On the last seismic attacs in Sofia region

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Върху последните сеизмични атаки в района на София

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Абстракт: В настоящата работа се анализират последните по-значими сеизмични атаки върху столичани – земетресенията от 15 Ноември 2008г, 27 Август и 10 Септември 2010. За тези земетресения е представена детайлна информация за макросеизмичните обследвания в различните квартали на София, както записите и спектралния анализ на акселерограмата на последното събитие. Анализира се сеизмичността на Софийския регион за последните две десетилетия, характерни с най-високо точни и хомогенни определения на параметрите на слабите земетресения в областта. Представена е карта на епицентрите на около 420 земетресения в частта от територията на България, ограничена от географска ширина 42.30^0 – 43.00^0 N и дължина 23.00^0 – 23.90^0 E. За споменатия период са представени и пространствено, времевите и енергетичните разпределения на земетресенията.

The concentration of governmental and other bodies of administrative and industrial significance as well as the quite fast growing of the human population make the permanent study of Sofia Region seismicity very important. Since 15 Nov.2008 up to nowadays several local earthquakes with magnitude more than M=3.0 shook the territory of Sofia city. The seismic events caused unexpected disturbance and excitation in the population. In fact, the influence of these events was assessed as an intensity of V or VI degree of MSC scale, and only two or three places with some isolate elements of VII degree during the last event on 10 September 2010. In the Figs.1 – 2 the macroseismic data for the three large felt events are presented.

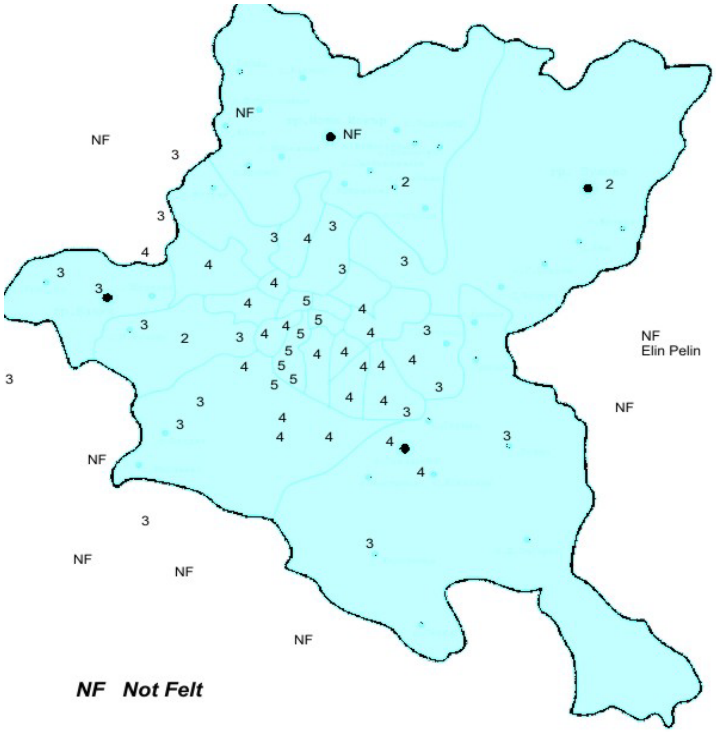
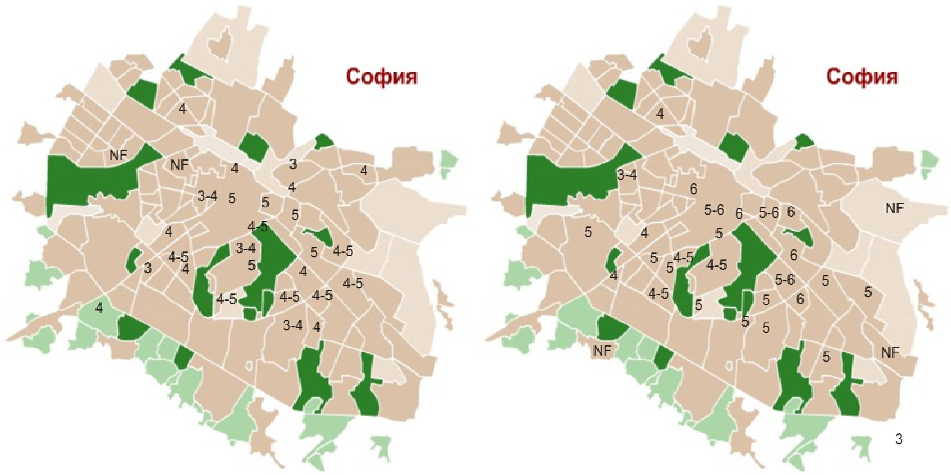


Fig.1. Macroseismic impacts (intensity EMS) for 15 Nov.2008 event



(a) (b)

Fig.2. Macroseismic impacts for 27 August (a) and 10 September 2010 events (b)

On 15 November 2008, the strongest earthquake (local magnitude 3.9) of the study period occurred. It was generated in the frames of the Vitosha fault structure. Macroseismic study was done through inquiries accumulated via internet or by hand as well as by telephone interviews; the resultant intensity distribution is shown in Fig.1. Because of big value of the hypocenter depth the maximum impact on the surface is only V degree of MSC scale, nevertheless the biggest magnitude of this event. The same maximum degree of intensity is felt during the second earthquake (Fig.2) when the magnitude is only M=3.3. Maximum intensity (I=VI+) is established for the last event when the depth is only 2 km.

