SEISMICITY ON THE TERRITORY OF BULGARIA AND THE ADJACENT LANDS RECORDED BY NOTSSI IN 2019

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Abstract. A map of epicenters of 129 earthquakes with magnitude M >= 2.5 that occurred during 2019 in Bulgaria and surroundings (sector outlined by latitude = 41°- 44.5° N and longitude = 22°- 29° E) registered by NOTSSI is presented. Expert generalized analysis is proposed. Catalog of earthquakes is applied.

Key words: Bulgaria, seismicity

The Balkan peninsula is one of the active regions in the Alpine-Himalayan seismic belt. High activity is observed in Western Turkey, Greece, Vrancha region – Romania, Bulgaria, Northern Macedonia, Albania, Serbia. The depth distribution is very characteristic. There are two highly active levels in the range of 20-40 km and 90-110 km and a less active one in 50-70 km.

Bulgaria is an earthquake prone country. Over the past centuries, Bulgaria has experienced strong earthquakes. Some of the European strongest earthquakes during the 20th century have been occurred in Bulgaria. At the beginning of the 20th century, from 1901 to 1928, five strong earthquakes with magnitude larger than or equal to 7.0 occurred on the territory of Bulgaria – 30.03.1901 Ms = 7.2 Shabla earthquake; 04.04.1904 Kresna earthquakes with Ms magnitudes 7.1 and 7.8; `14.6.1913 Ms = 7.0 G.Orjahovitsa earthquake and two earthquakes near the city of Plovdiv in 1928 - 14.04 with magnitude Ms = 6.8 and 18.04 with magnitude Ms = 7.0.

Strong seismic impact on the territory of Northern Bulgaria have the intermediate earthquakes in Vrancha – Romania region. The strongest being the one in 1944 with magnitude of 7.7 and some may remember the one in 1977 with magnitude of 7.4 caused a lot of deaths and destructions.

The present study contains generalized information and analysis of the data about the seismic events recorded by the National Operative Telemetric System for Seismological Information (NOTSSI) during 2018. Seismic data is gathered in real time by 26 Bulgarian stations and a number of stations from neighbouring countries which increases the accuracy of hypocentral locations. Between 2005 and 2010 almost all stations are modernized and equipped with broadband seismometers. A number of stations also are equipped with accelerometers of type RefTek 131A-02/3 of the company "Refraction Technology". The data from the digitizers DAS 130-01 are collected through the RTPD (Real time protocol demon) module and the data from foreign stations and from Quanterra digital systems are collected with the sl2rptd module.

Data are transferred to the National seismological center in the Geophysical Institute, BAS in real time. Then they are archived in PASSCAL format and additionally in the widely used miniSEED format. The data are processed automatically (relevant signals are recognized and the main parameters of the earthquake are evaluated) by the program Seismic Network Data Processor (SNDP) (Christoskov et al., 2012). The data are later processed manually by an on-duty seismologist and corrections are made if required. At present the body P-wave magnitude Mp is evaluated by:

$$M_p = log\left(\frac{A}{T}\right)_{max} + \sigma_{BB}(\Delta) + s_j \quad (1)$$

where $\left(\frac{A}{T}\right)_{max} = \frac{V_{max}}{2\pi}$, A is the amplitude in μm, T is a period in s, and V_{max} is the peak ground velocity in μm/s of P-phase recorded on the broadband seismograph vertical-component at epicentral distances less than 10°; $\sigma_{BB}(\Delta)$ is the calibration function; and s_j is the j station magnitude correction.

In the present study Mp is transformed into the more reliable and more widely used Mw magnitude, which would allow the creation of a uniform catalogue for earthquakes, needed for reliable evaluation of the seismic hazard on the territory of the country and surroundings. Mp is transformed into Mw through the formula (D. Solakov et al., 2018):

$$M_w = 0.93 * M_p + 0.31 \quad (2)$$

The high sensitivity of the seismographs allows recording and processing of a great number of local and regional earthquakes. Different magnitude's lower thresholds for reliable determination of local and regional earthquakes are established: Mw = 2.5 for the territory of Bulgaria, Mw = 3.0 for the central part of the Balkans, Mw = 5.0 for regional events. The accuracy of the epicenter location is different; except on the distance it depends also on the epicenter position with respect 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 reliable seismotectonic investigation.

