

The swarm seismic activity (august 2001) near Yambol city– Central East Bulgaria

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С. Димитрова - Сейсмический рой (Август 2001) возле города Ямбола, Центрально-Восточной Болгарии. Далее приводится описание исследования локального сейсмического роя происходящего около Ямбола и среды в течение августа 2001. Основной случай происходил 13 Августа (время по Гринвичу начало времени 14:26:12.05, магнитуда более чем 4.5, координаты 42.57 N, 26.48 E, приближенная глубина – около 15 km, максимума наблюдающих интенсивность - VI MSK). Это предшествовало и сопровождалось различными фетровыми землетрясениями и много из них (более чем 100) не почувствованны. Они регистрированы только локальной сейсмической станцией JMB. Разработка сейсмического процесса обсуждена. Последнее сейсмическое уменьшение деятельности очень быстро - не более чем две недели, является необычным поведением такого сейсмического процесса. Сравнительный анализ связи между этим последним роем и роями происходящими в течение 1909 года, показывает некоторое сходство и некоторые различия, обсужденные на бумаге. Впервые полный каталог этого роя опубликован. Он состоит из двух частей. Таблица 3 - землетрясения, зарегистрированные на более чем 3 сейсмических станциях (который допускает точное определение параметров) и очень слабые сейсмические события, регистрируемые только локальной станцией JMB. Для этих событий только точное время и магнитуда-возможно, который должен был определяться (Таблица 4).

Abstract. The paper describes the investigations of the local seismic swarm occurred near Yambol and surroundings during August 2001. The main event occurred on 13 August (origin time 14:26:12.05 GMT, magnitude more than 4.5, coordinates 42.57 N, 26.48 E, approximate depth – about 15 km., maximum observed intensity – VI MSK). It was preceded and followed by several felt earthquakes and many (more than 100) not felt, registered only by the local seismic station JMB earthquakes. The development of the seismic process is discussed. The recent seismic activity decrease very fast in time – no more than two weeks, which is unusual behavior of such seismic process. The comparative study about the relationships between this recent swarm and the swarm occurred during 1909 shows some similarities and some differences discussed in the paper.

For the first time the full catalogue of this swarm is published. It consists of two parts. Table 3 – the earthquakes registered on more than 3 seismic stations (which allows the exact parameters determination) and very weak seismic events, registered only by the local station JMB. For these events only the exact time and the magnitude is possible to be determined (Table 4).

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Key words: earthquakes; comparative swarm studies.

Introduction

During the time period 9-20th August a very fast earthquake swarm occurred near Yambol City – Central East Bulgaria (Fig.1.). The area is well known with its seismic activity during the earthquake swarm occurred during 1909 and well documented by (Вацов, 1911) and studied by (Григорова, Палиева, 1962) during 1962. The coincidence of the both swarms suggests that the activated area has its seismogenic peculiarities, very different from the other seismic sources located in the country and surroundings.

Previous seismic activation of the region

The well-known data are connected with the last large previous seismic activity – February-June 1909. This previous swarm (called swarm I) is extensively studied by (Григорова, Григоров, 1964) and (Григорова, Палиева, 1962). It consists of 9 events in the magnitude range 4.2-5.5 with an exceptional main event with a macroseismic magnitude 5.7 and obser-

ved intensity VIII MSK. The sequence started with a foreshock (magnitude 5.0 occurred 11 hours earlier) and lasted four months. (Table 1.) The comparative study and obtained results could be useful for different tectonic reconstructions and new interpretations.

The migration of the seismic process is specific. The process started at the west flank, than moved to east and after than goes back.

The macroseismic maps have been created for eight events and show a specific behavior with an E-W elongation of the isoseismals at the beginning of the process and followed by the N-S direction for the next events. The local observers have reported many earthquake sounds – like cannonade, blasts and thunderstorms. After the 1909 swarm, the following seismicity of the region is presented at Table 2.

It consists of only five felt seismic events during the time period 1910-1957 with maximum observed intensity of VII MSK observed during the event of 1926.

The epicentral distribution of the previously known seismicity of this region is presented in Fig. 2. The total seismic energy emitted during the swarm I is greater than $3.2 \cdot 10^{20} \text{ J}$.