It is interesting to compare excitation pattern over the city territory in the three latest cases of the local earthquakes:

No event	Date	^{o}N	^{o}E	Depth, km	Magnitude Md	I max, MSK
1	15 Nov 2008	42.65	23.34	10	3.9	V
2	27 Aug 2010	42.66	23.36	5	3.3	V
3	10 Sep 2010	42.63	23.39	2	3.7	VI+

1.)Common feature at all considered cases is the small felt area that means high attenuation of intensity. 2.) The obvious increase of the macroseismic area size with the penetrating of the earthquake source is a normal phenomenon. 3.) The areas covered by strongest excitation outline a few square kilometers. The smallest epicentral area is expected in the case of minimal source depth. However, the 2010, 27 August earthquake which originates at the medium depth among the three considered cases manifests I_{max} over most concentrated territory. The physical reason of this fact is forthcoming to be established. 4.) The latest case, that one of the intermediate magnitude (3.7), is a case of superficially penetrating seismic waves. On this reason, two elongated areas of high intensity have been formed in the macroseismic field: (i) the one, in the eastern part of the city and in the old its centre occasionally; (ii) another, along a known fault inside the city stretching SE-NW from the South Park across “Lagera” towards the Serdica combine. Generalizing, some intra-city faults have been activated.

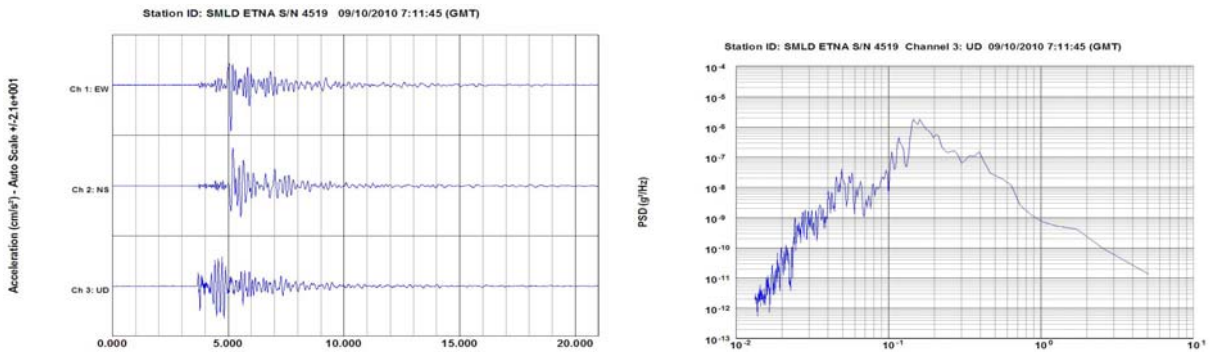


Fig.3. 3D accelerogram and Power Spectral Density of the last strong event (10 Sept 2010)

For the last strong event 3D accelerogram and Power Spectra are shown on Fig.3. The maximum acceleration of the records was computed for the frequency band (0.06 – 45) Hz -for the vertical component it is 13.34 cm/s^2. The dominant part of the seismic energy is carried out by the higher frequencies (>5 Hz).

