DATA AND ANALISIS OF THE EVENTS RECORDED BY NOTSSI IN 2014

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Abstract. A map of epicenters of 1602 earthquakes that occurred during 2014 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 947 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 2014. 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 2014 is realized by means of the new digital network (Solakov et al., 2006). 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 records duration by the formula (Christoskov and Samardjieva, 1983).

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

After bringing into use the new digital broadband seismometers of NOTSSI network, the magnitude determination for local and regional events is calculated by P wave amplitude ratio (Christoskov at all, 2011a, b).

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.

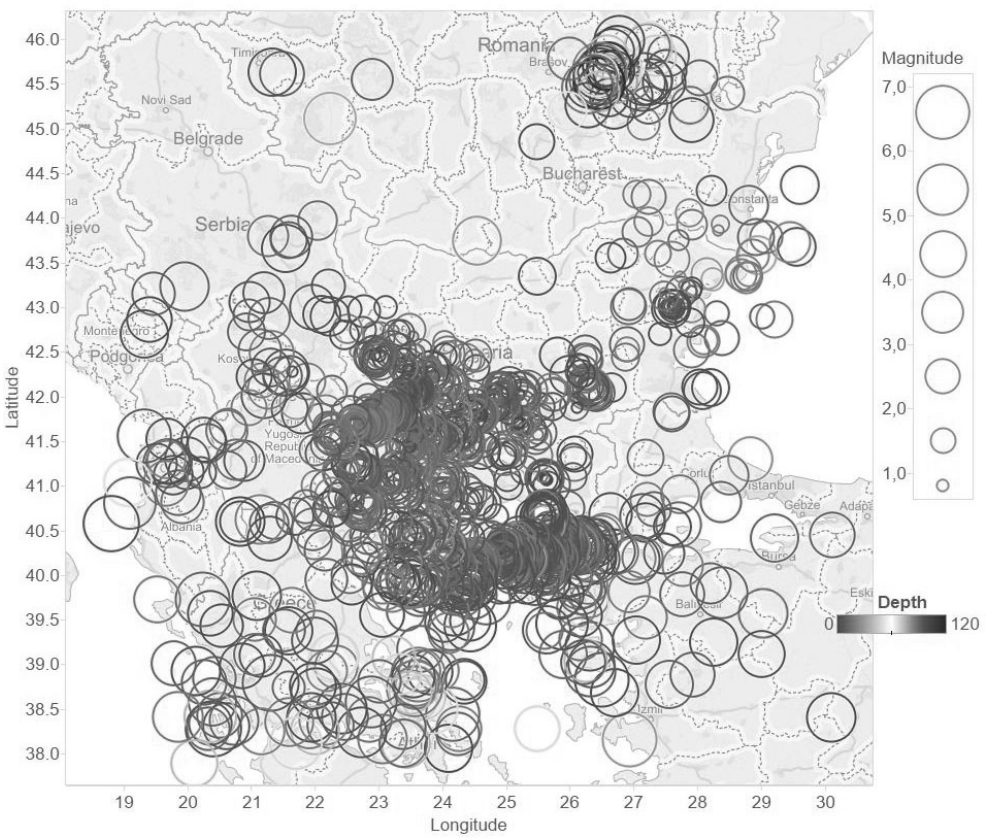

Fig.1. Map of epicenters in Central Balkans during 2014 (Open Street Map - Tableau Desktop 9.2.)

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 1602 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 657, in M=2-2.9 - 630, in M=3-3.9 - 237, in M=4-4.9 – 66, in M=5-5.9 – 11 earthquakes. During this not so active period there is 1 event with magnitude M=6.6. All earthquakes with magnitude more than 4 are out of Bulgarian borders.