After comprehensive analysis of the digital records and application of the above mentioned calculation procedures it is established that 129 of all registered earthquakes are on the territory of Bulgaria and surroundings outlined by space window 41° – 44.5° N and 22° – 29° E. In the Fig. 1 are plotted the earthquake epicenters using different magnitude levels.

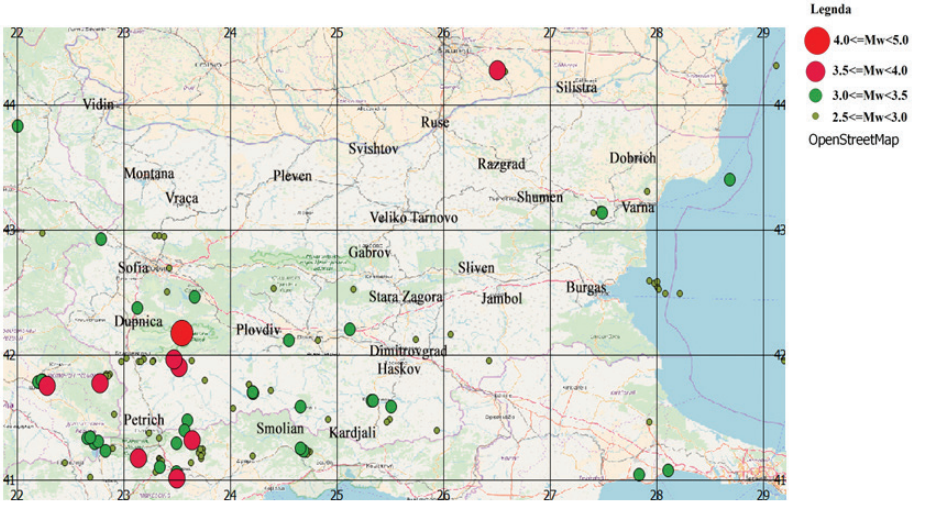


Fig. 1. The number of the events in the magnitude.

The number of the events in the magnitude interval Mw = 2.5-3 is 106, in Mw = 3.1-3.5 - 19, in Mw = 3.6-4 - 3, in Mw = 4.1-4.5 – 1 earthquakes (as shown in Fig. 2). Fig. 3 shows that the data fit well with theoretical expectations, meaning that all incoming earthquakes have been detected by the network.

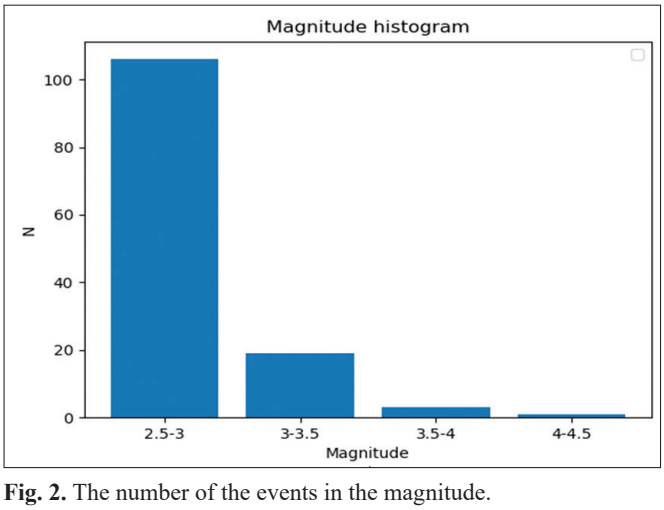


Fig. 2. The number of the events in the magnitude.

