DATA AND ANALISIS OF THE EVENTS RECORDED BY NOTSSI IN 2012

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

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

Abstract. A map of epicenters of 1508 earthquakes that occurred during 2012 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 2012. 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 2012 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.

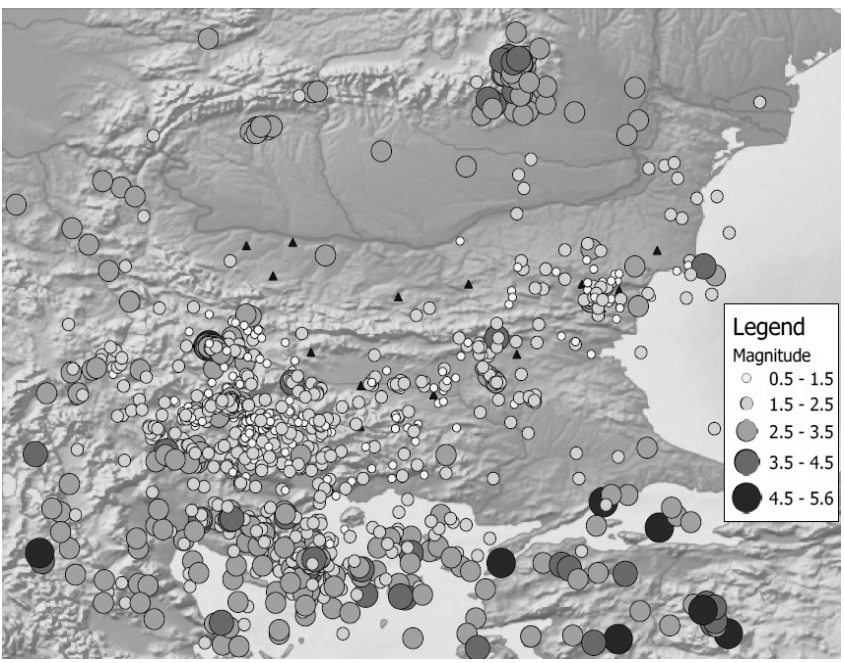

Fig.1. Map of epicenters in Central Balkans during 2012.

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 1508 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 744, in M=2-2.9 - 576, in

M=3-3.9 - 155, in M=4-4.9 – 33 earthquakes. During this not so active period there are 2 events with magnitude M>5. The maximum magnitude value is M=5.6.

As a whole, the seismic situation in the study part of the Balkans during 2012 is characterized by not so high activity - 1508 events against 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=5.8 while this value for the previous years is lower then five, as a rule, except 2011 – M=5.8. 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) wit magnitude M=5.3. 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.

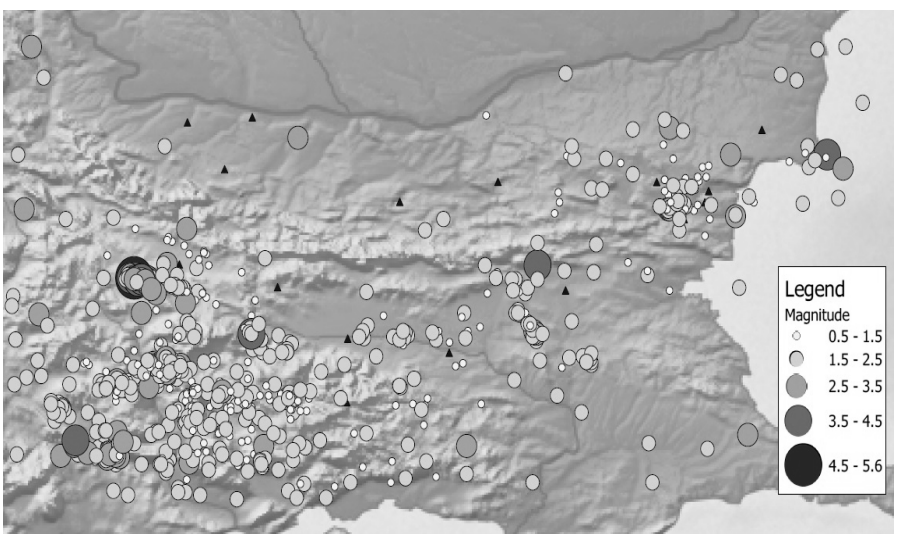

Fig.2. Map of epicenters in Bulgaria and adjacent lands during 2012

Fig.2 illustrates the seismicity just in the territory of Bulgaria and nearby lands ($\varphi = 41^0$ - 44.5^0N, $\lambda = 22^0$ - 29^0E). 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 $\geq$ 2.5 in Bulgaria and adjacent lands during 2012