Fig. 1. Tectonic map of Bulgaria (after Георгиев, Дабовски, 1997)

Table 1
Parameters of the seismic swarm during 1909

N	Year	Date (dd.mm)	T ₀ (hh:mm:ss) GMT	φ° (xx.xx)	λ° (xx.xx)	h (km) (xxx)	M _m (x.x)	I _{max} (MSK)
1	1909	15.02	00:28:39	42.48	26.52	10	5.0	VI
2	1909	15.02	11:34:19	42.52	26.48	4	5.7	VIII
3	1909	15.02	16:07:58	42.52	26.38	19-20	4.5	V
4	1909	15.02	17:16:55	42.48	26.52		4.5	V
5	1909	16.02	01:17:20	42.48	26.50	20-30	4.5	V
6	1909	16.02	02:14:28	42.62	26.17		4.5	V
7	1909	01.03	09:01:13	42.62	26.17	12	4.3	V
8	1909	01.03	09:12:30	42.50	26.42	5	4.2	V
9	1909	09.06	03:33:16	42.62	26.32	17	4.2	V

Table 2
Parameters of the observed earthquakes during the time period 1910-1957

N	Year	Date (dd.mm)	T ₀ (hh:mm:ss) GMT	φ° (xx.xx)	λ° (xx.xx)	h (km) (xxx)	M _m (x.x)	I _{max} (MSK)
1	1910	29.01	14:04:50	42.57	26.33	5-8	3.6	V
2	1910	10.03	19:15:00	42.62	26.33	5	4.3	VI
3	1912	15.02	19:30:00	42.57	26.37	2	3.3	VI
4	1912	02.05	04:30:00	42.52	26.58	6	3.6	V
5	1926	30.06	01:45:00	42.57	26.25	10	4.6	VII
6	1953	29.12	16:58:11	42.58	26.35	2-4	3.0	V
7	1957	29.05	03:41:41	42.62	26.17	6	3.3	V

The recent swarm

The last swarm (9-20th August 2001) (called swarm II) is characterized by a starting event with the magnitude 2.1 (this first one is considered as a foreshock) followed by 4 events in the magnitude range 3.2-3.5 (see Table 3.) in the time domain of about 3-4 hours. Most of them have been felt with maximum intensity III-IV degree MSK. Between them more than 15 smaller events have been recorded. The following 3-4 days more than 20 smaller earthquakes have been registered.

On 13th August a new event with a magnitude greater than 4.5 generated the maximal isoseismal of VI MSK with some effects of fallen chimneys, cracked walls, disconnected electric lines and population panic. Most of the strongest events have been accompanied by earthquake sounds reported by local observers. The main event (M>4.5 – according NEIS web page, M_b - 4.6 and (Glavcheva, 1990) – macroseismic magnitude - 4.8-4.9) has been followed by a sharply decayed after-

