DATA AND ANALISIS OF THE EVENTS RECORDED BY NOTSSI IN 2013

E.Botev, V.Protopopova, I.Popova, Bl.Babachkova, S.Velichkova, I.Aleksandrova, Pl.Raykova, Vl.Boychev

Geophysical Institute, BAS, Akad. G. Bonchev street, bl.3, Sofia, Bulgaria, e-mail: ebotev@geophys.bas.bg

Abstract. A map of epicentres of 1622 earthquakes that occurred during 2013 in the Balkan Peninsula (sector outlined by latitude $\varphi = 37^0 - 47^0$N and longitude $\lambda = 19^0 - 30^0$E) is presented. Expert generalized analysis of the seismicity over the territory of Bulgaria and its very adjacent lands (with more then 930 localized events) is proposed. Catalog of earthquakes with magnitude M>2.5 is applied.

Key words: Balkan Peninsula, Bulgaria, seismicity

The present scientific communication contains generalized information on the results of collection, processing and analysis of the data about the seismic events recorded by the National Operative Telemetric System for Seismological Information (NOTSSI) in 2013. The expanded information about the realized seismicity is suggested as a natural generalization and supplementation of the monthly compilations of the preliminary seismological bulletin of NOTSSI. The analysis and evaluation of the space, time and energy distribution of the seismicity, periodically been made, open up possibilities for searching for time correlations with the parameters of different geophysical fields aiming to find out eventual precursor anomalies.

The recording and space localization of the seismic events in NOTSSI during 2013 is realized by means of the new digital network (Solakov et al., 2005). The routine processing and acquisition of the initial data is organized in a real time duty regime. The operations are fulfilled by the authors of this communication. In such a way the main goal of NOTSSI, namely the seismicity monitoring in order to help the authorities' and social reaction in case of earthquakes felt on the territory of the country, is realized. The computing procedure for determining the parameters of the seismic events is an adaptation of the widespread product HYPO'71 (Solakov , 1993). The energy parameters of the events are presented mainly by the magnitude M calculated according to body wave amplitudes (Christoskov et al., 2011a, Christoskov et al., 2011b) and the record's duration by the

formula (Christoskov and Samardjieva, 1983).

$$M = 1.92 + 2.72\log\tau - 0.026\Delta$$

The focal mechanism parameters are obtained by means of a program FOCMEC (Snoke, 2009). The high sensitivity of the seismographs allows recording and processing of a great number of long distance earthquakes. As a result of the achieved experience in the authors interpretation work, different magnitude's lower threshold for successful determination of local, regional and long distance earthquakes is established: M=1.5 for the territory of Bulgaria, M=3.0 for the central part of the Balkans, M=5.0 for long distance events. The precision of the epicenter's determination is different; except on the distance it depends also on the specific position of the epicenter in relation to the recording network. The parameters of seismic events occurring at a distance more than 100-150 km outside the territory of Bulgaria should be accepted only informatively and cannot be used for responsible seismotectonic investigation.