Date			Time	Coordinates		H,km	M
2012/	1/	12	5:37:21.3	41.85	22.86	13	3.0
2012/	1/	19	13:41:34.4	41.26	23.45	5	2.6
2012/	1/	20	22:58:42.0	41.96	23.38	5	3.5
2012/	1/	24	5:25:45.7	41.72	24.26	8	3.0
2012/	2/	9	22:34:40.5	42.20	26.27	10	3.2
2012/	2/	9	22:37:20.6	42.18	26.29	8	2.6
2012/	2/	12	23: 8:46.9	42.68	23.27	15	2.6
2012/	2/	29	15: 1:48.2	43.65	27.38	12	2.8
2012/	3/	23	11: 2:34.9	41.34	22.83	7	2.6
2012/	3/	30	20:48:33.6	42.67	26.30	4	3.9
2012/	4/	8	15:27:12.7	42.19	25.22	2	2.5
2012/	5/	1	19:11:23.0	41.91	23.28	2	2.8
2012/	5/	4	13:20: 0.1	43.07	22.10	1	3.2
2012/	5/	7	12:44:14.2	41.82	22.02	15	2.5
2012/	5/	10	22:40:29.1	41.38	25.72	9	3.1
2012/	5/	12	7:32: 4.0	41.36	22.81	2	2.7
2012/	5/	15	17:30: 1.2	41.46	28.02	2	3.2
2012/	5/	18	2:50:14.4	41.92	23.26	2	2.6
2012/	5/	20	0: 0:32.5	42.58	23.00	9	5.6
2012/	5/	22	0: 4:52.6	42.58	22.97	8	3.9
2012/	5/	22	0:15: 5.0	42.55	23.15	13	2.5
2012/	5/	22	0:16:53.1	42.56	23.09	13	3.0
2012/	5/	22	0:23:35.4	42.56	23.06	11	2.9
2012/	5/	22	0:43:47.3	42.58	23.05	10	3.4
2012/	5/	22	0:49:24.5	42.57	23.04	9	2.7
2012/	5/	22	0:55:57.5	42.56	23.07	10	2.9
2012/	5/	22	1:30:50.6	42.58	23.01	9	4.4
2012/	5/	22	1:34:30.5	42.53	23.09	10	3.0
2012/	5/	22	1:37:21.9	42.54	23.12	12	2.9
2012/	5/	22	12: 4:59.1	42.33	23.06	2	2.8
2012/	5/	22	16:26:12.4	42.58	23.06	15	2.6
2012/	5/	22	17: 7:41.5	42.58	23.03	15	3.3
2012/	5/	22	19:52:35.2	42.59	23.03	15	2.9
2012/	5/	22	2:11: 6.3	42.60	22.97	12	3.2
2012/	5/	22	2:13:28.3	42.57	23.05	5	4.1
2012/	5/	22	3:23:26.9	42.40	23.42	2	2.9
2012/	5/	22	3:41:36.0	42.58	23.02	7	2.8
2012/	5/	22	4: 9:58.5	42.57	23.04	2	3.2
2012/	5/	22	4:29:11.5	42.58	23.08	15	3.1
2012/	5/	23	10:57:25.1	42.54	23.11	11	3.0
2012/	5/	23	11:41: 8.3	42.56	23.02	2	3.1
2012/	5/	23	13:31:32.4	42.58	23.03	15	2.6
2012/	5/	23	21:59:14.8	42.56	23.10	10	3.7
2012/	5/	24	22:49: 5.7	42.57	23.00	4	2.5

