DATA AND ANALYSIS OF THE EVENTS RECORDED BY NOTSSI IN 2008

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Abstract. A map of epicentres of 1775 earthquakes that occurred 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 than 1070 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 2008. 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.

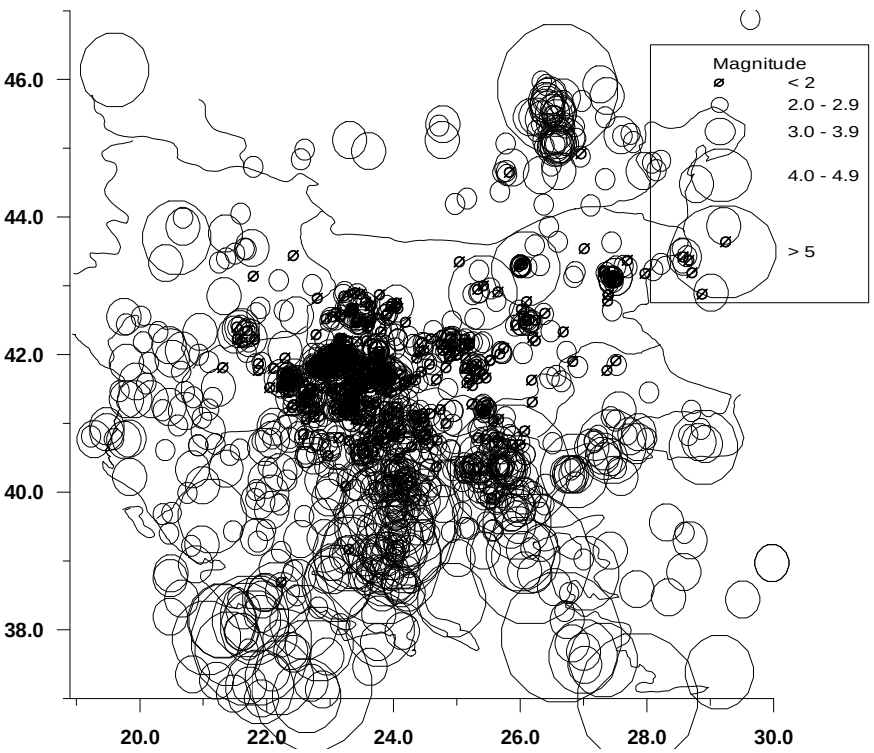

Fig.1. Map of epicenters in Central Balkans during 2007.

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 1775 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=1-1.9 is 692, in M=2-2.9 - 757, in M=3-3.9 - 271, in M=4-4.9 – 41 earthquakes. During this very active period there are 11 events with magnitude M>5.0. The maximum magnitude value is M=5.9.

As a whole, the seismic situation in the study part of the Balkans during 2008 is characterized by very high activity - 1775 events against 1152 in 2007, 1424 in 2006 and around 1100- 1300 for most of the previous years. The maximum realized earthquake is with magnitude approximately six 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 Southern Greece, North Aegean region, Romania, Marmara Sea, and the Aegean coast of Western Turkey.

The strongest event outside Bulgaria during the study period occurred in the Peloponnesus peninsula in Southern Greece on 8th June 2008 with magnitude M=5.9. According to the Euro-Mediterranean Seismological Centre, the earthquake magnitude was determined between 5.6 and 6.2, nevertheless it was not felt on the territory of Bulgaria. Out of the earthquakes caused by sources situated in the neighboring southern territories only two were felt. Their origins were in Aegean Sea and the source energy was assessed by magnitudes a bit greater than 5. Their influence was very slight, with intensity up to III degree EMS. One event in Romania with magnitude M=5.3 was felt slightly in Ruse and Silistra regions.

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.