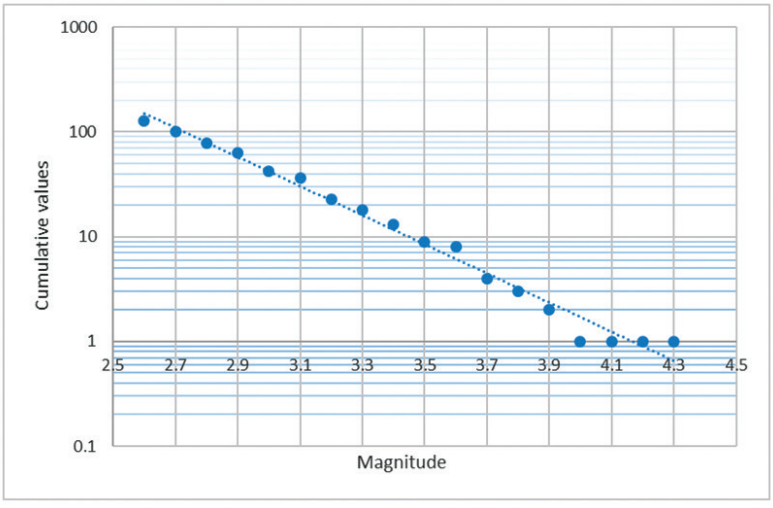


Fig. 3. The data fit well with theoretical expectations

Throughout the year 18 earthquakes in total were felt on the territory of Bulgaria from local and regional sources. The strongest event outside Bulgaria during the studied period occurred in the region of Tirana (Albania) with magnitude Mw = 6.4. Maximum intensity on the territory of Bulgaria is I_{max} =3.5.

As a whole, events with Mw<3.0 which occur outside Bulgaria are difficult to be localized by the national seismological system.

Table 1. List of earthquakes with M >= 2.5 in Bulgaria and adjacent lands during 2019

Date	Time	Latitude [N°]	Longitude [E°]	Depth [km]	Magnitude [Mw]
7.1.2019	03:23:21	42.97	22.24	2	3.0
25.1.2019	18:02:27	41.94	23.14	20	2.8
6.2.2019	03:42:30	42.49	28.08	20	2.6
6.2.2019	03:45:21	42.49	28.22	20	2.7
6.2.2019	03:51:01	42.54	28.01	10	2.9
6.2.2019	03:57:24	42.59	27.93	16	2.9
6.2.2019	04:41:42	42.54	28.01	18	2.7
6.2.2019	05:15:27	41.52	22.91	13	3.4
6.2.2019	05:46:00	42.57	27.98	19	2.6
6.2.2019	07:59:44	42.52	28.02	12	2.9
6.2.2019	08:29:10	42.58	28.01	16	2.6
6.2.2019	09:47:20	41.22	24.75	11	2.7
9.2.2019	20:59:18	41.23	24.73	9	3.4
9.2.2019	22:05:28	41.23	24.70	9	3.1