2012/	5/	25	15: 3: 3.5	41.49	22.76	2	2.5
2012/	5/	25	7: 8:40.1	42.59	23.01	9	2.8
2012/	5/	25	9:43: 5.9	42.53	23.07	7	2.8
2012/	5/	27	18:56:30.0	42.93	23.43	20	2.7
2012/	5/	29	7:23:31.7	42.56	23.03	6	3.8
2012/	5/	30	5:36:23.0	42.55	23.07	9	3.4
2012/	6/	3	20: 8:50.0	42.18	23.96	2	3.6
2012/	6/	5	0:43: 8.1	41.48	22.86	2	2.8
2012/	6/	16	4:51: 2.1	42.57	23.07	10	3.0
2012/	6/	17	4: 8: 6.3	41.38	22.87	8	2.5
2012/	6/	21	3:10:15.0	41.95	23.21	2	2.8
2012/	6/	23	8:58:48.4	41.90	23.27	2	3.4
2012/	6/	28	19:16:38.7	43.07	27.37	12	2.8
2012/	6/	29	1:27: 4.3	43.07	27.38	12	2.9
2012/	7/	2	13:26:32.2	41.80	23.12	3	2.9
2012/	7/	5	16:21:34.7	41.30	22.88	5	2.6
2012/	7/	5	6:43:44.8	41.31	22.85	1	2.6
2012/	7/	9	12:49:46.9	42.47	23.18	2	2.6
2012/	7/	14	12:52: 7.0	42.57	23.06	8	4.3
2012/	7/	22	22:10:51.4	41.32	22.80	2	3.5
2012/	7/	24	6:58:49.1	41.77	23.72	2	2.8
2012/	7/	31	0:10:21.4	42.54	23.10	7	3.3
2012/	8/	12	20:36:29.1	41.31	22.86	5	2.5
2012/	8/	16	2:11:54.4	42.57	23.06	10	3.0
2012/	8/	17	10:31:48.2	42.01	23.26	2	2.7
2012/	8/	17	19:54:44.5	42.01	23.26	2	2.5
2012/	8/	17	19:55:11.7	43.36	28.80	15	2.8
2012/	8/	19	6:36:13.7	42.32	22.22	1	3.0
2012/	8/	21	18:21:48.0	42.58	23.02	15	2.5
2012/	8/	25	12:31:33.8	43.09	27.30	8	2.5
2012/	8/	27	16:26:51.7	41.42	22.52	7	4.1
2012/	9/	3	16:54:32.4	41.41	22.91	4	3.0
2012/	9/	7	16:47:23.6	41.32	22.04	2	2.5
2012/	9/	14	11:32:37.0	42.57	23.00	2	2.7
2012/	9/	19	17: 0:48.6	42.56	23.09	15	2.7
2012/	9/	22	19:57:24.6	42.50	23.14	3	2.7
2012/	9/	27	19: 8:18.2	41.79	22.77	5	2.5
2012/	9/	28	9:47:45.4	44.23	22.16	2	2.6
2012/	10/	4	20:37:16.5	41.38	24.06	4	3.2
2012/	10/	12	7:59:53.4	41.06	22.83	2	2.5
2012/	10/	18	0:23:16.4	43.58	24.34	8	2.6
2012/	10/	24	1: 2: 6.7	41.36	23.70	2	2.5
2012/	11/	11	2:15: 5.7	41.31	22.83	10	2.5
2012/	11/	24	22:15:57.0	43.15	28.76	8	2.5
2012/	11/	25	5:58:54.5	41.12	27.24	10	2.5

2012/	11/	28	15:32:52.3	41.31	22.40	12	3.4
2012/	11/	29	23:52:21.7	41.91	23.25	6	2.5
2012/	12/	2	20:11:31.7	43.02	27.92	13	3.0
2012/	12/	3	18:58:39.4	43.46	28.67	15	4.1
2012/	12/	6	7:28:35.1	41.38	22.51	9	2.6
2012/	12/	10	16:58:29.0	43.46	27.88	15	2.7
2012/	12/	15	15:43:37.1	41.29	22.78	2	2.6
2012/	12/	23	20:31:16.4	41.33	22.62	2	2.6

On the territory of Bulgaria relatively low activity of earthquakes is observed during 2012: – only 932 events are observed, against 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 – 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 is Ms=5.8 (Mw=5.6) in the region of Pernik which is the highest earthquake, in comparison with the maximum magnitude in the course of previous years. The strongest Bulgarian event during 2012 occurs on 22 May and caused macroseismic effects with intensity of VII-VIII degree of MSC scale in the town of Pernik – close to Bulgarian capital Sofia. During the first day the main shock is followed by more then 30 events with maximum M=4.4, causing moderate damages in a wide area including the main city. According to the calculations of the national seismological centre the depth of the event is about 10 km. The epicentres of the shocks are in an area which was relatively silent for the last 100 years. The relatively short duration and low frequency of the aftershock sequence of this event does not increase significantly the relatively low number of all seismic events in Bulgarian territory during 2012.

As usual, the largest concentration of the epicenters in the other regions of Bulgarian territory during 2012 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 2012 about 50 events of $M<3.0$ and only 3 of $M\geq3.0$ occurred in this region. The strongest felt earthquake for the south-western part of Bulgarian territory is with magnitude M=3.5, it is felt on 20 January in Razlog region (southern slopes of Rila mountain) by intensity of III - IV degree of MSC scale.