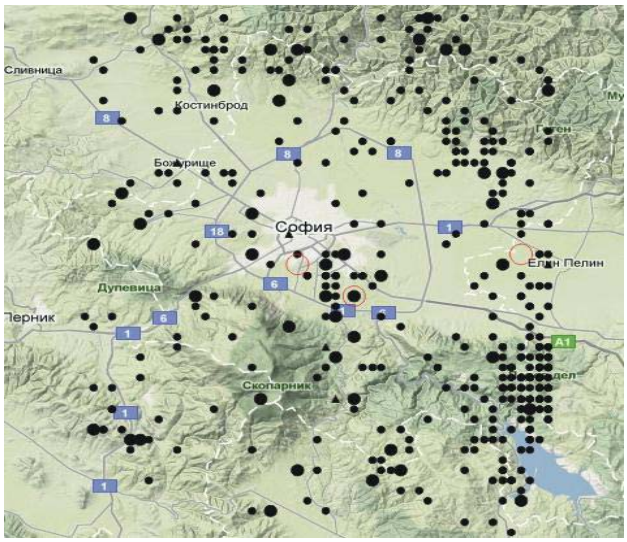


Fig.4. Epicentral distribution for the earthquakes 1991-2010 with M>1.5

Besides the information about the events with biggest macroseismic impacts in the capital city, the present study contains generalized information about the seismic events in Sofia region recorded by the National System for Seismological Information of Bulgaria for the last two decades – Fig.4, Botev et al.(1991-2010). The Sofia region covers the Sofia graben together with neighboring horsts. A number of faults separate the graben from the horsts. The seismicity of the study region is associated most of all with the tectonic activity of the fault structures that delimit the Sofia graben in the North and South; these are the Sub-Balkan deep fault zone and Maritza deep fault zone respectively (Bonchev, 1971; Karagjuleva et al., 1973). The strongest earthquakes in the considered time period are marked with red circles - the first one (1996) in the eastern part of Sofia graben and the latest (15 Nov 2008 and 10 Sept 2010) in the space of the Vitosha fault structure. Most significant concern to Sofia city comes from the last (Vitosha) tectonic unit. Another region of high seismic activity is observed along the Sub-Balkan fault system and the Iskar fault.

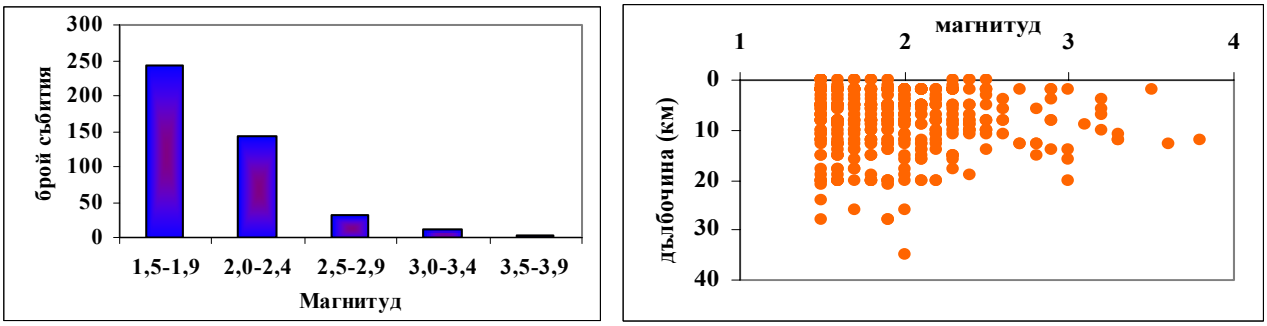


Fig. 5. Frequency-magnitude and depth distribution of the events (1991-2010)

Data about 420 seismic events are used to elucidate the space, time and energy peculiarities of earthquakes originated in the considered region. The observed seismic activity in the time-span of 1990-2010 is not high. Most of events are microearthquakes; only 23 of them are with magnitude M≥3.0 (Fig.5). The strongest earthquake is with a local magnitude 3.9. The hypocenters of the earthquakes are concentrated in the subsurficial layer of 20 km. It is not to be neglected the seismogenic potential of the underlying ten kilometers between 20 and 35. The magnitude-depth distribution of the earthquakes does not delineate any privilege seismogenic depth layer; the relatively stronger events (M>3.0) are realized at any depth, down to 15 km.

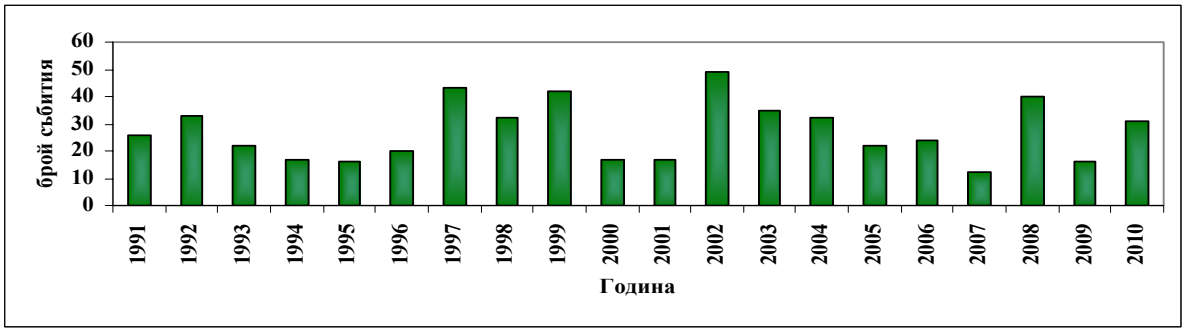


Fig. 6. Annually frequency-time distribution of the M≥1.5 earthquakes (1991-2010)

The frequency-time distribution of the seismic manifestations annually presented is illustrated in Fig.6. The biggest earthquake's amount has been displayed since 1997, 1999, 2002 and 2008 when more then 40 events occurred during any one of these years.

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