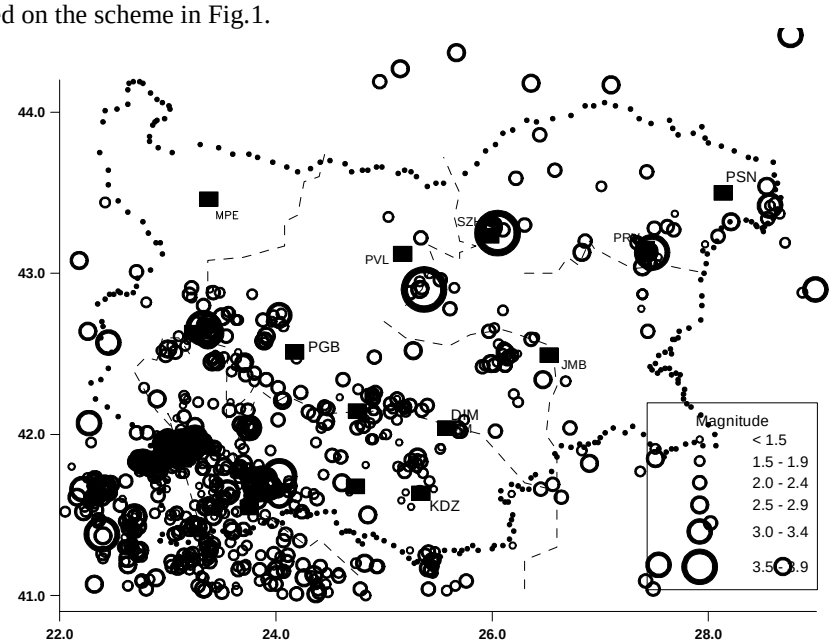

Fig.2. Map of epicentres in Bulgaria and adjacent lands during 2007

Fig.2 illustrates the seismicity just in the territory of Bulgaria and nearby lands (φ

= 41^0 - 44.5^0N, λ = 22^0 - 29^0E). 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 2008

Date	Time	Coordinates	H,km	M
20080105	18:03	41.19 22.63	7	2.6
20080106	02:05	43.08 22.18	20	2.7
20080109	10:35	43.42 28.57	21	3.0
20080110	15:59	41.42 23.28	20	2.5
20080113	17:06	42.46 23.44	4	2.6
20080114	17:06	42.45 23.41	14	2.5
20080122	09:01	43.27 25.99	6	2.5
20080122	09:39	42.64 22.26	11	2.7
20080125	04:23	41.84 22.85	12	2.5
20080125	10:10	42.51 26.12	15	2.7
20080129	02:22	41.59 23.83	18	2.5
20080129	05:29	43.28 25.98	7	2.9
20080129	05:41	43.29 26.01	5	2.5
20080130	06:35	44.18 26.36	2	2.9
20080131	22:21	42.21 24.06	10	2.5
20080219	01:54	41.82 22.78	15	2.6
20080219	03:17	44.37 25.67	36	2.8
20080223	03:14	41.83 22.71	20	2.8
20080228	13:07	42.53 23.00	6	2.8
20080307	02:57	43.13 27.45	2	2.8
20080315	21:50	42.57 22.45	8	3.4
20080317	17:43	41.98 23.00	2	2.9
20080324	12:46	41.98 23.25	2	3.4
20080326	17:08	41.20 24.82	20	2.6
20080326	20:52	41.49 22.69	11	3.3
20080410	06:40	41.92 23.19	2	3.0
20080415	03:43	42.90 25.37	9	4.3
20080415	18:02	42.90 25.33	12	2.6
20080416	03:17	42.05 23.25	5	2.5
20080423	03:44	43.32 28.21	15	2.8
20080424	12:50	41.86 25.31	14	2.7
20080428	09:53	41.07 22.32	7	2.5
20080506	00:20	41.64 23.55	10	3.3
20080506	17:39	44.17 27.10	12	2.5
20080512	10:11	43.25 26.05	11	4.2
20080514	10:12	41.01 24.37	12	2.5
20080515	13:25	41.42 22.65	10	2.7
20080516	14:29	41.82 22.77	7	2.7
20080522	15:47	41.83 22.81	15	2.9
20080523	11:37	42.74 24.03	2	3.2
20080523	23:32	41.72 23.90	5	3.2