The other Bulgarian seismic sources in 2012 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-V degrees of MSC scale. The maximum number of felt earthquakes is occurred around the Monastery uplift. About four cases of magnitudes less than 3.0 aroused shocks of intensity three or a bit more are felt in Monastery Highland territories. The maximum event with M=4.1 in Black sea caused V degree of MSC scale on 03 December in Shabla region (north-eastern Black sea cost). A strong event M=3.9 in the neighbor region of Sliven town caused effects of IV-V degree of MSC. A relatively so much significant seismic impact is associated with the Velingrad earthquake source zone in the Rhodopean region, where an event with magnitude M=3.6 shook the city of Velingrad with intensity of IV-V degree of MSC on 03 June. In the rest

part of the Bulgarian territory the felt events caused excitation of lesser intensity during 2012.

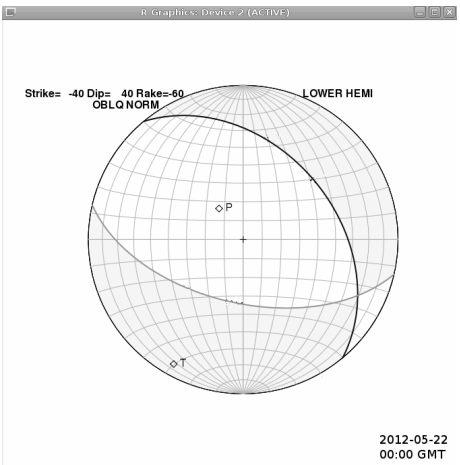

Fig.3. Focal plane solution of the strongest Pernik earthquake (22.05.2012, 00:00 GMT)

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 /2012/) 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.

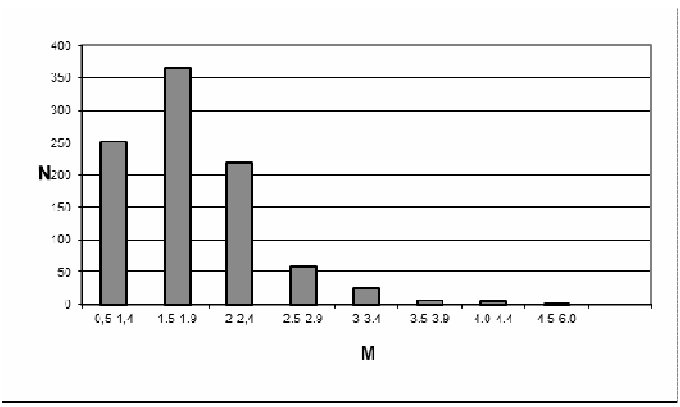

Fig.4. Magnitude - frequency distribution of the earthquakes

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>5 – 1 event, M= 4.0-4.5 is 5 events, M=3.5-3.9 is 7 events, for M=3.0-3.4 is 25 events, for M=2.5-2.9 - 59, for M=2.0-2.4 - 218 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.

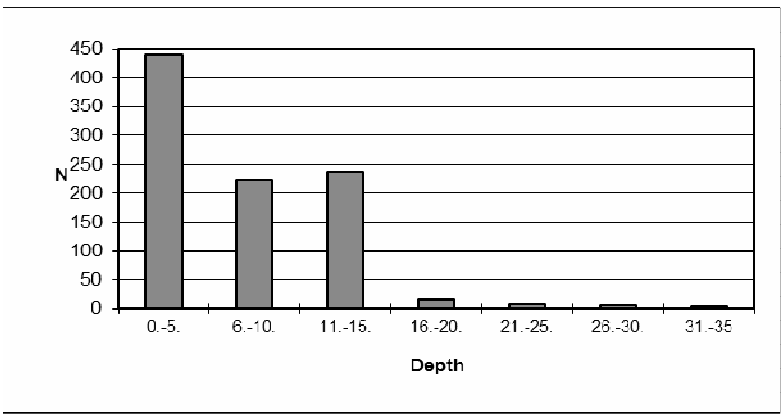

Fig.5. Depth - frequency distribution of the earthquakes

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.