As a whole, the seismic situation in the studied part of the Balkans during 2014 is characterized as not so high activity - 1602 events, similar with previous year (2013) – 1622events, 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=6.6 in North Aegean sea, 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 relatevely high activity is partly due to the high level of earthquake activation in North Aegean sea, Romania, Central Greece, Serbia, 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 North Aegean Sea (Greece) with magnitude M=6.6. This event caused VI - VII degree of MSC scale on 24 May in Kardzhaly region and Haskovo town. Shakable effects because of outside attack (earthquake with magnitude M=5.6 in Vranchea source zone in Romania) during the study period occurred in north-eastern Bulgaria - intensity IV-V degree of MSC in town of Silistra on 22 November 2014.

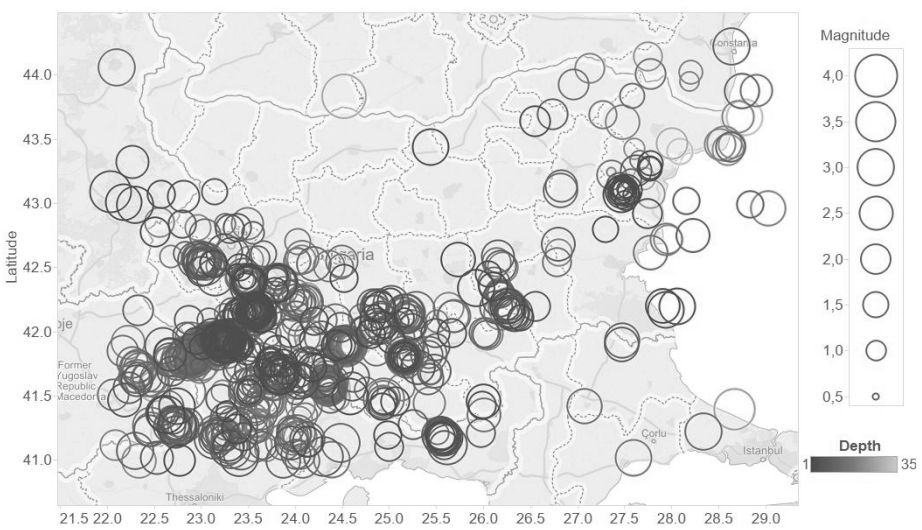

Fig.2. Map of epicenters in Bulgaria and adjacent lands during 2014 (Open Street Map - Tableau Desktop 9.2.)

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 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 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 2014

Date	Time	Latitude [N°]	Longitude [E°]	Depth [km]	Local magnitude
3.1.2014	11:33:33.6	41.28	22.74	5	3.2
5.1.2014	4:51:18.1	41.63	23.76	12	2.6
10.1.2014	7:22:21.5	41.64	24.00	20	2.7
12.1.2014	0:29:15.2	41.83	22.89	8	2.5
13.1.2014	3:34:17.2	41.55	22.86	15	2.6
14.1.2014	12: 5:48.5	41.92	24.54	18	3.2
14.1.2014	15:44: 1.5	41.91	24.53	17	3.1
16.1.2014	2: 1:10.1	42.22	26.24	20	3.0
19.1.2014	4:51:18.1	41.63	23.76	12	2.6
29.1.2014	10:40:17.1	41.93	24.55	18	2.7
29.1.2014	4:31: 4.7	41.92	24.52	12	2.5
29.1.2014	5: 5:10.8	41.92	24.54	20	3.4
29.1.2014	7:39:47.2	42.42	23.81	20	2.5
30.1.2014	7:39:47.3	42.42	23.81	18	2.5
30.1.2014	9:23:38.9	42.41	23.81	11	2.9
30.1.2014	9:32:29.4	42.41	23.81	3	2.8
2.2.2014	22:47:23.2	41.93	24.49	8	2.8
5.2.2014	1:56:44.4	41.42	28.64	26	3.4
5.2.2014	3:54:17.3	42.17	23.58	10	2.8
9.2.2014	22:31:11.0	41.92	24.53	20	2.7
17.2.2014	17:49:41.1	41.03	27.57	17	2.6
17.2.2014	21:55: 4.5	41.69	23.82	6	2.6
17.2.2014	9:26:30.2	41.68	23.84	2	2.5
18.2.2014	20:30:59.5	42.07	24.86	7	2.6
20.2.2014	15:12: 0.0	41.69	23.83	2	3.3
23.2.2014	16: 9:45.6	41.52	24.58	2	2.5
28.2.2014	15:35:14.5	41.14	25.60	8	3.2
28.2.2014	18:48:54.7	41.19	25.54	8	2.5
1.3.2014	20:24: 6.6	41.21	25.53	11	2.7
4.3.2014	0:49:11.7	42.41	23.82	9	2.9
6.3.2014	19:19:33.2	41.67	23.83	11	2.5
11.3.2014	18:50:48.1	43.12	22.04	4	3.5