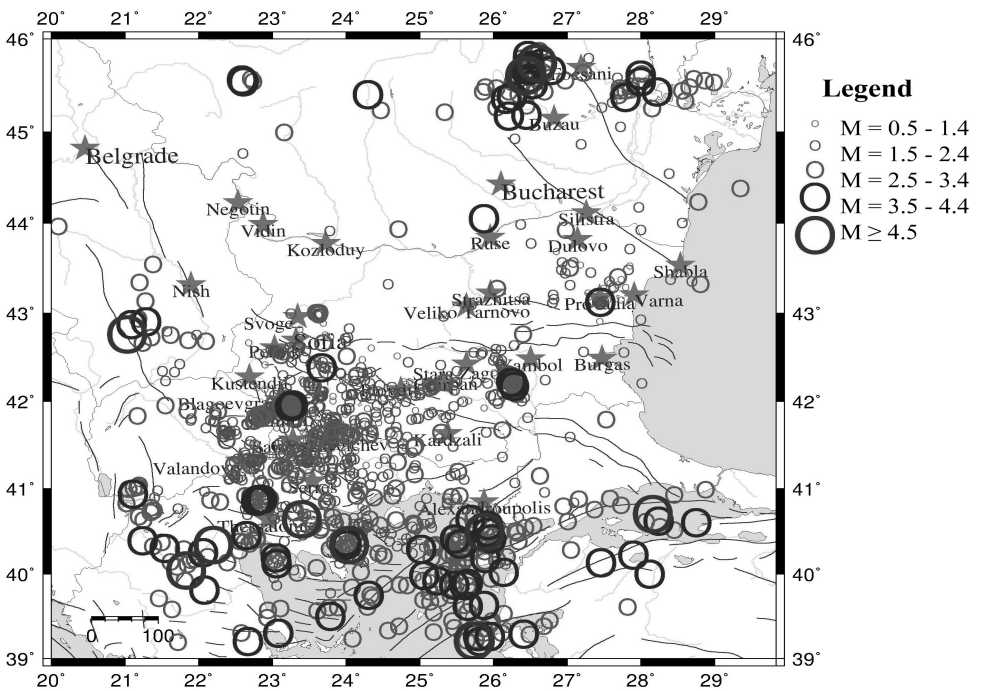

Fig.1. Map of epicenters in Central Balkans during 2013 (The Generic Mapping Tools - http://gmt.soest.hawaii.edu/home, the tectonic map is compiled after Barrier et al., 2004).

For the period of observations presented in this communication, the primary data about 2000 local, regional, distant earthquakes and industrial explosions on the territory of Bulgaria are recorded, classified and processed (as a work bulletin) in NOTSSI. After comprehensive analysis of the records and application of the above mentioned calculation procedures it is established that 1622 of all registered earthquakes are in the Balkan

Peninsula region outlined by geographic latitude 37^0 - 47^0 N and longitude 19^0 - 30^0 E. The epicenters of the earthquakes differentiated by magnitude levels are plotted on Fig.1. The number of the events in the magnitude interval M=0.5-1.9 is 788, in M=2-2.9 - 632, in M=3-3.9 - 175, in M=4-4.9 – 26 earthquakes. During this not so active period there is 1 event with magnitude M=5.0.

As a whole, the seismic situation in the study part of the Balkans during 2013 is characterized by not so high activity - 1622 events against 1508 in 2012, 1829 in 2011, 2401 in 2010, 2744 in 2009, 1775 in 2008, and around 1100- 1400 for most of the previous years. The maximum realized earthquake is with magnitude Ms=5.0 while this value for the previous years is lower then five, as a rule, except 2011 – M=5.8 and 2012 - M=5.6. It can be noted that the observed tendency of high increase of the activity compared with the former years is partly due to the high level of earthquake activation in Marmara sea, Central Greece, Serbia, Romania, and also due to increase of number of microearthquekes in the territory of Bulgaria.

The strongest event outside Bulgaria during the study period occurred in the region situated to the south of Marmara sea (Turkey) with magnitude M=5.0. Shakable effects because of outside attack (Vranchea source zone in Romania) during the study period occurred 3 times in north-eastern Bulgaria (intensity III in towns of Ruse, Tutrakan and Silistra).

As a whole, events with M<3.0 which occur outside Bulgaria are difficult to be localized by the national seismological system; consequently, not all of them have been marked on the scheme in Fig.1.