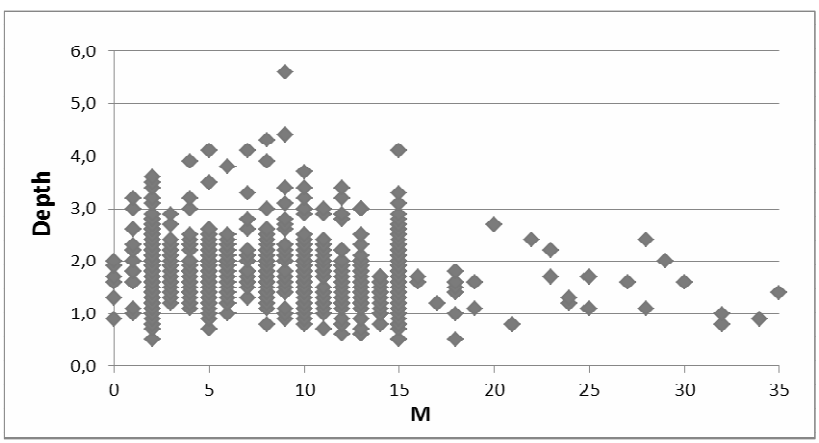

Fig.6. Magnitude - depth dependence

The picture of the depth distribution in Fig.5 shows that the majority of events occur down to 15 km depth. The number of events does not decreas 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. The magnitude distribution of the events in depth (Fig.6) permits to note some differentiation of depth "floors" with the increase of magnitude - the maximums can be traced out for the depth interval from 4 to 15 km. It is remarkable that the strongest events are not deep situated and the maximal event is associated with 9 km depth.

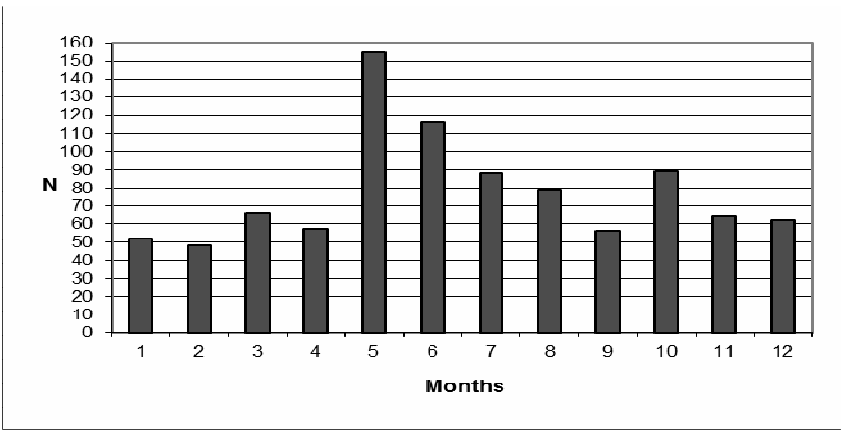

Fig.7. Time distribution of the earthquakes.

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 May, when more then 150 earthquakes occurred, and it is associated with aftershock activity of 22May maximal earthquake. The lowest earthquake quantity is in January - February, around 50 events. The energy release suggests that the period May - August, when the relatively short aftershock sequence in Pernik region occurred, is the time with maximum of energy release. Local maximum of events is observed in October, when about 90 earthquakes occurred.

Additionally, about 900 distant earthquakes have been recorded in the period under study, as well as more than 800 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.

Acknowledgements: The authors owe their gratitude to the engineering staff for the perfect software and hardware ensuring of NOTSSI.

References

Christoskov L. and E. Grigorova, 1968. Energetic and space characteristics of the destructive earthquakes in Bulgaria since 1900. *Izv.BAS, vol XII* .

Christoskov L. and E. Samardjieva, 1983. Investigation on the duration of the seismic signals like a energetic characteristic of the earthquakes. *BGJ, vol.IX, N1*.

Christoskov L. et al., 1987. Real time and background data processing in the Bulgarian seismological network. *Proc. Xx gen. Assembly 1986, Kiel.* , Zurich.

Deneva D. et al., 1988. On the discrimination between industrial explosions and weak earthquakes using records of local seismics networks. *Proc. of conference in Liblice, 1988*, Praha.

Snoke J.A, 2009. FOCMEC: FOCal MECanism Determinations. VirginiaTech, Blacksburg, VA, USA, 2009, Manual.

Solakov, D., 1993. An algorithm for hypocenter determination of near earthquakes. Bulg. Geophys. J. 19 (1), 56-69

Solakov, D. et all., 2005. National Seismological Network – state and development. Proceedings of Scientific-practical conference on management in extraordinary situations and people protection, BAS, Sofia, 2005, 265-272.

ftp://www.orfeus-eu.org/pub/data/continuous/2006/

The maps in Fig1. and Fig2. are made with Quantum GIS and Natural Earth - Free vector and raster map data@naturalearthdata.com.

Данни и анализ на сеизмичните събития регистрирани от НОТССИ през 2012

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

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 2012 г. Представена е карта на епицентрите на общо 1508 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.