4.7.1. GEODYNAMIC CONSIDERATIONS ON THE SPACE-TIME MIGRATION OF THE VRANCEA INTERMEDIATE-DEPTH SEISMICITY

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4.7.1.1. Introduction

Statistic considerations on the space-time evolution of the Vrancea intermediate-depth seismicity are made in the paper. An attempt is made to demonstrate that the elongated shape of the epicentral area in the Vrancea zone could be at least partly due to a space-time migration of the intermediate-depth seismicity developed within a smaller, more isometric active seismic volume moving generally south-westward.

4.7.1.2. Data

Statistics were performed on a data set provided by the ROMPLUS catalogue (Oncescu et al, 1998), which has been completed with more recent events as provided by the National Institute for Earth Physics (http://www.infp.ro/cgi-bin/recent). Earthquakes following the major event of November 1940 were considered. Based on previous assumptions on the crust thickness on the Romanian territory (Rădulescu et al., 1976, Rădulescu, 1989, Enescu et al., 1992, Hauser et al., 2002, and so on), to study

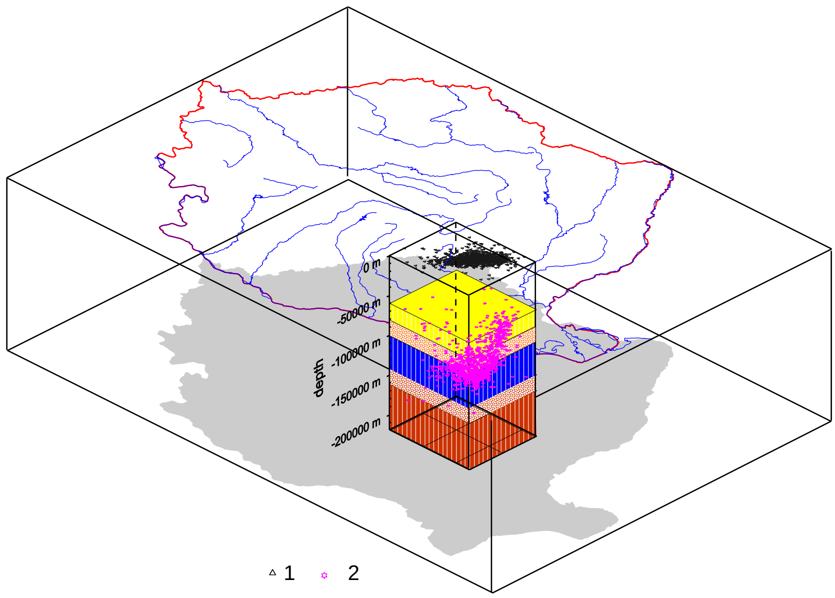

Fig. 4.7.1.1. Location of the analyzed intermediate-depth earthquakes within Vrancea zone

1, epicenter; 2, hypocenter

the intermediate-depth seismicity, earthquake hypocenters located beneath 60 km depth were considered only. Besides, several deep events located far outside Vrancea area were also excluded.

All in all, more than 2100 seismic events were taken into consideration, which represent, in our opinion, a significant database for a statistical analysis.

4.7.1.3. Time-related clustering

Basic idea in developing research was that an eventual migration of the seismic activity should be the result of two components: (i) random occurrence of earthquakes within an inhomogeneous seismogene environment, and (ii) a systematic (deterministic) trend generated by displacement of the assumed seismic body under the influence of convective currents in the upper mantle.

To avoid, or at least to attenuate the stochastic component, seismic activity was integrated within several time-clusters mainly ranging between major seismic events: 1940 (M_w = 7.7), 1977 (M_w = 7.4), 1986 (M_w=7.1), and 1990 (M_w = 6.9). In fact, the following time-spans were considered for the analysis: 1940 (after the major event) - 1950, 1950 - 1960, 1960 - 1970, 1970 - 1977 (ended with the major event of March 7, 1977), 1977 - 1986 (ended with the major event of August 31, 1986), 1986-1990 (ended with the major event of May, 31, 1990), and 1990-2000.

Both simple and weighted averages (according to the magnitude moment) of the events co-ordinates were performed to define location of a Seismic Activity Centre (SAC) for each time-span.