20080524	07:16	44.48	28.76	16	3.1
20080528	13:27	41.83	22.77	13	3.1
20080529	07:22	41.50	24.85	20	2.6
20080529	12:09	41.63	22.36	20	2.7
20080605	10:00	42.52	25.27	97	2.8
20080606	08:43	43.54	28.54	21	2.5
20080606	22:57	41.18	28.69	14	2.9
20080609	10:39	41.69	22.43	20	2.5
20080609	12:53	42.44	25.99	8	2.7
20080612	01:34	41.69	22.47	20	2.7
20080614	03:06	41.93	23.25	5	2.5
20080617	16:17	41.82	23.70	2	2.6
20080619	06:52	41.97	23.27	4	2.5
20080622	18:43	41.95	22.99	20	3.4
20080623	11:56	41.61	22.16	7	2.7
20080623	19:01	41.89	23.05	12	3.0
20080624	01:42	41.69	23.81	15	2.8
20080629	09:57	41.81	22.91	19	2.8
20080629	09:58	41.77	22.91	13	2.6
20080629	18:06	41.88	22.98	14	3.1
20080630	16:57	41.70	24.61	2	2.5
20080702	03:31	42.73	23.50	0	2.8
20080703	08:11	42.90	28.99	20	3.4
20080703	12:05	41.66	22.40	5	2.6
20080703	12:12	42.61	23.37	9	3.1
20080703	19:46	42.22	22.90	15	2.5
20080704	19:03	41.81	22.88	16	2.9
20080711	02:06	41.40	23.60	6	2.9
20080713	10:23	43.28	26.01	6	2.7
20080801	12:34	41.67	22.38	10	2.5
20080801	13:17	41.66	22.21	5	3.0
20080805	07:26	41.55	23.35	13	2.9
20080805	10:06	42.34	26.47	20	2.6
20080805	11:47	41.64	22.45	5	2.6
20080805	15:58	42.12	24.90	8	2.5
20080809	03:25	42.67	23.38	14	3.0
20080813	07:40	41.19	27.54	20	3.3
20080813	11:47	41.67	22.41	5	3.3
20080814	12:06	41.23	22.63	9	2.8
20080821	06:40	41.89	23.24	19	2.6
20080821	13:15	41.13	24.35	2	2.7
20080822	02:04	41.43	22.72	20	2.6
20080902	01:57	41.62	24.03	18	3.1
20080902	12:10	41.61	22.39	13	2.5
20080902	23:00	44.27	25.15	9	2.7
20080905	16:38	41.52	22.22	10	2.8
20080908	20:13	41.95	23.10	13	2.6
20080911	16:39	41.37	22.40	2	2.8

20080911	20:14	41.38	22.39	2	3.5
20080913	21:02	42.04	23.77	9	2.7
20080913	21:02	42.04	23.77	8	2.7
20080914	21:34	41.44	23.24	20	2.5
20080915	00:06	42.44	23.70	20	2.8
20080915	00:06	42.45	23.71	20	2.8
20080921	07:18	41.90	23.21	16	2.6
20080928	23:02	41.11	24.26	7	2.5
20081007	23:26	41.74	24.03	7	3.7
20081008	08:47	43.13	26.83	18	2.6
20081008	13:43	41.17	25.41	8	2.5
20081010	19:53	41.50	22.67	10	2.5
20081013	23:37	41.49	23.42	11	2.5
20081018	10:06	41.61	22.31	9	2.8
20081018	11:24	41.68	22.41	14	2.7
20081018	20:38	41.80	23.52	13	2.9
20081019	13:37	42.07	22.27	1	3.1
20081021	01:57	41.11	22.89	11	2.5
20081025	13:22	42.04	23.75	2	3.3
20081027	15:07	41.82	26.90	2	2.9
20081029	15:58	42.05	23.76	7	2.5
20081029	15:58	42.05	23.76	7	2.5
20081029	16:26	42.06	23.77	0	2.5
20081102	00:32	41.85	27.51	21	2.9
20081103	18:48	41.92	23.28	18	2.6
20081105	07:36	43.13	27.48	10	3.8
20081105	12:38	42.08	24.46	8	2.5
20081115	20:08	42.66	23.33	12	3.9
20081116	05:03	42.63	23.40	8	3.2
20081124	07:56	41.95	23.33	0	2.7
20081129	01:53	41.98	23.24	5	2.6
20081129	03:18	43.04	27.39	2	2.5
20081129	10:13	41.90	22.98	20	2.7
20081130	18:12	41.99	23.24	1	2.7
20081202	04:38	41.04	23.33	6	2.7
20081205	17:58	41.28	22.71	19	2.6
20081205	21:33	41.28	22.74	13	2.8
20081206	09:00	41.67	23.94	12	3.3
20081206	09:23	41.67	23.93	13	3.1
20081211	06:19	42.58	23.89	10	2.6
20081215	05:45	42.61	23.91	16	2.5
20081220	01:24	41.92	23.11	19	2.6
20081220	05:25	41.94	23.16	10	3.1
20081223	10:35	41.16	24.00	6	2.5
20081224	05:00	41.69	23.85	20	3.8
20081224	13:11	41.69	23.85	19	2.8
20081229	09:31	41.73	23.83	2	2.5

