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DETAILED SEISMICITY ANALYSIS IN THE VRANCEA AREA AND IMPLICATIONS FOR THE SEISMIC CYCLE EVOLUTION*

MARIA ROGOZEA, MIHAELA POPA, MIRCEA RADULIAN

National Institute for Earth Physics, PO Box MG-2, 077125, Magurele, Romania,
E-mail: mrogozea@infp.ro

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Abstract. Seismicity of the Vrancea region shows characteristic clustering features in space, time and energy that are clearly related to specific physical processes in the subcrustal domain. For the study of the frequency-magnitude distribution and seismic cycle behaviour we use Romanian routine catalogue for a 100-year time interval (6589 events) as well as the historical catalogue and information. In the last 100 years, several seismic cycles can be identified in the Vrancea subcrustal domain. Earth cycle is characterized by a shock larger than 6.5 and a relative lack of earthquakes at intermediate magnitudes (around 6), which suggests a percolation-type process for the major shocks. A sort of balance for the seismic energy release between an upper active segment located around 90 km depth and a lower active segment located around 140 km depth seems to control the evolution of the successive cycles (at least for the last 100 years). We investigate the implications of the specific seismicity parameters in the two segments related to background and aftershock earthquake activities on the earthquake process evolution.

Key words: seismicity, aftershocks, seismic cycle.

1. INTRODUCTION

Vrancea seismic region in the SE-Carpathians represents an interesting seismogenic area, characterized by the frequent occurrence of large earthquakes in a narrow area. The epicentral area is confined to about 20×60 km^2 (Fig. 1), and seismic activity ranges between 70 and 180 km depth within an almost vertical lithospheric body (Popa and Radulian, 2001).

The analysis of the Vrancea background activity (Fig. 2) suggests that there are two regions in the lower lithosphere, along the fault plane, able to generate major earthquakes: 80-110 km depth, (M_w = 7.5 for the 4 March 1977 and M_w = 6.9 for 30 May 1990), and 120–170 km depth (M_w = 7.7 for 10 November 1940, M_w = 7.2 for the 30 August 1986 and M_w = 6.9 for 30 May 1990).

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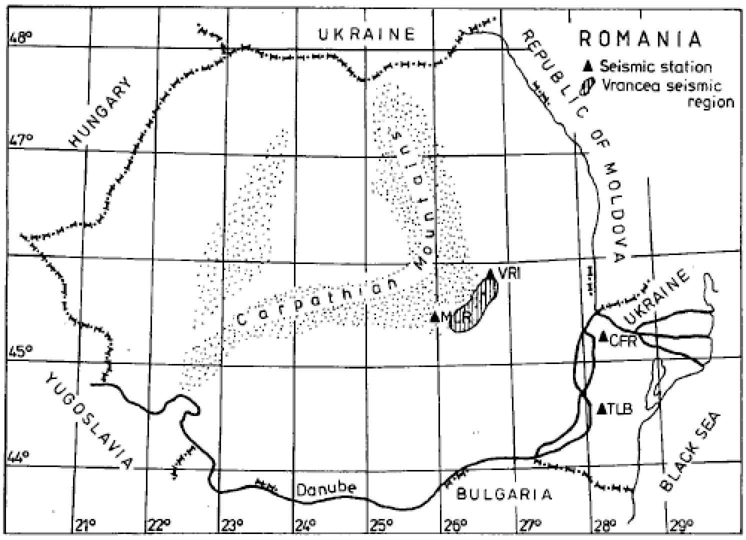


Fig. 1 – Epicentral area of the Vrancea subcrustal earthquakes (dashed area).