4.7.1.4. SAC migration

By simply representing on the map the above mentioned selections of seismic events, it has been revealed that beyond a slight overlapping, location of clusters of epicentres for each time-span seem to systematically move towards SW, except for the time interval following the major event of March 4, 1977, when the trend was reversed.

Following this observation, SAC were determined for every time-cluster, and a 3D representation of their location was performed (Fig. 4.7.1.2). It confirmed the first impression based on the clusters location visual analysis. The seismic activity seems to systematically move south-westward, with a slight deepening along the strike.

To get more intuitive pictures, the 3-D model was accompanied by 2D images representing northward and, respectively westward projections. A vertical exaggerated scale has been used to emphasize the planar migration of seismicity. For instance, a westward projection (Fig. 4.7.1.3.) shows a general slightly descending trend towards south, except for two moments: one is preceding the catastrophic event of March 4, 1977, and the second started after May 31, 1990 earthquake. The SAC behaviour shows a gently dipping for the whole 1940-2000 interval, interrupted around the moment of the major seismic event of March 4, 1977, when the seismic activity centre sharply fallen down by about 20 km, to come back on the previous trend for the next time span (1977-1986).

The second change in the general trend occurred after major seismic event on 1990. Unlike the period before the major earthquake of 1977, this time, it seems that the reverse trend in the SAC horizontal displacement is accompanied by a slight *uplift* of the SAC location.

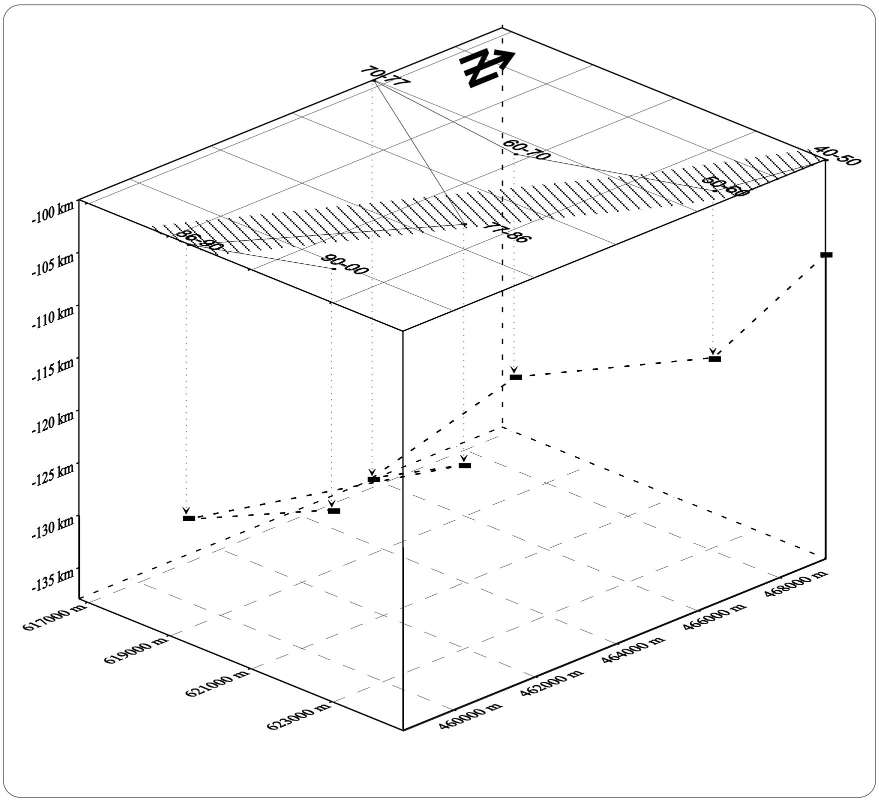

Fig. 4.7.1.2. A 3D diagram showing the SAC migration within the time span 1940-2000

