DATA AND ANALISIS OF THE EVENTS RECORDED BY NOTSSI IN 2010

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Abstract. A map of epicentres of 2401 earthquakes that occurred during 2010 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 1600 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 2010. 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 2008 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 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.

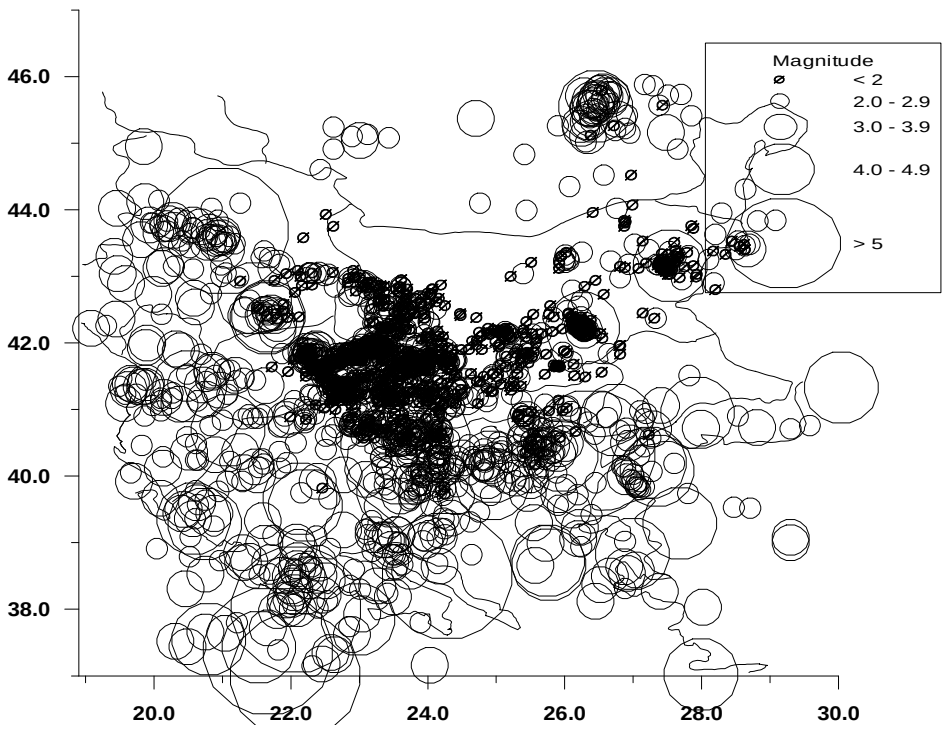

Fig.1. Map of epicenters in Central Balkans during 2010.

For the period of observations presented in this communication, the primary data about 3000 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 2401 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 1260, in M=2-2.9 - 852, in M=3-3.9 - 252, in M=4-4.9 – 30 earthquakes. During this very active period there are 7 events with magnitude M>5.0. The maximum magnitude value is M=5.5.

As a whole, the seismic situation in the study part of the Balkans during 2008 is characterized by very much high activity - 2401events against 2744 in 2009, 1775 in 2008, and around 1100- 1400 for most of the previous years. The maximum realized earthquake is with magnitude M=5.5 while this value for the previous years is lower then five, as a rule. 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 of Marmara sea (Turkey) on 03 November (M=5.5 and intensity I=III-IV of MSC scale in Kurdzhali region). Other strong shakable effect because of outside attack during the study period occurred in Kralevo region (Serbia) on 07th October (magnitude M=4.4 and intensity I=III-IV in Vidin).

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.