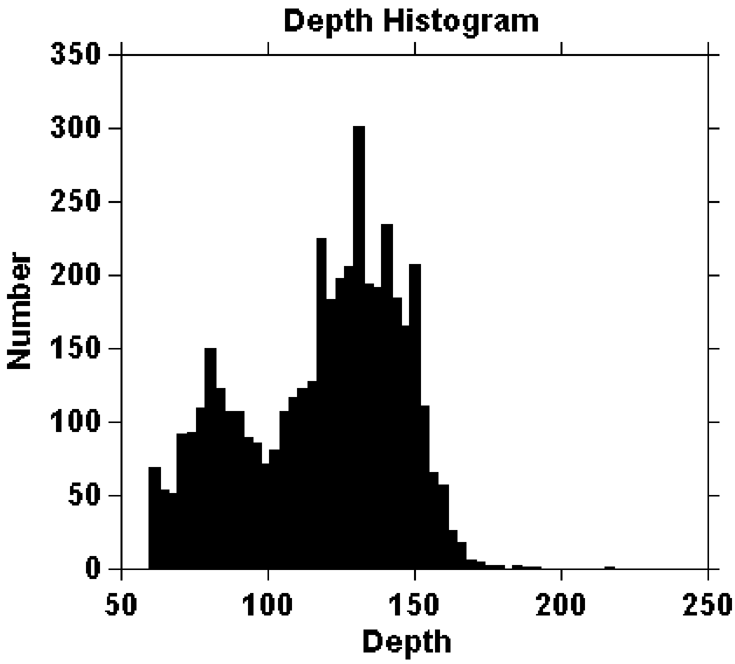


Fig. 2 – Depth [km] distribution of Vrancea intermediate-depth earthquakes (1908–2007).

The two active segments are separated by a zone with relative lower seismicity and lower recorded magnitudes.

Moreover, the depth distribution of seismic moment tensor principal axes proved that the 105–120 km depth interval is the only intermediate-depth region where a three-couple force system must be adopted (Oncescu and Trifu, 1987). This result agrees with the presence of fault plane curvature around the above-mentioned depth (Dziewonski et al., 1981).

2. SEISMIC CYCLE ANALYSIS

In the Vrancea subduction domain, in the last 100 years, several seismic cycles are identified. Each cycle is characterized by a shock larger than 6.5 and a relative lack of earthquakes at moderate magnitudes (around 6) in the frequency/magnitude distribution. Possibly, the major shocks are generated by a percolation-type process (Trifu and Radulian, 1991).

The succession of seismic cycles is given in Fig. 3 and Fig. 4. The evolution of seismic activity shows alternative acceleration and deceleration deformation release in the upper segment and lower segment, respectively, of subducting lithosphere.

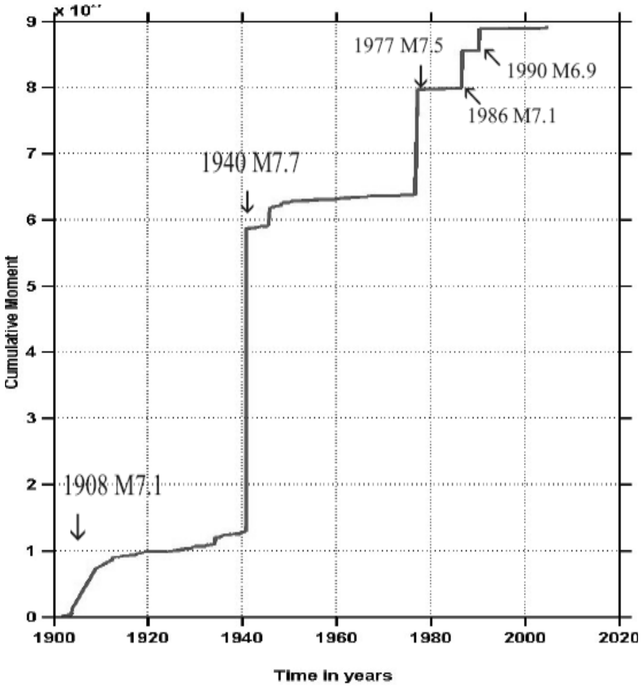


Fig. 3 – Benioff's cumulative curve for the last 100 years in the Vrancea subduction zone. Arrows mark the events with $M > 6.5$.