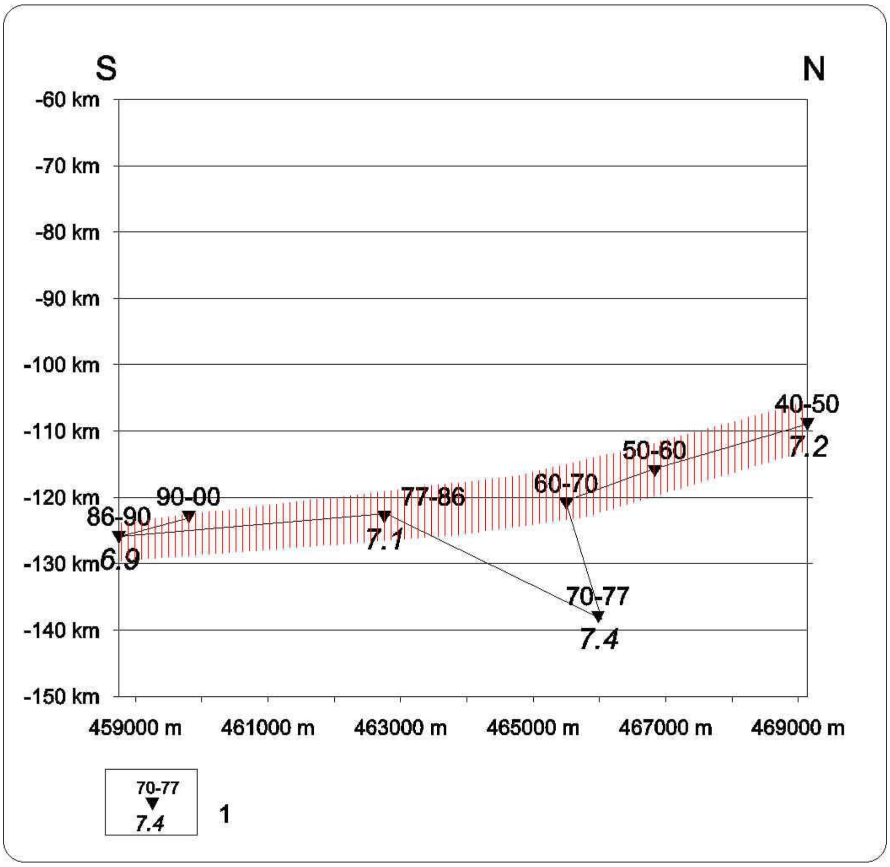

Fig. 4.7.1.3. A 2D representation of SAC migration for a westward projection
1, SAC location with the time-span (up) and moment magnitude of the strongest event (below)

4.7.1.5. Depth-related clustering

A brief analysis concerning the distribution of the intermediate earthquakes with the depth clearly showed several areas of increased frequency, mainly between 80 – 100 km (around 90 km), and between 130 – 150 km (Fig. 4.7.1.4.).

Those regions were interpreted as decoupling zones in the lithosphere that shear the seismic body at least in three compartments: 60-90 km, 90-150 km and below the 150 km depth.

The averaging approach previously applied to events occurring in the whole seismic body was distinctly used on each of the above mentioned compartments. Therefore, a double clustering was used: by depth and by time (the same time intervals were used). As it can be seen in the Fig. 4.7.1.4., SAC distinctly migrated within each depth interval, but a general WSW trend was preserved.