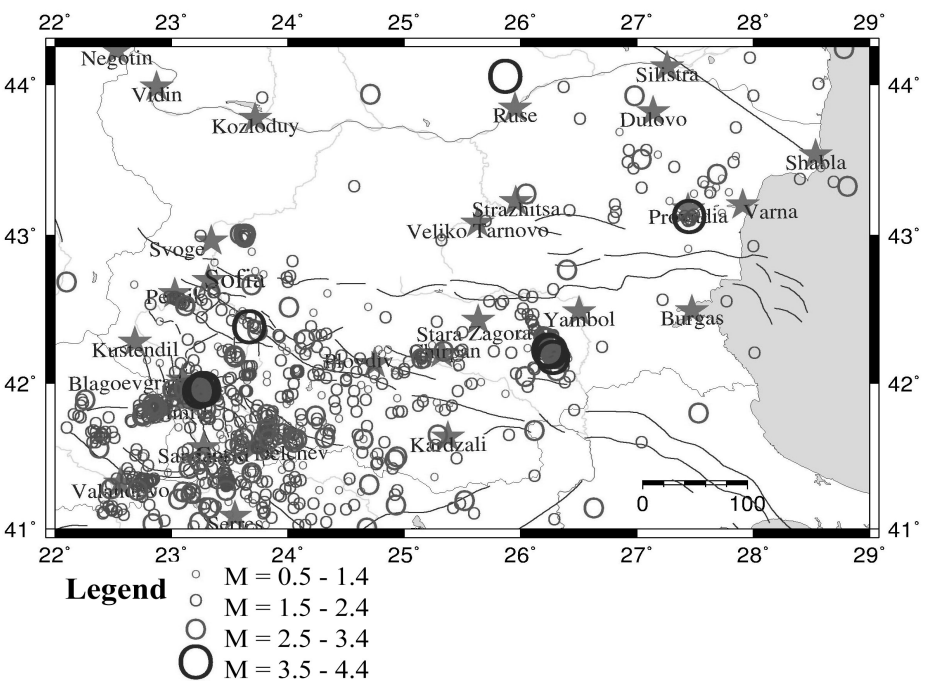

Fig.2. Map of epicentres in Bulgaria and adjacent lands during 2013

Fig.2 illustrates the seismicity just in the territory of Bulgaria and nearby lands ($\varphi = 41^0 - 44.3^0$N, $\lambda = 22^0 - 29^0$E). The earthquakes are differentiated by magnitude intervals. The seismic stations are also noted in the same figure by triangles. The parameters of relatively stronger earthquakes are presented in Table 1.

Table 1. List of earthquakes with M ≥ 2.5 in Bulgaria and adjacent lands during 2013

Date	Time	Coordinates		H,km	M
3.1.2013	1:26:31.3	41.21	23.06	1	2.7
3.1.2013	2:28:37.3	41.91	23.25	2	2.5
4.1.2013	1:26:32.3	41.26	23.1	6	2.8
13.1.2013	14:21: 7.2	41.89	22.26	5	2.8
15.1.2013	10:34:57.1	42.53	23.12	11	2.9
17.1.2013	2:16:23.2	41.01	24.68	14	2.6
20.1.2013	1:59:55.5	42.67	23.69	10	2.6
23.1.2013	18: 1:59.6	41.42	23.15	4	2.7
26.1.2013	7:13:45.9	41.17	24.93	2	2.5
26.1.2013	8:26:40.2	41.92	23.27	2	2.6
27.1.2013	18:37:13.4	41.8	27.53	2	2.8
5.2.2013	21:43:32.3	41.97	23.34	2	2.8
5.2.2013	6: 6:12.8	41.79	23.82	5	2.9
6.2.2013	22:45:19.9	43.33	28.81	2	3.4
11.2.2013	8:29:22.6	41.96	23.22	0	2.5
17.2.2013	16: 5:47.2	42.69	22.1	2	2.9
8.3.2013	18: 5:43.3	42.05	26.04	2	2.6
12.3.2013	17: 1: 6.9	42.36	23.74	5	2.5
21.3.2013	14:29:23.5	41.94	23.21	4	2.9
23.3.2013	18: 0:13.8	42.17	25.15	1	2.6
25.3.2013	17: 2:19.8	42.09	26.31	6	2.9
28.3.2013	13:13:37.8	44.24	28.78	4	2.5
9.4.2013	2:38:51.3	41.69	23.82	8	2.5
9.4.2013	6:59:23.4	42.23	26.24	6	3.7
9.4.2013	7: 3:42.5	42.27	26.2	4	3.4
9.4.2013	7: 9:56.9	42.26	26.2	2	2.9
9.4.2013	7:24:43.8	42.2	26.28	3	2.5
10.4.2013	2:14:59.4	42.23	26.25	2	2.5
14.4.2013	14:30:45.8	42.14	26.29	2	3
24.4.2013	23:17:16.2	41.89	23.22	15	2.5