On the territory of Bulgaria a very high degree of activity of weak earthquakes is observed during 2008 - 1079 events against 672 in 2007, 818 in 2006 and 600-700 for most of the previous years. The earthquakes of a magnitude higher than 3.0 are in a highest amount - 33 events compared with 9 events during 2007 and the averaged number of about 20-30 for most of the all previous years (and 31 for 2006). The maximum realized magnitude M=4.3 is one of the highest 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.2. The Kroupnik seismic source, known with the strongest crustal earthquakes in Europe (M=7.8, 7.1) for the last 160 years (Christoskov and Grigorova, 1968). In 2008 about 100 events of M<3.0 and only four of M≥3.0 occurred in this region. The 24 March, 22 June and 23 June events with magnitudes M=3.4, 3.4 and 3.1 respectively, are felt on Blagoevgrad region by intensity of IV EMS. The strongest earthquake for the all Bulgarian territory is in Central North Bulgaria with magnitude M=4.3, and it is felt in Dryanovo region by intensity of V-VI EMS on 15 April. Another two events are felt with at least V degree EMS – on 5 November in region of Provadia (North-east Bulgaria) with magnitude M=4.2 and on 15 November in the town of Sofia with magnitude M=3.9. As a whole at least 26 events are well felt in the territory of Bulgaria which is normal in comparison with the previous years. Twelve cases of magnitudes between 3.0 and 4.3 aroused shocks of intensity four or a bit more: 6 of them originated in South-Western territories, 3 are situated in central end eastern parts of North Bulgaria, 2 in Sofia seismic zone and one only in Maritsa seismic zone. In the rest part of the 2008 felt events caused excitation of lesser intensity. The prevailing number of them was caused by small dislocations in Rila-Rhodopean Region; three of them showed a certain seismic activity in the Central and Eastern part of the Balkan Mountain. In comparison with the previous years, a smallest felt earthquake (with magnitude M=2.4) reminded of activity in the Gorna Oryakhovitsa zone in January 2008.

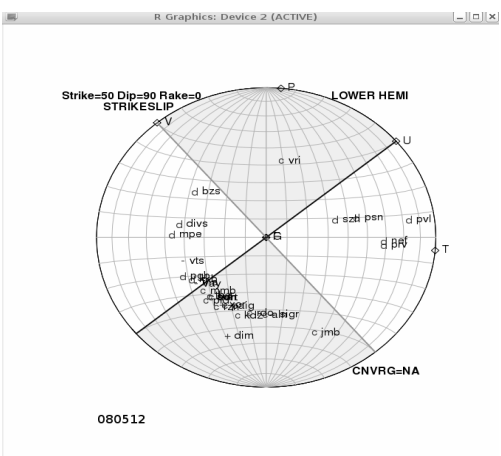

Fig.3. Focal plane solution for one of the strongest earthquake (12.05.2008)

For the determination of the earthquake mechanism the program FOCMEC is used. Input are polarities of the P wave. In the double - couple focal mechanism are included 21 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 polarity from seismological stations DIM is poor and the solution is with very good quality. The fault plane solutions of the rest events are with not so good quality because of a lower number of polarities.

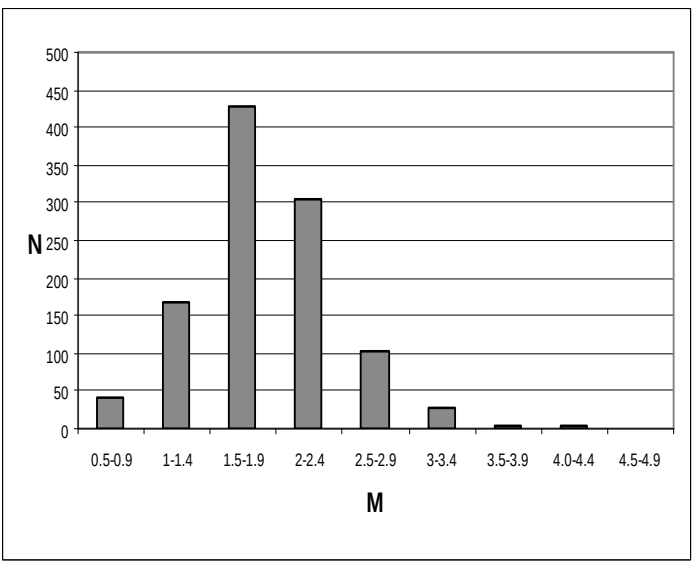

Fig.4. Magnitude - frequency distribution of the earthquakes

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=3.5-3.9 is 0 events for M=3.0-3.4 is 5 events, for M=2.5-2.9 - 50, for M=2.0-2.4 - 165 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. 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.