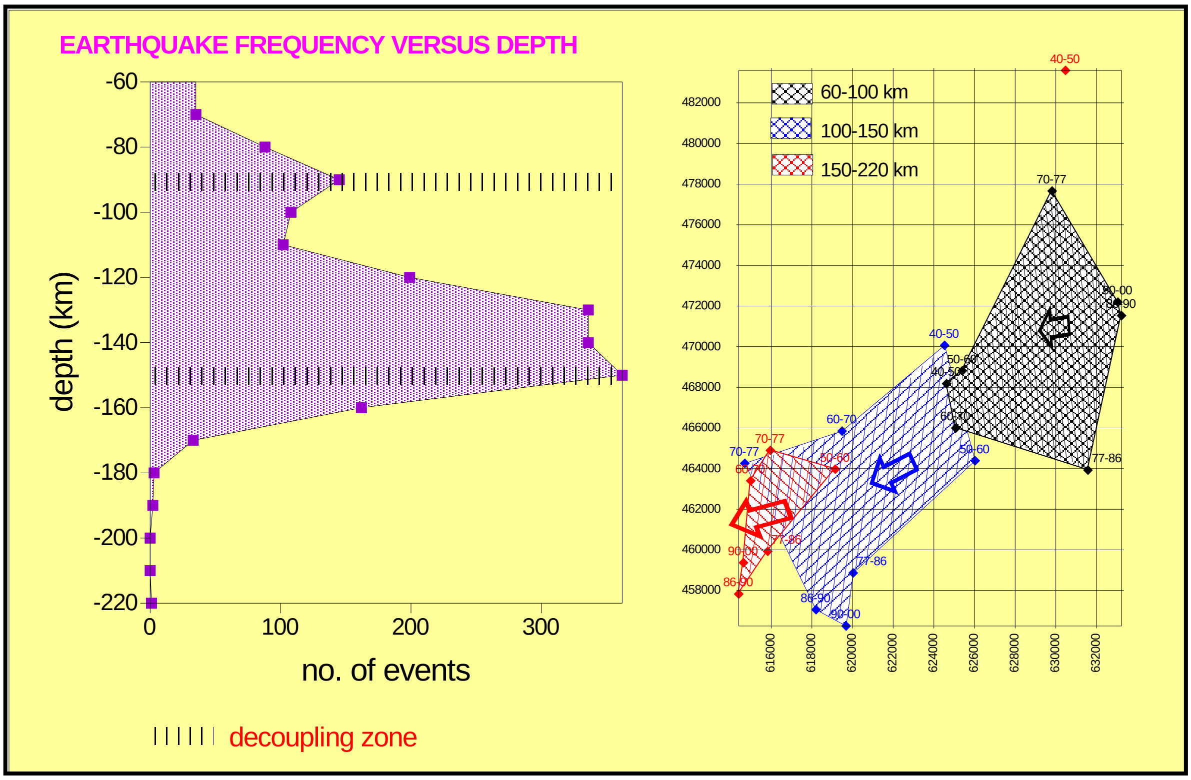

Fig. 4.7.1.4. Distinct migration with the depth of the Vrancea intermediate seismicity

Actually, the deeper the location, the larger appear the SAC migration. It looks like the seismic body was sheared at least at the depths of 90 km and, respectively 150 km and the three thus created lithosphere compartments are somehow distinctly moving. As the convective currents act at the base of the lithosphere, the largest effect occurs in that region.

4.7.1.6. Concluding remarks and speculations

By performing the above-mentioned statistic analysis a migration of the intermediate-depth seismicity in the Vrancea seismic zone was pointed out between 1940-2000.

On the overall, the seismic activity seems to gently sink south-westward, except for the moment around the major earthquake of March 4, 1977, when the trend reversed. SAC

migrated towards NE with a suddenly fall down at about 140 km depth, to come back on the trend within 1977-1986 time-span.

The analysis of the earthquake frequency versus depth outlined the presence of two decoupling zone in the lithosphere of the seismic body at the depths of 90 km, respectively 150 km. Therefore, three lithosphere compartments were outlined: 60-90 km, 90-150 km and 150-220 km. Statistic processing of the space-time evolution of the intermediate-depth seismicity within each of the thus delineated compartments confirmed the overall south-westward migration trend of the seismic activity, but with distinct amplitudes, increasing with the depth.

Some speculations might be made on two aspects revealed within the obtained results.

One of them associates the presence of SAC migration to the assumption concerning the existence and migration of an unstable triple junction (VTJ) within Vrancea area, and the active nature of the northern transform boundary of MoP (Visarion, Besutiu, 2001). Taking into account the tectonic factors, well reflected by the regional stress state on the Romanian territory (Zugrăvescu and Polonic, 1997), the SAC migration could be the result of the VTJ vertical collapsing combined with the horizontal displacement along the northern boundary of MoP, under the north-westward pushing of the Black Sea compartment, moved by active rifting in the SW Arabian Plate.

The second speculation is related to the seismic activity migration trend reversal before the disastrous earthquake of March 4, 1977. The new reversal revealed after 1990 looks somehow similar to the previous one. That might suggest the occurrence of a new major seismic event during the next years. The hypothesis seems to be consistent with some previous prognoses on a possible another catastrophic Vrancea earthquake within the time-span ranging between 2000 and 2011 (Enescu et al., 1974, Mârza, 1982, Enescu, 1983, Enescu si Enescu, 1996).

The major difference as referred to 1977 event would be that at the present, the seismic activity tends to uplift instead of collapsing.

4.7.1.7. References

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