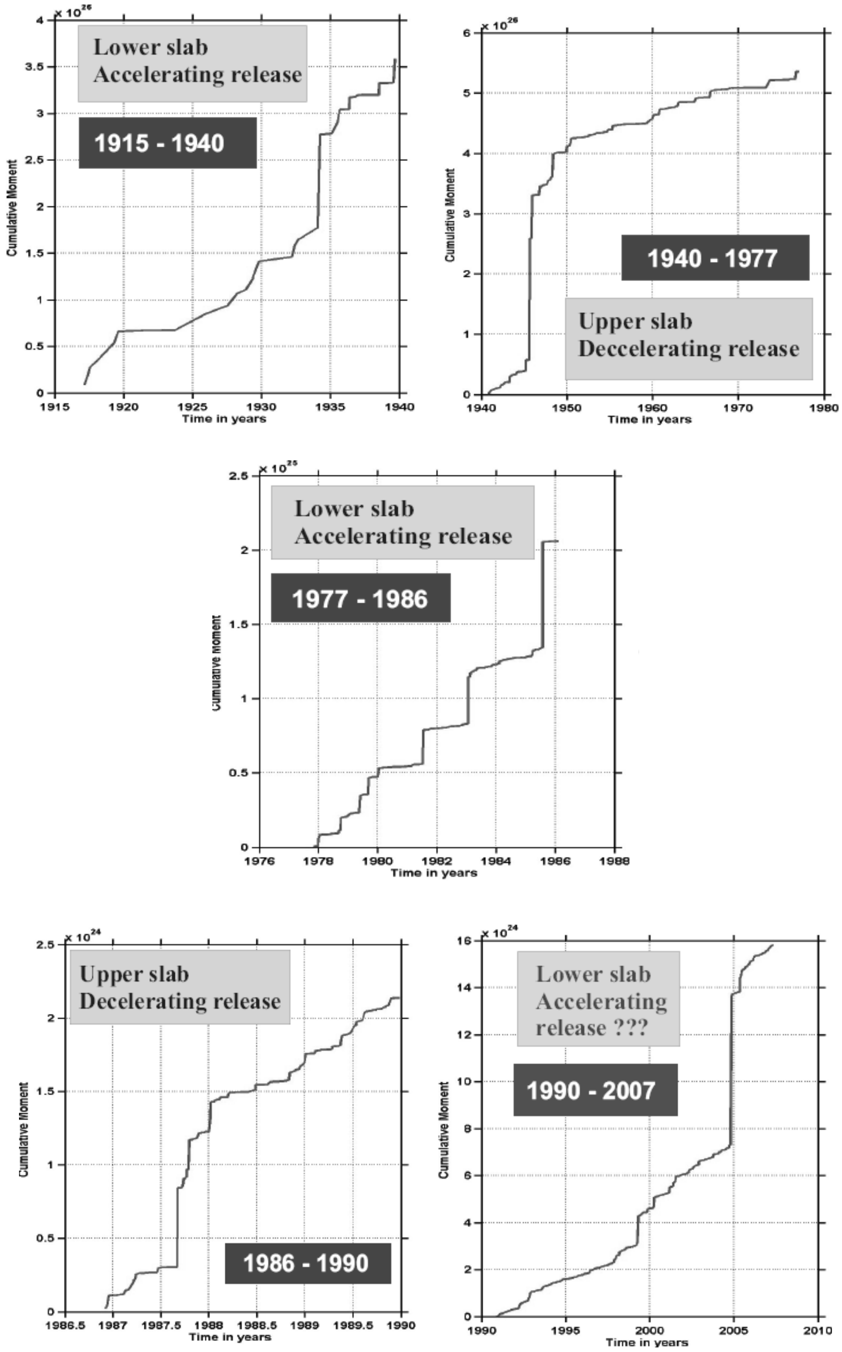


Fig. 4 – Successive cumulative processes in Vrancea as revealed by Benioff's curves. Cumulative moment variations after the main shock. Main shocks were excluded from the catalogs.

3. AFTERSHOCKS ANALYSIS

In order to investigate if the differences noticed in the seismic cycle behavior between the upper and lower active segments are detectable in the aftershock sequence characteristics, we examine the aftershocks for the last 3 major events in Vrancea: March 4, 1977 ($M_w = 7.4$), August 30, 1986 ($M_w = 7.2$), and May 30, 1990 ($M_w = 6.9$). The 1977 and 1990 shocks occurred in the upper segment, while the 1986 shock occurred in the lower segment.

A strong decay of the aftershocks number is noticed in all cases after 5 days suggesting a very efficient stress release process during the main shock (Fig. 5). This efficiency explains also the large gap between the main shock magnitude and the largest aftershock magnitude: 2.4 units for 1977, 1.7 units for 1986 and 2.3 units for 1990.