10.2.2019	14:20:44	41.21	23.14	13	2.7
10.2.2019	14:22:04	41.21	23.14	15	2.9
11.2.2019	01:46:11	41.20	24.72	15	3.1
18.2.2019	07:05:07	41.24	23.74	11	2.9
18.2.2019	07:13:41	41.24	23.74	11	2.6
22.2.2019	17:45:27	41.93	23.53	12	2.9
27.2.2019	09:13:35	41.22	23.73	15	3.3
27.2.2019	14:44:49	41.17	23.73	6	3.0
27.2.2019	15:53:49	41.22	23.71	11	3.1
27.2.2019	16:41:19	41.21	23.74	13	3.9
28.2.2019	00:05:15	41.21	23.71	17	2.7
28.2.2019	20:35:18	41.19	23.73	10	2.8
1.3.2019	20:35:19	41.24	23.72	15	2.8
6.3.2019	06:56:53	42.76	29.22	15	3.5
9.3.2019	23:32:59	42.52	25.16	14	2.7
13.3.2019	18:56:43	41.11	23.35	11	2.9
15.3.2019	03:26:55	41.71	24.38	13	2.9
15.3.2019	10:45:14	41.48	24.92	10	2.6
15.3.2019	16:46:34	43.3	27.91	17	3.1
19.3.2019	03:30:33	41.13	23.34	11	3.6
20.3.2019	10:39:39	44.31	29.12	10	2.8
25.3.2019	00:27:53	41.95	23.28	20	3.2
26.3.2019	00:27:54	41.94	23.27	17	2.9
26.3.2019	22:25:20	41.94	22.98	18	2.7
27.3.2019	11:53:55	41.17	23.33	7	2.6
28.3.2019	13:01:37	41.16	23.34	10	2.9
28.3.2019	20:28:03	41.16	23.34	11	2.6
1.4.2019	04:45:56	41.15	23.35	10	2.9
2.4.2019	20:04:13	41.57	24.03	20	2.8
3.4.2019	01:04:52	44.26	26.58	4	3.0
3.4.2019	14:48:38	42.95	23.33	16	2.9
11.4.2019	19:22:47	41.06	23.30	4	2.8
13.4.2019	11:05:24	41.96	23.19	11	2.8
14.4.2019	08:36:00	43.16	27.48	3	2.7
18.4.2019	10:50:57	41.13	23.63	7	2.7
18.4.2019	11:02:56	41.13	22.45	10	2.6
25.4.2019	01:11:53	41.02	22.69	16	3.2
30.4.2019	18:22:35	43.16	27.47	5	3.6
2.5.2019	13:08:36	42.50	23.41	18	2.7
4.5.2019	12:36:06	42.48	23.66	19	2.6
15.5.2019	06:15:12	41.95	23.64	18	2.9

18.5.2019	03:32:59	41.76	24.18	20	2.6
19.5.2019	03:32:59	41.76	24.18	18	2.6
21.5.2019	06:53:35	41.97	23.03	9	2.6
24.5.2019	08:48:13	42.12	25.74	17	3.3
24.5.2019	17:29:44	41.81	22.81	11	3.3
27.5.2019	01:51:40	41.84	22.87	12	2.9
28.5.2019	14:57:52	41.33	23.33	15	3.1
28.5.2019	15:39:44	41.37	23.24	11	3.1
2.6.2019	13:09:09	41.95	29.20	7	3.7
6.6.2019	03:45:50	41.46	27.93	17	3.1
9.6.2019	02:26:50	41.79	23.76	10	3.3
25.6.2019	13:23:59	41.15	23.36	6	2.9
10.7.2019	09:48:05	42.16	26.07	2	2.6
12.7.2019	07:06:52	41.84	22.84	13	2.8
12.7.2019	19:01:31	41.48	25.50	2	2.6
15.7.2019	13:50:19	41.83	22.86	8	3.2
16.7.2019	19:17:30	41.36	22.71	8	3.4
20.7.2019	21:04:30	41.94	23.16	16	2.6
21.7.2019	04:30:14	41.29	22.74	15	2.7
23.7.2019	17:09:13	42.95	23.29	17	2.8
24.7.2019	14:29:32	41.19	24.21	20	2.8
26.7.2019	20:58:21	41.46	25.47	15	2.6
4.8.2019	14:11:45	42.69	23.43	20	2.6
6.8.2019	17:56:56	42.53	24.41	20	3.2
8.8.2019	08:49:51	42.11	24.82	7	2.6
9.8.2019	11:44:01	41.39	25.94	8	2.9
10.8.2019	06:39:40	41.95	26.43	20	3.6
14.8.2019	09:25:02	41.23	24.64	20	2.6
15.8.2019	06:35:59	43.13	27.41	2	3.0
16.8.2019	12:04:45	41.83	22.83	20	2.6
22.8.2019	08:44:44	41.25	22.90	11	2.8
2.9.2019	15:27:56	42.94	23.38	14	2.8
7.9.2019	19:02:09	41.23	22.83	20	2.7
7.9.2019	19:38:15	43.13	27.49	2	2.6
16.9.2019	00:05:48	41.58	24.66	12	2.9
19.9.2019	22:33:36	42.20	25.12	12	3.0
22.9.2019	10:14:19	41.63	25.33	12	2.7
22.9.2019	12:13:22	41.63	25.34	13	3.6
24.9.2019	10:39:55	41.29	22.73	16	2.9