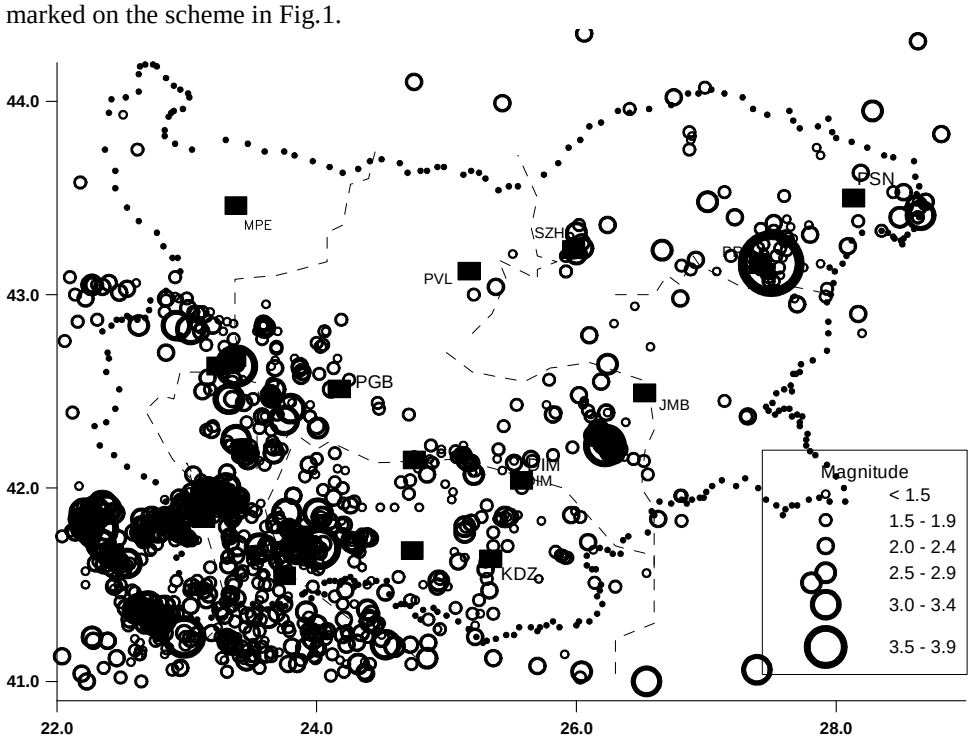

Fig.2. Map of epicentres in Bulgaria and adjacent lands during 2010

Fig.2 illustrates the seismicity just in the territory of Bulgaria and nearby lands ($\varphi = 41^0 - 44.5^0$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 rectangular. 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 2010

Date	Time	Coordinates	H,km	M
20100106	07:29	41.69 23.56	2	3.0
20100110	14:59	41.97 23.22	6	2.8
20100111	16:12	42.35 23.75	4	3.1
20100112	10:26	41.17 23.92	5	2.5
20100116	21:50	41.36 23.92	9	2.5
20100117	12:11	41.76 23.84	6	2.5
20100119	14:52	43.40 28.49	5	2.6
20100121	06:14	41.85 25.45	2	2.9
20100125	00:20	42.83 23.60	2	2.9
20100125	19:14	42.18 23.67	4	2.6
20100126	17:27	42.84 22.63	4	2.8
20100128	03:16	41.66 23.85	11	2.5
20100128	06:43	41.69 23.83	3	2.7
20100129	03:19	42.19 26.26	8	2.6
20100209	15:55	41.82 23.69	7	2.5
20100212	06:30	41.96 23.21	10	2.8
20100213	18:15	41.09 24.32	8	2.6
20100214	18:45	41.51 27.81	11	2.6
20100215	23:06	41.84 22.81	7	2.8
20100216	04:37	42.41 23.80	5	3.3
20100218	00:08	41.74 23.88	15	2.5
20100222	14:02	42.25 23.38	6	3.0
20100301	13:25	43.41 28.65	5	3.1
20100305	06:49	41.12 24.85	2	2.6
20100305	13:17	41.18 24.60	18	2.5
20100305	14:24	41.77 22.95	13	2.6
20100306	17:21	41.70 23.39	11	2.5
20100315	21:37	42.07 25.21	5	2.5
20100316	05:25	43.32 26.00	7	2.7
20100317	00:12	43.24 25.98	8	2.8
20100317	00:25	43.21 26.00	2	2.6
20100319	17:10	41.84 22.30	7	2.7
20100323	08:56	41.80 22.65	3	2.6
20100323	22:56	42.22 26.23	3	2.5
20100327	10:44	41.80 22.68	15	2.6
20100329	12:49	42.64 26.24	15	2.6
20100403	23:45	41.80 22.22	2	3.0
20100403	23:50	41.88 22.29	2	3.0
20100409	22:35	41.11 23.46	3	2.9
20100410	10:09	41.77 25.14	10	2.5
20100410	14:28	41.80 25.14	5	2.6
20100412	00:48	42.27 26.14	15	2.5