28.4.2013	10:27: 8.9	42.22	25.34	2	2.6
28.4.2013	22:18:35.3	42.32	26.2	1	2.9
29.4.2013	0: 8: 0.5	42.23	26.26	5	3
29.4.2013	6:19:36.1	42.21	26.26	5	2.9
2.5.2013	19:49:19.9	41.31	24.7	11	2.7
4.5.2013	2:20:28.2	42.31	26.23	10	2.5
5.5.2013	6:38:55.8	41.04	22.84	2	2.7
7.5.2013	1:31: 9.0	41.15	23.33	3	2.5
8.5.2013	9:27:46.2	41.43	23.38	8	3.2
9.5.2013	7:31: 2.8	41.97	23.23	5	2.5
14.5.2013	19:22: 3.2	41.15	26.63	15	2.5
17.5.2013	13:40:26.6	42.22	26.25	5	3.9
23.5.2013	21:47:53.5	41.2	25.52	2	2.5
26.5.2013	2:28:52.8	43.28	26.05	3	2.7
3.6.2013	14: 7:38.7	41.25	23.17	2	2.5
5.6.2013	13: 3:22.0	43.94	24.71	6	2.9
5.6.2013	17: 4:53.2	41.97	23.26	2	2.5
5.6.2013	3:46:41.6	41.83	23.3	8	2.6
6.6.2013	11: 6: 4.5	41.97	23.11	2	2.9
11.6.2013	12:46:36.8	41.15	23.32	2	2.8
4.7.2013	22:47:21.9	41.97	23.24	2	2.5
5.7.2013	13: 0:18.6	41.97	23.25	2	2.7
8.7.2013	11:24:51.1	41.97	23.26	1	3
8.7.2013	18:16:50.8	41.97	23.24	1	2.7
9.7.2013	17: 6:37.9	42.19	26.27	5	3
9.7.2013	17:12: 0.4	42.22	26.26	10	3.7
9.7.2013	18:11:38.4	42.18	26.28	8	3.7
10.7.2013	2:17: 3.6	41.96	23.26	2	2.7
10.7.2013	21:33: 7.5	42.23	26.24	4	2.5
10.7.2013	5:58: 5.6	41.97	23.27	2	2.6
10.7.2013	8:52:31.1	42.22	26.25	1	2.5
11.7.2013	12: 3:19.9	42.17	26.3	5	2.8
11.7.2013	6:29:37.1	42.18	26.29	5	3
11.7.2013	7:56:20.2	41.5	24.94	9	2.5
17.7.2013	19:25:22.3	41.58	23.59	7	2.6
19.7.2013	14:19:42.9	41.63	23.62	2	2.5