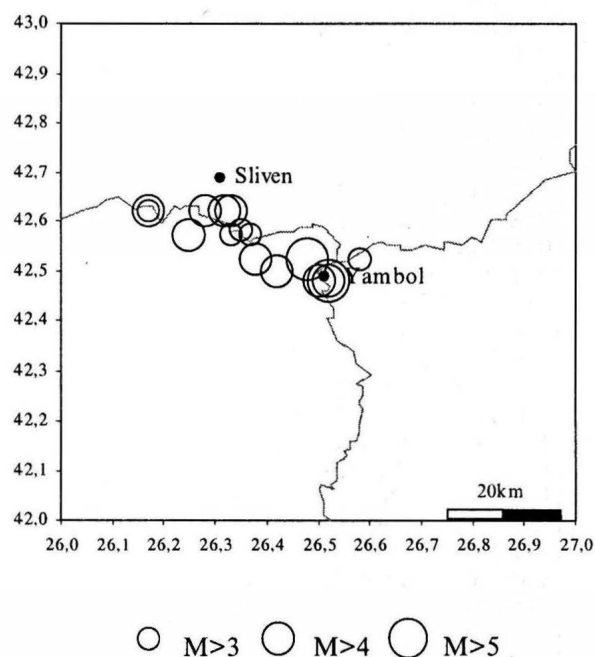


Fig. 2. Epicentral distributions of earthquakes for 1909-1957

Table 3

Parameters of the registered seismic events during the swarm II

Date (dd-mm-yyyy)	T ₀ (hh:mm:ss.s) GMT	φ° (xx.xx)	Err. (km)	λ° (xx.xx)	Err. (km)	h (km) (xx)	Err. (km)	Md (x.x)	Err. (SD)	Gap (deg)	I _{max} (MSK)
09.08.2001	00:56:14.80	42.56	1.04	26.47	0.91	15	1.0	2.1	0.31	90	IV
09.08.2001	00:58:16.04	42.55	1.18	26.51	1.00	18	1.2	3.8	0.49	114	
09.08.2001	01:17:40.02	42.57	1.53	26.45	1.11	15	1.3	1.2	0.43	107	
09.08.2001	01:44:02.18	42.49	1.67	26.55	1.37	17	1.4	3.5	0.50	175	III-IV
09.08.2001	04:00:04.00	42.56	1.59	26.56	1.43	13	1.6	3.2	0.65	94	
10.08.2001	21:56:47.21	42.36	2.41	26.56	6.28	20	4.4	1.1	0.74	241	III
11.08.2001	03:27:41.10	42.54	1.39	26.42	2.13	12	2.6	2.5	0.90	147	
13.08.2001	14:26:12.05	42.57	0.86	26.48	0.73	15	0.9	4.4	0.37	98	VI
13.08.2001	14:32:30.57	42.52	2.54	26.43	2.68	20	4.0	2.2	0.85	110	
13.08.2001	14:34:11.41	42.53	2.56	26.45	1.86	12	6.0	1.7	0.71	98	
13.08.2001	19:16:45.05	42.57	0.40	26.39	0.40	12	1.5	1.4	0.17	93	III
15.08.2001	06:18:52.30	42.56	1.32	26.49	1.01	20	10.6	3.0	0.54	166	
17.08.2001	09:00:42.41	42.47	2.11	26.57	5.62	19	2.0	1.5	0.41	260	
17.08.2001	09:03:53.90	42.53	3.53	26.48	4.97	17	6.3	0.9	0.54	199	

Table 4

Parameters of all seismic events registered during the time period – August 9-20th, 2001

N	dd.mm.yyyy	hh:mm:ss	M			
				42	13.08.2001	14:46:14
				43	13.08.2001	14:51:11
1	09.08.2001	01:16:24.7	1.1	44	13.08.2001	15:06:40
2	09.08.2001	01:18:13.4	1.4	45	13.08.2001	15:07:18.25
3	09.08.2001	01:18:51	0.9	46	13.08.2001	15:24:26.5
4	09.08.2001	04:27:04	0.6	47	13.08.2001	15:24:42.8
5	09.08.2001	05:01:38.8	0.6	48	13.08.2001	15:36:43
6	09.08.2001	06:11:53.3	0.3	49	13.08.2001	15:39:57.75
7	09.08.2001	07:23:44	1.4	50	13.08.2001	15:47:51.45