Date	Time	Latitude [N°]	Longitude [E°]	Depth [km]	Local magnitude
13.3.2014	6:16:45.9	41.19	25.57	5	2.6
15.3.2014	13:44:27.9	42.59	22.95	8	2.7
16.3.2014	23:44:36.9	41.15	24.47	12	3.0
20.3.2014	23:47:46.6	41.64	24.05	2	2.6
22.3.2014	15:21:16.0	41.93	23.24	2	2.8
27.3.2014	18:20:12.7	41.24	28.31	13	2.7
28.3.2014	4:41:44.8	42.16	23.58	8	3.2
1.4.2014	16: 6:13.6	41.78	23.78	16	2.5
5.4.2014	3:36:47.9	41.82	22.83	11	3.1
14.4.2014	7:44: 4.7	41.29	22.47	17	2.5
15.4.2014	12:27:48.6	42.65	23.24	7	2.5
17.4.2014	15:58:55.0	42.21	23.57	5	2.6
19.4.2014	16: 2:50.9	42.17	25.15	8	3.1
19.4.2014	23:39:51.1	42.18	25.17	15	2.8
23.4.2014	23:26: 8.5	42.17	23.57	9	2.5
24.4.2014	1: 7:29.9	42.42	23.49	14	2.5
30.4.2014	12:18: 1.7	42.17	26.31	9	2.5
3.5.2014	1:55:55.9	42.42	23.49	14	2.5
6.5.2014	1:54:22.5	42.54	23.04	11	2.9
6.5.2014	6: 2:22.7	44.23	28.61	10	2.7
14.5.2014	12:20:45.8	43.69	28.75	33	2.6
22.5.2014	8:24:50.9	42.23	28.03	4	2.5
22.5.2014	8:24:50.9	42.23	28.03	4	2.5
24.5.2014	9:32:40.5	42.46	23.15	8	2.8
26.5.2014	20:39:12.5	41.50	24.93	17	3.4
7.6.2014	7:58:59.3	41.44	22.74	3	2.6
20.6.2014	5:19:11.9	42.17	23.56	20	2.5
24.6.2014	19:39:53.3	43.85	24.51	28	4.0
25.6.2014	19:17:47.6	42.37	25.91	2	2.7
8.7.2014	17: 4:27.9	41.18	23.13	9	3.0
11.7.2014	7:45: 9.8	42.20	27.91	4	2.5
16.7.2014	22:45:13.3	41.60	24.33	15	2.8
30.7.2014	13:11:52.1	41.60	24.35	13	2.6
30.7.2014	13:59:25.5	41.59	24.35	14	2.6
2.8.2014	3:57: 5.6	41.60	24.34	16	2.8
5.8.2014	17:59:45.5	41.02	24.38	17	2.6
7.8.2014	16:34:15.5	43.10	27.44	2	2.6
16.8.2014	22:42:54.1	42.25	24.08	13	2.8
20.8.2014	1:29:30.4	41.61	24.34	14	2.8
21.8.2014	4:28:15.9	41.68	24.23	6	3.9
22.8.2014	7:16:21.1	42.15	23.42	10	2.7