27.7.2013	1:24:25.5	41.97	23.28	2	3.6
27.7.2013	1:48:32.2	41.96	23.28	2	3.8
27.7.2013	12:14:31.6	41.97	23.26	2	2.7
27.7.2013	17:32:21.6	41.97	23.24	6	2.6
27.7.2013	3:17: 0.7	41.97	23.27	2	3.7
27.7.2013	3:20:10.2	41.97	23.27	2	3.3
27.7.2013	3:21:55.2	41.95	23.24	2	3.7
27.7.2013	3:30:55.4	41.98	23.27	2	2.8
27.7.2013	3:40: 2.6	41.97	23.27	2	2.8
27.7.2013	3:51:21.7	41.96	23.25	6	2.9
27.7.2013	5:36:33.8	41.96	23.27	2	2.6
5.8.2013	13:42:55.3	41.98	23.17	10	2.7
9.8.2013	19:55:17.5	43.93	26.98	20	2.8
11.8.2013	14:26:35.1	41.98	23.26	8	2.8
13.8.2013	6:14:35.0	43.13	27.45	5	3.6
14.8.2013	11:29:21.7	42.99	23.63	9	3.1
14.8.2013	12:52:54.6	42.99	23.63	12	3.4
21.8.2013	15:39:25.7	43.01	23.62	10	2.5
22.8.2013	15:29:27.7	41.97	23.26	8	2.6
27.8.2013	3:25:39.6	41.48	24.92	14	2.6
28.8.2013	6:48:49.9	41.62	24.05	13	3.3
28.8.2013	8:43:43.2	41.6	24.05	15	3.4
29.8.2013	4: 6:15.8	44.06	25.87	20	4.1
30.8.2013	4:14:58.7	41.62	24.08	10	2.7
1.9.2013	21:22:57.7	41.86	22.84	12	2.7
1.9.2013	21:26:21.0	41.85	22.83	11	2.6
7.9.2013	16:21:59.0	43	23.63	10	2.7
8.9.2013	18: 8: 0.6	41.66	23.95	13	3
10.9.2013	18:56:39.0	43.01	23.59	10	3
10.9.2013	19:28:48.7	41.65	25.29	14	3.3
15.9.2013	19:53: 0.9	43.01	23.64	10	2.9
20.9.2013	10:48:10.9	41.84	22.86	20	2.9
20.9.2013	4:23:50.7	41.83	22.88	20	2.8
20.9.2013	4:45:21.4	41.82	22.84	15	2.7
22.9.2013	12:27: 1.1	42.39	23.67	15	3.7
23.9.2013	13:15:58.3	43.51	27.04	30	2.8

24.9.2013	14:38:22.9	41.27	23.47	13	2.6
29.9.2013	4:18:54.4	41.96	23.01	12	2.6
4.10.2013	13:44:41.9	42.77	26.4	5	2.9
14.10.2013	21:44: 6.6	41.79	22.76	8	3
15.10.2013	4: 5:50.3	41.79	22.76	5	2.6
16.10.2013	2:29: 6.7	41.62	23.84	2	2.5
17.10.2013	9:17:46.3	42.2	26.29	14	2.5
24.10.2013	10:10:43.5	41.05	23.24	18	2.7
26.10.2013	11:44:19.7	43.41	27.69	15	3.1
5.11.2013	8:50:57.6	42.3	24.15	12	2.5
6.11.2013	16: 0:33.2	41.78	22.75	9	2.8
10.11.2013	0: 1:25.7	41.63	24.32	1	2.5
10.11.2013	20:43:57.8	41.39	23.69	14	2.5
19.11.2013	16:50:54.5	41.62	24.65	17	3
22.11.2013	6:43:56.5	42.18	23.55	24	2.6
22.11.2013	9:28:46.1	41.68	26.12	2	2.5
23.11.2013	6:43:56.3	42.19	23.54	19	2.6
26.11.2013	14:18:58.8	41.78	24.24	11	2.5
4.12.2013	21:13:14.0	41.56	22.38	15	2.8
10.12.2013	2:35:37.6	41.28	22.48	12	3.2
15.12.2013	9:13: 0.0	41.47	23.24	15	2.8
19.12.2013	23:24:57.9	42.52	24.01	20	2.9
30.12.2013	11:33:33.2	41.27	22.71	8	3.3

On the territory of Bulgaria relatively normal activity of earthquakes is observed during 2013 – 1124 events are observed, against 932 in 2012, 1205 in 2011, 1607 in 2010, 2017 in 2009 and 1079 in 2008. The earthquakes of a magnitude higher than 3.0 are in normal amount – 32 events compared with an averaged number of about 20-35 for most of the all previous years (exception is 2009 with 147 events because of the aftershocks of Valandovo M=5.2 earthquake).

The maximum realized magnitude is Ms=4.1 in the region of Giurgiu (Rumania), next to the border with Bulgarian territory. This event is the highest earthquake for this region, in comparison with the maximum magnitude in the course of previous years. It is felt with maximum intensity of III-IV degree of MSC scale in the town of Rouse on 29 August 2013. The strongest Bulgarian event during 2013 (with magnitude M=3.9) occurs on 17 May and caused macroseismic effects with intensity of IV degree of MSC scale in the village of Skalitza – close to the Monastery uplift in Southeast Bulgaria.