26.9.2019	22:02:20	41.07	28.11	12	3.1
26.9.2019	23:48:10	41.04	27.84	13	2.6
2.10.2019	02:18:06	41.29	23.50	13	3.1
2.10.2019	03:33:32	41.30	22.76	12	2.9
3.10.2019	21:42:46	42.11	24.55	18	2.6
9.10.2019	21:29:51	42.92	22.79	4	2.8
13.10.2019	23:27:28	42.46	23.67	9	2.8
14.10.2019	07:48:26	41.33	22.66	2	3.3
14.10.2019	19:40:01	41.34	22.69	8	3.1
21.10.2019	12:21:39	41.70	24.21	13	2.7
22.10.2019	13:36:00	41.78	22.20	20	2.8
23.10.2019	21:16:43	41.23	24.69	12	3.1
28.10.2019	10:20:29	41.69	24.21	16	2.9
28.10.2019	10:30:28	41.69	24.22	17	2.7
28.10.2019	11:53:48	41.70	24.21	10	2.7
28.10.2019	22:46:50	41.79	22.24	8	3.0
30.10.2019	15:50:43	41.79	22.23	10	3.2
31.10.2019	11:04:31	41.10	23.34	7	2.7
16.11.2019	11:51:27	41.47	23.60	12	2.6
18.11.2019	04:49:38	42.37	23.13	14	2.7
21.11.2019	07:00:46	43.83	22.01	6	2.7
25.11.2019	21:09:00	41.25	24.66	10	3.1
28.11.2019	03:20:49	41.58	25.51	14	2.6
28.11.2019	11:37:50	43.40	28.69	15	3.4
30.11.2019	14:36:14	41.06	23.50	20	2.9
5.12.2019	22:08:33	41.39	23.57	13	2.6
8.12.2019	19:45:50	41.17	23.14	9	2.7
8.12.2019	22:26:30	41.90	23.52	15	2.7
11.12.2019	20:25:52	41.31	23.64	17	2.6
12.12.2019	00:35:19	44.27	26.51	23	2.6
12.12.2019	04:46:15	41.01	23.50	8	2.6
21.12.2019	04:43:32	41.77	22.78	8	3.1
28.12.2019	12:05:41	41.75	22.28	15	2.7
29.12.2019	17:36:52	41.96	23.47	17	3.8
30.12.2019	18:01:40	42.17	23.55	12	4.3

As usual, the largest concentration of the epicenters in the other regions of Bulgarian territory during 2019 is marked in the southwestern part of the investigated region (presented in Fig. 1 and Table 1). In 2019 only 1 event of Mw≥4.0 occurred in this region. Two are the felt earthquakes, which occurred in seismogenic zones on the territory of the country, with maximum intensity Imax = 4.5 (MSK-64). These events were on the 30.04.2019 – Mw = 3.6 and on the 30.12.2019 – Mw = 4.3.

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.1 characterize predominantly the seismicity parameters of the southwestern part of the territory under investigation.