Date	Time	Latitude [N°]	Longitude [E°]	Depth [km]	Local magnitude
23.8.2014	5:11: 1.0	41.94	23.05	13	2.5
1.9.2014	7:46:48.8	41.79	23.00	20	2.5
2.9.2014	2:37:16.0	42.25	25.01	9	2.5
2.9.2014	4:54:24.5	42.58	23.05	20	2.8
8.9.2014	3:41:10.3	41.85	22.85	13	2.5
13.9.2014	14: 3:20.9	41.59	23.48	14	2.7
13.9.2014	14: 4:25.8	41.60	23.49	13	2.7
17.9.2014	9:25: 4.9	41.85	25.41	13	2.5
23.9.2014	19: 3: 3.4	41.13	23.30	13	2.5
25.9.2014	22:13: 5.1	43.04	22.18	2	2.5
25.9.2014	22:49:15.5	43.02	22.30	3	2.7
26.9.2014	3:52:56.6	43.46	25.43	2	2.5
1.10.2014	9:47:54.8	41.10	23.32	10	3.0
5.10.2014	9:45: 2.3	41.04	24.29	8	3.1
10.10.2014	20:21:39.5	42.20	25.27	13	2.8
13.10.2014	19:58:32.6	41.23	24.01	13	2.7
15.10.2014	20:27:37.9	44.07	22.11	15	2.7
25.10.2014	20: 6: 7.7	41.08	23.42	11	2.5
5.11.2014	1:58:21.3	41.97	23.21	12	2.6
5.11.2014	11: 0:43.6	41.84	25.15	11	3.0
5.11.2014	19:19:31.5	41.74	22.34	18	2.5
5.11.2014	3:40:48.2	41.98	23.24	5	2.5
7.11.2014	7: 1:40.9	42.59	22.99	13	2.8
7.11.2014	7:42: 8.8	41.04	23.40	6	3.0
11.11.2014	13:16:22.9	41.38	22.63	1	2.8
20.11.2014	11:50: 8.5	41.98	23.23	2	2.6
20.11.2014	12:13:24.7	41.96	23.17	14	3.2
21.11.2014	8:30:32.2	41.97	23.23	5	2.6
28.11.2014	11:23:47.1	41.28	22.78	9	2.7
5.12.2014	1:17:20.8	41.92	22.60	8	2.6
12.12.2014	17:33:29.1	41.09	22.30	10	2.7
12.12.2014	19:59:20.6	41.16	23.87	15	2.5

On the territory of Bulgaria relatively normal activity of earthquakes is observed during 2014 – 947 events are observed, against 1124 in 2013, 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 – 22 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 on Bulgarian territory is Ms=3.9 (in the region of West Rhodopes), which is not the highest earthquake, in comparison with the maximum

magnitude in the course of previous years. The strongest event (with magnitude M=4.0) occurs on 24th of June 2014, close to Bulgarian border (on Romanian territory) and caused macroseismic effects with intensity of IV degree of MSC scale in the town of Belene.

As usual, the largest concentration of the epicenters in the other regions of Bulgarian territory during 2014 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 2014 only 3 events of M≥3.0 occurred in this region. The strongest felt earthquake for the south-western part of Bulgarian territory is with magnitude M=3.3, it is felt on 20th of February in Gotse Delchev region (western slopes of Rhodope mountain) by intensity of III - IV degree of MSC scale.

The other Bulgarian seismic sources in 2014 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 III - IV degrees of MSC scale. The maximum number of felt earthquakes is occurred around the Monastery uplift. Two cases of magnitudes about 3.0 aroused shocks of intensity up to IV degrees of MSC scale are felt in Monastery Highland territories. A relatively not so significant seismic impact is associated with the Pernik earthquake source zone in the central parts of West Bulgaria.

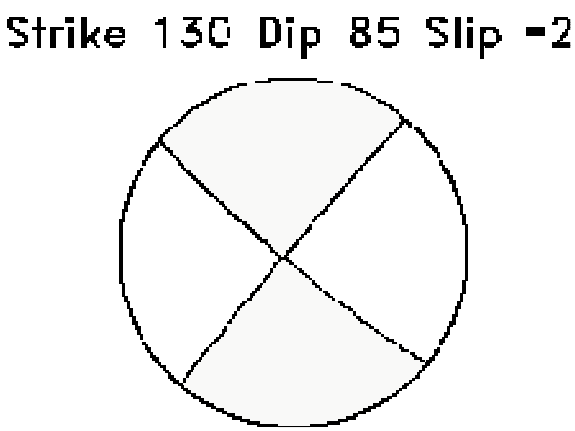

Fig.3. Focal plane solution of earthquake close to the Bulgarian NPP Kozloduy (24.06.2014, 19:39 GMT, Ml=4.0, H=28 km)