As usual, the largest concentration of the epicenters in the other regions of Bulgarian territory during 2013 is marked in the southwestern part of the investigated

region (presented in Fig.2). The Kroupnik seismic source is known with the strongest crustal earthquakes in Europe (M=7.8, 7.1) for the last 160 years. In 2013 about 40 events of M<3.0 and only 3 of M≥3.0 occurred in this region. The strongest earthquake for the south-western part of Bulgarian territory is with magnitude M=3.8, it is felt on 27 July in Kroupnik region (village of Gradevo) by intensity of V degree of MSC scale.

The other Bulgarian seismic sources in 2013 are relatively not so active than during the previous years. They produced not more than 15 earthquakes affecting different localities in this country by intensity of up to IV degrees of MSC scale. The maximum number of felt earthquakes is occurred around the Monastery uplift. About six cases of magnitudes more than 3.0 aroused shocks of intensity three or more are felt in Skalitza village. A relatively significant seismic impact is associated with the Mesta earthquake source zone in the southwestern Bulgaria. In the rest part of the Bulgarian territory the felt events caused excitation of lesser intensity during 2013.

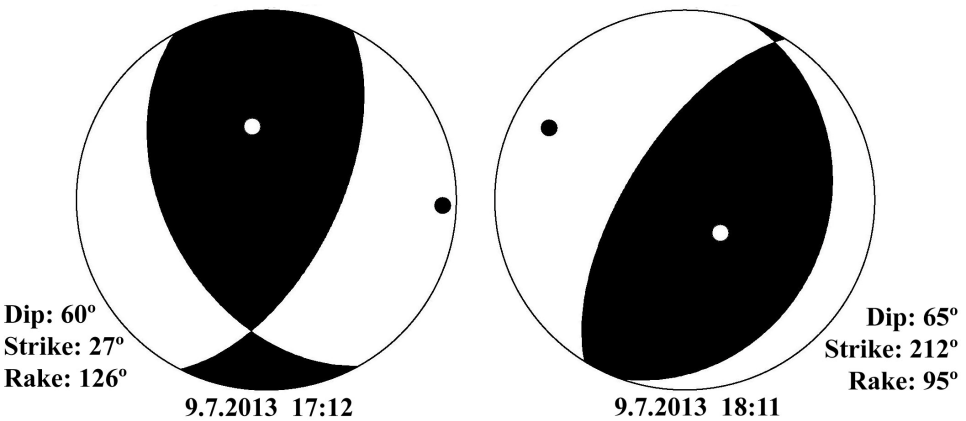

Fig.3. Focal plane solution of earthquakes at Monastery Uplifts (09.07.2013, 17:12 and 18:11 GMT)

For the determination of the earthquake mechanism the program FOCMEC is used. Input data are the polarities of the P wave. Twenty three first motion polarities data from seismological stations in Bulgaria and surrounding area taken from NOTSSI and ISC database (ftp://www.orfeus-eu.org/pub/data/continuous /2013/) are included in the double - couple focal mechanism - Fig.3. The solution is displayed on lower hemisphere. The polarities from ISC are check as waveform. The strike, dip and rake are determined in accuracy up to 10 degree. The earthquake is characterized as a normal faulting, with very small strike-slip component. The fault plane solutions of the some other events are with very bad quality because of a low number of polarities.

