetic precursor of Vrancea earthquakes. The electromagnetic method has been recently experimented to predict Vrancea intermediate-depth earthquakes (ENESCU *et alii*, 2001) and to look for electromagnetic seismic precursors. The theoretical reasons for using ratios Bz(t)/Bx(t) and Bz(t)/By(t) of the geomagnetic flux density components as earthquake prediction tools are first of all provided. Since the roughly EW-oriented By component was negligibly small, the time variation of the mean daily ratio

was both right and advisable. The results obtained for the time intervals December, 1997 – May 1999 and April, 2000 – December, 2001 prove that out of 68 Vrancea earthquakes of magnitudes M>3.9, 58 (85%) - were preceded by significant magnetic perturbations (ENESCU *et alii*, 2001; ZUGRAVESCU *et alii*, 2000). The merely 10 exceptions (15%) were cases in which either the precursor perturbations were not clear enough, or very strong magnetic storms distorted to a large extend the link between the earthquakes and any possibly precursor perturbations.

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