8	09.08.2001	07:30:02.7	0.9	51	13.08.2001	16:21:28.7
9	09.08.2001	15:14:50.5	1.1	52	13.08.2001	16:24:58.75
10	09.08.2001	22:24:42.75	0.6	53	13.08.2001	17:04:27
11	09.08.2001	22:49:38.75	-0.1	54	13.08.2001	17:09:01.2
12	09.08.2001	23:07:05.25	-0.1	55	13.08.2001	17:13:28.5
13	09.08.2001	23:07:13.5	0.6	56	13.08.2001	17:58:43.2
14	09.08.2001	23:20:30.2	-0.1	57	13.08.2001	18:11:41.5
15	10.08.2001	11:35:49	0.3	58	13.08.2001	18:17:08.7
16	10.08.2001	13:32:04	0.3	59	13.08.2001	19:08:03.25
17	10.08.2001	13:34:54.75	0.6	60	13.08.2001	19:12:24
18	10.08.2001	17:37:39.25	-0.1	61	13.08.2001	19:13:05.5
19	10.08.2001	20:59:03.25	0.3	62	13.08.2001	19:16:43.75
20	11.08.2001	03:38:56	1.4	63	13.08.2001	20:36:36.75
21	11.08.2001	05:45:18.05	0.0	64	13.08.2001	20:39:41
22	11.08.2001	05:46:34.7	-0.1	65	13.08.2001	20:41:36.7
23	11.08.2001	06:09:17	0.6	66	13.08.2001	20:46:45.25
24	11.08.2001	08:38:46.3	1.4	67	13.08.2001	23:38:50.75
25	11.08.2001	09:45:14.75	0.0	68	14.08.2001	01:51:02.2
26	11.08.2001	16:38:02.25	0.6	69	14.08.2001	02:14:08
27	11.08.2001	16:50:59.75	0.3	70	14.08.2001	03:26:14.3
28	11.08.2001	17:33:04.45	-0.1	71	14.08.2001	05:52:10.7
29	12.08.2001	05:25:52	0.9	72	14.08.2001	07:11:29.3
30	12.08.2001	05:31:13.75	0.0	73	14.08.2001	07:34:48
31	12.08.2001	17:05:56.5	-0.1	74	14.08.2001	08:03:56.7
32	12.08.2001	17:08:28	0.6	75	14.08.2001	08:41:34.75
33	12.08.2001	18:38:31	1.1	76	14.08.2001	14:35:56.25
34	12.08.2001	19:00:21.2	0.0	77	15.08.2001	04:59:00.3
35	12.08.2001	19:07:30.7	0.6	78	15.08.2001	17:07:47.3
36	13.08.2001	03:04:46.2	1.1	79	15.08.2001	17:31:33
37	13.08.2001	05:43:46.3	0.6	80	15.08.2001	17:52:27
38	13.08.2001	14:36:25.75	0.6	81	15.08.2001	18:31:32.5
39	13.08.2001	14:36:54.95	0.3	82	15.08.2001	18:44:52.75
40	13.08.2001	14:39:04.2	0.3	83	15.08.2001	20:30:53.7
41	13.08.2001	14:45:11	1.1	84	16.08.2001	16:17:02.7