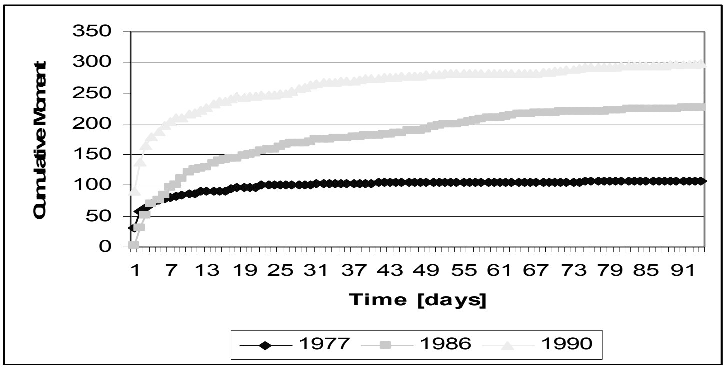
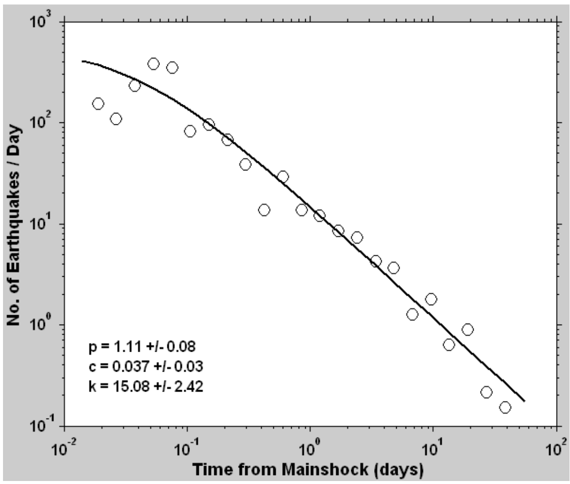
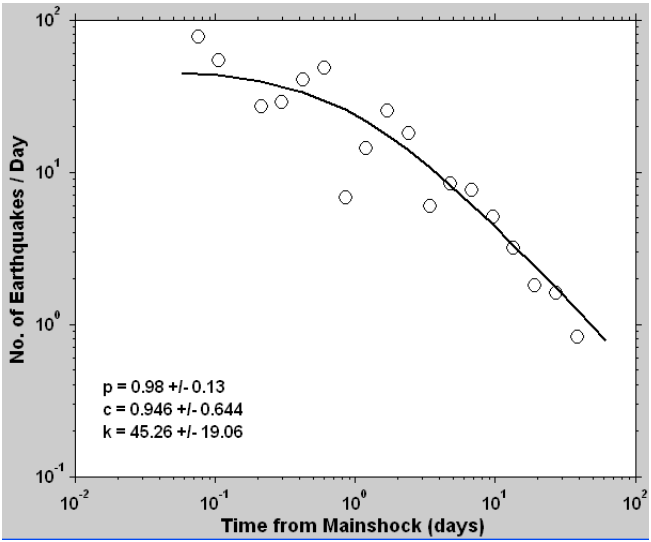


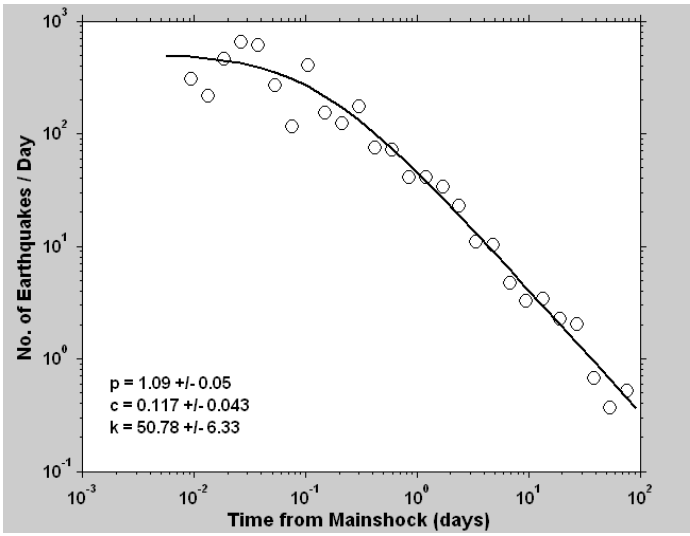
Fig. 5 – Cumulative moment release during the aftershock activity.



a)



b)



c)

Fig. 6 – Temporal change of the number of aftershocks per day: a) 1977, b) 1986, c) 1990. The values of the parameters *p*, *c* and *k* values in the modified Omori's formula are also given.

The modeling of the time decay of aftershocks number by Omori modified law indicates for the p parameter values of 1.11±0.008 for 1977, 0.98±0.13 for 1986 and 1.09±0.06 for 1990 (Fig. 6).