For the determination of the earthquake mechanism the program FOCMEC is used. Input data are the polarities of the P wave. Twenty five first motion polarities data from seismological stations in Bulgaria and surrounding area, taken from NOTSSI and Orfeus database (ftp://www.orfeus-eu.org/pub/data/continuous /2014/) are included in the double - couple focal mechanism - Fig.3. The solution is displayed on lower hemisphere. The polarities from Orfeus are check as waveform. The strike, dip and rake are determined in accuracy up to 5 degree. The earthquake is characterized as a strike-slip faulting, with very small dip-slip component. The fault plane solutions of the some other events are with very bad quality because of a low number of polarities.

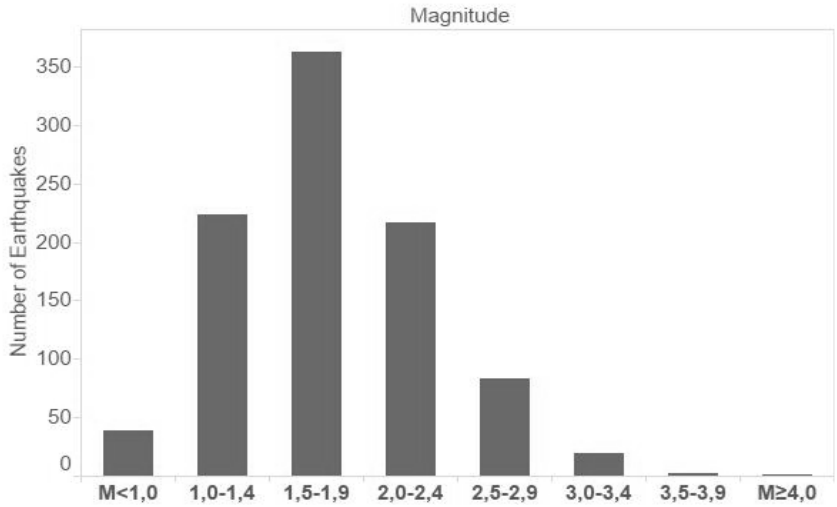

Fig.4. Magnitude - frequency distribution of the earthquakes

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.

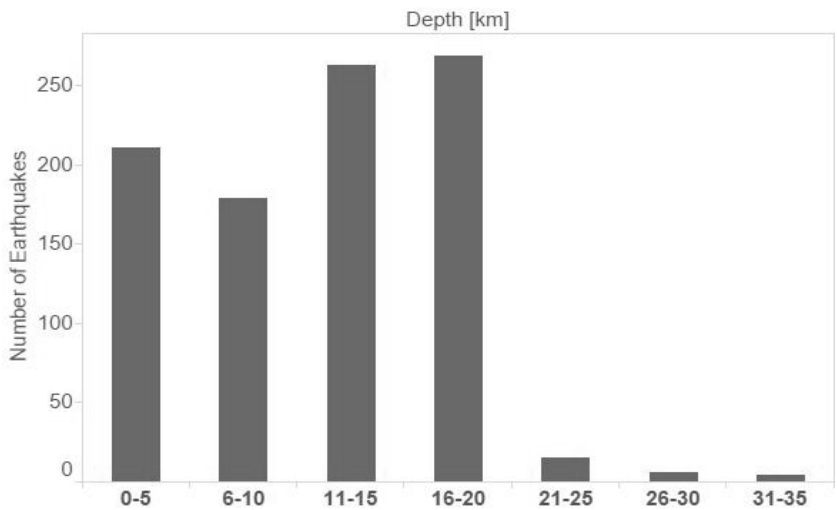

Fig.5. Depth - frequency distribution of the earthquakes

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 is 1 event, M=3.5-3.9 is 2 events, for M=3.0-3.4 is 19 events, for M=2.5-2.9 - 83, for M=2.0-2.4 - 217 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.