85	16.08.2001	18:00:13.25	0.3
86	16.08.2001	18:32:10.7	0.9
87	17.08.2001	09:51:19	0.6
88	17.08.2001	17:13:25.5	-0.1
89	17.08.2001	17:27:37.75	0.0
90	18.08.2001	07:00:29.7	0.6
91	18.08.2001	16:54:25.5	-0.1
92	18.08.2001	17:00:12.75	-0.2
93	18.08.2001	22:06:53	1.1
94	19.08.2001	01:55:03.5	-0.1
95	19.08.2001	02:09:01	0.0
96	19.08.2001	02:42:31.75	-0.2
97	19.08.2001	02:43:23	-0.1
98	19.08.2001	02:55:36.45	0.3
99	19.08.2001	04:17:55.95	1.1
100	19.08.2001	07:43:09.7	1.4
101	19.08.2001	09:40:07	-0.1
102	19.08.2001	14:22:05.8	-0.1
103	19.08.2001	16:03:56.75	-0.1
104	19.08.2001	19:11:19	0.3
105	19.08.2001	19:28:56.2	0.9

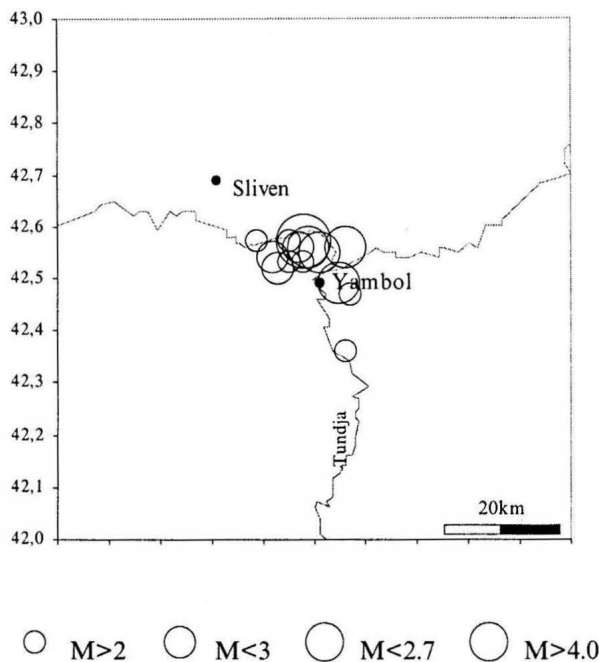


Fig. 3. Epicentral distributions of earthquakes for 09-19.08.2001

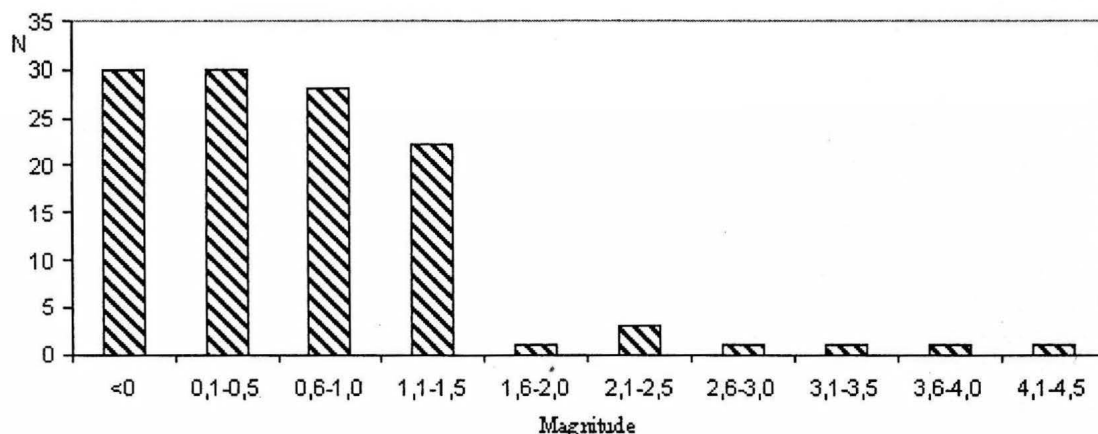


Fig. 4. Magnitude-frequency distribution of the swarm II

shock sequence lasted less than 10 days and composed of about 70-80 events within magnitude range $-0.2 - 2.2$ (Table 4.).

For about 8 hours during 15, 17 and 18th August the nearest seismic station JMB was out of operation and probably missed several of the weak shocks. Due to the lack of local recording network the rest part of the seismic events were not able to be processed and to establish all their parameters. Only the time was available, taken from the local station JMB records. All epicenters of the well-located events are presented in Fig.3.

The magnitude frequency distribution (Fig. 4) shows also specific behavior. There is a high number of low energetic earthquakes (magnitude less than 1.5) and a flat behavior for the rest part of events up to the higher magnitudes (1.6-4.5).

The depth distribution shows a seismogenic layer between 12 and 20 km. (Fig. 6).

The outline of this layer is based only on the data of the stronger events – well registered and located by the National seismic network. All other weaker events may have different depths and probably are located at the shallower depths.

The development of the rupturing process started in E-W direction and then changed in N-S finishing in the central part of the source, which is very similar with the behavior during the swarm I. Visually looks that only SE part of the source has been activated by the swarm II. (See Fig. 2 and Fig. 3)

The maximum number of events has occurred during the 9th and 13th August is in a very small time domain – only several hours.

The time-frequency distribution (Fig.5.) shows that and during the rest time only small, low energetic events occurred with lower intensity. The total energy emitted does not exceed $5.10 \cdot 18J$.