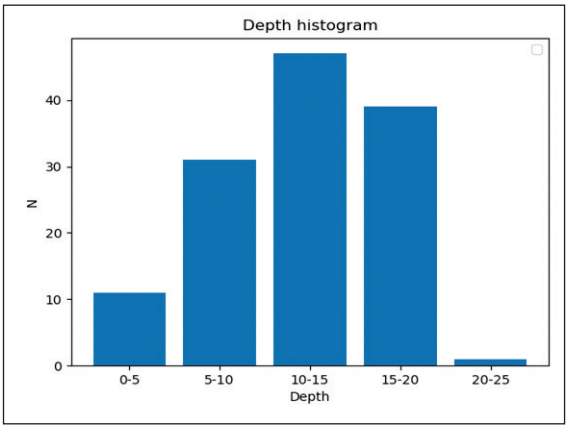


Fig. 4. The distribution of the number of events according to depth

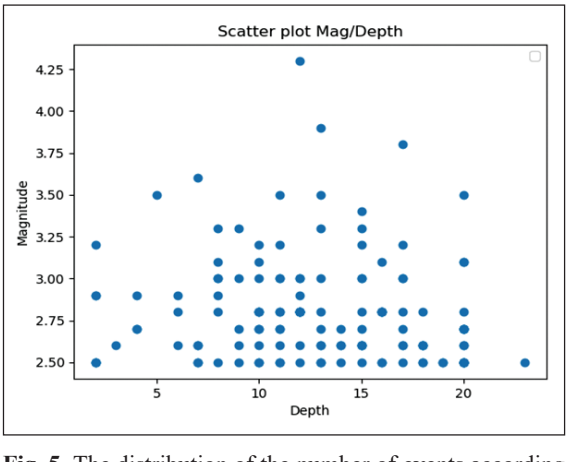


Fig. 5. The distribution of the number of events according to magnitude

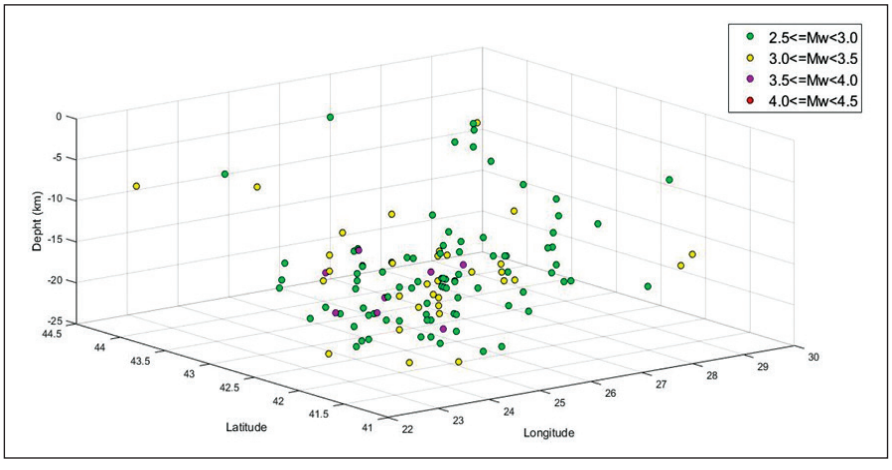


Fig. 6. The distribution of depth according to location

The graph of the depth distribution in Fig. 4, Fig. 5 Fig. 6 shows that the majority of events occur in range 5-20 km depth. Fig.6 does not show correlation between magnitude and depth, as the majority of the events occurred in the 5-20 km depth range. The number of events does not decrease smoothly with increase of the depth. In the same time the number of events in the interval 10-15 km is the largest. 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 5 to 20 km. The stronger events with magnitude Mw>= 3.5 have depth in the range 10-20 km.