20100421	01:13	43.24	26.05	2	2.5
20100426	15:11	42.46	23.32	6	3.2
20100427	15:11	42.46	23.33	4	3.2
20100429	14:15	41.69	24.02	9	3.8
20100429	22:27	41.21	23.33	3	2.8
20100430	14:15	41.69	24.02	9	3.8
20100503	04:16	41.23	22.27	28	2.6
20100515	08:10	42.26	26.24	2	2.5
20100516	18:03	41.85	22.73	2	2.8
20100520	03:09	43.46	28.62	12	2.6
20100520	16:52	41.37	24.39	5	2.5
20100521	00:29	41.31	24.41	4	2.6
20100521	08:42	41.92	23.25	8	2.5
20100527	07:56	41.33	22.76	2	3.4
20100527	07:56	41.39	22.70	2	3.3
20100529	05:13	41.00	26.54	15	3.3
20100531	02:54	43.48	27.01	12	2.5
20100601	07:20	41.79	22.31	2	3.6
20100601	07:41	41.89	22.38	5	3.0
20100602	08:03	43.95	28.28	5	2.6
20100605	05:37	41.93	23.35	2	2.6
20100608	02:02	41.72	23.90	5	2.5
20100609	18:39	41.37	22.63	9	2.8
20100610	22:19	41.72	23.91	5	2.6
20100611	10:13	41.99	23.18	2	2.5
20100615	07:31	41.23	22.98	0	3.6
20100628	12:48	42.23	26.22	2	2.6
20100703	15:26	41.85	24.04	5	2.9
20100705	21:07	41.61	22.54	2	3.1
20100708	08:25	41.95	23.40	3	2.9
20100708	16:20	41.80	22.25	6	3.1
20100709	23:32	41.83	22.83	3	2.8
20100710	01:33	41.84	22.81	7	2.5
20100710	02:33	42.26	26.19	5	2.8
20100710	04:33	41.70	23.89	10	3.1
20100712	10:41	43.05	22.27	2	2.5
20100713	11:36	41.37	22.62	1	3.3
20100713	16:40	41.84	22.65	15	2.6
20100715	09:52	42.15	23.47	5	2.7
20100716	15:00	41.71	22.34	10	3.0
20100716	15:00	41.78	22.38	8	2.7
20100717	14:46	42.17	23.45	7	2.9
20100728	14:27	41.30	22.68	15	2.5
20100731	13:59	41.72	24.27	4	2.8
20100811	23:24	42.00	23.30	5	3.4
20100812	21:57	41.87	22.21	15	3.0
20100816	22:03	41.84	22.17	2	2.5
20100818	03:34	41.99	23.15	2	2.8

20100818	06:34	41.98	23.16	5	3.0
20100818	19:38	41.83	22.86	12	2.6
20100819	04:30	41.82	22.83	10	2.6
20100820	02:34	42.22	26.22	6	4.0
20100820	21:13	42.18	26.29	2	2.6
20100821	02:34	42.19	26.26	5	3.9
20100821	02:37	42.30	26.17	2	2.5
20100826	22:52	41.87	23.77	5	3.1
20100827	10:16	42.66	23.36	6	2.8
20100902	01:14	41.34	22.78	2	2.7
20100907	13:33	41.89	22.26	6	2.8
20100910	00:43	41.91	22.35	3	3.1
20100910	07:11	42.63	23.38	4	3.5
20100914	18:36	41.19	24.53	1	3.0
20100918	03:46	41.30	22.78	2	2.5
20100919	17:53	42.23	26.21	2	2.8
20100928	15:34	41.87	24.01	8	3.0
20100930	04:52	42.47	23.65	15	2.9
20101007	19:51	43.16	27.50	2	4.4
20101010	15:40	41.52	24.94	12	2.5
20101012	10:17	42.82	23.03	8	3.2
20101013	19:43	42.84	22.92	4	3.0
20101013	21:57	41.33	23.63	10	2.5
20101014	05:39	41.19	23.35	5	2.5
20101026	22:09	41.06	27.39	2	3.1
20101029	13:27	43.23	26.66	11	2.7
20101031	09:41	41.71	24.30	5	2.7
20101031	09:52	41.94	23.09	12	2.5
20101101	12:13	41.22	23.97	5	2.9
20101103	02:29	41.39	22.83	10	2.5
20101103	21:56	42.51	23.68	7	2.8
20101107	06:27	41.91	22.96	12	2.8
20101108	01:59	42.27	26.21	1	2.8
20101109	12:24	41.29	24.00	5	2.8
20101110	21:52	42.23	26.22	4	2.9
20101203	19:51	41.87	22.44	2	2.6
20101210	20:47	41.83	22.25	2	2.5
20101215	19:50	42.31	24.01	5	2.6
20101216	13:38	41.05	26.04	2	2.7
20101227	22:47	41.97	23.25	2	2.7
20101228	04:11	41.96	23.24	6	2.8