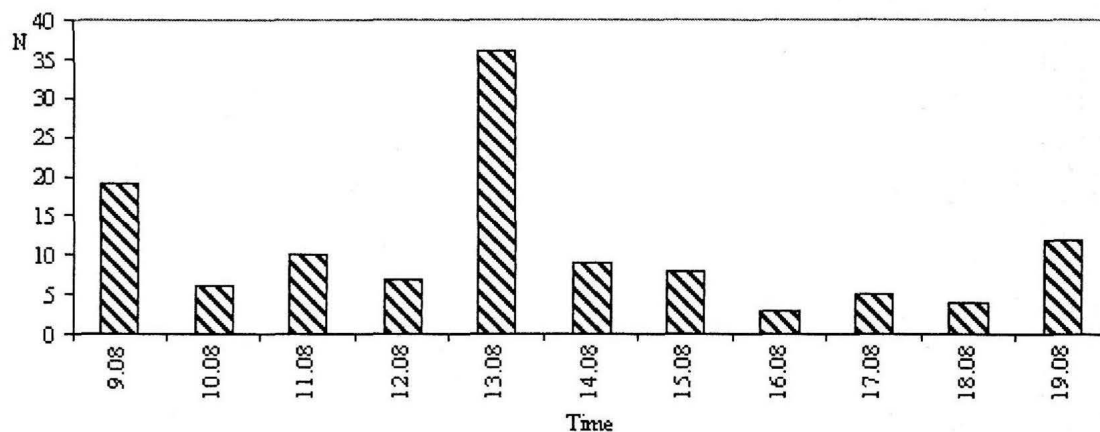


Fig. 5. Time-frequency distribution of the swarm II

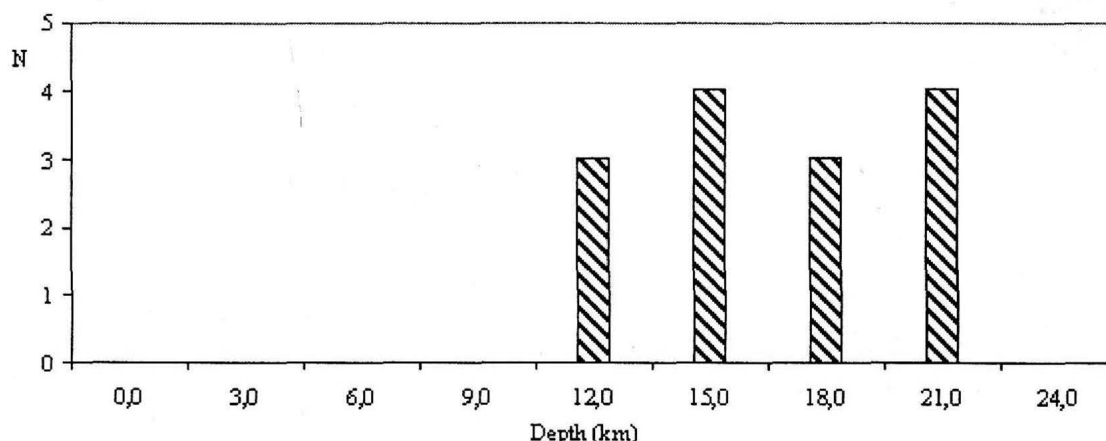


Fig.6. Depth distribution of the swarm II

Discussion

According the Knopof's relationship (Knopoff, 1974) the magnitude 5.7 event in average needs more than 350 days (about 1 year) aftershock sequence and more than 50 km rupture length.

The magnitude 4.5 event in average respected more than 80 days aftershock sequence and the rupture length about 40 km. The both swarms are outside this rule. They show smaller rupture lengths (established by the earthquakes location) and much smaller time duration. This means that they are typical seismic swarms – concentrated in space and time domain.

The similarity between the both swarms is visibly clear. Both swarms started with a foreshock smaller than the main shock. In the case of 1909 the difference between the first and the main shock is about 0.7 magnitude units and for the last case – August 2001 – 2.5. But

this change is at the different magnitude level. Both swarms started in E-W direction and than lasted to N-S.

The location of the activated sources is approximately at the same space domain, which means that belongs to the same seismogenic source. Both sequences have been accompanied by the seismic acoustic sounds.

The differences – for the swarm I, is no data about the low energy earthquakes. For the second one (swarm II) – particular swarm of several felt events preceded the main shock. A lot of very weak earthquakes have been registered with a fast speed of decay in numbers.

There are two possible explanations of these specific behaviors:

The first one – unusually fast aftershock sequences for both swarms are generated by the local source conditions. The second – may be the observed swarm II is a foreshock activity of the expected stronger event. This fact needs time to be improved.

Conclusions

The comparative study of the earthquake swarms (February – June, 1909 and 9-20th August, 2001) occurred near Yambol City have been investigated.

The obtained results show close similarity about the space and time behavior of the seismic processes during both swarms.

On the other hand – the first swarm emitted more seismic energy (because of the larger events included) that the second one and lasted longer time, which is physically acceptable due to the stronger events, involved. The second swarm finished in a very short time and emitted much less seismic energy. The possible extension of the process is expected.

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