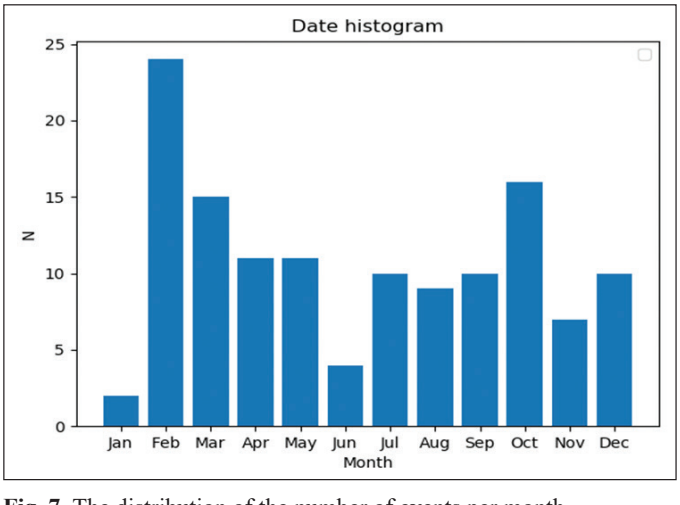
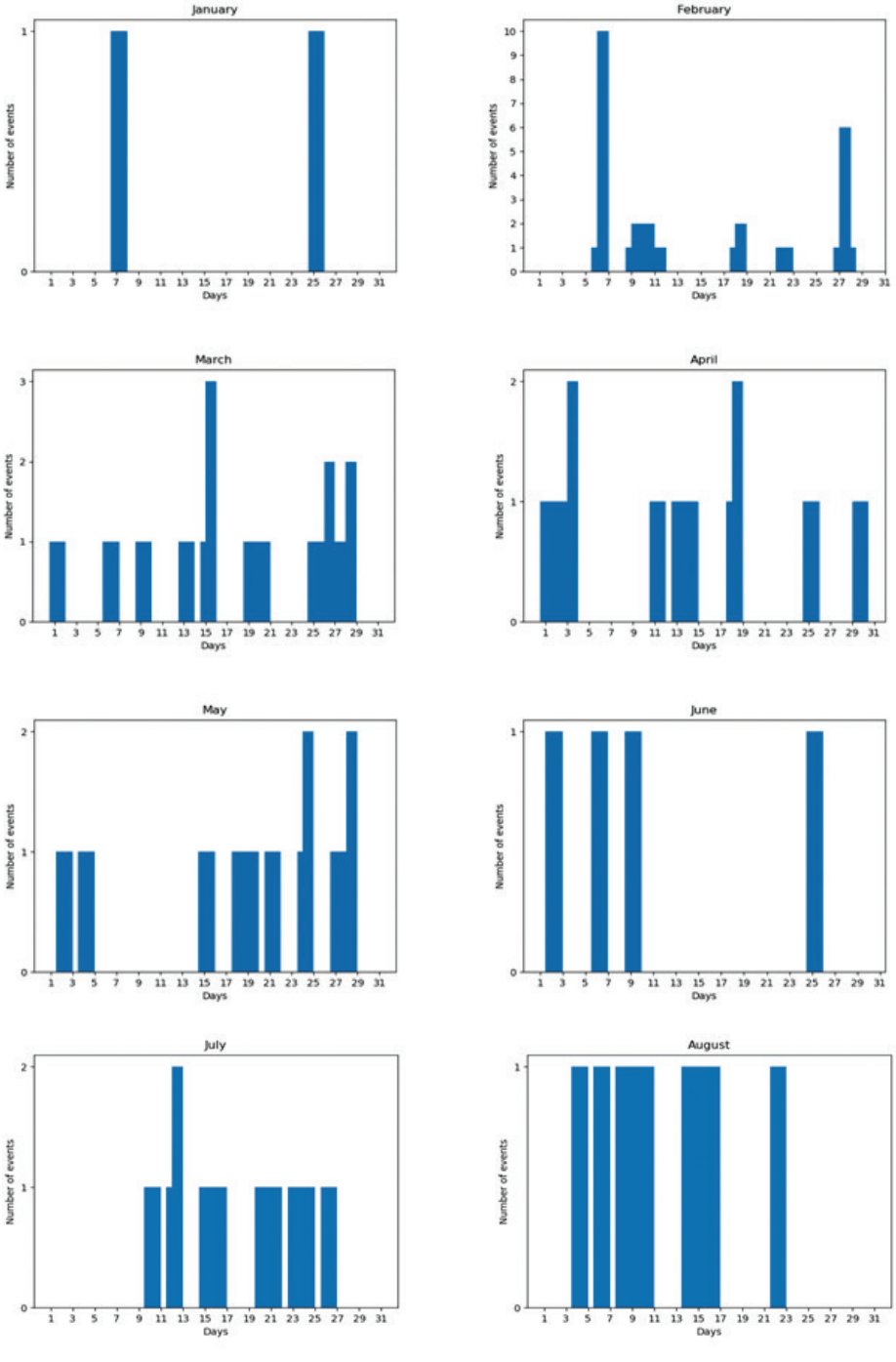