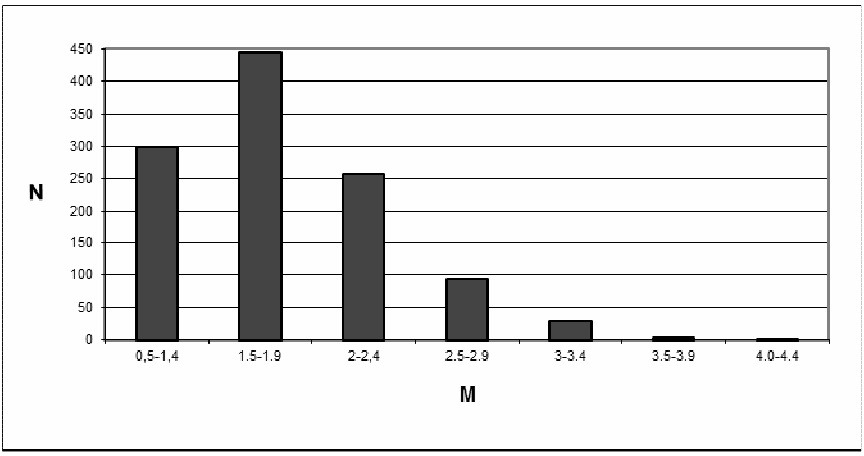

Fig.4. Magnitude - frequency distribution of the earthquakes

A detailed analysis of seismicity in the individual seismic zones is hard to be fulfilled because of the insufficient quantity of events and the narrow magnitude range of the earthquakes. The joint statistics of all the events in Fig.2 characterize predominantly the seismicity parameters of the southwestern part of the territory under investigation.

The magnitude-frequency distribution for the entire data set is presented in Fig.4. The number of localized events increases with the magnitude decreasing: for M= 4.0-4.5 is 1 event, M=3.5-3.9 is 8 events, for M=3.0-3.4 is 28 events, for M=2.5-2.9 - 96, for M=2.0-2.4 - 252 and so on. The abrupt diminishing of the number of earthquakes in the first interval (M<1.5) in Fig.4 determines also the registration power of the seismic stations network. It can be supposed that the magnitude sample for levels with M > 1.5 is comparatively closer to the reality for the bigger part of the Bulgarian territory.