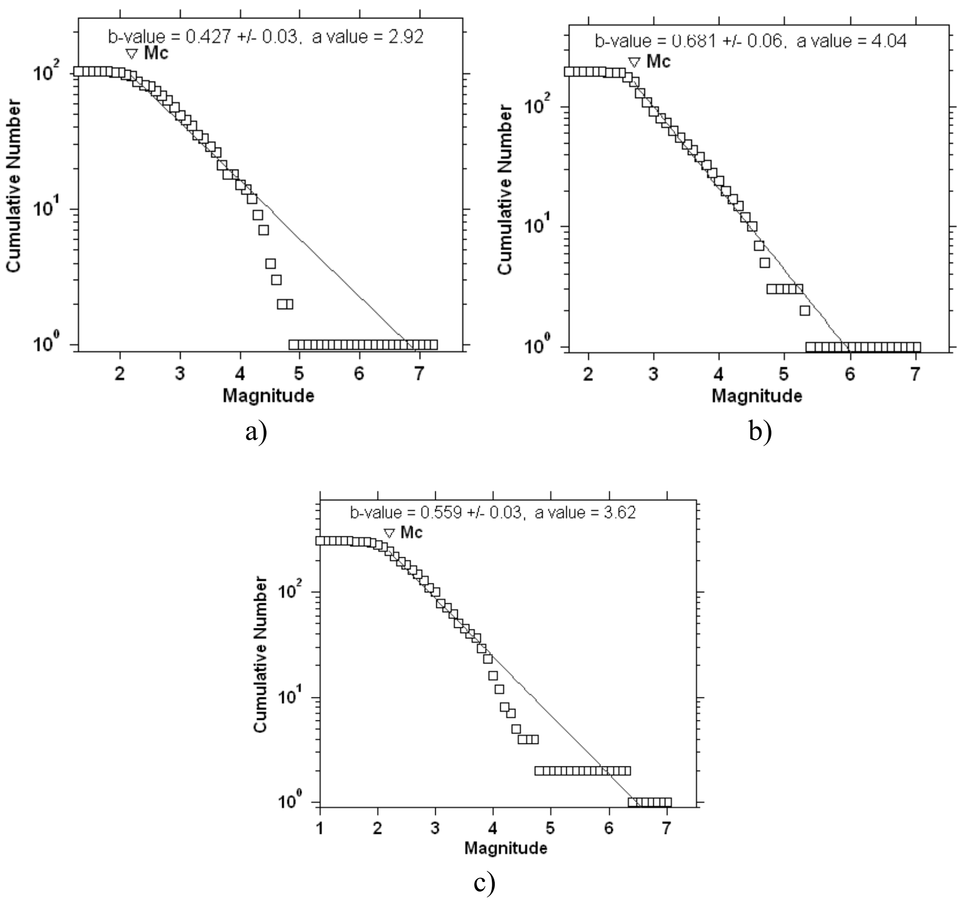


Fig. 7 – Frequency-magnitude distribution for: a) 1977 event (M_c = 2.2), b) 1986 event (M_c = 2.7), and c) 1990 event (M_c = 2.2). The b value and its standard deviation and a value are given in each case. *Mc* is the magnitude of completeness.

The analysis of the frequency-magnitude distribution for the 3 sequences (Fig. 7) shows b-slope values smaller than the normal activity: 0.43 ± 0.03 for 1977, 0.68 ± 0.06 for 1986 and 0.56 ± 0.03 for 1990 as compared with the normal b value of 0.79 (Radu, 1974).

4. CONCLUSIONS

Different studies on Vrancea intermediate-depth seismicity outlined the presence of two characteristic seismic active segments in the lithospheric body pulled down below crust. One is hypothetically related to the nucleation of strong events around 90 km depth (events of March 4, 1977 and May 30, 1990), the other to the nucleation in the deeper part, around 140 km depth (events of November 10, 1940 and August 30, 1986). The differences in seismic process pointed out between the two segments are presumably ascribed to different physical processes that are responsible for earthquake generation in the two segments.

In the present paper we investigate how these differences manifest in the seismic cycle behavior and aftershock sequences characteristics. The processes generating the large earthquakes in the lower and upper part of the Vrancea seismic active body differ significantly: accelerated seismic release is characteristic in the lower slab, while decelerated seismic release seems to control the deformation in the upper slab. These processes apparently alternate from one cycle to the other between the two segments.

The study of the aftershocks available for the last three major Vrancea events outlines some differences for the two segments. For example, the b slope of the frequency-magnitude distribution seems to be smaller in the upper part of the subducting lithosphere (0.43 and 0.56 versus 0.68, respectively). As concerns the decay parameter of the Omori law, the values are slightly larger in the upper part as compared to the lower part (1.11 and 1.09 versus 0.98, respectively). The stress release during the major shock is very efficient in both segments explaining the sharp decay of the number of aftershocks after 5 days and the magnitude gap between the main shock and the largest aftershock (2.4 and 2.3 in the upper segment and 1.7 in the lower segment).

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