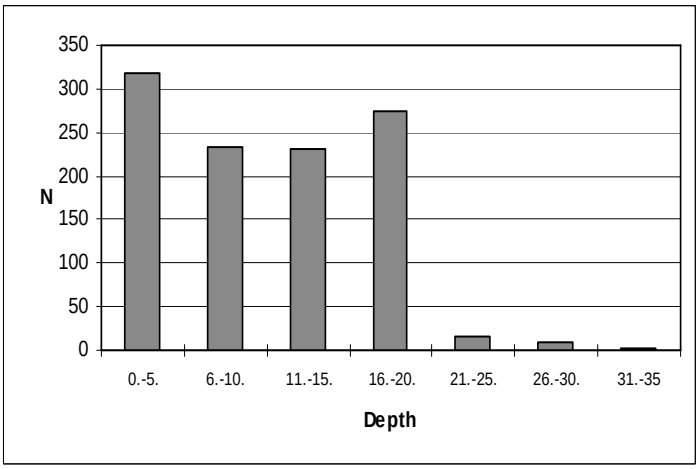

Fig.5. Depth - frequency distribution of the earthquakes

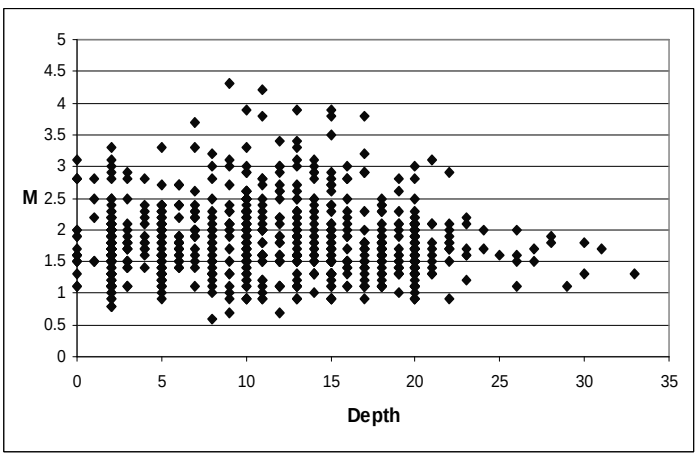

Fig.6. Magnitude - depth dependence

The picture of the depth distribution in Fig.5 shows that the majority of events occur down to 20 km 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 too. The magnitude distribution of the events in depth (Fig.6) permits to note some differentiation of depth "floor" with the increase of magnitude - the maximums can be traced out for the depth interval from 7 to 17 km.

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 about 120 earthquakes occurred. The other months with relatively big amount observed events are May, September and December, when about one hundred earthquakes occurred. The

lowest earthquake quantity is in August, 68 events. The energy release suggests that May, one of the months with maximum number of events is the month with maximum seismic energy accumulated. In the same time in April, with only 70 events, the earthquake with maximum magnitude occurs. Some other strongest events occurred in November.

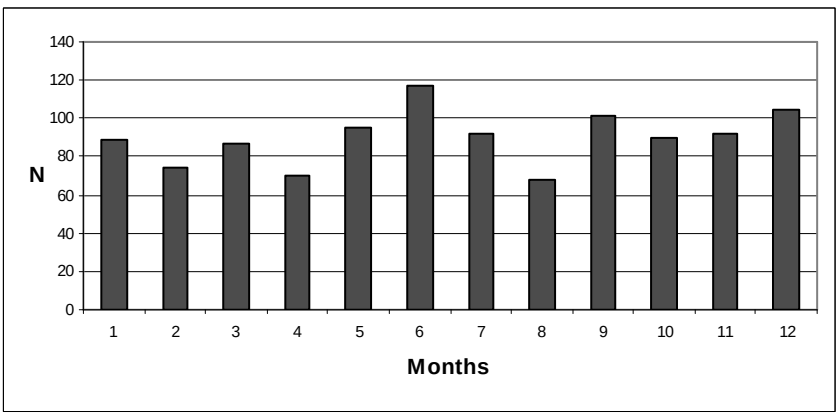

Fig.7. Time distribution of the earthquakes.

Additionally, about 1100 distant earthquakes have been recorded in the period under study, as well as more than 500 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 2008

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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 2008 г. Представена е карта на епицентрите на общо 1775 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 (1079 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.