On the territory of Bulgaria a very much high degree of activity of weak earthquakes is observed during 2010 - 1607 events against 2017 in 2009, 1079 in 2008, and 600-800 for most of the previous years. The earthquakes of a magnitude higher than 3.0 are a little higher then normal amount - 35 events compared with an averaged number of about 20-30 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 M=4.4 in

the region of Provadia is almost normal too, in comparison with the maximum magnitude in the course of previous years. As usually, the largest concentration of epicenters is marked in the southwestern part of the territory presented in Fig.1. The Kroupnik seismic source is known with the strongest crustal earthquakes in Europe (M=7.8, 7.1) for the last 160 years. In 2010 about 70 events of M<3.0 and 6 of M≥3.0 occurred in this region. The 16 May event with M=3.3 is felt on Blagoevgrad region by intensity of IV EMS. The strongest earthquake for the south-western part of Bulgarian territory is with magnitude M=3.5, it is felt on 28 January in Gotce Delchev region (western slopes of Rhodope mountain) by intensity of IV-V EMS.

The Bulgarian seismic sources in 2010 are relatively more active than during the previous year. They produced more than 20 earthquakes affecting different localities in this country by intensity of up to IV degrees EMS. Sixteen cases of magnitudes between 2.2 and 2.8 aroused shocks of intensity three or a bit more originated in Monastery Highland territories and only one with M=3.9 caused IV-V of MSK on 21 August. In the rest part of the 2010 felt events caused excitation of lesser intensity. The prevailing number of them was caused by small dislocations in Rila-Rhodopean Region; two of them showed a certain seismic activity in the Central and Eastern part of the Balkan Mountain. The strongest event with magnitude Ms=4.4 occur in north-eastern Bulgaria on 07 October and caused macroseismic impact with intensity of VI degree EMS scale. Most significant seismic activity is associated with the Vitosha fault structure in the Sofia region where three shocks during the time of two weeks shook the city center with maximum intensity of VI EMS since 27 August to 10 September.

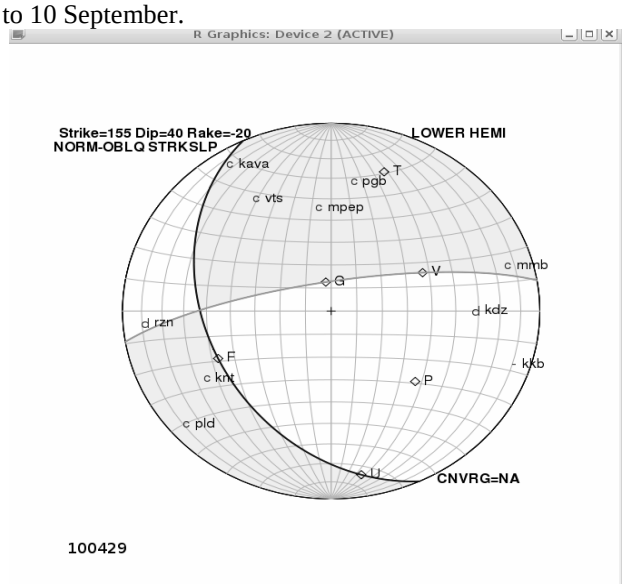

Fig.3. Focal plane solution of the strongest Rhodope (Kovachevitca) earthquake (29.04.2010)

For the determination of the earthquake mechanism is used program FOCMEC. Input are polarities of the P wave. In the double - couple focal mechanism are included 12 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

/2006/) - Fig.3. The solution is displayed on lower hemisphere. The polarities from ISC are not check as waveform. The polarities from seismological stations KAVA and PGB are poor and the solution is not with very good quality. The fault plane solutions of the some other events are with very bad quality because of a low number of polarities.

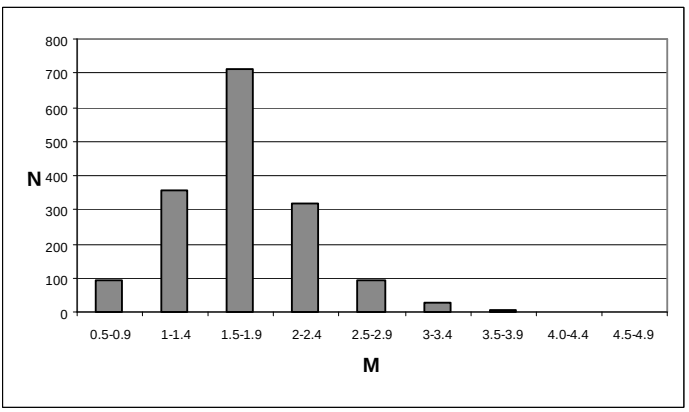

Fig.4. Magnitude - frequency distribution of the earthquakes

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=4.0-4.4 is 1 event for M=3.5-3.9 is 6 events, for M=3.0-3.4 is 28 events, for M=2.5-2.9 - 95, for M=2.0-2.4 - 317 and so on. The abrupt diminishing of the number of earthquakes in the first two intervals (M<1.5) in Fig.4 determines also the registration power of the seismic stations network.