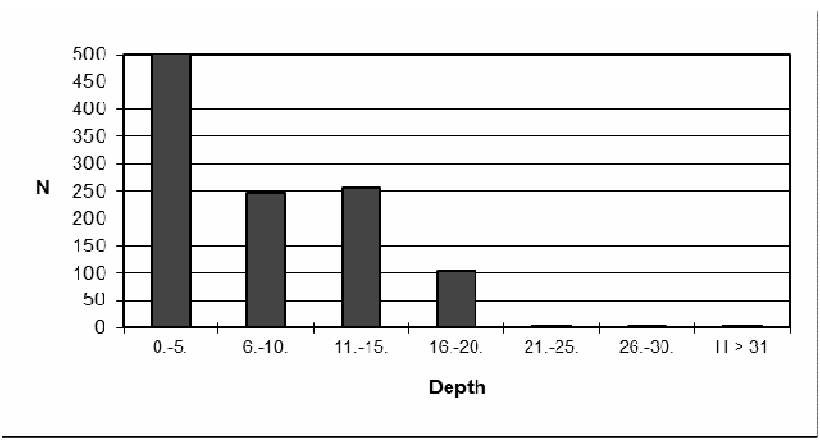

Fig.5. Depth - frequency distribution of the earthquakes

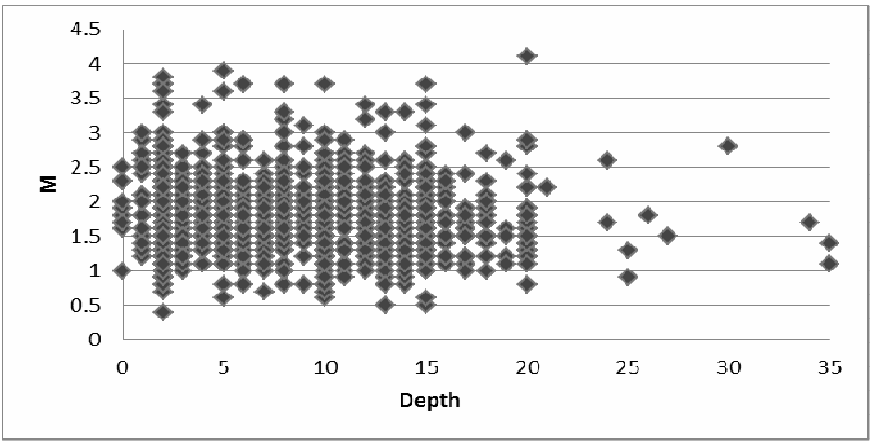

Fig.6. Magnitude - depth dependence

The picture of the depth distribution in Fig.5 shows that the majority of events occur down to 15 km depth. The number of events does not decrease smoothly with increase of the depth. It is possible the established predominating depth (from 0 to 5 km) to be also due to the presence of small number of unidentified industrial explosions. In the same time the number of events in the interval 11-15 km is bigger than this in the previous interval. The magnitude distribution of the events in depth (Fig.6) does not permit to note some differentiation of depth "floors" with the increase of magnitude – the relatively the same maximums can be traced out for the depth intervals down to 20 km depth. As usual the strongest event is deep situated at 20 km depth.

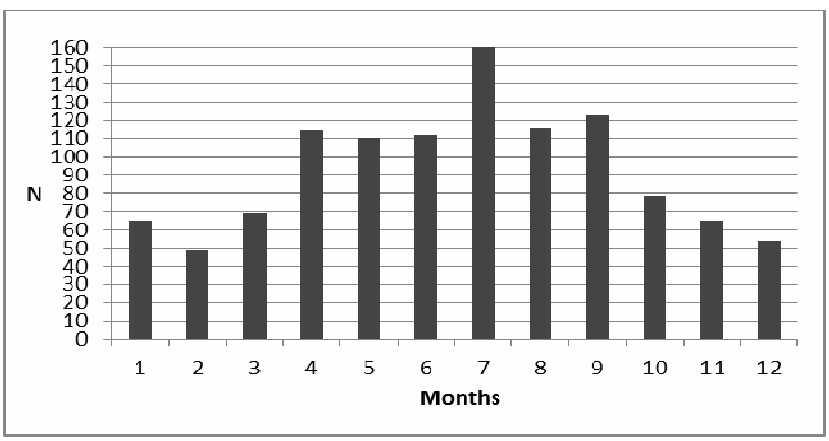

Fig.7. Time distribution of the earthquakes.

Fig.7 illustrates the distribution of seismicity in time according to the number of events per months. The biggest earthquake's amount is displayed in July, when about 160 earthquakes occurred, and it is associated with a swarm activity around of 27 July maximal

earthquake in southwest Bulgaria. The lowest earthquake quantity is in February, around 50 events.

Additionally, about 1000 distant earthquakes have been recorded in the period under study, as well as more than 900 industrial explosions, processed and classified in the preliminary monthly bulletins. In order to identify the artificial seismic sources the methodical approach described by Deneva et al. (1988) and some information about the quarry sites in Bulgaria have been used.

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Данни и анализ на сеизмичните събития регистрирани от НОТССИ през 2013

Е.Ботев, В.Протопопова, И.Попова, Бл.Бабачкова, С.Величкова, И.Александрова, Пл.Райкова, Вл.Бойчев

Резюме. Предлаганото научно съобщение съдържа обобщена информация за резултатите от събирането, обработката и анализа на първичните данни за сеизмичните събития, регистрирани от Националната Оперативна Телеметрична

Система за Сеизмологична Информация (НОТССИ) през 2013 г. Представена е карта на епицентрите на общо 1622 земетресения в частта от Балканския полуостров, ограничена от географска ширина 37^0 - 47^0 N и дължина 19^0 - 30^0 E. По-подробно се анализира сеизмичността за територията на България и прилежащите й земи (повече от 930 сеизмични събития в район с координати $\lambda = 22^0$ - 29^0E и $\varphi = 41^0$ - 44.5^0N). Предлага се и каталог на земетресенията с магнитуд M>2,5. Сеизмогенните прояви се обсъждат по зони, сравнени със съседни периоди време.