Fig. 7. The distribution of the number of events per month


January
February
March
April
May
June
July
August
Number of events
Days

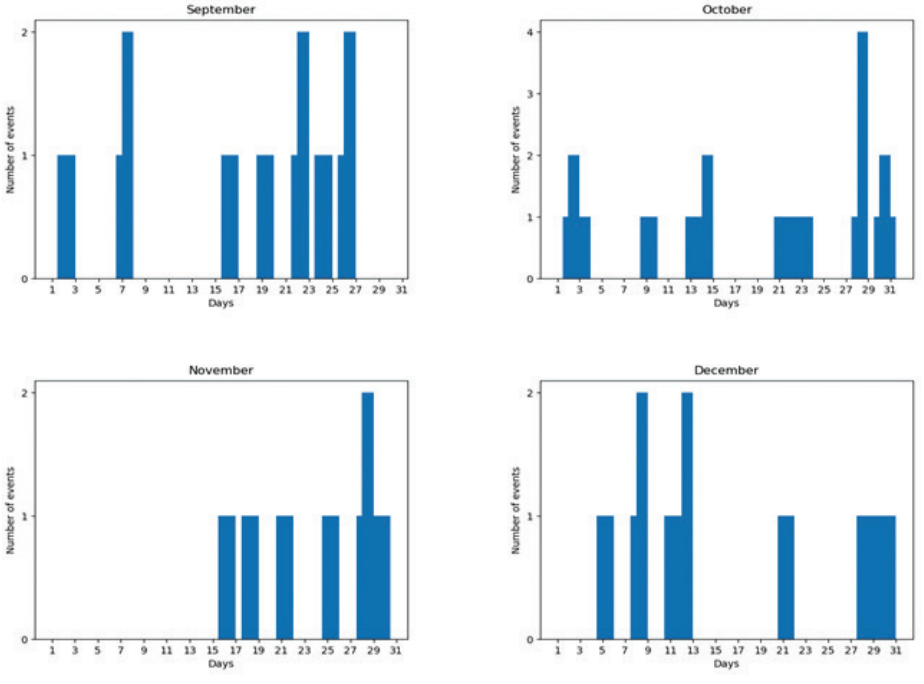


Fig. 8. The distribution of seismicity in time according to the number of events per month

Fig. 7, 8 illustrates the distribution of seismicity in time according to the number of events per months. The highest amount of earthquakes is displayed in February, when 24 earthquakes occurred, and it is associated with seismic activity in South-Western Bulgaria – Bulgaria-Greece border and Western Black Sea. The lowest earthquake quantity is in January, when only 2 events with magnitude larger than 2.5 occurred. Fig. 7 shows that there is no definite distribution of the earthquakes throughout the months.

The figures below show the daily distribution of the number of earthquakes/day for each month. We can see that the distribution is not spread out equally and while in some days 10 earthquakes may occur, like the first week of February, there are periods, like in January, May, June, July, November, where for periods of 10-15 days no events occur on the territory of Bulgaria.

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Сеизмичност на територията на България и прилежащите земи по данни от НОТССИ през 2019 г.

Д. Драгомиров, Е. Ойнаков, В. Бучакчиев, Й. Милков

Резюме: Представена е карта с епицентрите на 129 земетресения, с магнитуд M >= 2.5 случили се през 2019 г. в България и околностите (сектор ограничен от географска ширина ϕ =41°- 44.5°N и географска дължина λ=22°-29°E) регистрирани от Националната Оперативна Телеметрична Система за Сеизмологична Информация (НОТССИ). Експертен, обобщен анализ е представен. Приложен е каталог със земетресения.

Ключови думи: България, сеизмичност

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