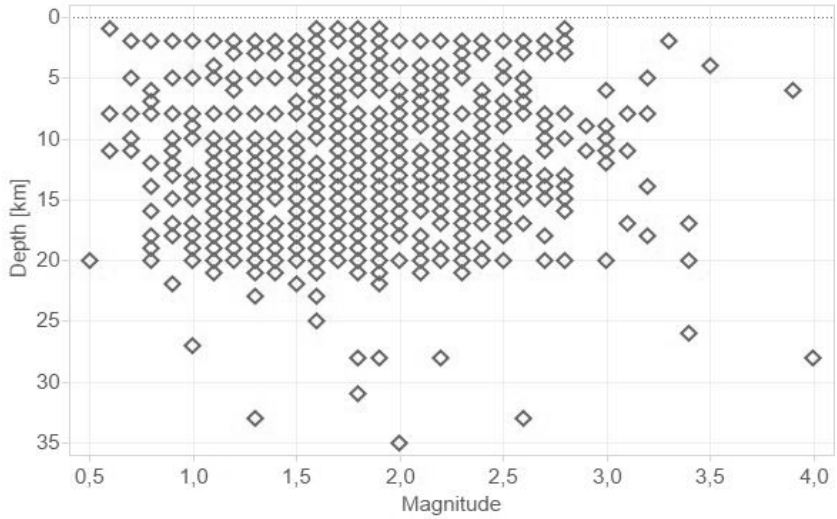

Fig.6. Magnitude - depth dependence

The picture of the depth distribution in Fig.5 shows that the majority of events occur in range 11-20 km depth. The number of events does not decrease smoothly with increase of the depth. It is possible the established predominating depth (from 11 to 20 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 28 km. It is remarkable that the strongest events are relatively uniformly deep situated.

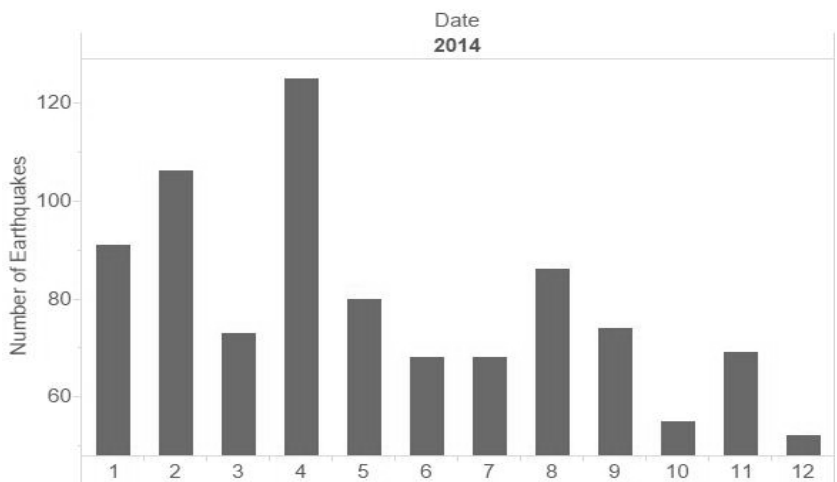

Fig.7. Time distribution of the earthquakes.

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 April, when more then 120 earthquakes occurred, and it is associated with seismic activity in Central Bulgaria – Monastery Uplifts region and Parvomay town region. The lowest earthquake quantity is in October and December, less than 30 events per month. The maximum energy release during the period May - August does not corresponded to the maximum number of events during the first half of the year.

Additionally, about 1100 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 2014

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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 2014 г. Представена е карта на епицентрите на общо 1602 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 947 сеизмични събития в район с координати $\lambda = 22^0$ - 29^0E и $\varphi = 41^0$ - 44.3^0N). Предлага се и каталог на земетресенията с магнитуд M>2,5. Сеизмогенните прояви се обсъждат по зони, сравнени със съседни периоди време.