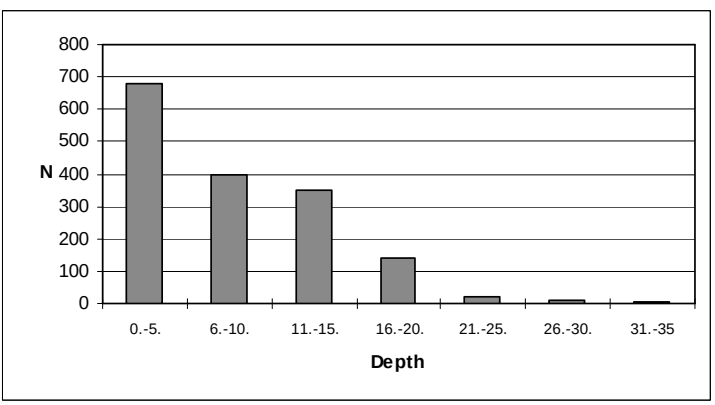

Fig.5. Depth - frequency distribution of the earthquakes

Taking the latter into account, 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.

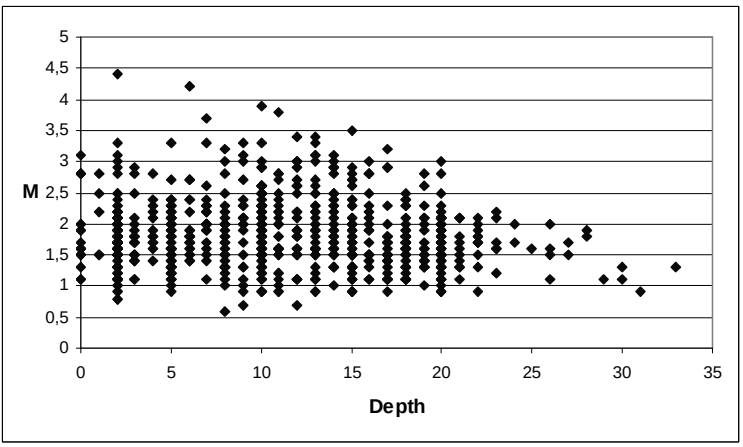

Fig.6. Magnitude - depth dependence

The picture of the depth distribution in Fig.5 shows that the majority of events occur down to 20 km depth. The number of events decreases 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 unidentified industrial explosions. In the same time the number of events in the interval 15-20 km is bigger. The magnitude distribution of the events in depth (Fig.6) don't permits to note some differentiation of depth "floors" with the increase of magnitude - the maximums can be traced out for all of the depth interval from 2 to 20 km. It is remarkable that the strongest events are not deep situated.

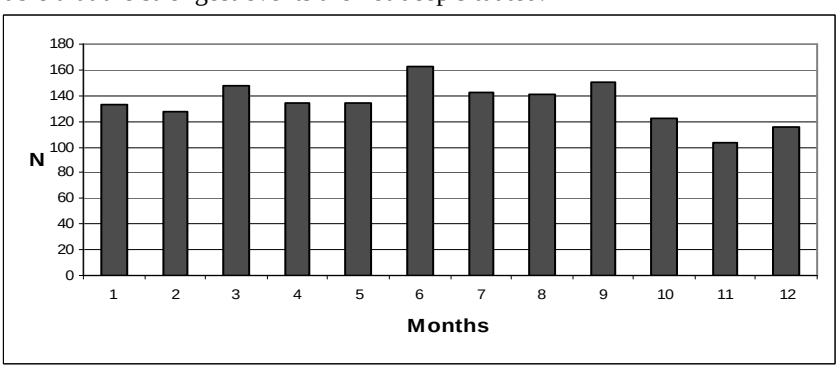

Fig.7. Time distribution of the earthquakes.

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 June, when more then 160 earthquakes occurred, approximately the similar situation in March and September is observed – 149 and 151 events. The lowest earthquake quantity is in November, 104 events. The energy release suggests that in October, when 122 events occurred, is the month with maximum of energy release.

Additionally, about 900 distant earthquakes have been recorded in the period

under study, as well as more than 600 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 2010

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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 2010 г. Представена е карта на епицентрите на общо 2401 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 (1607 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.